NASA TECHNICAL NOTE

NASA TN D-4487

$c.1$

NASA TN D-4487
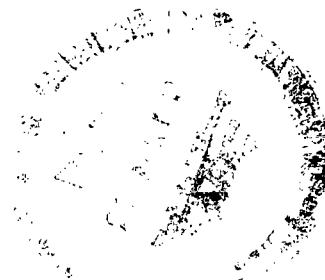
RECORDING AND SIGNAL-CONDITIONING TECHNIQUES AND EQUIPMENT USED IN A 1,000-FLIGHT BIOMEDICAL STUDY

by Richard Carpenter and James Roman

Flight Research Center
Edwards, Calif.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION • WASHINGTON, D. C. • APRIL 1968

RECORDING AND SIGNAL-CONDITIONING TECHNIQUES AND EQUIPMENT

USED IN A 1,000-FLIGHT BIOMEDICAL STUDY

By Richard Carpenter and James Roman

Flight Research Center
Edwards, Calif.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

RECORDING AND SIGNAL-CONDITIONING TECHNIQUES AND EQUIPMENT

USED IN A 1,000-FLIGHT BIOMEDICAL STUDY

By Richard Carpenter and James Roman
Flight Research Center

SUMMARY

The NASA Flight Research Center recently concluded a biomedical monitoring program involving 1,000 flights in high-performance aircraft by students of the USAF Aerospace Research Pilot School and by NASA aerospace research pilots. To permit accurate and reliable data acquisition of electrocardiogram (ECG), respiration rate, and normal acceleration, it was necessary to design and develop a means of reliably recording and transcribing flight medical data in a format compatible with computer reduction. Signal conditioners and interconnecting harnesses were designed and fabricated, and guidelines were established for the construction of a five-channel analog tape recorder to record these data while the recorder is being carried on the pilot with minimum interference or discomfort. The equipment operated reliably and enabled satisfactory data acquisition of biomedical information both in extended biomedical instrumentation studies and in remote-site medical monitoring.

INTRODUCTION

Early in 1964, plans were made to instrument test-pilot students at the USAF Aerospace Research Pilot School, located near the NASA Flight Research Center at Edwards, Calif. The primary purpose of this study, as outlined in reference 1, was to obtain statistically valid baseline information on potential astronaut candidates.

For monitoring purposes the USAF Aerospace Research Pilot School provided an excellent operational environment; however, a rigorous curriculum and tight schedule dictated that data collection proceed on a noninterference basis. Thus, instrumenting the more than 30 aircraft used at the school was not considered practical. This led to the requirement for instrumentation that could be quickly attached and carried by the pilot and that would be entirely independent of aircraft systems.

Using this design philosophy, electrocardiography electrode techniques were developed (refs. 2 and 3) that did not require shaving the chest and could be applied in 15 seconds. In addition, a multichannel tape recorder, an ECG signal conditioner suitable for use with high-impedance electrodes, a pneumotachometer to measure respiration rate, and a system for recording normal acceleration and voice were developed. Figure 1 illustrates the biomedical instrumentation system as carried by the pilot with a minimum of discomfort in a flight-ready state. This paper describes the recording and signal-conditioning techniques, equipment, and ground checkout instrumentation used in this project, which involved 1,000 flights in high-performance aircraft over a period of 22 months.

ECG electrode
ECG electrode
Ground electrode
Signal conditioners and accelerometer inside suit
*Communications
*Flowmeter attaches to aircraft oxygen system
*Automatic quick disconnect
Cabling
Tape recorder

Connect to aircraft systems on parachute harness on upper chest
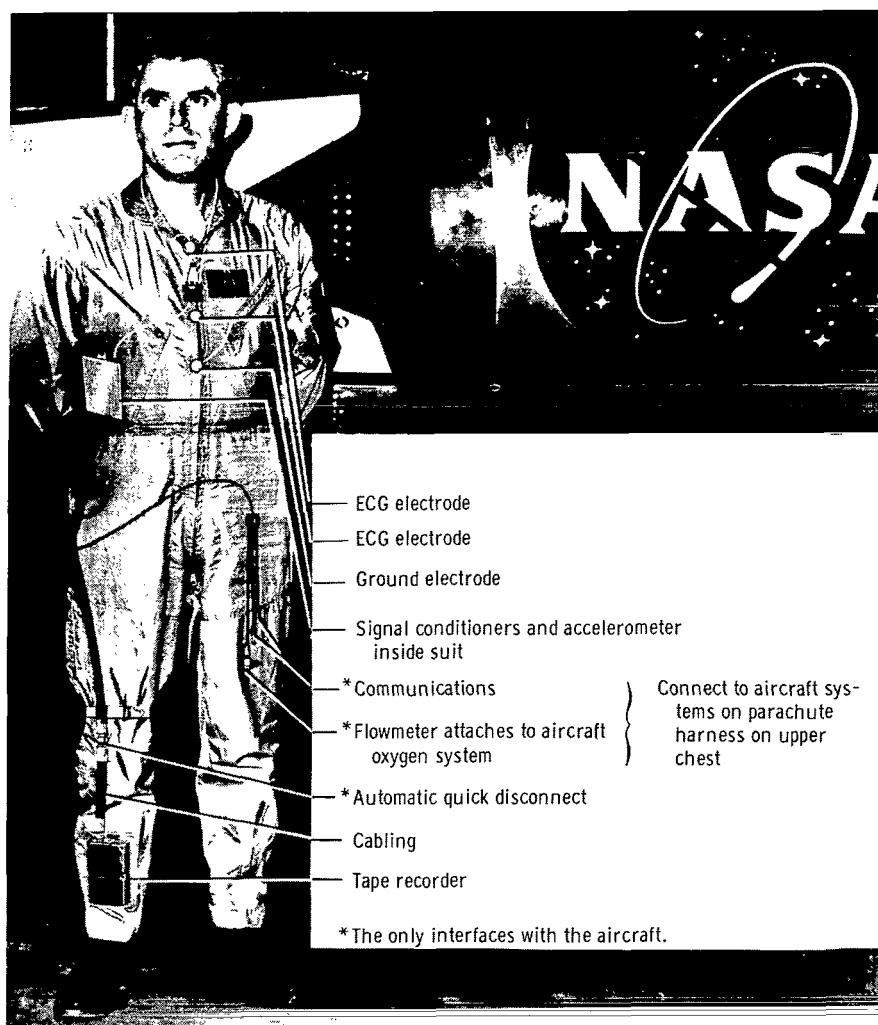
*The only interfaces with the aircraft.

Figure 1.— Complete bioinstrumentation package, shown pictorially on a pilot.
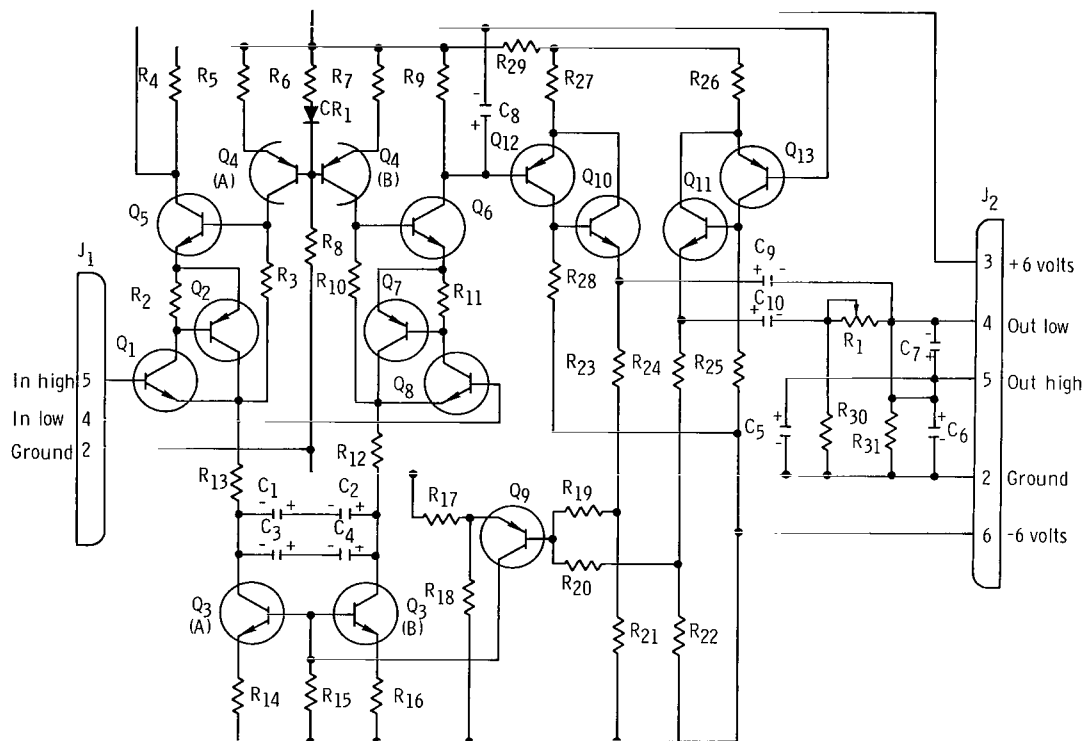
DESCRIPTION OF FLIGHT EQUIPMENT

Electrocardiogram

In obtaining electrocardiogram data, a sternal lead is applied by using spray-on electrodes (ref. 2). These electrodes are characteristically of high impedance and consequently require a signal conditioner with a high input impedance, preferably 20 megohms or greater. The use of a differential-amplifier input and output configuration, as opposed to single-ended designs, optimizes the common-mode rejection from the signal source to the airborne recorder. Differential and common-mode overscale protection with a minimal overload recovery time protects and enhances signal-conditioner operation, especially with a changing baseline signal from the electrodes.

2

The packaging and signal-conditioning circuitry* (shown in figs. 2(a) and 2(b)) allow external gain adjustments by resistor R_1 from 1 to 20. This permits adjusting system
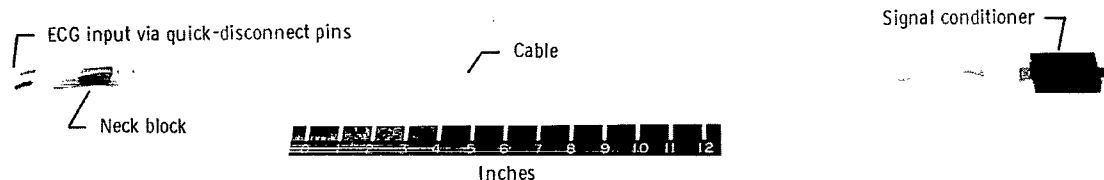
(a) ECG signal conditioner and neck block with attaching cable.

R_1	Variable resistor, 5 kΩ ±5%, 1 watt	R_{16}	Resistor, 47 kΩ, 1/4 watt	R_{31}	Resistor, 750 Ω, 1/4 watt
R_2	Resistor, 68.3 kΩ, 1/4 watt	R_{17}	Resistor, 3 kΩ, 1/4 watt	$C_1, C_2, C_3, C_4,$	Capacitor, 220 μf, 6 volt ±10%
R_3	Resistor, 10 kΩ, 1/4 watt	R_{18}	Resistor, 8.2 kΩ, 1/4 watt	C_9, C_{10}	
R_4	Resistor, 51 kΩ, 1/4 watt	R_{19}	Resistor, 47 kΩ, 1/4 watt	C_5, C_6	Capacitor, 0.1 μf, 35 volt ±10%
R_5	Resistor, 75 kΩ, 1/4 watt	R_{20}	Resistor, 47 kΩ, 1/4 watt	C_7	Capacitor, 1 μf, 10 volt ±10%
R_6	Resistor, 7.5 kΩ, 1/4 watt	R_{21}	Resistor, 6.2 kΩ, 1/4 watt	C_8	Capacitor, 0.01 μf, 35 volt ±10%
R_7	Resistor, 75 kΩ, 1/4 watt	R_{22}	Resistor, 6.2 kΩ, 1/4 watt	CR_1	Diode, 1N914A
R_8	Resistor, 20 kΩ, 1/4 watt	R_{23}	Resistor, 4.7 kΩ, 1/4 watt	Q_1, Q_6, Q_8	Transistor, 2N3117
R_9	Resistor, 51 kΩ, 1/4 watt	R_{24}	Resistor, 4.7 kΩ, 1/4 watt	$Q_2, Q_7, Q_9,$	Transistor, 734-001-9002 (Garrett)
R_{10}	Resistor, 10 kΩ, 1/4 watt	R_{25}	Resistor, 470 kΩ, 1/4 watt	Q_{12}, Q_{13}	
R_{11}	Resistor, 68 kΩ, 1/4 watt	R_{26}	Resistor, 240 Ω, 1/4 watt	Q_3	Transistor, SA2132 (Garrett)
R_{12}	Resistor, 5.1 kΩ, 1/4 watt	R_{27}	Resistor, 240 Ω, 1/4 watt	Q_4	Transistor, MD1124 (Garrett)
R_{13}	Resistor, 5.1 kΩ, 1/4 watt	R_{28}	Resistor, 470 kΩ, 1/4 watt	Q_5	Transistor, 134-001-9003 (Garrett)
R_{14}	Resistor, 24 kΩ, 1/4 watt	R_{29}	Resistor, 910 Ω, 1/4 watt	Q_{10}, Q_{11}	Transistor, 734-001-9001 (Garrett)
R_{15}	Resistor, 24 kΩ, 1/4 watt	R_{30}	Resistor, 750 Ω, 1/4 watt	J_1, J_2	Connector, ME95185 (Cannon)

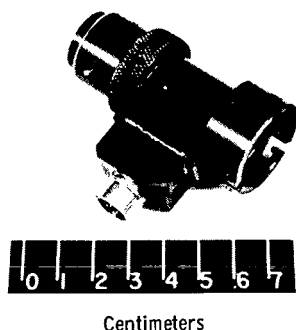(b) Schematic of ECG signal conditioner. Note capacitive coupling at the output.

Figure 2.— ECG signal conditioner and wiring harness.

*Designed by the AiResearch Division of the Garrett Corporation, Los Angeles, Calif.
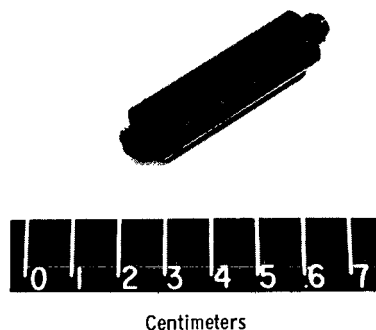
gain to an acceptable level for the magnetic-tape-recorder input. The signal conditioner has a low noise of 4 microvolts (referred to the input) through the band pass of interest. The band pass between the -3 dB points is from 0.11 hertz to 100 hertz. Rolloff of the lower and higher frequencies is at -6 dB per octave, providing baseline stability and diminishing the higher frequency noise present. Total power requirements for this signal conditioner are less than 24 milliwatts, or less than 2 milliamperes current from each of the two 6-volt supplies provided by the tape-recorder batteries. Mechanical features include resistance to shock, acceleration, vibration, and altitude. Welded circuitry was used for miniaturization, resulting in dimensions of the signal conditioner, after packaging, of 0.44 inch by 1.42 inches by 1.92 inches.
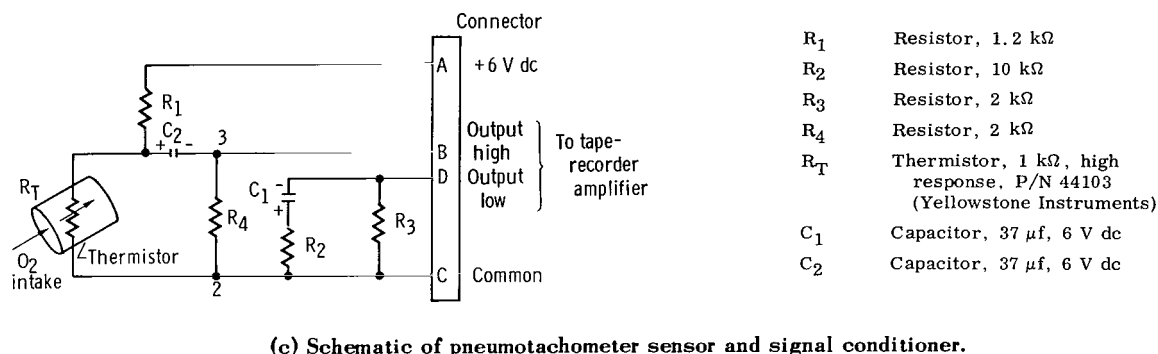
Respiration Rate

Respiration rate was measured by means of a pneumotachometer sensor* (fig. 3(a)) that consisted of a thermistor (R_T) suspended inside a barrel configuration that snapped into the oxygen line between the pilot's mask and regulator. The thermistor is self-heated above ambient under static conditions. An equilibrium temperature is achieved that balances the electrical power input and the heat-loss rate resulting from the temperature differential of the thermistor in its surroundings. The control function of the thermistor was chosen to obtain a ±15-percent change over the temperature range of 20° F to 125° F. Figure 3(b) shows the miniaturized packaged signal conditioner, and figure 3(c) shows the simplified circuitry for the pneumotachometer and related signal

Centimeters

(a) Pneumotachometer sensor.

Centimeters

(b) Pneumotachometer signal conditioner.

R_1	Resistor, 1.2 kΩ
R_2	Resistor, 10 kΩ
R_3	Resistor, 2 kΩ
R_4	Resistor, 2 kΩ
R_T	Thermistor, 1 kΩ, high response, P/N 44103 (Yellowstone Instruments)
C_1	Capacitor, 37 μf, 6 V dc
C_2	Capacitor, 37 μf, 6 V dc

(c) Schematic of pneumotachometer sensor and signal conditioner.

Figure 3.— Pneumotachometer system.

*Built by AiResearch Division of the Garrett Corporation, Los Angeles, Calif.

4

conditioning used in this study. The sensing thermistor (R_T) is located in the air-stream. During inhalation the thermistor temperature changes, thereby providing a resistance change. Resistors R_T and R_1 form a voltage divider network between the +6 volts and common. Changes in R_T thus provide voltage changes that are a function of breathing. Capacitor C_2 blocks the dc level between R_T and R_1 from being applied to the input of the downstream tape-recorder amplifier. Resistor R_3 is equal to R_4, C_1 is equal to C_2, and R_2 is the equivalent resistance of the voltage divider R_T and R_1. This design improves common-mode rejection, since the inputs to the recorder amplifier will both have the same source impedance. During inhalation, a signal on the order of 10 millivolts magnitude is obtained. The bridge output signal is capacitively coupled to the recorder amplifier, thereby eliminating dc voltages resulting from absolute temperature and component drift.

An additional benefit from the capacitor coupling is that although thermistor response to flow is very rapid, the recovery under stagnation conditions is much slower. Consequently, during rapid breathing the direct bridge signal does not return to zero, thus providing an equivalent dc offset. The capacitor eliminates this offset effect and provides a reduced amplitude signal without offset. This allows the sensing element rather than the network to establish these high-frequency cutoff conditions.

This respiration-rate-sensing concept was desirable for use in this program since it requires very low power (less than 250 milliwatts) for the bridge and does not require any active signal conditioning. Also, there are no biasing problems with dynamic signal coupling and no requirements for tuning or calibration for offset errors. The circuitry can be packaged within the sensor connector, providing excellent sensitivity and reliability. Earlier experimental flight versions of a thermistor-type respiration-rate sensor were continually malfunctioning because of noise artifact, system unreliability, and lack of sensitivity during temperature extremes.
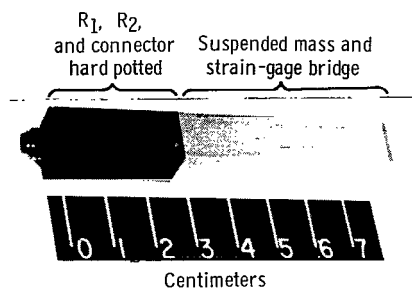
Accelerometer

The accelerometer* (figs. 4(a) and 4(b)), which was chosen and modified for mounting on the pilot, measures mass displacement head to foot. The signal output is from a bridge circuit. The legs of the circuit are four strain-gage units mounted so that two wires act in tension and two in compression, thus providing changes due to up or down motion of the suspended mass. External load resistors R_1 and R_2 limit extreme sensitivity and provide a dc offset voltage for full-scale compatibility with downstream requirements. The accelerometer is mounted in a canvas packet snapped inside the right breast of the pilot's flight suit.
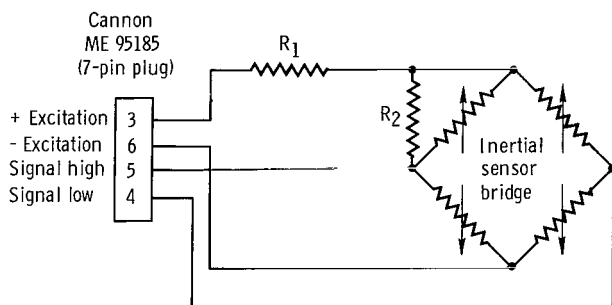
The accelerometer was designed for a range of ±4g. However, this range was limited by the voltage-controlled oscillator (VCO) of the tape recorder to a range of −1g to 3g. The accelerometer output was linear within this range, with output voltages from −16 millivolts at −1g to +16 millivolts at 3g.

*Built by Statham Instruments, Los Angeles, Calif.

R_1, R_2, and connector hard potted — Suspended mass and strain-gage bridge

Centimeters

(a) Accelerometer sensor.

Cannon
ME 95185
(7-pin plug)

+ Excitation 3
- Excitation 6
Signal high 5
Signal low 4

R_1

R_2

Inertial sensor bridge

(b) Schematic of accelerometer.

Figure 4.— Accelerometer system.

Voice Recording

The voice was obtained from the air-craft communications system by a special adapter plug (fig. 1) designed into the biomedical flight harness. The voice-monitoring system was designed to be limited only by the direct-recording tape-recorder-channel frequency response which rises 6 dB per octave from 300 cps to 1500 cps.

Flight Harness

The flight harness (fig. 1) that connects the various sensors to the analog flight recorder was specially constructed to provide reliability, pilot comfort, and safety features that guard against this equipment harming the pilot in the event of an emergency. Considerable difficulty was experienced in developing a cable that would meet these design objectives; approximately 25 cable configurations were experimentally test flown at the Flight Research Center and abandoned because of lack in pilot comfort, reliability, and safety features. The cable finally developed (fig. 5), operated satisfactorily on more than 100 flights before a malfunction occurred.

The problems encountered were eventually solved by constructing the cable in two parts, one part for use underneath the flying suit and the other part external to the suit. The inner portion, as shown in figure 5(a) (bottom strand) and figure 2(a), consists of a flat, flexible, silastic-coated cable* with miniaturized connectors soft-potted to the cable. To prevent failure in tension or by tearing, a strain-relief wire is embedded near each edge of this cable. To prevent flapping during flight or if ejection is necessary, the chest pack containing the signal conditioners and accelerometer is snapped to the flight suit and to the neck block (figs. 1 and 5(a)). The inner-cable assembly, which is used to connect the ECG signal conditioner to the ECG leads (fig. 5(b)), is color-coded to prevent errors in connecting the leads. Noise problems were considerably reduced in the ECG leads by placing two megohm resistors from each lead to ground, as shown in figure 5(b), and cable integrity and reliability were maintained by molding these resistors in the cable block. The Winchester pins used to connect directly to the ECG lead wires proved to be reliable in withstanding mechanical wear, vibration, and corrosion.
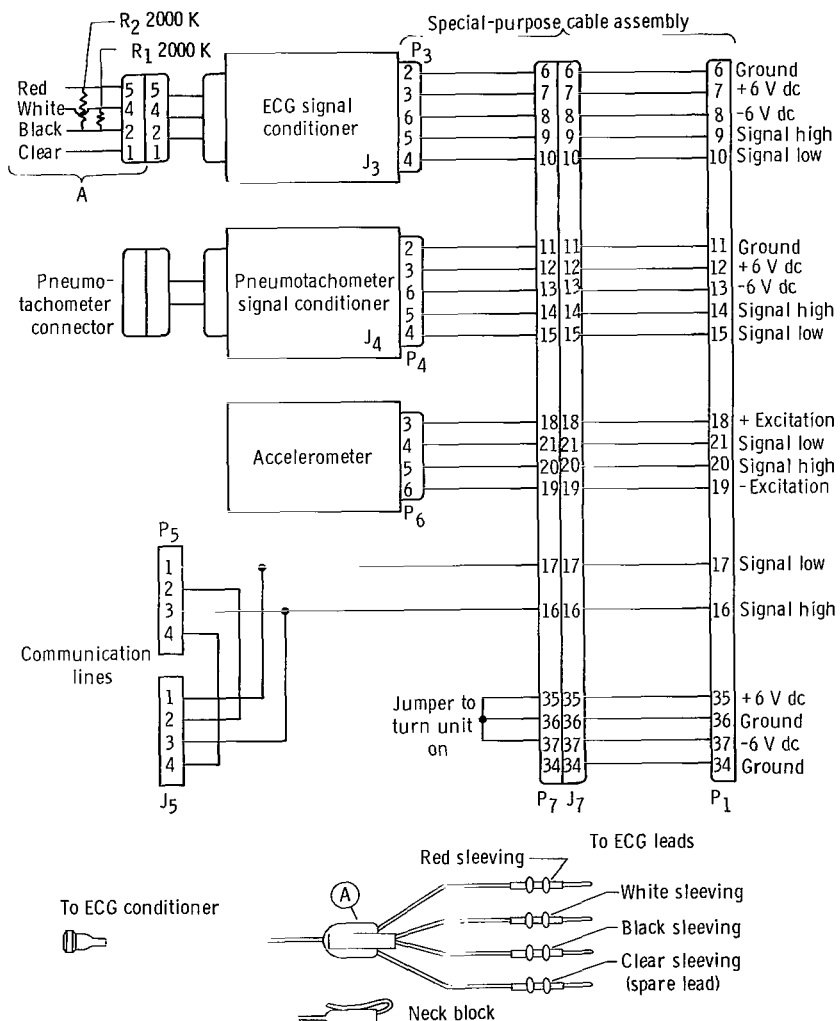
The outer portion of the cable external to the suit was constructed by using 24-strand nylon braid covering Teflon-coated lead wires, with miniaturized connectors

*Built by CeCoil Corporation, Van Nuys, Calif.
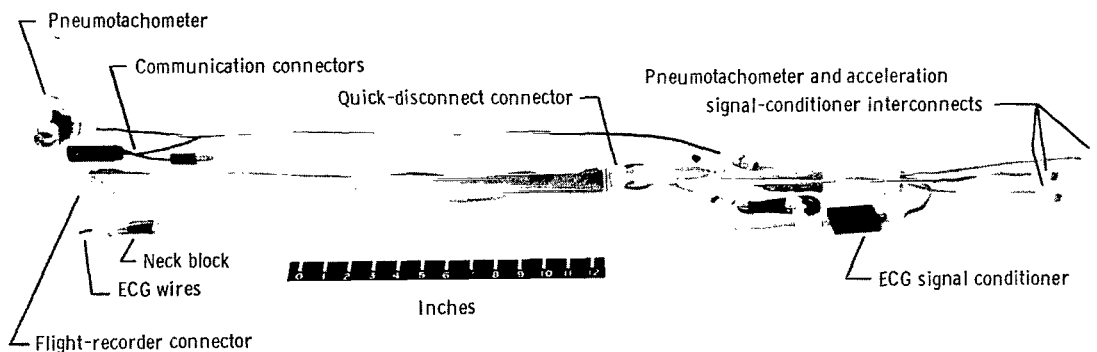
(a) Flight harness, including pneumotachometer and signal conditioner.

(b) Schematic of flight harness.

Figure 5.— Flight harness.

7

potted into the cable*. All connectors were hard-potted to the cable and then covered with a soft-potting to eliminate rough edges. The lower part of the cable that attaches to the flight recorder was covered with a silk jacket bound onto the connectors at either end by silk thread. The silk jacket, rather than stress wires, was used for this portion of the cable to prevent failure by pulling or tearing because strain-resistant wire would be unsafe if this portion of the cable were pulled hard against the pilot's leg. Stress wires could, in the event of a mishap, severely cut the pilot's legs. The quick-disconnect connector is positioned to allow easy attachment to the parachute harness, and during a seat ejection (approximately 15g) will allow the recorder positioned in the leg pocket to be torn from the pilot's flight suit, thus eliminating any possible flailing of the 5-pound flight recorder after ejection. In addition, the cable-recorder disconnect serves as an off-on switch for the entire system (fig. 5(a)).

Biomedical Tape Recorder

Stringent design requirements were established by the Flight Research Center for an analog tape recorder for use in this program and with a potential for use in future programs. The requirements (table I) stipulated that the recorder must fit in the leg pocket of an Air Force flying suit. Thus, the maximum size specified was 2 inches by 5 inches by 9 inches, and the maximum loaded weight could not be in excess of 5 pounds. It was also required that four FM channels and one direct channel be recorded simultaneously in a high vibration and shock environment, such as encountered in high-performance aircraft. The recorder was to be self-contained with a capacity for 1.5 hours of continuous running and, in addition, supply power for the pneumotachometer operation, ECG signal conditioner, and accelerometer. The industrial market was carefully surveyed, and it was determined that such an instrument did not exist or was even in the developmental stage. Consequently, in late spring of 1964 negotiations were begun with AiResearch Division of the Garrett Corporation to develop and construct analog tape recorders meeting the preceding criteria. The recorders were delivered in the early autumn of 1964 and experimentally test flown at the Flight Research Center. The experimental flights indicated the need for a number of changes and modifications, which were incorporated into the flight recorder. The recorders were put into operational status at the Aerospace Research Pilot School in January 1965.

A photograph of the tape recorder and a schematic of its circuitry are shown in figures 6(a) and 6(b). The black boxes in the electrical portion of figure 6(a) are amplifiers, oscillators, and power conditioners, modular in design for reliability and ease of replacement. Of the three large cylinders shown in figure 6(a), the two longer ones are the motor-drive and electronics supply batteries, and the shorter one is the accelerometer battery.

The tape recorders proved to be reliable in accumulating in-flight physiological data and routinely provided a signal-to-noise ratio of 39 dB; this ratio was never allowed to fall below 37 dB. Although reliable, the recorders required continuous daily preventive maintenance. After every 25 hours of operation or after 30 days, whichever occurred first, each recorder was returned to the instrumentation laboratory for major preventive maintenance.

---

*Built by Carter Engineering Corporation, Los Angeles, Calif.

Mechanical portion

Electrical portion

Inches
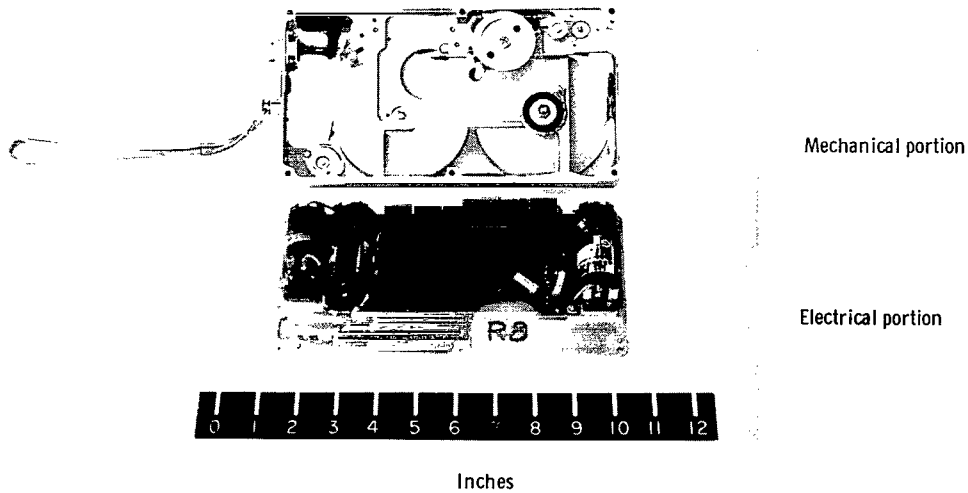
(a) Photograph of the two major portions of the recorder.
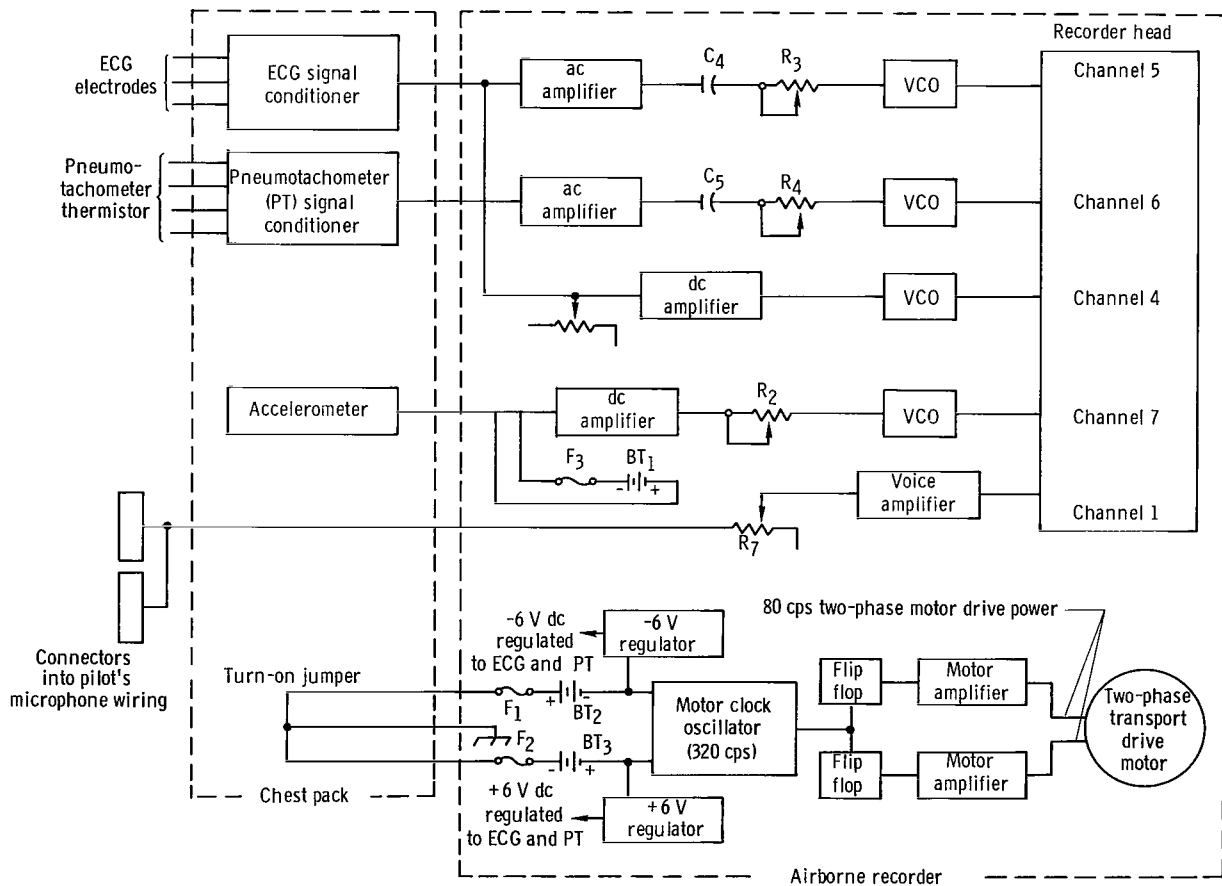
(b) Block diagram of the recorder.

Figure 6.— Flight tape recorder.

To achieve the long running time of 90 minutes, a tape speed of 15/16 inch per second was used together with a center frequency of 843 cps on the FM channels. This slow tape speed conforms to the Inter Range Instrumentation Group (IRIG) standards but is rarely used and consequently required special playback equipment. The playback equipment and the total FM handling format are discussed in detail in reference 4.

During this program, the routine collection of high-quality data was maintained by incorporating extremely rigid schedules of preventive maintenance on all flight equipment, especially the tape recorder. To facilitate short recorder turnaround times, the preventive maintenance, both minor and major, was performed at the Aerospace Research Pilot School where the pilots were instrumented. Special facilities were installed, such as dirt-free workbenches and a complete supply of all parts. Part of the original design criteria for the recorder was to modually construct all the electronics so that any component could be quickly replaced and to design the mechanical portions (fig. 6) in such a manner that they could be repaired easily with a minimum of special tools. Logs were maintained on the replacement of components and parts. After several hundred flight hours, sufficient history was accumulated to allow replacement of parts generally before the point of failure. After the rigorous preventive maintenance schedules were in force and the parts failure history established, less than 1 percent of the flights were lost because of flight-equipment failure, and the total system signal-to-noise ratio was maintained at values higher than 37 dB for 95 percent of the data collected.

Flight Equipment Power

As previously discussed, three nickel-cadmium batteries (fig. 6(a)) were enclosed in the flight tape recorder. Two of the batteries were used to power the tape drive motor, recorder electronics, pneumotachometer, and ECG signal conditioner. The third battery was used to power the accelerometer circuitry. The batteries* were discharged from 11.0 volts to 8.6 volts at the rate of 165 milliamps per hour during a flight. Each flight lasted about 1 1/2 hours. The batteries were found to be reliable and rugged; however, the reliability was dependent on the care exercised during recharging. For example, it was necessary to discharge each battery to 7.5 volts after each flight, and then trickle charge for a minimum of 36 hours. To facilitate recharging the large number of batteries, special equipment was constructed to automatically discharge and charge for the prescribed lengths of time.

During the charge cycle, a voltage regulator was set for a maximum charge of 11 volts, and the battery was not removed until this charge had dropped to a bare trickle and 36 hours had passed. During long flights, data became distorted when the power voltage dropped to less than 8.6 volts; however, strict adherence to the discharge-charge cycle routinely allowed 100-minute recordings.

PREFLIGHT AND POSTFLIGHT PROCEDURES AND EQUIPMENT

The preflight equipment checks to insure that the flight equipment was functioning properly were performed in several phases. The biomedical cable harness,

---

*Manufactured by Gulton Industries, Metuschen, N. J.

pneumotachometer sensor, and accelerometer were thoroughly cleaned. The pneumo-tachometer was cleaned ultrasonically, since it connects directly into the aircraft oxygen system. The equipment was then thoroughly checked for grounds, shorts, and intermittent operation by using quick-connecting test apparatus. If found flight-worthy, the equipment was tagged ready for flight and hung on special racks, designed to pre-vent stressing the cable, in the pilot instrumenting laboratory. The recorder was pre-pared in the fully loaded condition with new analog tape and freshly charged batteries. As a student pilot entered the instrumenting laboratory for the spray-on electrode application (ref. 2), a technician simultaneously took a monitoring cable from the rack and a recorder, connected them, and applied power to the total system. Using quick-disconnect plugs into the system, all channels were simultaneously dis-played on a specially designed check-out console (fig. 7). The large equip-ment rack, shown in figure 7(a), con-tained the equipment for preflight calibration and sections for demodu-lation and presentation of recorded data from each channel. The flight
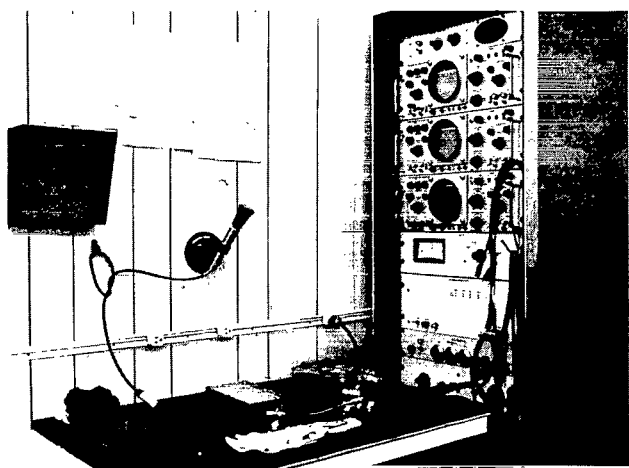
(a) Preflight checkout console.
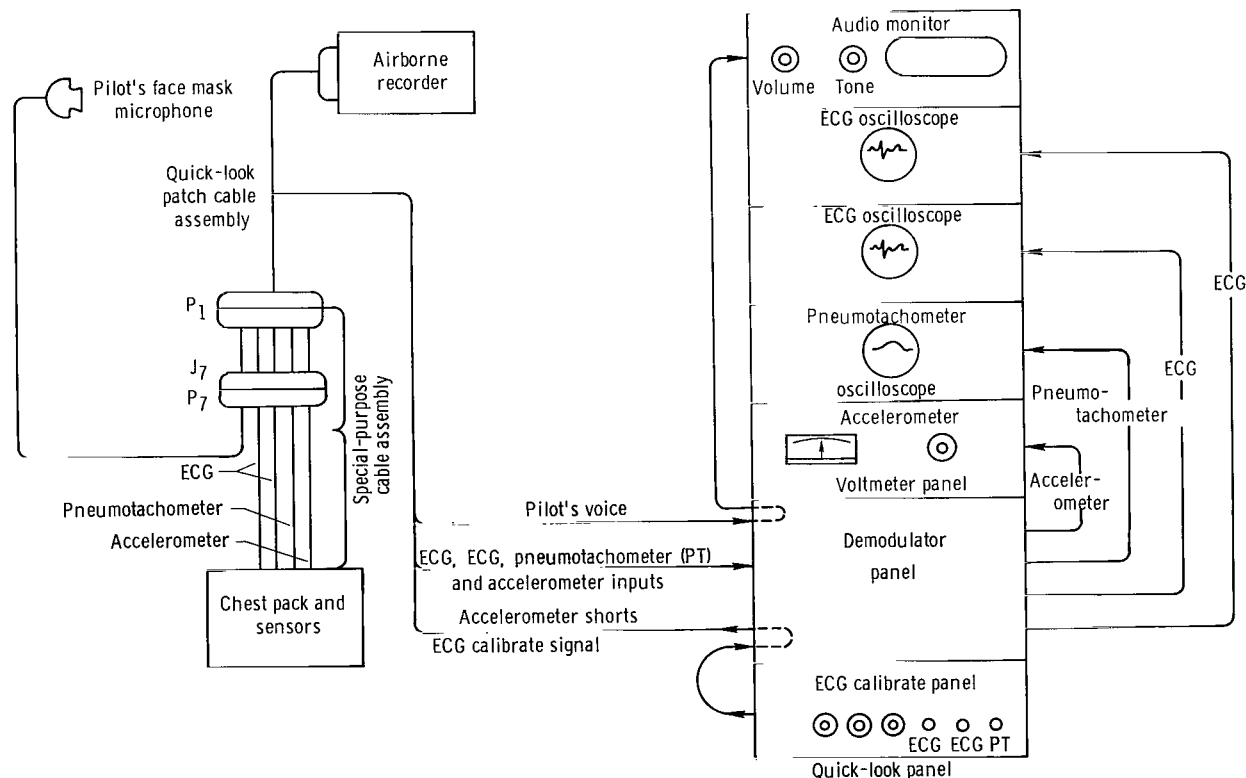
(b) Block diagram of preflight checkout system.

Figure 7.— Preflight checkout system.

11

equipment is shown on the bench, laid out as it would be for preflight calibration and checkout. By using simulated signals for the ECG, pulsing air through the pneumo-tachometer, and manually turning the accelerometer, the resulting signals were displayed in real time by oscilloscopes in the preflight console. For 30 seconds the equipment was subjected to abrupt motions and vibrations, allowing the operator to immediately detect any system malfunction. Figure 7(b) shows the interfaces necessary for complete system checkout and preflight calibration. The oscilloscopes may show either the calibrate signal or recorded data. At all times, for each scheduled flight at least two backup flight systems were available in the event of a last-minute system failure.

Additional features of the preflight console allowed it to be used as a trouble-shooting analyzer. For example, system components could be isolated through a plug-board where the signals, in and out, could be monitored on the oscilloscopes. The console was considered vital for maintaining data quality control and contributed appreciably to rapid flight-equipment turnaround by making it possible to quickly isolate and identify the type of system failure.

Immediately after a flight, a check was made of each flight system to determine if a failure had occurred in flight. Malfunctions were routinely detected by making a comparison between the results of the preflight and postflight tests.

Incorporated into the preflight checkout console (fig. 7) is a calibration panel that is driven by preset signal sources for the ECG, pneumotachometer, and acceler-ometer. Immediately after the preflight test, calibration signals were automatically placed on the appropriate channels. The calibration signal for both the ECG and pneu-motachometer is a 2-cycle-per-second square wave, providing a 20-millivolt peak-to-peak signal out of the ECG and pneumotachometer signal conditioners, which deviated the voltage-controlled oscillators (VCO) to their linear limits of ±40 percent of the center frequency of 843 cycles per second (fig. 8). Thus, as indicated in figure 8, an ECG calibration signal of 1.35-millivolt peak voltage is amplified to a 10-millivolt peak, which deviated the voltage-controlled oscillator to its linear limits. This, in turn, provided a 1-volt root mean square signal to be read on the oscilloscope.

The pneumotachometer calibration signal is designed to provide the same amplitude readout. The accelerometer is calibrated by placing the sensor in the 1g position for 30 seconds, rotating it to the 0g position for 30 seconds, and then to the -1g position for an additional 30 seconds. This method provides a 0.7-volt peak change on the oscilloscope for each g increment, as indicated in figure 8. These procedures and equipment rapidly and accurately provide the operator with last-minute information relative to the sensitivity of the total flight system and assure him that the calibration has been properly applied to the tape-recorder head. The cali-bration is completed by shorting all signal inputs for 30 seconds, which is rapidly accomplished by switch control and allows later automatic compensation during data reduction for dc offset. The total time required for the preflight checkout and cali-bration is less than 3 minutes.

As each flight returns, a technician assists the pilot from the aircraft and immediately disconnects the flight harness from the tape recorder. He then hand carries the tape recorder directly to the laboratory where the tape is immediately played back for 15-second periods during each quarter of the flight, providing data
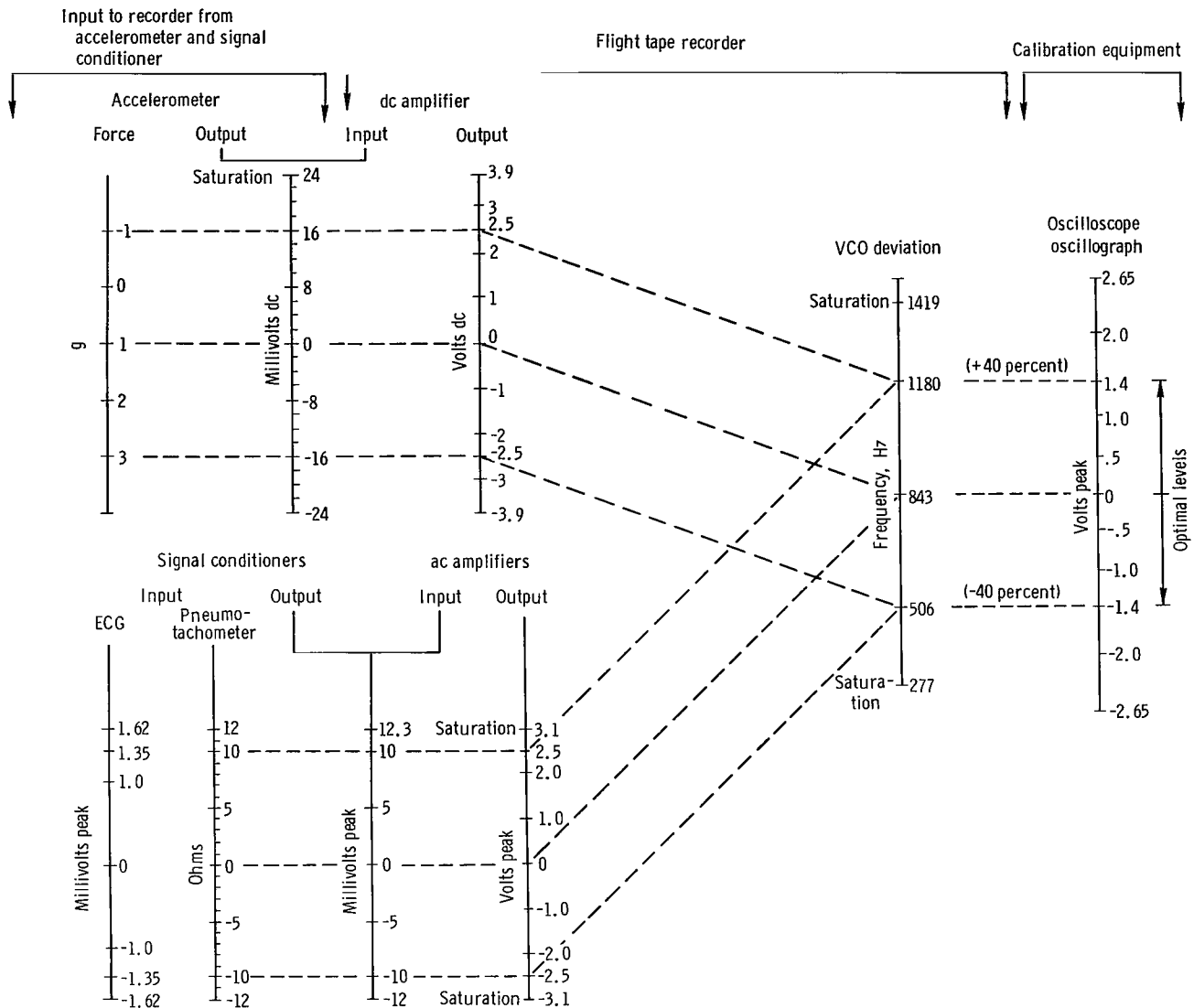
Figure 8.— Voltage-controlled-oscillator (VCO) deviations for each calibrated input signal and the resultant output signal level.

for a quick-look system analysis. These tracings (figs. 9(a) and 9(b)), read at the end of each flight, are marked by flight number, and any observation relative to system performance is noted. The tracings are returned to the Flight Research Center to allow system quality control by the principal investigator on a daily basis. The pilot returns directly to the laboratory where the biomedical harness is disconnected and the spray-on electrodes are removed with a solvent. Total deinstrumentation requires about 3 minutes. The recorder, the sensors, and the harness are immediately taken to the instrumentation laboratory for the full postflight checkout.
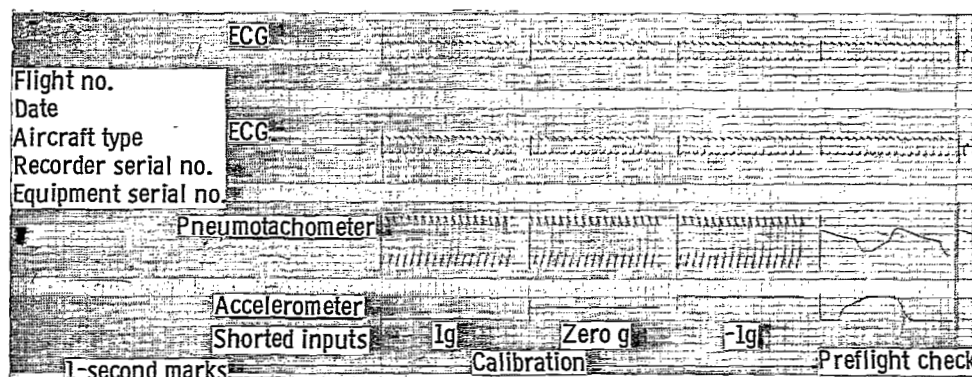
(a) Preflight records.
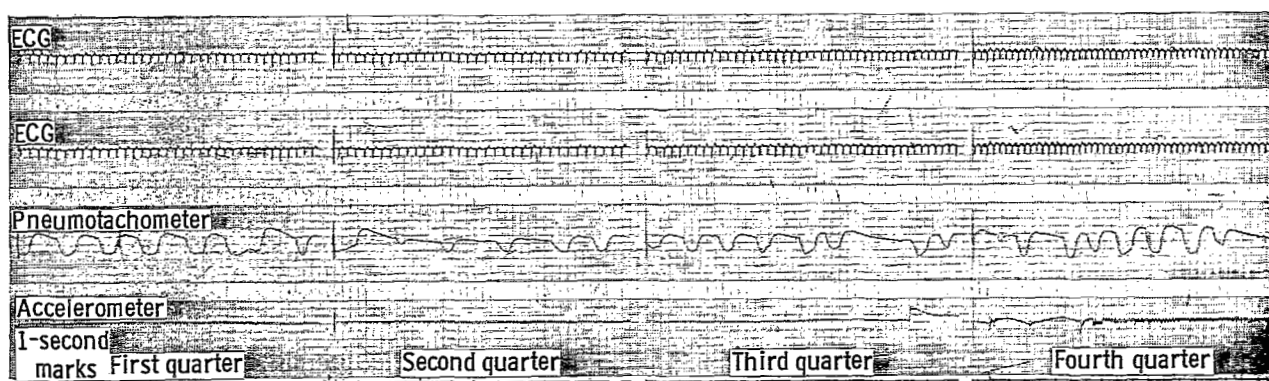
(b) Quick-look flight records.

Figure 9.— Bioinstrumentation tape-recorder readouts.

OPERATIONAL EXPERIENCE

The monitoring equipment and procedures developed for this study were used successfully in 1,000 flights over a period of 22 months. System malfunction accounted for less than 3 percent of the flights on which poor data were obtained, and 95 percent of these data were collected with the instrumentation signal-to-noise ratio maintained higher than 37 dB.

In addition to the 1,000 flight study, the techniques and equipment proved to be effective in the field and have been used extensively in other programs, including monitoring the Air Force Thunderbirds in close-formation acrobatics, NASA test pilots flying experimental craft such as the M2-F2 lifting body and the lunar-landing

research vehicle (LLRV), and combat pilots operating from aircraft carriers off the coast of Viet Nam (refs. 5 and 6).

Flight Research Center,
    National Aeronautics and Space Administration,
        Edwards, Calif., November 27, 1967,
            127-49-06-02-24.

REFERENCES

1. Roman, James: Long-Range Program to Develop Medical Monitoring in Flight. The Flight Research Program-I, Aerospace Medicine, vol. 36, no. 6, June 1965, pp. 514-518.

2. Roman, James: Flight Research Program—III. High Impedance Electrode Techniques. Aerospace Medicine, vol. 37, no. 8, Aug. 1966, pp. 790-795.

3. Patten, Charles W.; Ramme, Frank B.; and Roman, James: Dry Electrodes for Physiological Monitoring. NASA TN D-3414, 1966.

4. Carpenter, Richard; and Roman, James: FM Handling and Analog-to-Digital Conversion of Biomedical Data During a 1,000-Flight Study. NASA TN D-4488, 1968.

5. Roman, James; Older, Harry; and Jones, Walton L., Jr.: Flight Research Program: VII. Medical Monitoring of Navy Carrier Pilots in Combat. Aerospace Medicine, vol. 38, no. 2, Feb. 1967, pp. 133-139.

6. Lewis, Charles E.; Jones, Walton L., Jr.; Austin, Frank; and Roman, James: Flight Research Program: IX. Medical Monitoring of Carrier Pilots in Combat — II. Aerospace Medicine, vol. 36, no. 6, June 1967, pp. 581-592.

TABLE I. – BIOMEDICAL TAPE-RECORDER SPECIFICATIONS

Purpose - To record five channels of biomedical information during flight

Type - Battery operated, 5 channel, recording (no rewind or playback)

Size, maximum - 2.075 in. by 5.0 in. by 9.15 in.

Weight, maximum - 5 pounds

Tape -
    Speed - 15/16 inch per second
    Type - Mylar
    Width - 1/2 inch
    Thickness - 1.5 mil or less

Wow and flutter - 1 percent (maximum) dc to 100 Hz, 2.5 percent (maximum) 100 Hz
            to 1.0 kHz

Format - IRIG standard wide-band FM for data channel, direct for audio channel

Capacity, minimum - 1.5 hours continuous

Crosstalk between channels, maximum - -25 dB

Input impedance -
    Differential channels, minimum - 100,000 ohms
    Common mode, minimum - 1,000,000 ohms
    Single-ended channel, minimum - 100,000 ohms

Full-scale input signal, peak to peak - 20 mV

Voice-channel response - Magnetization vs frequency characteristic rising 6 dB per
            octave from 300 Hz to 1500 Hz

Channels - 5

Gap locations - In-line

ac amplifier -

Input-signal amplitude, mV	Input-signal frequency, Hz	Peak-to-peak output-signal amplitude, volts
20	1	5 ±0.2
20	100	5 ±0.2

    Output noise, peak to peak - Less than 20 mV
    Size, maximum - 0.96 in. by 0.72 in. by 1.06 in.

dc amplifier -

Input-signal amplitude, mV dc	Output-signal amplitude, V dc
16	+2.5 ±0.5
-16	-2.5 ±0.5

"The aeronautical and space activities of the United States shall be conducted so as to contribute . . . to the expansion of human knowledge of phenomena in the atmosphere and space. The Administration shall provide for the widest practicable and appropriate dissemination of information concerning its activities and the results thereof."

—NATIONAL AERONAUTICS AND SPACE ACT OF 1958

NASA SCIENTIFIC AND TECHNICAL PUBLICATIONS

TECHNICAL REPORTS: Scientific and technical information considered important, complete, and a lasting contribution to existing knowledge.

TECHNICAL NOTES: Information less broad in scope but nevertheless of importance as a contribution to existing knowledge.

TECHNICAL MEMORANDUMS: Information receiving limited distribution because of preliminary data, security classification, or other reasons.

CONTRACTOR REPORTS: Scientific and technical information generated under a NASA contract or grant and considered an important contribution to existing knowledge.

TECHNICAL TRANSLATIONS: Information published in a foreign language considered to merit NASA distribution in English.

SPECIAL PUBLICATIONS: Information derived from or of value to NASA activities. Publications include conference proceedings, monographs, data compilations, handbooks, sourcebooks, and special bibliographies.

TECHNOLOGY UTILIZATION PUBLICATIONS: Information on technology used by NASA that may be of particular interest in commercial and other non-aerospace applications. Publications include Tech Briefs, Technology Utilization Reports and Notes, and Technology Surveys.

Details on the availability of these publications may be obtained from:

SCIENTIFIC AND TECHNICAL INFORMATION DIVISION

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Washington, D.C. 20546