NASA CR-166347

XV-15 RESEARCH INSTRUMENTATION
AND
DATA ACQUISITION MANUAL

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V/STOL TILT ROTOR RESEARCH AIRCRAFT

VOLUME I - GENERAL INFORMATION

301-099-022

REVISION C

BELL HELICOPTER COMPANY
POST OFFICE BOX 482 · FORT WORTH TEXAS 76101 · A textron COMPANY

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AND
DATA ACQUISITION MANUAL

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VOLUME I

GENERAL INFORMATION

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FOREWARD

This manual defines the configuration, operation, and maintenance requirements for the contractor-furnished portion of the XV-15 research instrumentation and data acquisition system. Interface with Government Furnished Equipment (GFE) is established through schematics and block diagrams. Operation, maintenance, and checkout procedures for GFE are not included in this manual. Organization of the Research Instrumentation and Data Acquisition Manual is as follows:

VOLUME I - GENERAL INFORMATION:
This volume contains descriptions of systems operation, maintenance and checkout procedures, calibration procedures, cable designations and definition of the CFE/GFE interface.

VOLUME II - AIRCRAFT S/N 702 CONFIGURATION:
This volume establishes the instrumentation configuration for XV-15 Aircraft No. 1 (S/N 702). Transducer calibration data and PCM setup sheets applicable to Aircraft No. 1 are included.

VOLUME III - AIRCRAFT S/N 703 CONFIGURATION:
This volume establishes the instrumentation configuration for XV-15 Aircraft No. 2 (S/N 703). Transducer calibration data and PCM setup sheets applicable to Aircraft No. 2 are included.

VOLUME IV - CFE TECHNICAL DATA:
This volume contains manufacturer drawings and specifications for contractor-furnished transducers and related equipment.

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SECTION 1. SYSTEM DESCRIPTION

This section describes the installation and operation of the research instrumentation and data acquisition system.

1.1 Research Instrumentation System. The XV-15 research instrumentation system consists of a pallet-mounted data acquisition system, system controls and indicators, various sensors installed throughout the aircraft, an L-band telemetry system, interconnect cabling, connectors and junction boxes. Two independent pulse code modulated (PCM) data channels are provided. Each data channel has a capacity of approximately 47 channels of 100 Hz data, 52 channels of 50 Hz data, and 32 channels of 12 Hz data. Figure 1-1 illustrates the research instrumentation system in block diagram form.

1.2 CFE/GFE Interface. The data acquisition system is Government Furnished Equipment (GFE) and interfaces with the Contractor Furnished Equipment (CFE) as shown in Figure 1-2. Functional interfaces are shown as vertical dashed lines with CFE on one side and GFE on the other. Design responsibility follows these same interface lines. Power available to the research instrumentation system is detailed in the notes on the diagram. The nose boom is identified as the only sensor which is GFE. Components of the GFE data acquisition subsystem are mounted on an instrumentation pallet which is installed in the cabin area of the fuselage. Arrangement of GFE components on the instrumentation pallet is shown in Figure 1-3. The CFE components other than sensors, controls, and indicators are mounted on an auxiliary instrumentation pallet installed in the aft cabin area of the fuselage. Arrangement of CFE components on the auxiliary instrumentation pallet is shown in Figure 1-4.

1.3 System Operation. Data from the transducers are forwarded to the remote multiplexer-demultiplexer units (RMDU) which provide signal conditioning for the transducer, adjust signal gain to programmed value, convert analog data to digital form and encode the data into a pulse code modulation (PCM) serial bit stream. Transducer excitation (if required) is supplied from a separate low voltage (±3V) power source. Two 64-channel preamplifier filters are available to condition low level signals which require special filtering or amplification. An additional active network panel may be used to condition or process transducer signals whose characteristics do not readily match the interface requirements of the RMDU. A time correlation base for the total system is supplied from a time code generator. A remote time code display is mounted in the center area of the instrument panel. All data are recorded on a standard airborne magnetic tape recorder. An interface is available for inflight transmission of data from one RMDU via L-band telemetry.

1.4 Data Acquisition System. The GFE data acquisition system provides signal conditioning, time base, PCM encoding, and data recording functions.

1.4.1 Remote Multiplexer/Demultiplexer Unit. The remote multiplexer/demultiplexer unit (RMDU) accepts transducer signals in analog or discrete digital form; conditions, normalizes, and multiplexes the input data; converts the analog data to a digital format; and outputs the data in a PCM format. Each unit can accept up to 256 channels of data with a serial output of up to 125,000 twelve-bit words per second. The word rate for the XV-15 system is limited by the tape recorder bits/inch packing density.

1.4.1.1 Interface Cards. Interface cards are used in conjunction with the RMDU to provide the correct signal conditioning for the various aircraft sensors. The RMDU is configured for a research mission by inserting the appropriate interface cards into any of 10 card slots. The following interface cards are used.

a. Analog Multiplexer Card (AMX). The AMX card accepts 32 analog input signals and multiplexes them into one signal channel. This signal is then presented to the gain programmable amplifier (GPA). Analog signals from position potentiometers, temperature scanner, voltmeters and pre-sample filter cards are processed by AMX cards.

b. Pre-Sample Filter Card (PSF). Each PSF card accepts four signal inputs from strain gage transducers, and filters them through 100 Hz or 50 Hz filters. The PSF then amplifies the signals with a gain of 256. Filter frequency and gain are factory adjustable. The output of the PSF is presented to an AMX card.

c. Discrete Multiplexer Card (DMX). The DMX card accepts any three 12-bit words or 36 bits of information, and multiplexes this information into the PCM data stream. Digital inputs such as record number, control words, and fuel quantity are processed by DMX cards.

d. Scannivalve Driver Card (SVD). The SVD card contains a programmable clock which is used to control the scannivalve stepper drive. The clock is set for four pulses per second. The card also generates a 12-bit control word which is used for the scannivalve position encoder.

1.4.1.2 Gain Programmable Amplifier (GPA). The RMDU contains a programmable amplifier which provides for eight preselected programmable gains to amplify signal strength to ±5.12V full scale (gains are 1, 2, 4, 16, 64, 128, 256, and 512).

1.4.1.3 SAT-M Module. The RMDU is programmed for frame format, frame sync words, subframe ID word, and gain by a Stand-Alone Timing Module (SAT-M) which is pre-programmed on a ground based PROM programmer. The SAT-M provides PCM outputs of serial NRZ code to a telemetering transmitter and serial Miller Code (DM-M) to the tape recorder.

1.4.2 Preamplifier Filter Unit (PAF). A preamplifier filter unit is used for low level signals that require extensive filtering. The unit provides for 64 channels with a gain from 128 to 1024 (NASA cards are pre-set to a gain of 256) and a three-pole active low pass Butterworth filter. Two PAF units are used in the data acquisition subsystem.

1.4.3 Tape Recorder. The research instrumentation recorder (MARS 1414 LT-3D) is a wide-band, FM, 14-track analog recorder which takes a 14-inch reel of magnetic tape. A PCM bit stream from each RMDU, the time code generator output, and pilots' voices are recorded on separate tracks. The re aining tracks are used to record active network channel outputs if required. Tape deck track assignments are shown in Table 1-I. The tape recorder is the limiting item in the system due to its bit packing density capability as related to amount of tape available, speed of recording and length of record required for flight testing. The MARS 1414 LT-3D recorder is operated at 30 inches per second, a record rate of 46,666 words (12-bit words) per second which allows approximately one hour of full time data recording. Miller code is used to achieve this word rate capacity.

1.4.4 Time Code Generator. The time code generator with integral battery pack produces an IRIG-B output for recording on the tape recorder and provides both a local and remotely-mounted pilots' display. This unit can be synchronized with ratio station WWV (time standard station) and acts as the time base for the research instrumentation system.

1.4.5 R-Cal Boxes. The R-Cal boxes use a relay to shunt a precision resistor across the C-D leg of each strain gage input signal at the PAF boxes. Each R-Cal box has a 32-channel capability. Five R-Cal boxes are installed on the instrumentation pallet. All five boxes are operated by a single push button switch located on the front face of the active network panel.

1.4.6 Active Network Panel. Circuit cards are installed in the active network panel to provide special processing for transducer signals which are not compatible with the RMDU and for special purpose instrumentation requirements such as thermocouple signal conditioning. Special circuits used in the active network panel are described in Section 8 and include the following functions:

a. Digital stick position
b. Temperature scanner
c. Left rotor azimuth
d. Right rotor azimuth
e. Data control logic
f. Mean/peak-to-peak detector (blade beam bending)
g. Mean/peak-to-peak detector (hub flapping)
h. Fuel quantity
i. Tape speed control

1.4.7 Excitation Power Supply. A common ±3 Vdc power source is provided for excitation of the research instrumentation transducers (other than air data). The ±3 Vdc power supply is located in the instrumentation pallet and all 20 signal distribution cables are wired in parallel to this power supply.

1.4.8 Patch Panel. The signal interface between aircraft sensors and the Government-furnished data acquisition system is at the patch panel installed on the aft end of the instrumentation pallet. The patch panel consists of a fixed housing with a removable program board. The program board has two sections, each 32 x 40 points, for a total of 2560 points. Signal distribution cables are wired into the lower program board (Figure 1-5). The upper program board (Figure 1-6) serves as the input to the GFE data acquisition system. Spare program boards are provided with each aircraft to allow different data acquisition programs to be pre-wired.

1.4.9 Telemetry System. Complete provisions for L-band telemetry are installed in the aircraft for the contractor flight test program. The telemetry (TM) system consists of an L-band TM transmitter, a pre-modulation filter, TM antenna, TM track select switch, TM OFF-ON light, and a TM reset switch. The TM transmitter and antennas are provided by BHT for the contractor flight test program and will be removed from the aircraft prior to government acceptance of the aircraft. The PCM bit stream is routed from RMDU A and RMDU B to the pre-modulation filter unit. Pre-modulation filtering is recommended to conserve the RF spectrum required for TM. Both PCM bit streams are present at the pre-modulation filter and either bit stream may be selected for telemetry by the TM select switch located on the center pedestal. The selected PCM bit stream (RMDU A or RMDU B) is routed to the TM transmitter and then to the antennas. Wiring diagrams for the telemetry system and pre-modulation filter are contained in Section 4.

1.5 Controls and Indicators. Cockpit mounted controls and indicators for the research instrumentation and data acquisition system include: control monitor (pilot information panel), critical function monitor, rotor flapping indicator, temperature monitor, a time code generator control panel, and a control position indicator.

1.5.1 Control Monitor. The control monitor (Figure 1-7) is mounted in the copilot instrument panel. This instrument has five colored lights, three switches and a three-digit record number display with reset buttons. The Master Power switch is located on the right side of the indicator. When this switch is placed in the up position the green PWR ON light should illuminate signifying the system is powered. The Pull Tape switch is located on the left side of the indicator. When this switch is placed in the up position, the blue PULL TAPE light should illuminate signifying the tape is being pulled in the tape deck. When the Prime Data button (push-button switch located on the right side of each power lever) is pushed, the amber PRIME DATA light should begin to blink. This shows that the system logic is in the prime data mode. When the Prime Data button is pushed again, the record number shown on the three-digit display is advanced by one digit and the PRIME DATA light will cease blinking showing the system is once again out of the prime data mode. Should the red FAULT light illuminate, it indicates a fault has occurred in the system. Pressing the FAULT button should clear or turn off the FAULT light. If the red FAULT light does not go out, data is considered unreliable and the system should be shut down. Should the white TAPE REMAIN light illuminate, this indicates that five minutes of tape remain on the reel. Only a few (if any) prime data records should be taken before replacing tape in the tape recorder.

1.5.2 Prime Data Switch. The prime data switch is a push button type switch located on the pilot's and copilot's power lever. When the prime data switch is pressed the control monitor PRIME DATA light will blink indicating that the data acquisition system logic is in the prime data mode. Pressure and temperature sensor scans are initiated by the prime data switch. The scan is terminated at the end of the prime data record or at the end of one complete scan cycle. When the prime data switch is pressed a second time the prime data record is terminated and the PRIME DATA light will cease blinking. The data record number displayed on the control monitor will update at the end of each prime data record.

1.5.3 TM Control Panel. The TM control panel (Figure 1-8) contains controls and indicators associated with the L-band telemetry system. The control panel is installed in the center pedestal and contains the following controls and indicators.

a. TM Channel Select Switch. The TM channel select switch is a 9-position rotary control switch used to select the data channel to transmitted. FM data channels are selected by placing the switch in positions 1 through 6. Data from either RMDU A or B may be transmitted by placing the switch in the "A" position. The desired RMDU is then selected with the RMDU select switch. A CAL position is also available for use in system check-out.

b. RMDU A/B Select Switch. The RMDU A/B switch is a two-position guarded toggle switch located on the TM control panel (Figure 1-8). When placed in the A position, the output of RMDU A is selected for inflight transmission of data via L-band telemetry. When the TM switch is placed in the B position, the output of RMDU B is selected for inflight data transmission. The TM switch does not affect the output from either RMDU to the tape deck.

c. TM Reset Switch and Indicator. The TM reset switch is a push button type switch located on the cockpit center pedestal. This switch is used to reset the TM transmitter power following a power interruption or bus transient. TM power on is indicated by a light installed adjacent to the TM reset switch.

1.5.4 Critical Function Monitors. Two critical function monitors are installed in the aircraft to enable the crew to monitor critical research instrumentation measurements. These indicators (Figures 1-9 and 1-10) are located on the left side of the instrument panel directlv below the control monitor. The two channels selected for display are fore/aft hub flapping and blade beam bending at blade station 52.

1.5.4.1 Critical Load Meter. The critical load meter (Figure 1-9) is mounted directly below the control monitor. It is a meter that is driven by the data system and calibrated to display a given critical parameter during flight and ground runs. The channel chosen as the most critical channel, or the channel that would first detect an irregularity in the rotating system, is considered to be blade beam bending at Sta. 52. The face of the meter is marked with green and red arcs to indicate the critical limit of this parameter.

1.5.4.2 Flapping Indicator. The flapping indicator (Figure 1-10) is mounted in the copilot instrument panel directly below the critical load meter. It is a meter driven by the data system and is calibrated to indicate rotor plane flapping (F/A hub spring motion), stop to stop.

1.5.5 Temperature Monitor. The temperature monitor (Figure 1-11) is mounted in the upper left side of the copilot instrument panel. This monitor consists of two function lights (CYCLING and FAULT), a four-digit readout, and channel selection switches.

1.5.5.1 Function Lights. When the prime data switch on the power lever is pressed, the CYCLING light will illuminate and stay illuminated until thermocouple and pressure scanning systems have scanned all available channels (i.e., the 30 channels for each of the three temperature scanner locations and the 48 pressure ports have each been sampled once). The CYCLING light will extinguish when one cycle is complete. The duration of one complete scan cycle is 12 seconds. A new cycle can be taken by pressing the prime data switch once more to turn off prime data, then pressing it again to turn prime data back on. The temperature monitor will cycle once for each prime data record. Should a malfunction occur in any of the three temperature scanner locations, the FAULT light will illuminate. The FAULT light can be extinguished only by correcting the malfunction.

1.5.5.2 Digital Readout. A four-digit readout displays temperature directly in °F of the selected channel. The digital readout will flicker while prime data cycling is occurring. This is because the system is reading the input thermocouples at the rate of four per second and the readout is displaying these inputs at the same rate.

1.5.5.3 Channel Selection Switches. Three thumb wheel switches are provided on the left of the temperature monitor for channel selection. The first switch (left to right) selects which scanner location is being monitored. There are three scanner locations: (1) left nacelle, (2) aft fuselage, and (3) right nacelle. The next two switches control the channel which the system is monitoring. There are 30 channels (numbered 0 through 29) available at each scanner location. A random access feature permits any channel to be monitored at any time simply by dialing the desired scanner location and channel number. See Table 1-II. When the prime data is started, the monitor switches back to the zero chanel, and completes one cycle. At the completion of prime data, the temperature monitor returns to the selected channel.

1.5.6 Time Code Display Panel. The time code display panel (Figure 1-12) is mounted at the top of the center instrument panel. It consists of an ON-OFF-LAMP TEST switch, a lamp intensity control and a six-digit readout. Placing the ON-OFF switch in the ON position turns the display on. Placing the switch to the LAMP TEST position checks all the lamp segments (all segments illuminate showing the numeral eight). The control on the right regulates the intensity of the display. The two digits on the left of the display are hours, the center two digits are minutes and the two on the right are seconds.

1.5.7 Control Position Indicator. The control position indicator (Figure 1-13) is mounted in the lower left side of the pilot instrument panel. It consists of four two-digit displays. Control stick and pedal position are displayed in percent of full travel. Each display is identified by both a written title and a symbol. Stick positions to be measured are:

a. F/A cyclic stick position (0% is full aft, 99% is full forward)

b. Lateral cyclic stick position (0% is full left, 99% is full right)

c. Collective stick position (0% is full down, 99% is full up)

d. Rudder pedal position (0% is full left and 99% is full right)

1.5.8 Digital RPM Indicator. The digital rpm indicator is a 3-place liquid crystal display (LCD) mounted on the instrument panel glareshield. The indicator (Figure 7-14) displays percent rotor rpm to the nearest tenth of one percent. When the rpm exceeds a reading of 99.9 percent the first digit begins to flash indicating that the displayed reading is above 100 percent e.g. (-)1.2 indicates 101.2 percent RPM. This indicator is driven by the pilot's triple tachometer.

1.5.9 Mast Torquemeter. Two mast torquemeters are installed on the top center of the instrumentation glareshield. The mast torquemeters (Figure 7-15) are driven by the data system and display left and right mast torque from zero to 200,000 inch-pounds.

1.6 Sensors. A variety of aircraft sensors are installed to measure aircraft systems performance, control and surface positions, loads, temperatures and other engineering data. Sensors are selected to provide the most direct method of measurement. Accessibility for maintenance and calibration checks is provided. Interference with other aircraft systems is minimized through use of lightweight transducers with compact, rigid linkages and mounts. Selection of sensors is restricted to those units which have proven reliability. Table 1-III contains a generic listing of required aircraft sensors and their functions. Additional sensors may be installed for special test programs. Further description of measurements available and a complete listing of required data channels is given in Section 2. Sensor characteristics are given in Table 3-I of Section 3. Vendor specification sheets for sensors are included in Volume IV.

1.7 PCM Data Processing. A flow diagram of the PCM data processing procedure used at the BHT Ground Data Center (GDC) is shown in Figure 1-16 for reference. The tape generated by the airborne data acquisition system is brought to the GDC for processing. The tape is mounted on analog playback equipment in preparation for data reduction. The Xerox 530 computer set up program selects the proper track from the analog tape deck, sets up the PCM decom equipment, loads the data conversion program, starts the analog tape deck and generates the 530 PCM digital tape. The digital tape contains the PCM data in parallel words instead of a serial bit stream. The data on the digital tape is reformatted and written on a second digital tape which is compatible with BHT time history and loads analysis programs. The formulas used for PCM calibration are contained in Appendix I and II.

TABLE 1-I. TAPE DECK TRACK ASSIGNMENTS

Tape Deck Track	Record/Reproduce Module Type	Item Recorded	NASA Program Board Input Channel
1	FM	Right Engine Vibration	5
2	Direct	PCM "B"	-
3	FM	Spare	6
4	Direct	PCM "A"	-
5	FM	Right Engine Vib[illegible]	7
6	FM	Left Engine Vibration	1
7	FM	Right Engine Vibration	8
8	Direct	Time Code Generator	-
9	Direct	PCM "B"	-
10	FM	Left Engine Vibration	2
11	Direct	PCM "A"	-
12	FM	Left Engine Vibration	3
13	Direct	Time Code Generator	-
14	Direct	Voice (ICS)	4

TABLE 1-II. TEMPERATURE MONITOR CHANNEL NUMBERS
(EXAMPLE)

Description	Item Code L	Item Code R	Channel No. L	Channel No. R	Limit °F
Engine:					
Inlet Housing	-	T506	-	309	250
Accessory Housing	-	T506	-	310	350
Axial Compressor	-	T506	-	302	400
Centrifugal Compressor	-	T506	-	303	450
Compressor Diffuser	-	T506	-	304	800
Exhaust Diffuser	-	T506	-	301	1200
Ignition Unit	-	T506	-	305	250
Fuel Control	-	T506	-	312	250
Ignitor Solenoid Valve	-	T506	-	306	300
Airbleed Control	-	T506	-	314	250
Thermocouple Harness Air-frame Interface Connector	-	T506	-	315	250
Oil in Cooler	T513	T506	114	311	300
No. 2 Bearing Oil Scavenge	T513	T506	117	313	430
T-7 Harness	T513	T506	100	500	
IAT at 0°	T513	-	109	-	-
IAT at 120°	T513	-	110	-	-
IAT at 210°	T513	-	111	-	-
N_1 Tach Generator	-	T506	-	317	
Ambient	-	T506	-	318	
Transmission:					
Case - Inlet	T513	T506	104	-	
Case - Conversion Axis	T513	T506	112	327	
Case - Swivel	T513	T506	113	328	
Case - Inlet	T513	T506	115	321	
Ambient	T513	T506	-	323	
Oil In	T513	T506	124	325	230
Oil Out	T513	T506	125	326	230
Driveshaft Hanger Bearing:					
Inboard	T351	T351	209	206	250
Outboard	T351	T351	208	205	250
Conversion Spindle	T351	T351	207	204	250
Center Gearbox	-	T351	-	214	260
OAT	-	T322	-	210	-
Hub Spring Bearing	T513	T506	116	316	

TABLE 1-III. RESEARCH INSTRUMENTATION TRANSDUCERS

AREA	NUMBER OF TRANSDUCERS	DESCRIPTION
Propulsion System		
Fuel	2	Total fuel used and fuel flow rate
Inlet	2	Total and static pressure, 17 ports
Inlet	2	Temperature, 4 IC thermocouples
Tailpipe	(to inlet transducer)	Static pressure, 4 ports
Turbine Section	(to inlet transducer)	Temperature, engine T7 thermocouple harness
Torque	3	Transmission, interconnect
Trubine	2	Gas producer speed (N1)
Turbine	2	Power turbine speed (N2)
Engine vibration	6	Fore and aft, vertical, lateral
Pylon temperatures	(to inlet transducer)	Transmission case and oil, engine oil (15 thermocouples, each engine)
Engine fuel control	2	Fuel control lever position (N1)
Airframe Loads		
Right wing	2	Upper and lower panel, bending
Right wing	11	Beam and chord bending, torque and shear
Right horizontal stabilizer	2	Beam bending, upper and lower skin
Right horizontal stabilizer	6	Beam and chord bending, and torque
Right vertical stabilizer	6	Beam and chord bending, and torque
Right pylon conversion spindl	2	Beam and chord bending
Right conversion actuator	1	Axial load
Flaps	4	Torque and beam bending
Flaperon	4	Control arm force and beam bending
Elevator	4	Torque and beam bending
Rudder	4	Torque and beam bending
Pilot Flight Controls, Loads		
Cyclic stick	2	Fore and aft, and lateral force
Power lever	1	Force
Rudder pedals	2	Force
Landing Gears, Main, Loads		
Trunnion arm	2	Vertical bending
Oleo strut	4	Fore and aft, and lateral bending
Drag strut	2	Axial force
Nose Gear, Loads		
Trunnion	2	Vertical bending
Oleo	2	Fore and aft, and lateral bending
Drag strut	1	Axial force

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TABLE 1-III. (CONTINUED)

AREA	NUMBER OF TRANSDUCERS	DESCRIPTION
Rotors and Controls, Loads		
Blades	18	Beam and chord bending and torque (R&L), stress
Hub spindle	4	Beam and chord bending
Masts	6	Bending (2 directions) and torque
Pitch link	6	Axial force on all links
Swashplate	2	Drive force
Control Boost Actuators, Loads		
Cyclic, F/A	2	Axial force
Cyclic, Lateral	2	Axial force
Collective	2	Axial force
Airframe, Position		
Control surfaces	8	Position measurements
Main landing gear	4	Position measurements
Nose landing gear	3	Position measurements
Horizontal stabilizer	1	Position measurements
Pilot Controls, Position		
Cockpit control	7	Position measurements
SCAS system	3	Position measurements
Rotor Position		
Hub spring motion	4	Position measurements
Gimbal trunnion flapping	2	Position measurements
Blade feathering (single)	2	Position measurements
Collective motion	2	Position measurements
Swashplate motion	4	P[illegible]sition measurements
Conversion motion	2	[illegible]tion measurements
Rotor azimuth	2	[illegible] per rev
Rotor azimuth	2	512 per rev
Aircraft State Measurements		
Airspeed	1	Pitot port, from nose boom
Altitude	1	Static port, from nose boom
	1	Radar altimeter
Outside air temperature	1	Temperature probe
Relative wind angles	1	Angle of attack, from nose boom
	1	Angle of sideslip, from nose boom
Aircraft attitude	3	Pitch, roll, and yaw
Aircraft angular rates	3	Pitch, roll, and yaw
Vertical acceleration	1	Aircraft c.g

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TABLE 1-III. (CONCLUDED)

AREA	NUMBER OF TRANSDUCERS	DESCRIPTION
Aircraft System Monitors		
Hydraulic system	3	Pressure
Electrical system	4	dc voltage and current
Fuel system	2	Quantity
Temperature, wing fuselage	2	Thermocouples A/R to temp. scanner
Oil, engine	2	Pressure
Oil, transmission	2	Pressure
Aircraft Accelerations		
Aircraft center of gravity	3	Fore and aft, lateral and vertical
Pylons	6	Fore and aft, lateral and vertical
Cockpit	4	Lateral and vertical
Test Equipment		
Exciter mechanism	4	Exciter mechanism positions and loads as applicable
Total	218	

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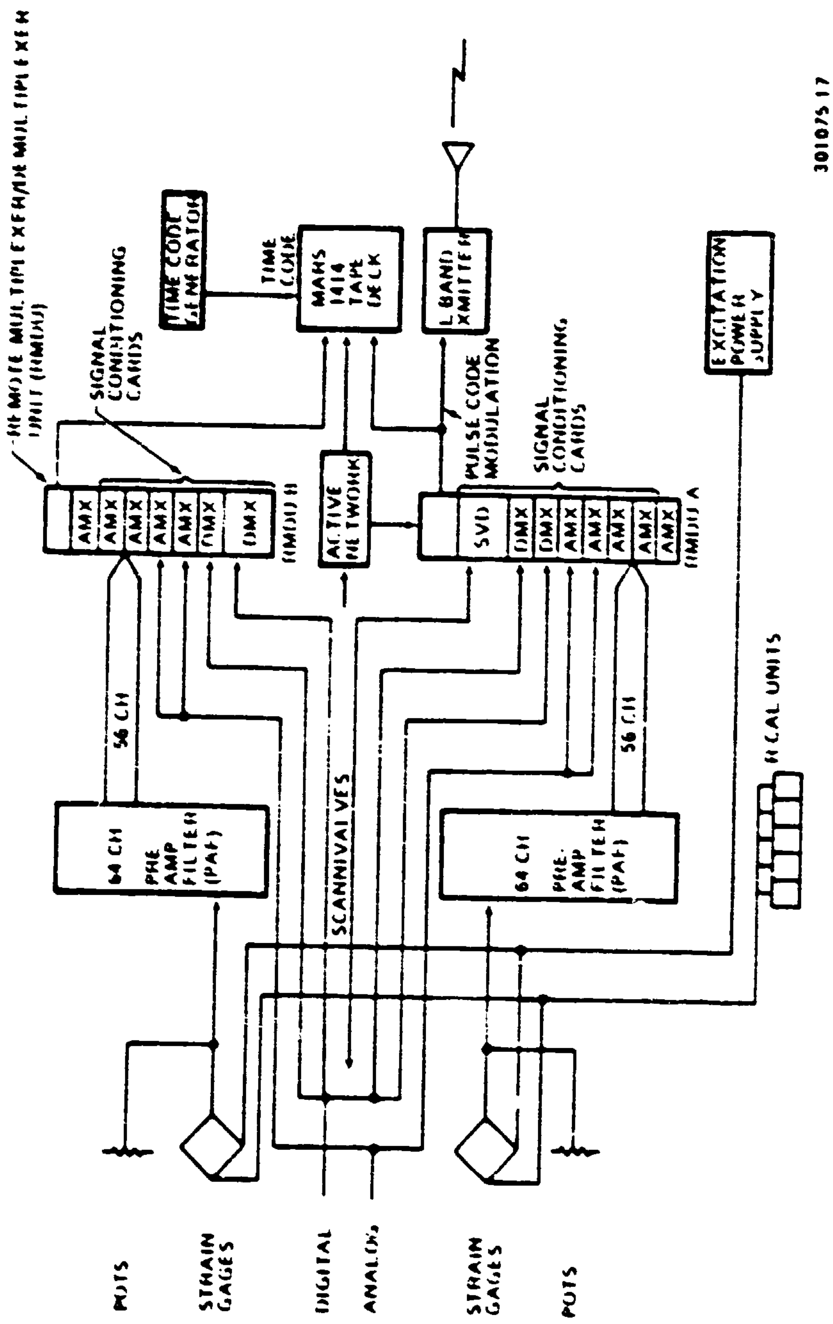

Figure 1-1. Research instrumentation block diagram.

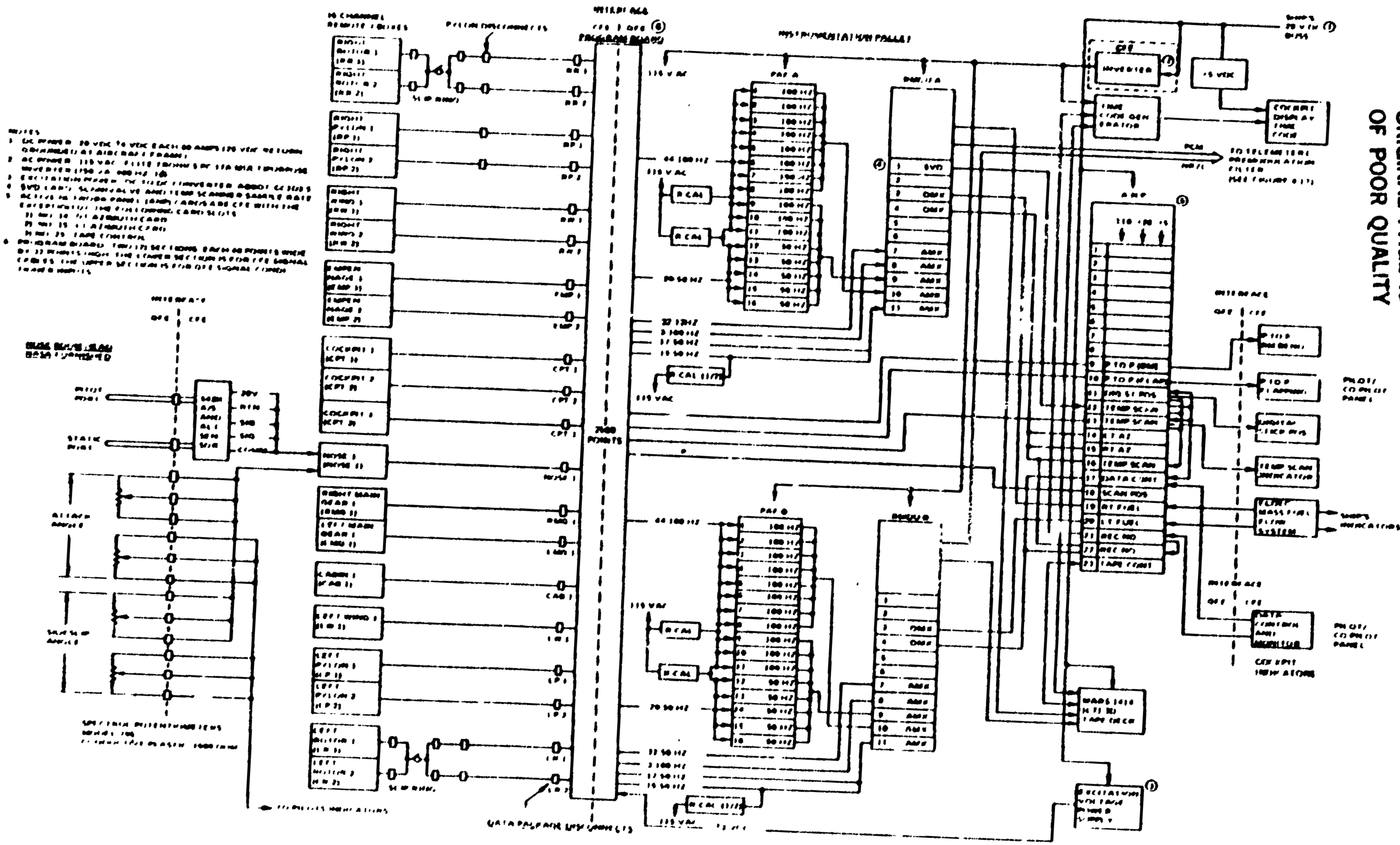

Figure 1-2. CFE/GFE Interface Diagram

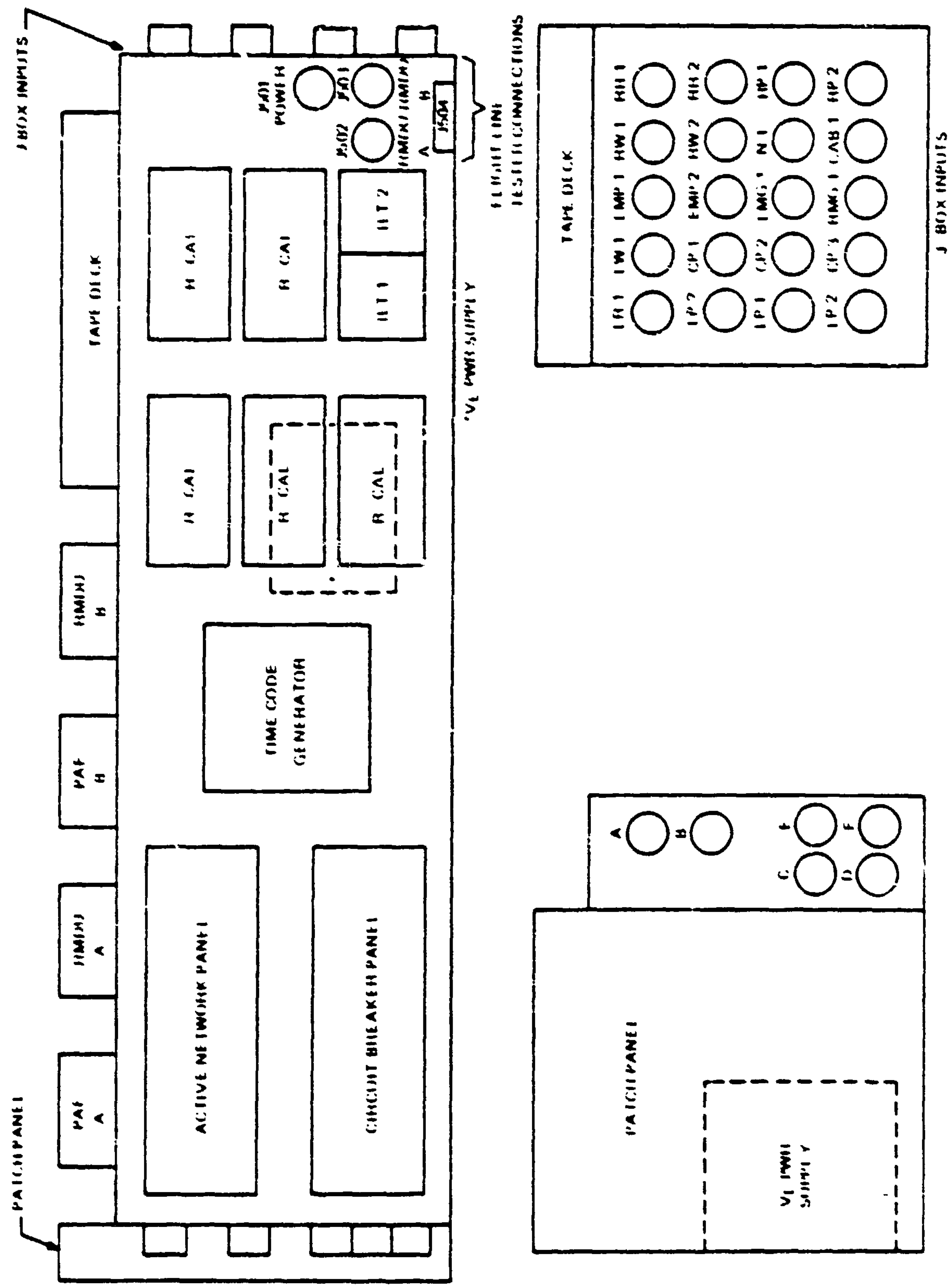

Figure 1-3. Instrumentation pallet layout.

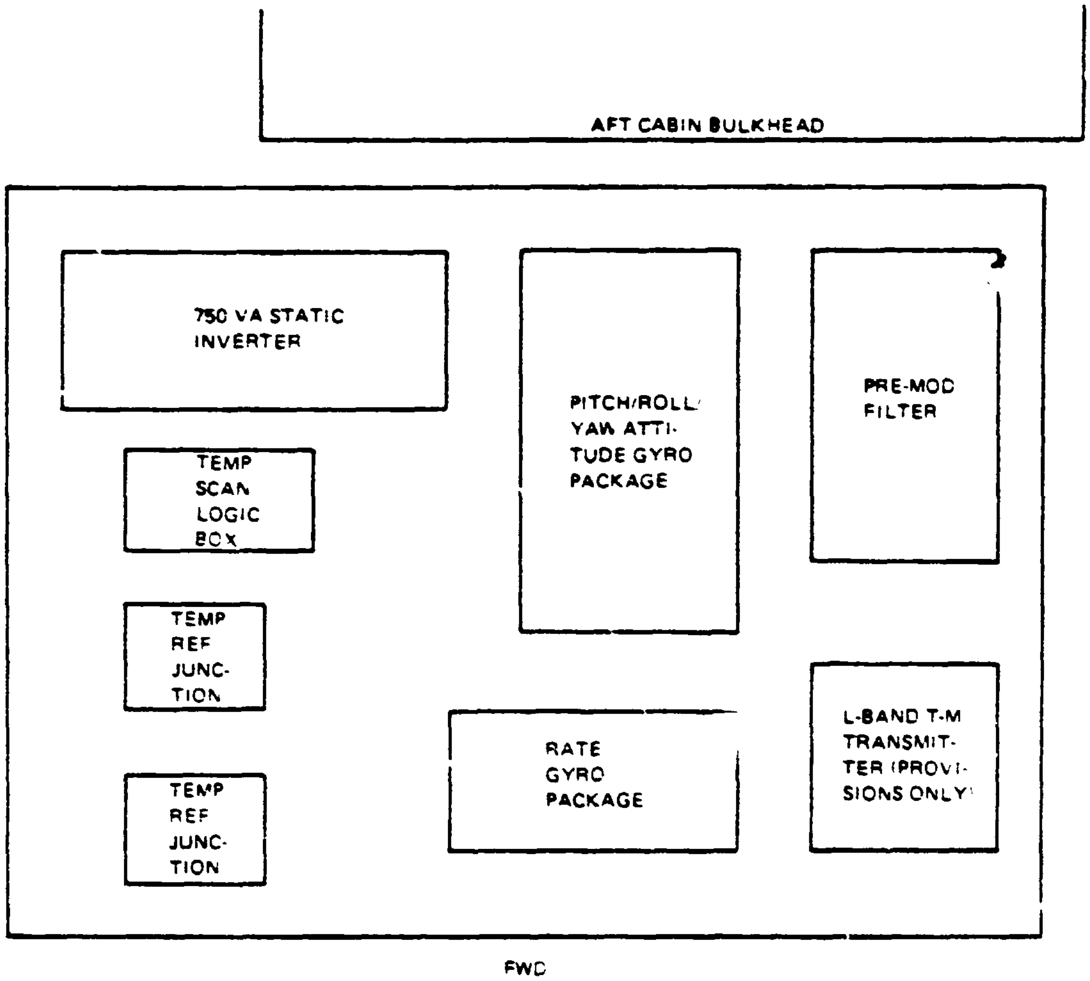

Figure 1-4. Auxiliary instrumentation pallet.

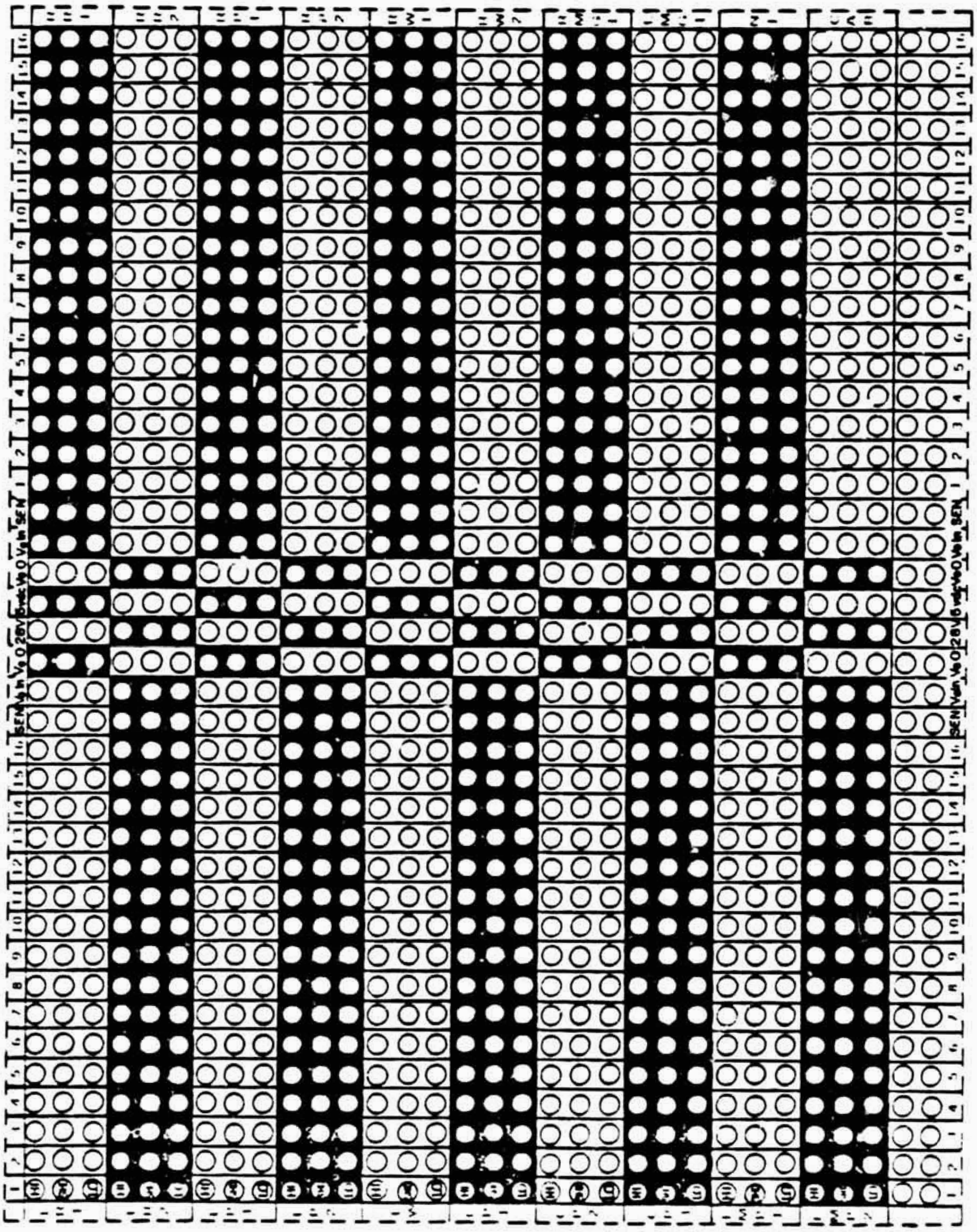

Figure 1-5. Lower program board - BHT signal cable interface.

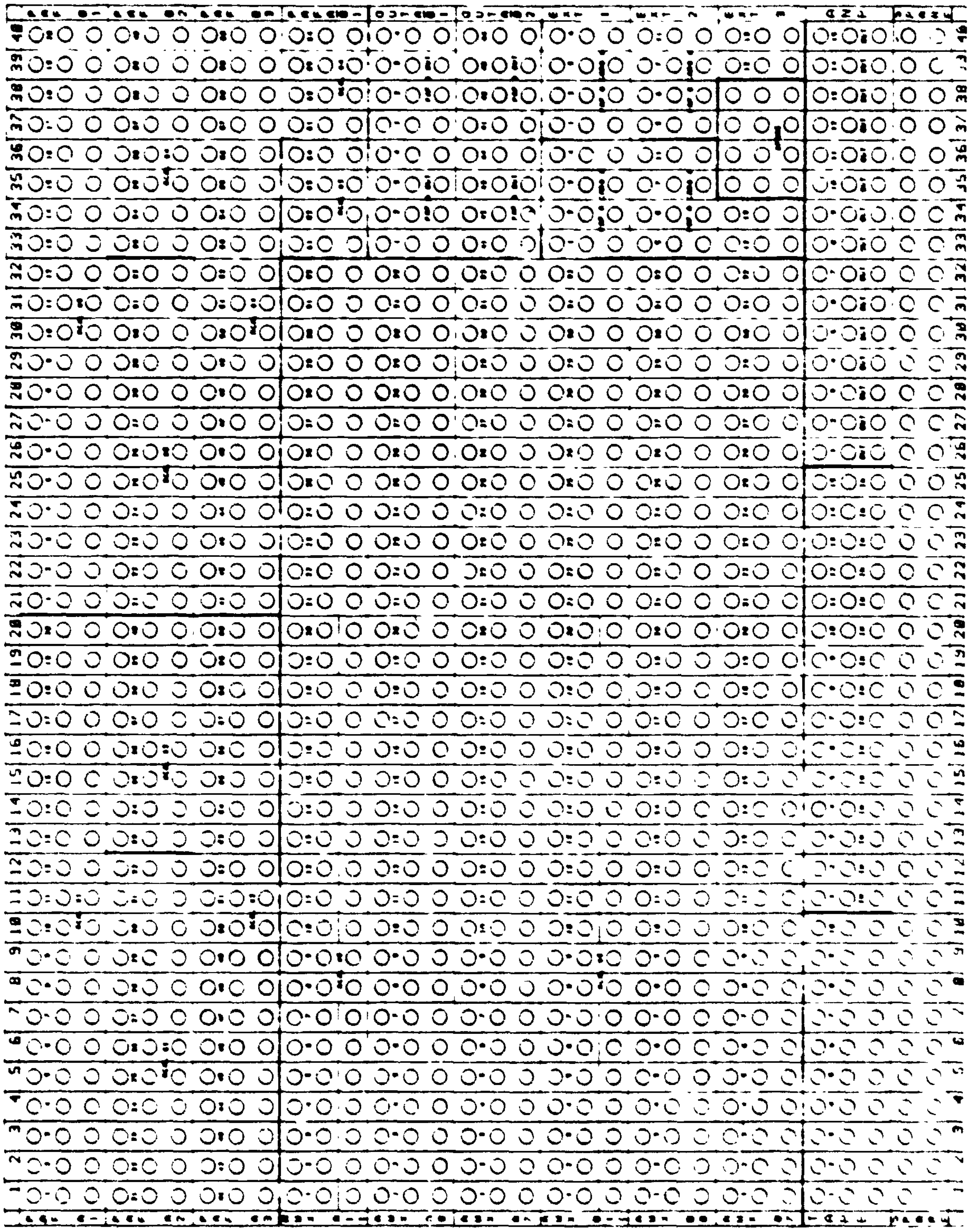

Figure 1-6. Upper program board--NASA data acquisition system interface.

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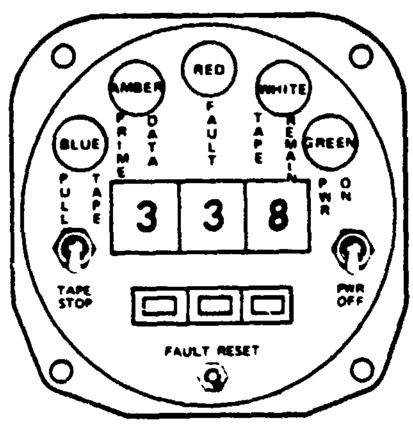
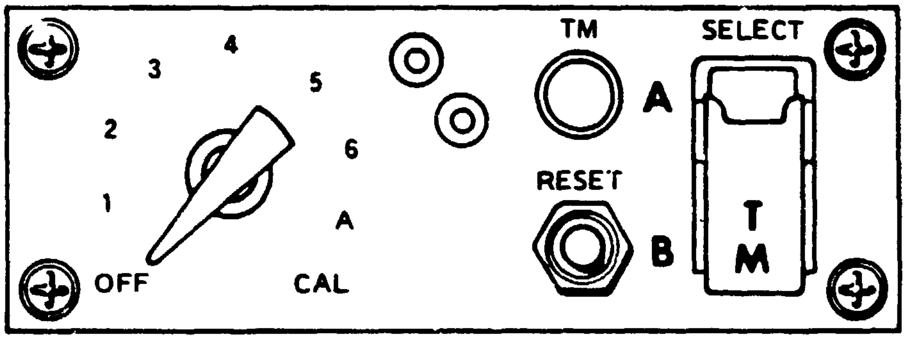
DATA RECORDER CONTROL AND MONITOR
(PILOT'S INFORMATION PANEL)



301075-25

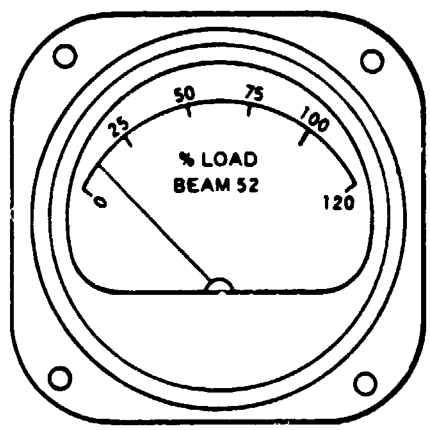
Figure 1-7. Control-monitor.



301075-39

Figure 1-8. Telemetry control panel.

CRITICAL FUNCTION MONITOR



GREEN ARC — 0 TO 100%

RED ARC — 100 TO 120%

301075-24

Weston Meter: 0—100 μamp

Figure 1-9. Critical load meter.

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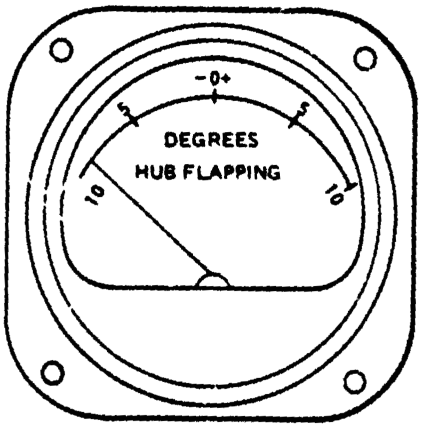
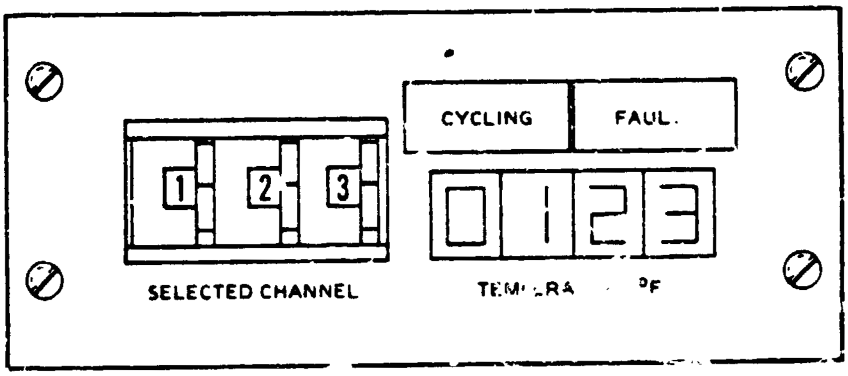
ROTOR FLAPPING INDICATOR



301075-23

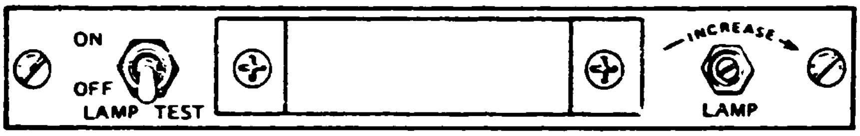
Weston Meter: 50—0—50 μamp

Figure 1-10. Flapping indicator.



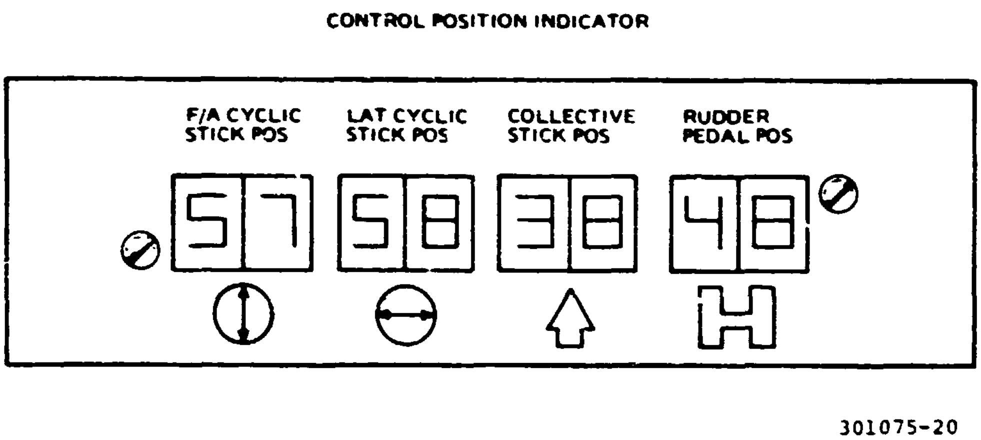
301075-22

Figure 1-11. Temperature monitor.



301075-21

Figure 1-12. Time code display panel.

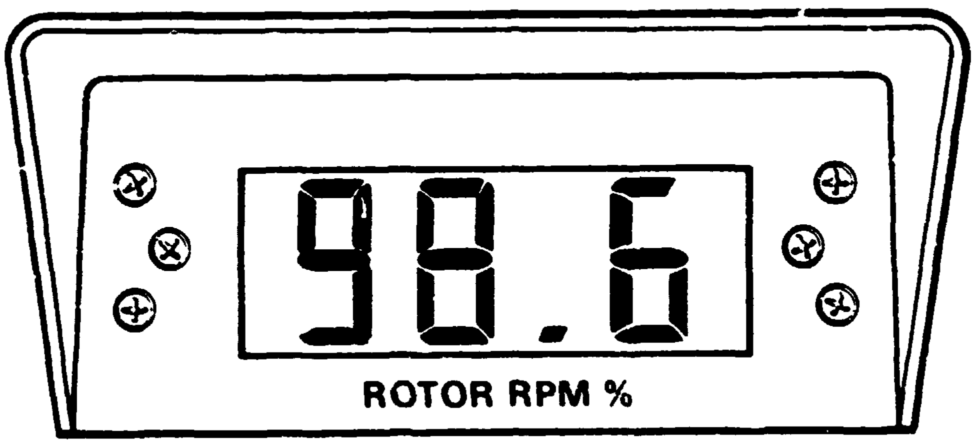


NOTE.

Control Positions are as follows:

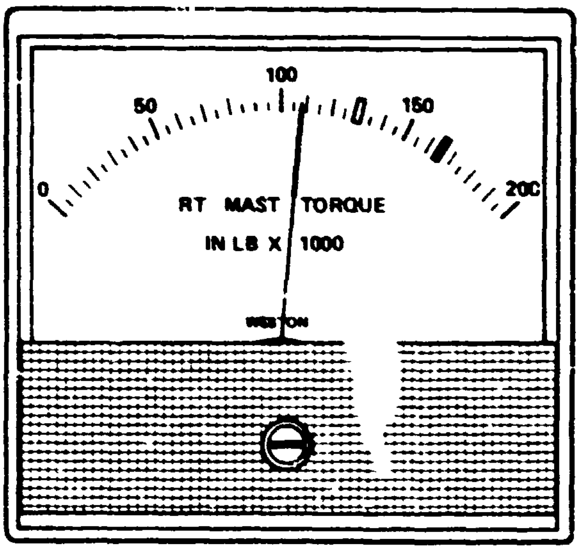
F/A Cyclic Stick — 0% Full Aft, 100% Full Fwd
Lateral Stick — 0% Full Left, 100% Full Right
Collective Stick — 0% Full Down, 100% Full Up
Rudder Pedal — 0% Full Left, 100% Full Right
100% = 00

Figure 1-13. Control position indicator.



301075-33

Figure 1-14. Digital rpm indicator.



YELLOW LINE AT 130,000 IN-LB — MAXIMUM CONTINUOUS

RED LINE AT 163,000 IN-LB — MAXIMUM TRANSIENT

301075-36

Figure 1-15. Mast torquemeter.

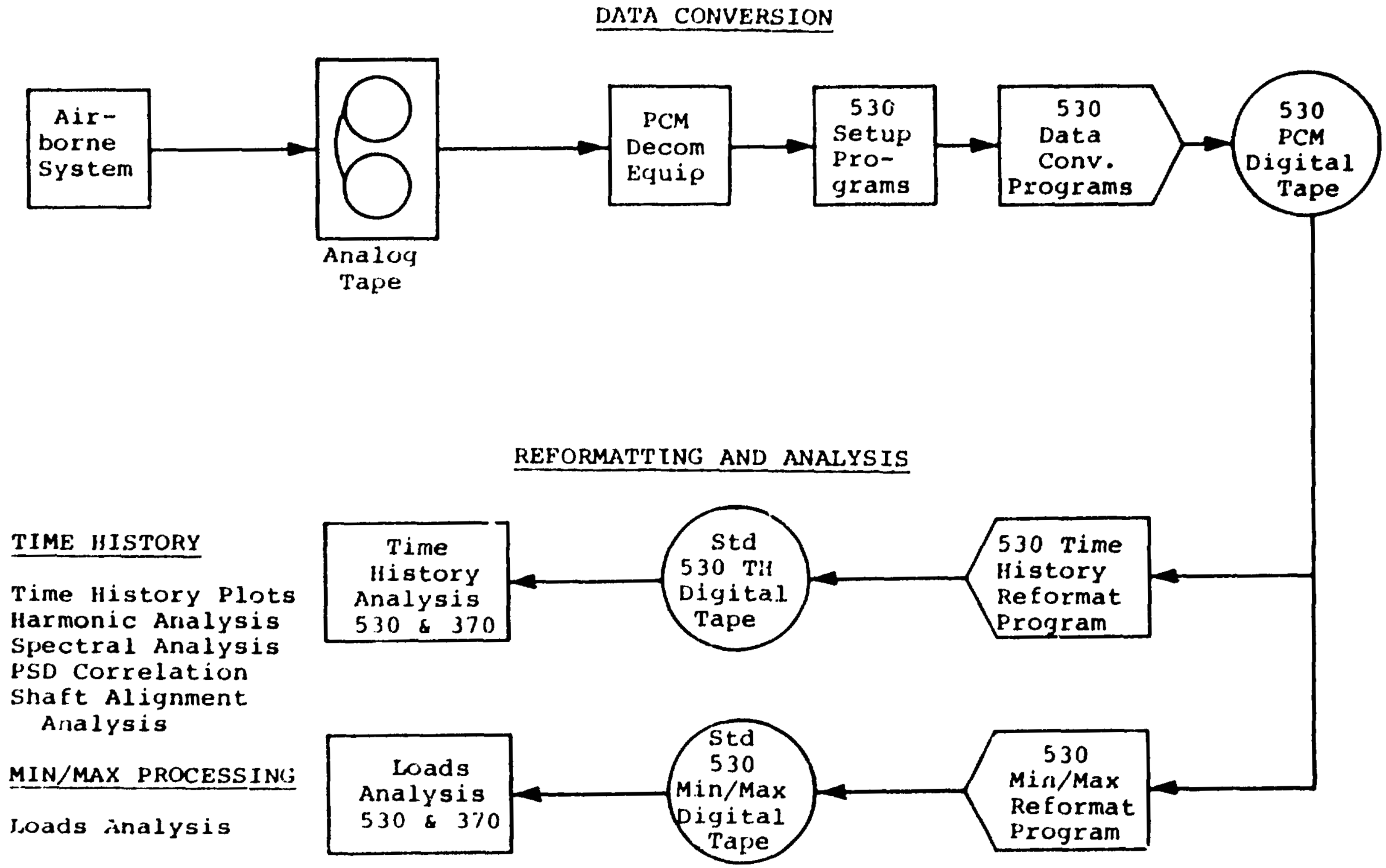


Figure 1-16. PCM data processing at the BHT ground data center.

SECTION 2. MEASUREMENTS

This section describes the measurement capabilities of the research instrumentation system. Sensor characteristics and installation are also discussed.

2.1 Propulsion System Measurements. Propulsion system measurements are centered around engine monitoring and performance data as recommended by the engine manufacturer. Transmission and interconnect system operating parameters are also included in this measurement classification. Propulsion system measurements are defined in Table 2-I.

2.1.1 Fuel Systems. Flow rate and total fuel consumed are measured for each engine by a turbine-type mass fuel flow system manufactured by Eldec Corporation. This system has buffered outputs separating the cockpit indicator from the research instrumentation system. The turbine-type fuel flow transducer furnishes a pulsed signal output to the fuel flow signal conditioner which produces a voltage output proportional to flow rate and generates a 12-bit binary word for total fuel consumed.

2.1.2 Torque Measurements. Engine torque measurements are provided by a Lycoming torque sensor system which is incorporated in the LTC1K engine. This system measures engine shaft torque by sensing the magnetostrictive effect of a ferromagnetic material. Transmission interconnect shaft torque measurements are provided by a Simmonds precision torque system. This system uses a three-gear phase displacement technique to measure shaft deflection as a function of applied torque. The data signal is available at the system signal conditioner as a high level dc signal voltage.

2.1.3 Turbine Speed Measurements. Standard tachometer generators are mounted on existing engine pads for measuring N_I and N_{II} speed. These two pole units produce a sinewave whose frequency tracks some fixed multiple of turbine rpm. This frequency is approximately 70 Hz at rated rpm. The rpm signal is routed through standard signal cables to Anadex Model PI-355 frequency to dc converters located in the cabin area. Data is transferred approximately 10 times per second to fully define rpm transients.

2.1.4 Engine Vibration Measurements. The transducers used for engine vibration measurements are ENDEVCO Model 2271A piezo-electric accelerometers. The transducer signal output is processed by a dual output charge amplifier, ENDEVO Model 2647M77. The two output signals from the special charge amplifier consist of an unbiased ac output voltage and a rectified and filtered dc level output. The ac signal output is connected to the tape recorder where it is recorded on an FM track for broad band data. The rectified dc level output which represents the average acceleration level is processed by the PCM data acquisition system and recorded as a PCM data channel.

2.1.5 Pylon and Engine Temperature Measurements. A low level temperature scanning switch (30 points/switch) will be used in each pylon. This unit provides reference junctions for 26 IC-type and 4 CA-type thermocouples. Fluid temperatures are measured by inserting a thermocouple into a fluid line through a packing gland. Case temperatures are measured by thermocouples which are silver soldered to a slotted washer placed under a convenient bolt head or nut. Compartment air temperatures are measured by an exposed silver solder thermocouple junction.

2.1.5.1 Temperature Scanning System. The temperature scanning system can be used as an instrument to monitor any relevant temperatures on a one at a time basis, or it can be used to scan through all thermocouples at a rate of 4 thermocouples per second. It cannot, however, be used to scan and monitor at the same time.

When prime data is not selected, the copilot can dial in the number corresponding to any one thermocouple and monitor its temperature on the temperature monitor (Figure 1-10). Numbers 100-129 correspond to thermocouples in the left pylon, numbers 200-229 correspond to thermocouples in the fuselage, and numbers 300-329 correspond to thermocouples in the right pylon. All other channels are inoperative.

Channels 100, 101, 102, 103, 200, 201, 202, 203, 300, 301, 302, and 303 are designed for CR-AL wire. All others are for I-CN wire.

When prime data is selected, the system automatically begins to scan. The scan begins with channels: 100 (left pylon), 200 (fuselage) and 300 (right pylon) and is synchronized with the pressure scanning system. Scanning continues until prime data is terminated or one cycle is completed. Each remote switching unit dumps its data into a separate data channel; therefore, only 30 scanning periods are required to record a complete set of temperature data.

The temperature monitor also contains two warning lights. One light is labeled FAULT. It indicates that either the temperature reference junctions are not at the proper temperature, or there is an electrical fault in the system. The other light is labeled CYCLING. The light comes on when prime data is selected and goes off when a complete set of temperature and pressure data has been recorded or prime data is terminated.

2.1.5.2 Engine Exhaust Temperature Measurements. Engine exhaust measurements are made at the engi.. turbine inlet using a Lycoming T7 thermocouple harness. This arrangement is necessary since the LTC1K-4K engine does not have provisions for additional temperature probe ports in the turbine discharge case. The average of the 4 IC thermocouples in the T7 harness are routed to the temperature scanner.

2.1.6 Pylon and Engine Pressure Measurements. A pressure scanning system is installed in the left nacelle to provide left engine inlet pressure, left engine exhaust gas pressure, and left engine compartment pressures. Additional transducers are installed to provide high frequency engine inlet pressure data at the 160 and 320 degree bellmouth positions on the left engine. Transmission compartment and nacelle static pressures are provided for the left pylon by separate pressure transducers.

2.1.6.1 Pressure Scanning System. The pressure scanning system consists of scannivalve control box, pressure ports, scannivalve and integral pressure transducer. The scannivalve is a solenoid driven rotary pressure switch capable of switching up to 48 pressure ports to the diaphragm of the integral pressure transducer. The pressure transducer is a 1/2-inch flush diaphragm unbonded strain gage unit with a ±2.5 psi range. This unit (Statham PM131) is temperature compensated between -65° and +250°F and provides ±4mV/Vex full scale output. The transducer may be removed from the scannivalve if range changes are required. The scannivalve provides position encoding for port identification and is furnished with a solid state driver for logic level drive compatibility. Physically, the scannivalve is a cylinder 1.98-inches in diameter and is 6.63-inches long. Weight is approximately 1.75 pounds. The transducer connections and pressure input ports, including reference port, are accessible at one end. Stepper connections and encoder are at the other end. The unit is mounted in the aircraft left-hand nacelle adjacent to access panels. The selected scannivalve is a Model 48J9 which requires no lubrication and is specifically designed for flight testing. When PRIME DATA is selected, the system automatically begins to scan at a rate of 4 pressure ports per second. The scan begins at the HOME position and continues to cycle until it returns to the HOME position (one complete cycle). This cycle is repeated during each PRIME DATA record.

2.1.6.2 Engine Inlet Pressure Measurements. The left engine inlet bellmouth is fitted with an inlet rake consisting of pressure probe arrays in nine azimuth positions (see Figure 2-1). The low pressure and static probes are connected through strip tubing to a scannivalve mounted ahead of the engine inlet. The two high frequency probes at the 160 and 320 degree positions are connected to separate transducers. The inlet rake is fabricated at BHT from 1/16-inch diameter stainless steel tubing. Inlet rake data provides average inlet pressure measurements and indicates inlet distortion patterns.

2.1.6.3 Engine Exhaust Measurements. Engine exhaust gas pressure measurements are made at the tail pipe. This arrangement is necessary since the LTC1K-4K engine does not have provisions for pressure ports in the turbine discharge case. The BHT stainless steel tail pipe is fitted with four static pressure ports at the locations shown in Figure 2-2. These ports are routed through the firewall with stainless steel tubing to the scannivalve.

2.2 Load Measurements. Strain gages bonded directly to aircraft structure are utilized to measure loads. Gages are placed at locations that will provide high output and linear calibrations. Most gages are foil type configured in a four-active-arm 350 ohm bridge circuit. This circuit provides benefits of self-compensation for both temperature and certain types of cross talk. Gages are applied under controlled conditions with BR600 cement. Individual gages are connected into bridges with [illegible] gage epoxy insulated wire and Budd-type foil terminal strips. Parts are then oven baked (150°F) to drive out moisture and covered with Shell 956.3 epoxy for protective covering. Testing is performed on the bridge to determine natural balance and resistance to ground. Temperature compensation is performed as required and is effective only when it may be assumed that each gage in a bridge is at the same temperature such as on control rods up to 1.5-inch diameter and other small parts. Large parts such as main rotor blades and control surfaces cannot be compensated other than with the inherent compensation of a four-active-arm bridge.

Calibration is performed by application of load and measurement of gage output. Those parts with multiple gages (wing, blades) are loaded in beam, chord, and torque. All gages are observed and cross talk is noted. If cross talk is greater than 5 percent of full scale, then regaging is generally required after reconsidering gage location. Strain gage calibrations are performed with standard load cells in series with hydraulic cylinders and a scanning digital millivoltmeter. Large parts will be calibrated on the aircraft. Tubes, links, and small parts are calibrated in fixtures. Calibration loads cover the full operating range expected of the part. Section 7 further describes calibration procedures and requirements.

Selected strain gage locations have redundant bridges installed with terminals in accessible areas. These terminals are the solder post type and become the interface between sensor and the data system. All calibration data are measured at these terminals.

2.2.1 Airframe Loads. Airframe load measurements are shown in Table 2-II and require a 50 Hz response with the exception of the wing which require a 10 per rev (100 Hz) response. All airframe load sensors are calibrated on the aircraft with the exception of those on the control tubes, support strut, conversion spindle, and actuator. Airframe co-ordinates used to define gage location are shown on Figure 3-3.

2.2.1.1 Right Wing. Upper and lower wing panel stress at the wing center section are measured with a single gage on each side of the panel at BL 0. Wing shear is measured at two stations (WS 66 and WS 142) with single gages at the front and rear spars. Right wing beam and chord bending are measured at WS 22. Right wing torque is measured at WS 22 with gages on the upper and lower wing panel surfaces fixed on diagonal axes at WS 22.

2.2.1.2 Left Wing (Aircraft No. 1 Only). Left wing beam and chord bending are measured at WS 22. Left wing torque is measured at WS 22 with gages on upper and lower wing panel surfaces fixed on diagonal axes.

2.2.1.3 Right Horizontal Stabilizer. Strain gage bridges are installed to measure beam bending moment at two locations (BL 8 and 65). Chord bending moment and torque are measured at one location (BL 8).

2.2.1.4 Right Vertical Stabilizer. Strain gage bridges are installed to measure beam bending moment on the upper portion of the vertical stabilizer at WL 110 and WL 114.

2.2.1.5 Pylon. The right and left conversion spindles are gaged at the root for bending in both planes. These planes rotate with the pylon during conversion. The right and left conversion actuator shaft trunnions are gaged for beam bending and are calibrated to measure conversion actuator axial force. The lower cowl inboard and outboard support struts on the left and right nacelles are gaged for axial load.

2.2.1.6 Control Surfaces. The various control arms or tubes are gaged with bridges measuring input force to the control surfaces. All are temperature compensated. The flap torque tubes are gaged for torque. The bending gages on the various surfaces are located approximately midway between hinge points. The horizontal stabilizer incidence actuator has been replaced by a fixed link which is gaged for axial force. If at a later date the actuator is installed, it will be gaged for axial force at the end connected to the stabilizer.

2.2.1.7 Flight Controls. The pilot's control sticks and pedals are gaged with temperature compensated bridges to measure pilot effort in pounds of force at the center of the grip or pedal. These gages will accommodate maximum pilot effort.

2.2.1.8 Landing Gear. The three gear assemblies are gaged to measure oleo strut lateral bending. Each drag strut is gaged for axial force.

2.2.2 Rotor Loads. Rotor load measurements are shown in Table 2-III. The measurements from the rotating control system pass through slip rings to make the transition to the fixed control system. The slip rings mount above the collective cross head and provide 84 circuits. The limitations on the number of circuits is based on the number of wires that can be routed through the center of the collective actuator boost tube. The core, or ring portion, is fixed and the brushes rotate with the rotor. Two contacts per circuit of silver-graphite material ride on coin silver rings. The contacts are replaceable and are designed to wear much faster than the rings. Design brush speed and wear rates show brushes should be inspected and cleaned every 50 hours. Signal shields are not carried through the slip rings to allow room for 36 signal pairs, 4 redundant voltage pairs, and 2 voltage sense pairs. This slip ring installation is accessible by removing the spinner for ease of maintenance and trouble-shooting.

All wiring in the rotating systems used highly flexible fatigue-resistant wire. Disconnects are furnished to allow teardown of pylons.

2.2.2.1 Rotor Blades. The red blade on each pylon is gaged at four stations. Each station measures beam and chord bending (except Station 22.5 which will have only a beam bridge). In addition, Station 52.5 and 112 measure torque. Blade bridges are wired together at Budd terminals at each station. Four enameled wires per bridge are then routed down the trailing edge under an epoxy coating to terminal posts close to the root end of the blade. The hub and blades are calibrated in a fixture as a unit and complete cross talk data are recorded.

2.2.2.2 Rotor Hub. Both hubs are strain gaged for beam and chord bending on each of the three spindles. Enameled wire connects the gages to accessible terminal posts. Each mast is gaged to measure bending in two planes and torque. Parallel bending is in line with the red blade and perpendicular bending is in quadrature with the red blade. Mast torque is measured by gages in a clean area of the mast close to the upper mast cage bearing. Redundant gages are installed on both masts. All gages are temperature compensated. Since the gages are out of sight under the hub spring assembly, fine super-flex wire is used to route the signals up the mast through the spline master tooth at the hub attachment to the mast. Cross talk data is provided. Tolerances are approximately halved for the torque bridges in order to maintain required accuracy for performance data.

2.2.2.3 Pitch Change Links. All three links in each rotor are gaged for axial force. These links are temperature compensated and calibrated in a test machine.

2.2.2.4 Swashplate. The links driving the swashplate of both rotors are gaged to measure driving force in pounds.

2.2.2.5 Control Boost Actuators. Three actuators are gaged with redundant bridges for each pylon. Gages measure axial force on the actuator output shaft. Each bridge is temperature compensated.

2.3 Position Measurements. Table 2-IV lists the position measurements and gives the individual transducers selected for the most direct method of measurement, for accuracy with environmental variations, for elimination of hysteresis, and for minimum weight and lack of mechanical interference. Linear cermet element potentiometers are used for position transducers because of increased life and reliability. The elements provide 10K ohm resistance in order to limit current drain and line voltage drop from the power supply. The standard transducer harness is used up to the potentiometer. The potentiometer is used as a voltage divider in the circuit and utilizes a high impedance signal conditioner in order to prevent loading of the source. Mechanical advantage is used in the form of levers, cable and pulleys, and low backlash nylon and aluminum gears in order to transform small mechanical motion into linear potentiometer travel equivalent to 60 percent to 90 percent of allowable electrical travel of the potentiometer.

Calibration of the position transducer potentiometers is accomplished after installation on the test vehicle. The calibration is done by measuring applicable surface motion relative to the transducer electrical output. The calibration accuracy must be within ±1 percent of full scale. Hysteresis and linearity are similarly limited and checked during calibration. Full mechanical travel is noted along with the current mechanical rigging of the control surface. These full throw points become points of reference until mechanical rigging is changed.

2.3.1 Airframe.

2.3.1.1 Flaps and Flaperons. The measurement of flap and flaperon positions is by direct drive with a hinge-mounted bellows type alignment coupling to a rotory pot. Control surface motion is 20 degrees up and 75 degrees down for flaps and 36 degrees up and 61 degrees down for flaperons. Calibrations and data are presented in units of degrees.

2.3.1.2 Elevator. The measurement of elevator position is made at the elevator coupled to the contol shaft. Calibrations and data are presented in units of degrees.

2.3.1.3 Rudder. Position of both rudders is measured using a linear potentiometer coupled to the rudder actuator shaft. Calibrations and data are presented in units of degrees.

2.3.1.4 Main Landing Gear. Spring-loaded cable-controlled rotary potentiometers are used to measure the relatively large motion of both actuators and both oleo extensions. The actuator displacements are calibrated in units of degrees and the oleo extensions in units of inches.

2.3.1.5 Nose Landing Gear. Two spring-loaded cable-controlled rotary potentiometers are used to measure and retraction motion between the airframe and the nose landing gear actuator and oleo extension. The oleo extension position is calibrated in units of inches displacement while actuator position is in units of degrees.

2.3.1.6 Ailerons. The measurement of aileron position is made by monitoring displacement of the left and right hand flaperon actuators. A linear potentiometer is used to sense actuator position and is calibrated in degrees of aileron displacement.

2.3.2 Pilot Controls. Primary flight controls are instrumented to measure pilot control position.

2.3.2.1 Control Stick (Cyclic Stick). Rotary potentiometers are used in close proximity to the stick to sense position. Fore and aft as well as lateral motion is sensed and calibrated in percent of full travel from full aft (0%) and full left (0%) positions.

2.3.2.2 Power Lever (Collective Stick). A linear potentiometer is connected to the power lever and calibrated in percent of full travel from the full down (0%) position.

2.3.2.3 Rudder Pedals. A rotary potentiometer is connected between the rudder pedals to sense position. The motion is calibrated in percent of full left and right travel from neutral position (0%).

2.3.2.4 Throttle (Fuel Control Lever). The throttle position is measured by using a rotary potentiometer at the gas producer fuel control lever on each engine. The positions are calibrated in units of degrees.

2.3.2.5 Flap Controls. A voltage divider circuit is installed to measure the flap lever inputs from the pilot The lever input is calibrated in units of degrees.

2.3.2.6 SCAS System. The stability and control augmentation system inputs are measured by installing linear potentiometers on the fore and aft SCAS actuator, on the lateral SCAS actuator, and on the directional SCAS actuator. Each of these actuators is calibrated in units of inches displacement.

2.3.2.7 Differential Cyclic Washout Actuator. The electro-mechanical differential cyclic washout actuator has a linear potentiometer installed across the actuator which is used to measure actuator position. The potentiometer is calibrated in inches.

2.3.3 Rotor Positions.

2.3.3.1 Hub Spring Motion. Spring-loaded pull-string potentiometers are installed to measure the hub spring position relative to the pylon in the fore and aft as well as lateral planes. These measurements are made on both hubs. Calibrations are in units of degrees.

2.3.3.2 Gimbal Trunnion Flapping. The gimbal trunnion flapping position is measured at each hub. This measurement is made using gear-driven rotary potentiometers between the hub and mast. Calibrations are in units of degrees.

2.3.3.3 Red Blade Feathering. Red blade feathering position is measured on each rotor. This measurement is made using gears to drive a rotary potentiometer located on the collective lever (walking beam). Calibration is in units of degrees.

2.3.3.4 Collective Motion. The collective input at the hub is measured using linear potentiometers at the collective slider on both the left and right rotors. Calibration units are in degrees of blade angle.

2.3.3.5 Swashplate Motion. Linear potentiometers are installed to measure swashplate motion in the fore and aft as well as lateral planes. Both left and right hand swashplates are measured. Calibration units are in degrees of angular motion.

2.3.3.6 Conversion Angle. Synchro transmitters are linked to the transmission conversion spindle to measure the pylon angle during conversion. Synchro-to-dc converters are installed to provide the desired input to the data acquisition system. Both right and left pylons are measured at the axis of rotation at the wingtip. Calibrations are in units of degrees.

2.3.3.7 Rotor Azimuth. A light-interrupted photo cell is used to determine the position of the rotor within 1/512 of a revolution. Another photo cell provides one output per revolution in order to index the higher pulse rate to the red blade.

2.4 Miscellaneous Measurements. Three categories are covered under this heading: aircraft state measurements, system monitors, and accelerations. These measurements are given in Table 2-V.

2.4.1 Aircraft State Measurements. These measurements relate to the rigid-body response of the aircraft with respect to the outside world. This group of variables provides essential performance and handling qualities data and therefore must be measured with high accuracy. System calibrations are performed on the aircraft with the exception of the rate gyros.

2.4.1.1 Airspeed. Pitot and static pressure ports are located in the GFE nose boom data head. Pitot and static pressure lines are routed from the nose boom to a Rosemount differential pressure transducer (Type 542K) whose range is 0 to 5 psid or 350 knots full scale. This transducer has excellent specifications for helicopter environment and is a capacitive-sensed, temperature-compensated diaphragm unit. Excitation is 28 ± 4 volts dc and output is 0 to 7 volts dc. Linearity is ±0.1 percent full scale, hysteresis is ±0.02 percent full scale. Temperature variations are less than ±1 percent full scale from 25° to 125°F, referenced to 75°F. The pilot's airspeed indicator is connected to the nose boom data system. The copilot's airspeed indicator is connected to the aircraft's pitot-static system.

2.4.1.2 Altitude. Altitude is recorded from the same transducer as airspeed. The Rosemount transducer (Type 542K) measures absolute pressure from 0 to 10 psia. Output voltage is proportional to nose boom static pressure, 0 to 8.2 volts for -1,000 to 40,000 feet of altitude. Radar altitude will be furnished by the recorder output of the radar altimeter electronics.

2.4.1.3 Outside Air Temperature. A Rosemount total (ram free) temperature probe in conjunction with Rosemount linearizing electronics provides air temperature data as a high level (0-5 volts dc) signal. The OAT sensor is mounted under the nose of the aircraft.

2.4.1.4 Relative Wind Angle. Angle of attack and angle of sideslip is furnished by the GFE data head on the nose boom. A dual element potentiometer furnishes one signal to the data system and one signal to a cockpit display.

2.4.1.5 Aircraft Attitude. Pitch. roll, and yaw angles are measured with Humphrey modified M.H. 7044 vertical gyros located on the auxiliary instrumentation pallet. Pitch and roll angles are measured by one gyro. Yaw angles are measured by another identical gyro which is mounted on its end. These gyros have erection motors and can be caged.

2.4.1.6 Aircraft Angular Rates. A three-axis packaged rate gyro located on the auxiliary instrumentation pallet provides angular rate data. The gyro is powered with 28 ± 4 volts dc and provides ±5.4 volts dc outputs for ±70 degrees pe second input rates. This unit is calibrated on a standard rate table and incorporates a self-test torque device.

2.4.1.7 Vertical Acceleration. A servo force balance accelerometer (Kistler Model 303) measures mean acceleration at the aircraft center of gravity. A filter network is incorporated in the servo feedback loop to restrain the sensing mass from high frequency effects. The cutoff frequency for this unit is 5 Hz. This unit provides ±5 volts dc output for ±2.5g input and is powered by 28 ± 10 percent volts dc. A self-test torque coil is provided.

2.4.2 Aircraft System Monitors. The primary aircraft systems that are monitored are the hydraulic system. the electrical system, and the fuel system. Critical structural temperature measurements are also monitored.

2.4.2.1 Hydraulic System. Three Statham Model PL722TC, 0-5000 psi, general purpose unidirectional pressure transducers are installed, one in each system. These transducers utilize a diaphragm attached to a 350 ohm resistive unbonded strain gage bridge arranged into a four-active-element configuration. Full-scale output is 5 mv/V. Hysteresis and linearity are ±0.75 percent full scale. Thermal shift is 0.01 percent full scale per degree F and zero shift is 0.01 percent full scale per degree F. The units are temperature-compensated from -65° to +250°F. Natural frequency is 50 KHz. Response to acceleration is 0.01 percent full scale per g. The transducers are installed close to the pressure source and are calibrated with a dead-weight tester.

2.4.2.2 Electrical System. A calibrated shunt is installed into both the left-hand and right-hand direct current electrical systems between the source and the distribution buses. At the shunt, voltage is monitored by use of a voltage divider. Current is related to the voltage drop produced by the shunt and similarly measured as a voltage. The circuits for recording these data are calibrated on the aircraft. These signals are checked using a calibrated digital voltmeter at the point of introduction into the instrumentation system.

2.4.2.3 Fuel System. Fuel quanitty measurements are provided for right and left fuel tanks. Fuel quantity data is taken from the Simmonds capacitance-type fuel quantity measuring system consisting of a signal conditioner and fuel tank probe assembly. (Fuel flow and total fuel consumed measurements are described in 2.1.1.)

2.4.2.4 Temperature. Three 30-point temperature scanners (reference 2.1.5.1 for description of thermocouple scanning system) are installed to monitor critical structural temperatures. One will be located in the left nacelle, one in the right nacelle, and one in the fuselage.

2.4.2.5 Oil Pressure. Four Statham Model PL722TC, 0-150 psi, general purpose unidirectional pressure transducers are installed one on each engine and one on each transmission. These transducers utilize a diaphragm attached to a 350-ohm resistive unbonded strain gage bridge arranged into a four-active-element configuration. Full-scale output is 5 mv/V. Hysteresis and linearity are ±0.75 percent full scale. Thermal shift is 0.01 percent full scale per degree F and zero shift is 0.01 percent full scale per degree F. The units are temperature compensated from -65° to +250°F. Natural frequency is 50 KHz. Response to acceleration is 0.01 percent full scale per g. The transducers are installed close to the pressure source and are calibrated with a dead weight tester.

2.4.3 Aircraft Accelerations. Statham Model A69TC linear accelerometers are used to measure acceleration. These accelerometers employ viscous liquid to achieve 0.7 of critical damping at room temperature. They are temperature compensated between -65° and +250°F, limiting the thermal sensitivity shift to below 0.01 percent per degree F and the thermal zero shift to 0.01 percent full scale per degree F. Full scale output is approximately four mv/V from the four-active-arm unbonded 350-ohm strain gage element. Linearlity and hysteresis are 0.75 percent of full scale and transverse acceleration response is 0.01 g/g. Flat frequency response is 260 Hz. The weight per unit is three ounces. This small size was selected so very little change in specimen dynamic characteristics would be encountered when the units are installed. Units are calibrated on a electromagnetic shaker with a standard accelerometer for reference. Upon installation, all units are bolted tightly in place to ensure sensing only airframe acceleration.

2.4.3.1 Aircraft Center of Gravity. A cluster of three accelerometers mounted triaxially are installed. The cluster is located in close proximity to airframe BL 0 and STA 212 on the deck and aligned for lateral, vertical, and fore and aft measurements. The Statham Model A69TC, ±5g accelerometers are installed and calibrated in units of g.

2.4.3.2 Pylons. Each pylon has a triaxial cluster of three Statham A69TC, ±10g accelerometers installed to the pylon structure. Each cluster is aligned for fore and aft, lateral, and vertical acceleration measurements. The units are calibrated in units of g.

2.4.4 Sensor Excitation Voltage. Sensor excitation voltage is monitored at each of the 20 junction boxes.

2.5 Airspeed Boom and Trailing Cone Installation. A nose boom is fabricated of two-inch O.D., 1/8-wall aluminum tube extending four feet two inches ahead of the aircraft nose to adapt to a GFE head containing pitot, static, angle-of-attack, and angle-of-sideslip detectors. Necessary plumbing and electrical harnesses are installed.

An adapter is provided at the aft fuselage and similarly wired and plumbed for a GFE trailing cone.

2.6 Measurement Item Codes. Each sensor requirement is assigned an item code consisting of an alpha prefix which designates the measurement type followed by a three-digit number. The three-digit numbers are assigned sequentially from designated blocks representing sensor location. Table 2-VI defines the alpha measurement types and the number assignments used in the item code. Table 2-VII lists item codes in numerical order. Open item codes are included for future use.

TABLE 2-I. PROPULSION SYSTEM MEASUREMENTS

Area	Location	Description	Item Code	Number & Type of Channels	Units	Response (hertz)	Approx Full Scale Xducer Signal Output	Transducer
Fuel systems	Right engine	Total fuel	R516	**1 DMX	lb			Mass fuel flow
	Left engine	Total fuel	R517	**1 DMX	lb			Mass fuel flow
	Right engine	Fuel flow rate	R328	1 AMX	lbs/hr	10		Mass fuel flow
	Left engine	Fuel flow rate	R329	1 AMX	lbs/hr	10		Mass Fuel Flow
Torque system	Right engine	Torque	M335	1 AMX	in.-lb	50	±2.5 V	Magnetostrictive
	Left engine	Torque	M336	1 AMX	in.-lb	50		Magnetostrictive
	Interconnect	Torque (Simmonds Precision system)	M337	1 AMX	in.-lb	50		Phase Shift
Turbine speeds	Right engine	Gas producer speed (N_I)	R503	1 AMX	rpm	50		Tachometer generator
	Left engine	Gas producer speed (N_I)	R515	1 AMX	rpm	50		Tachometer generator
	Right engine	Power turbine speed (N_{II})	R338	1 AMX	rpm	10		Tachometer generator
	Left engine	Power turbine speed (N_{II})	R339	1 AMX	rpm	10	±2.5 V	Tachometer generator
Engine vibration	Right engine	Inlet case - fore and aft	A500	1 AMX	g	50	±5 V	Accelerometer
		Inlet case - vertical	A502	1 AMX	g		±5 V	Accelerometer
		Inlet case - lateral	A501	1 AMX	g		±5 V	Accelerometer } RMS detector
	Left engine	Inlet case - fore and aft	A507	1 AMX	g		±5 V	Accelerometer
		Inlet case - vertical	A514	1 AMX	g		±5 V	Accelerometer
		Inlet case - lateral	A508	1 AMX	g	50	±5 V	Accelerometer
Pylon temperatures	Right system	1. Transmission compartment ambient	T506	1 AMX*	°F	100	6 mV	Temperature scanner
		2. Blower air - outlet of heat exchanger						
		3. Transmission oil into cooler						
		4. Transmission oil into cooler						
		5. Transmission case surface						
		6. Transmission case surface	T506	1 AMX*	°F	100	6 mV	Temperature scanner

*Thermocouples go through a switch and appear as a single channel at the program board.
**12-bit binary word

TABLE 2-I. (CONTINUED)

Area	Location	Description	Item Code	Number & Type of Channels	Units	Response (hertz)	Approx Full Scale Xducer Signal Output	Transducer
	Right system (continued)	7. Transmission case surface	T506	1 AMX*	°F	100	6 mV	Temperature scanner
		8. Transmission case surface						
		9. ECU bleed air to swivel						
		10. PC_2 hyd reservoir pressure port						
		11. Engine oil outlet						
		12. Turbine inlet (Lycoming T-7 harness)						
		PC_2 hyd cooler fluid in						
		PC_2 hyd cooler fluid out						
		ECU cooler bleed air in						
		Fuel						
		Engine inlet housing						
		Engine accessory housing						
		Engine axial compressor						
		Engine centrifugal compressor						
	⚠	Engine compressor diffuser						
		Engine exhaust diffuser						
		Engine ignition unit						
		Engine fuel control						
		Engine igniter solenoid valve						
		Engine air bleed control						
		Engine thermocouple harness connector						
		Starter generator						
		N_1 techometer generator						
		Engine compartment above inlet						
		Tail pipe fairing compartment	T506	1 AMX*	°F	100	6 mV	Temperature scanner

*Thermocouples go through a switch and appear as a single channel at the program board. Sensitivities are 1 mV - 100°F

TABLE 2-I. (CONTINUED)

Area	Location	Description	Item Code	Number & Type of Channels	Units	Response (hertz)	Approx Full Scale Xducer Signal Output	Transducer
	Left system ⚠2	1. Transmission compartment ambient 2. Blower air outlet of heat exchanger 3. Transmission oil into cooler 4. Transmission oil out of cooler 5. Transmission case surface 6. Transmission case surface 7. Transmission case surface 8. Transmission case surface 9. PC_1 hyd reservoir pressure port 10. PC_3 hyd reservoir pressure port 11. Engine oil outlet 12. Turbine inlet (Lycoming T-7 harness) PC_1 hyd cooler fluid in PC_1 hyd cooler fluid out PC_3 hyd cooler fluid in PC_3 hyd cooler fluid out Inlet temperature 0° position Inlet temperature 120° position Inlet temperature 240° position Transmission case surface Transmission case surface Transmission case surface	T513	1 AMX*	°F	100	6 mV	Temperature scanner

* Thermocouples go through a switch and appear as a single channel at the program board. One for each pylon and one for the fuselage. Sensitivities are 1 mV = 100°F.

TABLE 2-I. (CONCLUDED)

Area	Location	Description	Item Code	Number & Type of Channels	Units	Response (hertz)	Approx Full Scale Xducer Signal Output	Transducer
Pylon pressures	Right system (3)	Atmospheric (static ref)	P505	1 PSF	psi	100	±10 mV	Pressure Transducer
		Transmission compartment static	P504	1 PSF	psi	100	±10 mV	Pressure Transducer
	Left system (4)	Atmospheric (static ref) Transmission compartment static Engine compartment air scoop (Total and static - 5 ports) Engine inlet bell mouth (Total and static - 39 ports) Engine tail pipe (Static - 4 ports)	P512	1 PSF	psi	100	±10 mV	Scanivalve
		Engine inlet bell mouth High frequency @ 160°	P518	1 AMX	psi	100	50 mV	Transducer
		Engine inlet bell mouth High frequency @ 320°	P519	1 AMX	psi	100	50 mV	Transducer

(1) These 19 measurements may not be required after cooling and temperature surveys are documented.

(2) These 10 measurements may not be required after cooling, temperature, and inlet surveys are documented.

(3) These 2 measurements may not be required after temperature and cooling surveys are documented.

(4) These 52 measurements may not be required after cooling, temperature, inlet, and tail pipe surveys are documented.

TABLE 2-II. AIRFRAME LOAD MEASUREMENTS

Area	Location	Description	Item Code	Number & Type of Channels	Units	Response (hertz)	Approx Full Scale Xducer Signal Output	Transducer
Right Wing	BL 0.0	Upper panel outer skin stress	S628	1 PSF	in.-lb	50	±5 mV	4-arm strain gage
		Lower panel outer skin stress	S629					
		Upper panel inner skin stress	S609					
		Lower Panel inner skin stress	S610					
	WS 22.0	Wing chord bending	B603					
		Wing beam bending	B600					
		Wing torque	M606				±5 mV	
	WS 66.0	Wing front spar shear (upper)	S630				±2.5 mV	
		Wing front spar shear (lower)	S631					
		Wing rear spar shear (upper)	S632					
		Wing rear spar shear (lower)	S633					
	WS 142.0	Wing front spar shear (upper)	S634					
		Wing front spar shear (lower)	S635					
		Wing rear spar shear (upper)	S636					
		Wing rear spar shear (lower)	S637					
Left Wing	WS 22.0	Left wing chord bending	B625					
		Left wing beam	B626					
		Left wing torque	M627					
Right horizontal stabilizer								
	BL 7.7	Beam bending	B262					
	BL 7.7	Chord bending	B263					
	BL 8.0	Torque bending	M266					
Left horizontal stabilizer	BL 65.0	Beam bending	B264					
	BL 7.7	Beam bending	B242			50	±2.5 mV	
Right vertical stabilizer						100	±5 mV	
	WL 108.9	Beam bending	B270				±5 mV	
							±2.5 mV	
	WL 114.0	Beam bending	B268					
						100		
Right pylon								
Pylon conversion spindle	*	Beam bending	B165			50		
		Chord bending	B166	1 PSF	in.-lb	50	±2.5 mV	4-arm strain gage

TABLE 2-II. (CONTINUED)

Area	Location	Description	Item Code	Number & Type of Channels	Units	Response (hertz)	Approx Full Scale Xducer Signal Output	Transducer
Pylon conversion actuator		Axial load	F611	1 PSF	lb	100	±50 mV	4-arm strain gage
Cowl support		Lower cowl outboard support strut axial load	F522			50	±10 mV	
		Lower cowl inboard support strut axial load	F523		lb	50	±10 mV	
Left Pylon								
Pylon conversion spindle		Beam bending	B190	1 PSF	in.-lb.	50	±2.5 mV	
		Chord bending	B191	1 PSF	in.-lb.	50	±2.5 mV	
Pylon conversion actuator		Axial load	F638	1 PSF	lb	100	±50 mV	
Cowl support		Lower cowl outboard support strut axial load	F520			50	±10 mV	
		Lower cowl inboard support strut axial load	F521		lb	50		
Control surfaces								
Right flap	WS 25.0	Drive tube torque	M612		in.-lb	100		
		Beam bending	B613					
Left flap		Drive tube torque	M619		in.-lb			
		Beam bending	B618					
Right flaperon	WS 107.0	Control arm force	F614		lb			
		Beam bending	B615		in.-lb			
Left flaperon		Control arm force	F621		lb			
		Beam bending	B622	1 PSF	in.-lb	100	±10 mV	4-arm strain gage

TABLE 2-II. (CONTINUED)

Area	Location	Description	Item Code	Number & Type of Channels	Units	Response (hertz)	Approx Full Scale Xducer Signal Output	Transducer
Elevator								
Right elevator	BL 3.8 BL 49.5	Drive tube torque Beam bending	M275 B274	1 PSF	lb in.-lb	100	±10 mV	4-arm strain gage
Left elevator	BL 3.8 BL 49.5	Drive tube torque Beam bending	M279 B282	1 PSF	lb in.-lb			
Right rudder	WL 105.93 WL 118.76	Drive tube torque Beam bending	M276 B278	1 PSF	lb in.-lb			
Left rudder	WL 105.93 WL 118.76	Drive tube torque Beam bending	M277 B280	1 PSF	lb in.-lb			
Horizontal* Stabilizer		Incidence actuator force	F286	1 AMX	lb	100	±10 mV	4-arm strain gage

* To be used at a later date.

TABLE 2-II. (CONTINUED)

Area	Location	Description	Item Code	Number & Type of Channels	Units	Response (hertz)	Approx Full Scale Xducer Signal Output	Transducer
Pilot flight controls								
Cyclic stick		Fore and aft force Lateral force	F330 F331	1 PSF	lb	10	±25 mV	4-arm strain gage
Right pedal		Force	F333					
Left pedal		Force	F334	1 PSF	lb	10	±25 mV	
Landing gear, right main								
				1 AMX	in.-lb	50	±10 mV	
Oleo strut		Lateral bending	B316		in.-lb		±10 mV	
Drag strut		Axial force	F303		lb		±25 mV	
Landing gear, left main								
					in.-lb		±10 mV	
Oleo strut		Lateral bending	B312		in.-lb		±10 mV	
Drag strut		Axial force	F313	1 AMX	lb	50	±25 mV	4-arm strain gage

TABLE 2-II. (CONCLUDED)

Area	Location	Description	Item Code	Number & Type of Channels	Units	Response (hertz)	Approx Full Scale Xducer Signal Output	Transducer
Nose gear								
Oleo strut trunnion		Lateral bending (right) Lateral bending (left)	B343	1 AMX	in.-lb	50	±10 mV	4-arm strain gage
Drag strut		Axial force	F847	1 AMX	lb	50	±25 mV	4-arm strain gage

TABLE 2-III. ROTOR LOAD MEASUREMENTS

Area	Location	Description	Item Code	Number & Type of Channels	Units	Response (hertz)	Approx Full Scale Xducer Signal Output	Transducer
Rotor blade	Sta 9.5	Leading edge stress	S145	1 PSF	psi	100	±10 mV	4-arm strain gage
		Trailing edge stress	S146		psi			
Right rotor red blade	Sta 22.8	Beam bending	B120		in. lb		±5 mV	
	Sta 52.5	Beam bending	B172				±25 mV	
		Chord bending	B123				±25 mV	
		Torque	M129				±25 mV	
	Sta 75.0	Beam bending	B124				±10 mV	
		Chord bending	B125				±10 mV	
	Sta 112.5	Beam bending	B126				±10 mV	
		Chord bending	B127				±5 mV	
		Torque	M128				±10 mV	
Left rotor red blade	Sta 22.8	Beam bending	B130				±5 mV	
	Sta 52.5	Beam bending	B132				±25 mV	
		Chord bending	B133				±25 mV	
		Torque	M139				±25 mV	
	Sta 75.0	Beam bending	B134				±10 mV	
		Chord bending	B135				±10 mV	
	Sta 112.5	Beam bending	B136				±10 mV	
		Chord bending	B137				±5 mV	
		Torque	M138		in.-lb		±10 mV	
Left rotor red blade	Sta 9.5	Leading edge stress	S147		psi		±10 mV	
		Trailing edge stress	S148				±10 mV	
Rotor hub								
Right red spindle	Sta 9.0	Beam bending	B112				±5 mV	
		Chord bending	B113		psi		±5 mV	
Right white spindle	Sta 9.0	Beam bending	B171		in.-lb		±5 mV	
		Chord bending	B172					
Right Green spindle	Sta 9.0	Beam bending	B173				±5 mV	
		Chord bending	B174	1 PSF	in.-lb	100	±5 mV	4-arm strain gage

TABLE 2-III. (CONTINUED)

Area	Location	Description	Item Code	Number & Type of Channels	Units	Response (hertz)	Approx Full Scale Xducer Signal Output	Transducer
Left red spindle	Sta 9.0	Beam bending	B114	1 PSF	in.-lb	100	±5 mV	4-arm strain gage
		Chord bending	B115	↓	↓	↓	↓	↓
Left white spindle	Sta 9.0	Beam bending	B192	↓	↓	↓	↓	↓
		Chord bending	B193	↓	↓	↓	↓	↓
Left green spindle	Sta 9.0	Beam bending	B194	↓	↓	↓	↓	↓
		Chord bending	B195	↓	↓	↓	↓	↓
Right mast		Parallel bending	B108	↓	↓	↓	↓	↓
		Perpendicular bending	B109	↓	↓	↓	±5 mV	↓
		Torque	M107	1 PSF	in.-lb	100	±2.5 mV	4-arm strain gage

TABLE 2-III. (CONTINUED)

Area	Location	Description	Item Code	Number & Type of Channels	Units	Response (hertz)	Approx Full Scale Xducer Signal Output	Transducer
Left mast		Parallel bending	B140	1 PSF	in.-lb	100	±5 mV	4-arm strain gage
		Perpendicular bending	B141				±5 mV	
		Torque	M143				±2.5 mV	
					in.-lb			
Rotor pitch change links								
	Right	Red link axial force	F103		lb		±5 mV	
		White link axial force	F104					
		Green link axial force	F055					
	Left	Red link axial force	F060					
		White link axial force	F061					
		Green link axial force	F062					
Swashplate drive link								
	Right	Driver bending	B052					
	Left	Driver bending	B147	1 PSF	lb	100	±5 mV	4-arm strain gage

TABLE 2-III. (CONCLUDED)

Area	Location	Description	Item Code	Number & Type of Channels	Units	Response (hertz)	Approx Full Scale Xducer Signal Output	Transducer
Control boost actuators								
	Right pylon	Cyclic fore and aft axial force	F162	1 PSF	lb	100	±5 mV	4-arm strain gage
		Lateral axial force	F163	↕	↕	↕	↕	↕
		Collective axial force	F164	↕	↕	↕	↕	↕
	Left pylon	Cyclic fore and aft axial force	F187	↕	↕	↕	↕	↕
		Lateral axial force	F188	↕	↕	↕	↕	↕
		Collective axial force	F189	1 PSF	lb	100	±5 mV	4-arm strain gage

TABLE 2-IV. POSITION MEASUREMENTS

Area	Location	Description	Item Code	Number & Type of Channels	Units	Response (hertz)	Approx Full Scale Xducer Signal Output	Transducer
Airframe								
Flaps and flaperons	Right flap	Position measurement	D617	1 AMX	deg	10	±3 mV	Rotary potentiometer
Elevator	Right elevator		D281					
Rudder	Right rudder		D284					Rotary potentiometer
Main landing	Right actuator		D317		deg			Cable potentiometer
	Oleo extension		D305		in.			
	Left actuator		D314		deg			
	Oleo extension		D315		in.			
Nose landing gear	Actuator		D348		deg			
	Oleo extension		D349		in.			
					deg			Cable potentiometer
Horizontal* Stabilizer	Incidence actuator		D287		deg			Linear potentiometer
Ailerons	Right		D645		deg			
	Left	Position measurement	D646	1 AMX	deg	10	±3 mV	Linear potentiometer

* To be used at a later date.

TABLE 2-IV. (CONTINUED)

Area	Location	Description	Item Code	Number & Type of Channels	Units	Response (hertz)	Approx Full Scale Xducer Signal Output	Transducer
Pilot controls								
Cyclic stick	Fore and aft	Position measurement	D021	1 AMX	percent	10	±3 V	Rotary potentiometer
	Lateral		D022		percent			
Power lever			D023		percent			
Rudder pedals			D024		percent			
Fuel Control lever	Right		D509		deg			
	Left		D510		deg			
Flap controls	Flap lever		D309		deg	10		Rotary potentiometer
SCAS system	Fore and aft		D306		in.	50		Linear potentiometer
	Lateral		D307		in.	50		
	Directional		D308		in.	50		
Diff. cyc. washout act pos.			D318		in.	10		Linear potentiometer
Rotor positions								
Hub spring motion.	Right - fore and aft		D156		deg			LVDT
	Right - lat.		D157					
	Left - fore and aft		D181					
	Left - lat.	Position measurement	D182	1 AMX	deg	10	±3 V	LVDT

TABLE 2-IV. (CONCLUDED)

Area	Location	Description	Item Code	Number & Type of Channels	Units	Response (hertz)	Approx Full Scale Xducer Signal Output	Transducer
Gimbal trunnion flapping	Right rotor	Position measurement	D110	1 AMX	deg	10	±3 V	Rotary potentiometer
	Left rotor		D144			10		
Red blade feathering	Right rotor		D111			50		
	Left rotor		D066		deg	50		Rotary potentiometer
Collective motion	Right act.		D158		in.	10		Linear potentiometer
	Left act.		D183					
Swashplate motion	Right - fore and aft		D159					
	Right - lat.		D160					
	Left - fore and aft		D184					
	Left - lat.		D185		in.	10		Linear potentiometer
Conversion motion	Right pylon		D161		deg	10		Rotary potentiometer
	Left pylon	Position measurement	D186	1 AMX	deg	10	±3 V	Rotary potentiometer
Rotor azimuth	Right rotor	One per rev	R018	1 DMX	blip			Photo cell encoder
		512 per rev	R053	1 DMX	blip			Photo cell encoder
	Left rotor	One per rev	R058	1 DMX	blip			Photo cell encoder
		512 per rev	R059	1 DMX	blip			Photo cell encoder

TABLE 2-V. MISCELLANEOUS MEASUREMENTS

Area	Location	Description	Item Code	Number & Type of Channels	Units	Response (hertz)	Approx Full Scale Xducer Signal Output	Transducer
Aircraft state measurements								
Airspeed	Nose boom	Pitot port	P002	1 AMX	psi	10	±5 V	Pressure transducer
Altitude	Nose boom	Static port	P142		psi		±5 V	Pressure transducer
	cockpit	Radar altimeter	D327		feet		0-40 V	Altimeter output
Relative wind angles	Nose boom	Angle of attack	D008		deg		±3 V	Government-furnished equipment
	Nose boom	Angle of sideslip	D007		deg		±3 V	Government-furnished equipment
Outside air temperature	Lower belly panel	Temperature probe	T322		°F		3 mV	Total air temperature system
Aircraft attitude		Roll	D009		deg		±3 V	Attitude gyro
		Pitch	D010		deg		±3 V	Attitude gyro
		Yaw	D011		deg		±3 V	Attitude gyro
Aircraft angular rates		Roll	V012		deg/sec		±2.5 V	Rate gyro
		Pitch	V013		deg/sec		±2.5 V	Rate gyro
		Yaw	V014		deg/sec	10	±2.5 V	Rate gyro
Vertical acceleration	Aircraft cg	Vertical acceleration	A352	1 AMX	g	10	±5 V	Servo accelerometer
Aircraft system monitors								
Hydraulic system	Right pylon	Pressure #2	P153	1 PSF	psi	100	±25 mV	Pressure transducer
	Left pylon	Pressure #1	P178	1 PSF	psi	100	±25 mV	Pressure transducer
	Left pylon	Pressure #3 (standby)	P149	1 PSF	psi	100	±25 mV	Pressure transducer

TABLE 2-V. (CONTINUED)

Area	Location	Description	Item Code	Number & Type of Channels	Units	Response (hertz)	Approx Full Scale Xducer Signal Output	Transducer
Electrical system	Right	Dc generator - potential	E154	1 AMX	volt	100	0-28 V	
		Dc generator - current	E155		amp	100	0-50 mV	Shunt
	Left	Dc generator - potential	E179		volt	100	0-28 V	
		Dc generator - current	E180		amp	100	0-50 mV	Shunt
Fuel system	Right	Quantity	R320		lb	10	±25 mV	Signal cond output
	Left	Quantity	R321		lb	10	±25 mV	Signal cond output
Temperature	Right wing, left wing, and fuselage	Thermocouples	T351	1 AMX*	°F	100	3 mV	Temperature scanner
Oil pressure	Right engine	Pressure	P323	1 PSF	psi	10	±10 mV	Pressure transducer
	Left engine	Pressure	P324		psi	10		Pressure transducer
	Right trans-mission	Pressure	P325		psi	10		Pressure transducer
	Left trans-mission	Pressure	P326		psi	10		Pressure transducer
<u>Aircraft Accelerations</u>								
Aircraft center of gravity	Fore and aft	Accelerations	A301		g	50		Strain gage accel-erometer
	Lateral		A300			50	±10 mV	
	Vertical		A005			50	±25 mV	
Pylons	Right - fore and aft		A150			100		
	Right - lat.		A151					
	Right - vert.		A152					
	Left - fore and aft		A175					
	Left - lat.		A176					
	Left - vert.	Accelerations	A177	1 PSF	g	100	±25 mV	Strain gage accel-erometer

* 1 CHAN AMX (Temp switch) temp ref 3 mV ~100°F

TABLE 2-V. (CONCLUDED)

Area	Location	Description	Item Code	Number & Type of Channels	Units	Response (hertz)	Approx Full Scale Xducer Signal Output	Transducer
Cockpit - pilot	Lateral	Accelerations	A302	1 PSF	g	50	±25 mV	Strain gage accel-erometer
	Vertical		A019					
Cockpit - copilot	Lateral		A306					
	Vertical	Accelerations	A020	1 PSF	g	50	±25 mV	Strain gage accel-erometer
Inst J-box	RR1	J-Box Signal Power Supply Voltage	E072	1 AMX	Volts	10	0-10V	Hardware at J-box
	RR2		E073					
	RP1		E196					
	RP2		E197					
	RW1		E647					
	RW2		E648					
	TR1		E074					
	TR2		E075					
	TP1		E198					
	TP2		E199					
	TW1		E649					
	CP1		E369					
	CP2		E370					
	CP3		E371					
	CAB1		E373					
	N1		E372					
	RMG 1		E374					
	LMG1		E375					
	EMP1		E298					
	EMP2	J-Box Signal Power Supply Voltage	F299	1 AMX	Volts	10	0-10V	Hardware at J-box

TABLE 2-VI. ITEM CODE DEFINITIONS

Measurements Types

A - Acceleration, Linear or Angular

B - Bending, Moment

D - Position, Linear or Angular, Displacement

E - Electrical, Voltage, Current, Power, Etc.

F - Force, Axial

L - Miscellaneous

M - Moment, Torque

P - Pressure

R - Rate, Flow, RPM, Rotor Blip, Etc.

S - Stress

T - Temperature

V - Velocity, Linear or Angular

X - Event, Firing Mark, Pod Release, Etc.

Number Assignments

1-49	Standard Items
50-199	Pylon and Rotating
200-299	Empennage
300-499	Fuselage (Nose-Cabin-Cockpit)
500-599	Engine
600-699	Wing
700-999	Miscellaneous

TABLE 2-VII. ITEM CODE ASSIGNMENTS
(SHEET 1 OF 40)

SHIP XV-15 PROGRAM Tilt Rotor Research Aircraft

Standard Items 001-049

001	
P 002	Nose Boom Airspeed
003	
004	
A 005	Aircraft C.G. Accel (Vert)
006	
D 007	Nose Boom Angle of Side Slip
D 008	Nose Boom Angle of Attack
D 009	Cabin Roll Attitude Gyro
D 010	Cabin Pitch Attitude Gyro
D 011	Cabin Yaw Attitude Gyro
V 012	Cabin Roll Rate Gyro
V 013	Cabin Pitch Rate Gyro
V 014	Cabin Yaw Rate Gyro
015	
016	
017	
R 018	R/H Rotor 1/Rev
A 019	Pilot Seat Vert Accel
A 020	Co-Pilot Seat Vert Accel
D 021	Pilot F/A Cyclic Stick Pos
D 022	Pilot Lat Cyclic Stick Pos
D 023	Pilot Power Lever Pos
D 024	Pilot Rudder Pedal Pos
025	

TABLE 2-VII. (SHEET 2 OF 40)

Standard Items - (cont)

__026 ____________________
__027 ____________________
__028 ____________________
__029 ____________________
__030 ____________________
__031 ____________________
__032 ____________________
__033 ____________________
__034 ____________________
__035 ____________________
__036 ____________________
__037 ____________________
__038 ____________________
__039 ____________________
__040 ____________________
__041 ____________________
__042 ____________________
__043 ____________________
__044 ____________________
__045 ____________________
__046 ____________________
__047 ____________________
__048 ____________________
__049 ____________________

TABLE 2-VII. (SHEET 3 OF 40)

Pylon Area · 050-099

__050	
__051	
B 052	R/H Rotor Swashplate (Driver Bending)
R 053	R/H Rotor 512/Rev
__054	
F 055	R/H Ro or Pitch Link (Green) Axial
__056	
__057	
R 058	L/H Rotor 1/Rev
R 059	L/H Rotor 512/Rev
F 060	L/H Rotor Pitch Link (Red) (Axial)
F 061	L/H Rotor Pitch Link (White) (Axial)
F 062	L/H Rotor Pit h Link (Green) (Axial)
__063	
__064	
__065	
D 066	L/H Roto. Blade (Red) Feathering Pos
__067	
__068	
__069	
__070	
__071	
E 072	Right Rotor 1 Voltage Sense
E 073	Right Rotor 2 Voltage Sense
E 074	Left Rotor 1 Voltage Sense
E 075	Left Rotor 2 Voltage Sense

TABLE 2-VII. (SHEET 4 OF 40)

Pylon Area - (cont)

__076	______
__077	______
__078	______
__079	______
__080	______
__081	______
__082	______
__083	______
__084	______
__085	______
__086	______
__087	______
__088	______
__089	______
__090	______
__091	______
__092	______
__093	______
__094	______
__095	______
__096	______
__097	______
__098	______
__099	______

TABLE 2-VII. (SHEET 5 OF 40)

Main Rotor 100-199

	100	
	101	
	102	
F	103	R/H Rotor Pitch Link (Red) Axial
F	104	R/H Rotor Pitch Link (White) Axial
	105	
	106	
M	107	R/H Rotor Mast Tor
B	108	R/H Mast Para
B	109	R/H Rotor Mast Perp
D	110	R/H Rotor Gimbal Flapping Pos
D	111	R/H Rotor Blade (Red) Feathering Pos
B	112	R/H Rotor Hub Spindle (Red) Bm Bend
B	113	R/H Rotor Hub Spindle (Red) Ch Bend
B	114	L/H Rotor Hub Spindle (Red) Bm Bend
B	115	L/H Rotor Hub Spindle (Red) Ch Bend
	116	
	117	
	118	
	119	
B	120	R/H Rotor Blade (Red) Bm Bend Sta 22.8
	121	
B	122	R/H Rotor Blade (Red) Bm Bend Sta 52.5
B	123	R/H Rotor Blade (Red) Ch Bend Sta 52.5
B	124	R/H Rotor Blade (Red) Bm Bend Sta 75
B	125	R/H Rotor Blade (Red) Ch Bend Sta 75

TABLE 2-VII. (SHEET 6 OF 40)

Main Rotor - (cont)

B 126	R/H Rotor Blade (Red) Bm Bend Sta 112.5
B 127	R/H Rotor Blade (Red) Ch Bend Sta 112.5
M 128	R/H Rotor Blade (Red) Torq Sta 112.5
M 129	R/H Rotor Blade (Red) Torq Sta 52.5
B 130	L/H Rotor Blade (Red) Bm Bend Sta 22.8
131	
B 132	L/H Rotor Blade (Red) Bm Bend Sta 52.5
B 133	L/H Rotor Blade (Red) Ch Bend Sta 52.5
B 134	L/H Rotor Blade (Red) Bm Bend Sta 75
B 135	L/H Rotor Blade (Red) Ch Bend Sta 75
B 136	L/H Rotor Blade (Red) Bm Bend Sta 112.5
B 137	L/H Rotor Blade (Red) Ch Bend Sta 112.5
M 138	L/H Rotor Blade (Red) Torq Sta 112.5
M 139	L/H Rotor Blade (Red) Torq Sta 52.5
B 140	L/H Rotor Mast Para
B 141	L/H Rotor Mast Perp
B 142	L/H Rotor Swashplate (Driver Bending)
M 143	L/H Rotor Mast Torq
D 144	L/H Rotor Gimbal Flapping Pos
S 145	R/H Rotor Blade (Red) L E Stress Sta 9.5
S 146	R/H Rotor Blade (Red) T E Stress Sta 9.5
S 147	L/H Rotor Blade (Red) L E Stress Sta 9.5
S 148	L/H Rotor Blade (Red) T E Stress Sta 9.5
P 149	L/H Pylon Standby Hydraulic Pressure (#3)
A 150	R/H Pylon F/A Accel

TABLE 2-VII. (SHEET 7 OF 40)

Main Rotor 151-175

A 151	R/H Pylon Lat Accel
A 152	R/H Pylon Vert Accel
P 153	R/H Pylon Hydraulic Pressure (#2)
E 154	R/H Pylon D C Generator (Volts)
E 155	R/H Pylon D C Generator (Current)
D 156	R/H Pylon Hub Spring F/A Motion
D 157	R/H Pylon Hub Spring Lat Motion
D 158	R/H Pylon Collective Actuator Pos
D 159	R/H Pylon Swashplate F/A Motion
D 160	R/H Pylon Swashplate Lat Motion
D 161	R/H Pylon Conversion Pos
F 162	R/H Pylon Control Boost Actuator F/A Cyclic Axial Force
F 163	R/H Pylon Control Boost Actuator Lat Cyclic Axial Force
F 164	R/H Pylon Control Boost Actuator Collective Axial Force
B 165	R/H Pylon Conversion Spindle Beam Bend
B 166	R/H Pylon Conversion Spindle Chord Bend
F 167	R/H Pylon Conversion Spindle Axial Load
F 168	L/H Pylon Conversion Actuator Axial
169	
170	
B 171	R/H White Spindle Beam Bend Sta 9.0
B 172	R/H White Spindle Chord Bend Sta 9.0
B 173	R/H Green Spindle Beam Bend Sta 9.0
B 174	R/H Green Spindle Chord Bend Sta 9.0
A 175	L/H Pylon F/A Accel

TABLE 2-VII. (SHEET 8 OF 40)

Main Rotor - (cont)

A 176	L/H Pylon Lat Accel
A 177	L/H Pylon Vert Accel
P 178	L/H Pylon Hydraulic Pressure (#1)
E 179	L/H Pylon DC Generator (Volts)
E 180	L/H Pylon DC Generator (Current)
D 181	L/H Pylon Hub Spring F/A Motion
D 182	L/H Pylon Hub Spring Lat Motion
D 183	L/H Pylon Collective Actuator Pos
D 184	L/H Pylon Swashplate F/A Motion
D 185	L/H Pylon Swashplate Lat Motion
D 186	L/H Pylon Conversion Pos
F 187	L/H Pylon Control Boost Actuator F/A Cyclic Axial Force
F 188	L/H Pylon Control Boost Actuator Lat Cyclic Axial Force
F 189	L/H Pylon Control Boost Actuator Collective Axial Force
B 190	L/H Pylon Conversion Spindle Bm Bend
B 191	L/H Pylon Conversion Spindle Ch Bend
B 192	L/H White Spindle Beam Bend Sta 9.0
B 193	L/H White Spindle Chord Bend Sta 9.0
B 194	L/H Green Spindle Beam Bend Sta 9.0
B 195	L/H Green Spindle Chord Bend Sta 9.0
E 196	Right Pylon 1 Voltage Sense
E 197	Right Pylon 2 Voltage Sense
E 198	Left Pylon 1 Voltage Sense
E 199	Left Pylon 2 Voltage Sense

TABLE 2-VII. (SHEET 9 OF 40)

Tail Rotor 200-249

__200 ____________________
__201 ____________________
__202 ____________________
__203 ____________________
__204 ____________________
__205 ____________________
__206 ____________________
__207 ____________________
__208 ____________________
__209 ____________________
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__212 ____________________
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__218 ____________________
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__220 ____________________
__221 ____________________
__222 ____________________
__223 ____________________
__224 ____________________
__225 ____________________

TABLE 2-VII. (SHEET 10 OF 40)

Tail Rotor - (cont)

__226 ____________________
__227 ____________________
__228 ____________________
__229 ____________________
__230 ____________________
__231 ____________________
__232 ____________________
__233 ____________________
__234 ____________________
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__245 ____________________
__246 ____________________
__247 ____________________
__248 ____________________
__249 ____________________

TABLE 2-VII. (SHEET 11 OF 40)

Tail Boom 250-299

	250	
	251	
	252	
	253	
	254	
	255	
	256	
	257	
	258	
	259	
	260	
	261	
B	262	R/H Horz Stab Spar Bm Bend Sta 8 (BL)
B	263	R/H Horz Stab Spar Ch Bend Sta 8 (BL)
B	264	R/H Horz Stab Spar Bm Bend Sta 72 (BL)
	265	
M	266	R/H Horz Stab Spar Torq Bend Sta 8 (BL)
	267	
B	268	R/H Vert Stab Bm Bend Sta 98 (WL)
	269	
B	270	R/H Vert Stab Bm Lead Sta 108 (WL)
	271	
	272	
	273	
B	274	R/H Elevator Control Arm Beam Bend
M	275	R/H Elevator Drive Tube Torque

TABLE 2-VII. (SHEET 12 OF 40)

Tail Boom - (cont)

	M 276	R/H Rudder Drive Tube Torque
	M 277	L/H Rudder Drive Tube Torque
	B 278	R/H Rudder Control Arm Bm Bend
	M 279	L/H Elevator Drive Tube Torque
	B 280	L/H Rudder Control Arm Bm Bend
	D 281	R/H Elevator Pos
	B 282	L/H Elevator Control Arm Bm Bend
	__283	
	D 284	R/H Rudder Pos
	__285	
	F 286	Horizontal Stab Incidence Act Force
	D 287	Horizontal Stab Incidence Act Pos
	__288	
	__289	
*	B 290	Lt Horiz Stab Bm Bend (Skin) Sta 8.0
*	B 291	Lt Horiz Stab Bm Bend (Skin) Sta 66.0
*	B 292	Lt Horiz Stab Bm Bend (Skin) Sta 8.0
*	B 293	Lt Horiz Stab Bm Bend (Skin) Sta 66.0
*	S 294	Emph Attach Point Stress LH Lug
*	S 295	Emph Attach Point Stress RH Lug
	__296	
	__297	
	E 298	Emp[illegible]age 1 Voltage Sense
	E 299	E[illegible]age 2 Voltage Sense

*Aircraft No. 1 only

TABLE 2-VII. (SHEET 13 OF 40)

Fuselage	300-499
A 300	Aircraft CG Accel (Lat)
A 301	Aircraft CG Accel (F/A)
A 302	Pilot Seat Lat Accel
F 303	R/H Main Landing Gear Drag Strut Axial Force
A 304	Co-Pilot Seat Lat Accel
D 305	R/H Main Landing Gear Oleo Extension Pos
D 306	R/H SCAS Actuator F/A Pos
D 307	R/H SCAS Actuator Lat Pos
D 308	R/H SCAS Actuator Directional Pos
D 309	Pilot Flap Lever Pos
310	
311	
B 312	L/H Main Landing Gear Oleo Strut Lat Bend
F 313	L/H Main Landing Gear Drag Strut Axial Force
D 314	L/H Main Landing Gear Actuator Pos
D 315	L/H Main Landing Gear Oleo Extension Pos
B 316	R/H Main Landing Gear Oleo Strut Lat Bend
D 317	R/H Main Landing Gear Actuator Pos
D 318	Diff Cyclic Washout Actuator Pos
319	
R 320	R/H Engine Fuel Quan
R 321	L/H Engine Fuel Quan
T 322	Outside Air Temp
P 323	R/H Engine Oil Pressure
P 324	L/H Engine Oil Pressure
P 325	R/H Transmission Oil Press

TABLE 2-VII. (SHEET 14 OF 40)

Fuselage - (cont)

P 326	L/H Transmission Oil Press
D 327	Instrument Panel Radar Altitude
R 328	Instrument Panel R/H Engine Fuel Flow Rate
R 329	Instrument Panel L/H Engine Fuel Flow Rate
F 330	Pilot F/A Cyclic Stick Force
F 331	Pilot Lat Cyclic Stick Force
F 332	Pilot Power Lever Force
F 333	Pilot Right Pedal Force
F 334	Pilot Left Pedal Force
M 335	R/H Engine Torq
M 336	L/H Engine Torq
M 337	Interconnect Shaft Torq (Cockpit System)
R 338	R/H Engine N_1 RPM
R 339	L/H Engine N_2 RPM
340	
341	
P 342	Nose Boom Altitude
B 343	Nose Landing Gear R/H Trunnion Vert Bend
B 344	Nose Landing Gear L/H Trunnion Vert Bend
B 345	Nose Landing Gear Oleo Strut F/A Bend
B 346	Nose Landing Gear Oleo Strut Lat Bend (Right)
F 347	Nose Landing Gear Drag Strut Axial Force
D 348	Nose Landing Gear Actuator Pos
D 349	Nose Landing Gear Oleo Extension Pos

TABLE 2-VII. (SHEET 15 OF 40)

Fuselage - (cont)

	350	
T	351	Right Wing, Left Wing and Fuselage Temp
A	352	Aircraft CG Accel (Servo)
	353	
	354	
F	355	R/H Main Landing Gear Drag Strut Axial Force
F	356	L/H Main Landing Gear Drag Strut Axial Force
B	357	Nose Gear Oleo Strut Lat Bend (Left)
	358	
	359	
D	360	Temp Scanner Encoder
	361	
	362	
	363	
	364	
X	365	Record Number Box A
X	366	Record Number Box B
	367	
	368	
E	369	Cockpit 1 Voltage Sense
E	370	Cockpit 2 Voltage Sense
E	371	Cockpit 3 Voltage Sense
E	372	Nose 1 Voltage Sense
E	373	Cabin 1 Voltage Sense
E	374	Right Main Gear 1 Voltage Sense
E	375	Left Main Gear 1 Voltage Sense

TABLE 2-VII. (SHEET 16 OF 40)

Fuselage - (cont)

___376 ____________________

___377 ____________________

___378 ____________________

___379 ____________________

___380 ____________________

___381 ____________________

___382 ____________________

___383 ____________________

___384 ____________________

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___391 ____________________

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___396 ____________________

___397 ____________________

___398 ____________________

___[illegible] ____________________

TABLE 2-VII. (SHEET 17 OF 40)

Fuselage - (cont)

__400 ____________________

__401 ____________________

__402 ____________________

__403 ____________________

__404 ____________________

__405 ____________________

__406 ____________________

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__423 ____________________

__424 ____________________

__425 ____________________

TABLE 2-VII. (SHEET 18 OF 40)

Fuselage - (cont)

__426 ______________________________

__427 ______________________________

__428 ______________________________

__429 ______________________________

__430 ______________________________

__431 ______________________________

__432 ______________________________

__433 ______________________________

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__447 ______________________________

__448 ______________________________

__[illegible] ______________________________

TABLE 2-VII. (SHEET 19 OF 40)

Fuselage - (cont)

___450 ______________________________

___451 ______________________________

___452 ______________________________

___453 ______________________________

___454 ______________________________

___455 ______________________________

___456 ______________________________

___457 ______________________________

___458 ______________________________

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___469 ______________________________

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___472 ______________________________

___473 ______________________________

___474 ______________________________

___475 ______________________________

C-2

TABLE 2-VII. (SHEET 20 OF 40)

Fuselage - (cont)

__476 ____

__477 ____

__478 ____

__479 ____

__480 ____

__481 ____

__482 ____

__483 ____

__484 ____

__485 ____

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__496 ____

__497 ____

__498 ____

__499 ____

TABLE 2-VII. (SHEET 21 OF 40)

Engine	500-599
A 500	R/H Engine Inlet Case F/A Accel
A 501	R/H Engine Inlet Case Lat Accel
A 502	R/H Engine Inlet Case Vert Accel
R 503	R/H Engine Gas Producer N_1 RPM
P 504	R/H Nacelle Atmospheric (Static Ref)
P 505	R/H Transmission Compartment Static
T 506	R/H Engine Temperature Scanner
A 507	L/H Engine Inlet Case F/A Accel
A 508	L/H Engine Inlet Case Lat Accel
D 509	Pilot R/H Engine Throttle Pos
D 510	Pilot L/H Engine Throttle Pos
D 511	L/H Engine Scanivalve Position Encoder
P 512	L/H Engine Pressure (Scannivalve)
T 513	L/H Engine Temperature Scanner
A 514	L/H Engine Inlet Case Vert Accel
R 515	L/H Engine Gas Producer N_1 RPM
R 516	R/H Engine Total Fuel
R 517	L/H Engine Total Fuel
P 518	L/H Engine Bellmouth High Freq @ 160°
P 519	L/H Engine Bellmouth High Freq @ 300°
F 520	L/H Lower Cowl Outboard Support Strut Axial Load
F 521	L/H Pylon Lower Cowl Inbd Support Strut Axial Load
F 522	R/H Pylon Lower Cowl Outbd Support Strut Axial Load
F 523	R/H Pylon Lower Cowl Inbd Support Strut Axial Load
524	

TABLE 2-VII. (SHEET 22 OF 40)

ORIGINAL PAGE IS
OF POOR QUALITY

Engine - (cont)

A 525	R/H Engine Oil Outlet F/A Accel	FM Channels
A 526	R/H Engine Oil Outlet Lat Accel	FM Channels
A 527	L/H Engine Oil Outlet F/A Accel	FM Channels
A 528	R/H Engine Lifting Eye F/A Accel	FM Channels
A 529	L/H Engine Oil Outlet Lat Accel	FM Channels
A 530	L/H Engine Lifting Eye F/A Accel	FM Channels
531		
532		
533		
534		
535		
536		
537		
538		
539		
540		
541		
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543		
544		
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546		
547		
548		
549		

TABLE 2-VII. (SHEET 23 OF 40)

Engine - (cont)

N 550	Lt Mast Torque	Special Item for Engine Torsional Test (A/C No. 1)
A 551	Lt F/A Accel (Comb Flange)	
A 552	Lt Lat Accel (Comb Flange)	
A 553	Lt F/A Accel (Top of Engine)	
A 554	Lt Lat Accel (Top of Engine)	
S 555	Lt Gear Box Stress	
D 556	Lt 215 Shaft Chucking Motion	
557		
558		
559		
560		
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568		
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573		
574		

TABLE 2-VII. (SHEET 24 OF 40)

Engine - (cont)

__575 ______________________________

__576 ______________________________

__577 ______________________________

__578 ______________________________

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__599 ______________________________

TABLE 2-VII. (SHEET 25 OF 40)

Wing	600-699
B 600	R/H Wing Spar Beam Sta 22
601	
602	
B 603	R/H Wing Spar Chord Sta 22
604	
605	
M 606	R/H Wing Spar Torq Sta 22
607	
608	
S 609	R/H Wing Upper Panel Inner Skin Stress
S 610	R/H Wing Lower Panel Inner Skin Stress
F 611	R/H Wing Conversion Actuator Axial Load
M 612	R/H Flap Drive Tube Torque
B 613	R/H Flap Beam Bend
F 614	R/H Flaperon Control Arm Force
B 615	R/H Flaperon Beam Bend
616	
D 617	R/H Flap Pos
B 618	L/H Flap Beam Bend
M 619	L/H Flap Drive Tube Torque
620	
F 621	L/H Flaperon Control Arm Force
B 622	L/H Flaperon Beam Bend
623	
624	

TABLE 2-VII. (SHEET 26 OF 40)

Wing - (cont)

B 625	Left Wing Chord Bending Sta 22 } A/C No. 1 Wind Tunnel Test
B 626	Left Wing Beam Bending Sta 22 }
M 627	Left Wing Torque Bending Sta 22 }
S 628	BL 0.0 Right Wing Upper Panel Outer Skin Stress
S 629	BL 0.0 Right Wing Lower Panel Outer Skin Stress
S 630	WS 66 Right Wing Front Spar Shear (Upper)
S 631	WS 66 Right Wing Front Spar Shear (Lower)
S 632	WS 66 Right Wing Rear Spar Shear (Upper)
S 633	WS66 Right Wing Rear Spar Shear (Lower)
S 634	WS 142 Right Wing Front Spar Shear (Upper)
S 635	WS 142 Right Wing Front Spar Shear (Lower)
S 636	WS 142 Right Wing Rear Spar Shear (Upper)
S 637	WS 142 Right Wing Rear Spar Shear (Lower)
F 638	Left Pylon Conversion Actuator Axial Load
639	
640	
641	
642	
643	
644	
D 645	Rt Aileron Pos
D 646	Lt Aileron Pos
E 647	Right Wing 1 Voltage Sense
E 648	Right Wing 2 Voltage Sense
E 649	Left Wing 1 Voltage Sense

TABLE 2-VII. (SHEET 27 OF 40)

Wing - (cont)

__675 ____________________

__676 ____________________

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TABLE 2-VII. (SHEET 28 OF 40)

Wing - (cont)

L 650	Cabin Mike (For Noise Level) - A/C No. 1	
651		
652		
653		
654		
B 655	Right Wing Sta 22 Chord Bend	A/C No. 1 Wind Tunnel Test
B 656	Right Wing Sta 22 Beam Bend	A/C No. 1 Wind Tunnel Test
M 657	Right Wing Sta 22 Torque	A/C No. 1 Wind Tunnel Test
658		
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TABLE 2-VII. (SHEET 29 OF 40)

External Stores 700-799

E 700	GPA Gain - 4 RMDU-A	
E 701	GPA Gain - 16 RMDU-A	
E 702	GPA Gain - 64 RMDU-A	
E 703	GPA Gain - 128 RMDU-A	
E 704	GPA Gain - 256 RMDU-A	
E 705	GPA Gain - 512 RMDU-A	
E 706	LLC Gain - 512 (Card Slot - 7) RMDU-A	
E 707	LLC Gain - 512 (Card Slot - 8) RMDU-A	
E 708	LLC Gain - 512 (Card Slot - 9) RMDU-A	
E 709	LLC Gain - 512 (Card Slot - 10) RMDU-A	
E 710	LLC Gain - 512 (Card Slot - 11) RMDU-A	
E 711	HLC RMDU - A	
E 712	PSB RMDU - A	
713		
714		
715		
F 716	Lat Stick Force (Cal Span)	
D 717	Lat Stick Pos (Cal Span)	
E 718	Primary Governor RPM Error	
E 719	Primary Governor #1 LVDT	RPM GOVERNOR TESTS
E 720	Primary Governor Actuator Velocity	RPM GOVERNOR TESTS
E 721	Primary Governor Command RPM	RPM GOVERNOR TESTS
E 722	Primary Monitor Command RPM	RPM GOVERNOR TESTS
E 723	Primary Monitor RPM Error	RPM GOVERNOR TESTS
E 724	Standby Governor RPM Error	RPM GOVERNOR TESTS

TABLE 2-VII. (SHEET 30 OF 40)

External Stores - (cont)

E 725	GPA Gain - 4 RMDU-B	
E 726	GPA Gain - 16 RMDU-B	
E 727	GPA Gain - 64 RMDU-B	
E 728	GPA Gain - 128 RMDU-B	
E 729	GPA Gain - 256 RMDU-B	
E 730	GPA Gain - 512 RMDU-B	
E 731	LLC Gain - 512 (Card Slot - 7) RMDU-B	
E 732	LLC Gain - 512 (Card Slot - 8) RMDU-B	
E 733	LLC Gain - 512 (Card Slot - 9) RMDU-B	
E 734	LLC Gain - 512 (Card Slot - 10) RMDU-B	
E 735	LLC Gain - 512 (Card Slot - 11) RMDU-B	
E 736	HLC RMDU-B	
E 737	PSB RMDU-B	
738		
739		
740		
741		
P 742	Airspeed Sensor Lat Cyc Cont Box	Lat Cyclic & Exciter Tests
D 743	Pos (Rt LVDT) Lat Cyc Cont Box	
D 744	Pos (Lt LVDT) Lat Cyc Cont Box	
E 745	Servo Drive Volts Exciter	
D 746	Pos (Collective LVDT) Exciter	
D 747	Pos (Flaperon LVDT) Exciter	
E 748	Volts (Coll Solenoid Valve) Exciter	
E 749	Volts (Flaperon Solenoid Valve) Exciter	

TABLE 2-VII. (SHEET 31 OF 40)

External Stores - (cont)

__750 ____

__751 ____

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TABLE 2-VII. (SHEET 32 OF 40)

External Stores - (cont)

__775 ______________________________
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__798 ______________________________
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TABLE 2-VII. (SHEET 33 OF 40)

Miscellaneous 800-999

___800 ______________________________

___801 ______________________________

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TABLE 2-VII. (SHEET 34 OF 40)

Miscellaneous - (cont)

__825 ____________________

__826 ____________________

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TABLE 2-VII. (SHEET 35 OF 40)

Miscellaneous - (cont)

__850 ____
__851 ____
__852 ____
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__874 ____

TABLE 2-VII. (SHEET 36 OF 40)

Miscellaneous - (cont)

__875 ______

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__899 ______

TABLE 2-VII. (SHEET 37 OF 40)

Miscellaneous - (cont)

__900 ____

__901 ____

__902 ____

__903 ____

__904 ____

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TABLE 2-VII. (SHEET 38 OF 40)

Miscellaneous - (cont)

__925 ______________________________

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TABLE 2-VII. (SHEET 39 OF 40)

Miscellaneous - (cont)

__950 ____________________
__951 ____________________
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TABLE 2-VII. (SHEET 40 OF 40)

Miscellaneous - (cont)

__975 ____

__976 ____

__977 ____

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__980 ____

__981 ____

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__999 ____

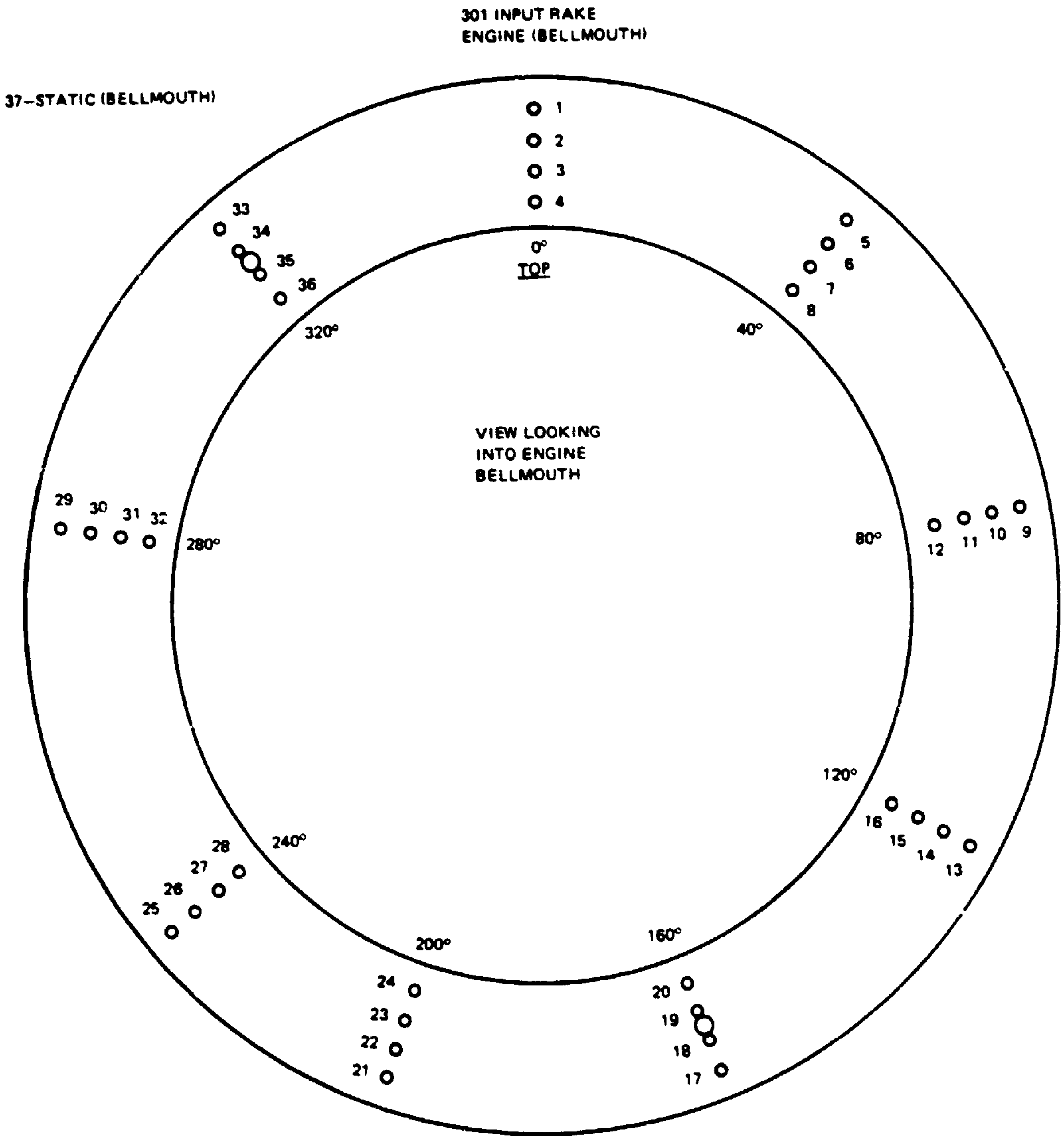

Figure 2-1. 301 input rake engine (bellmouth)

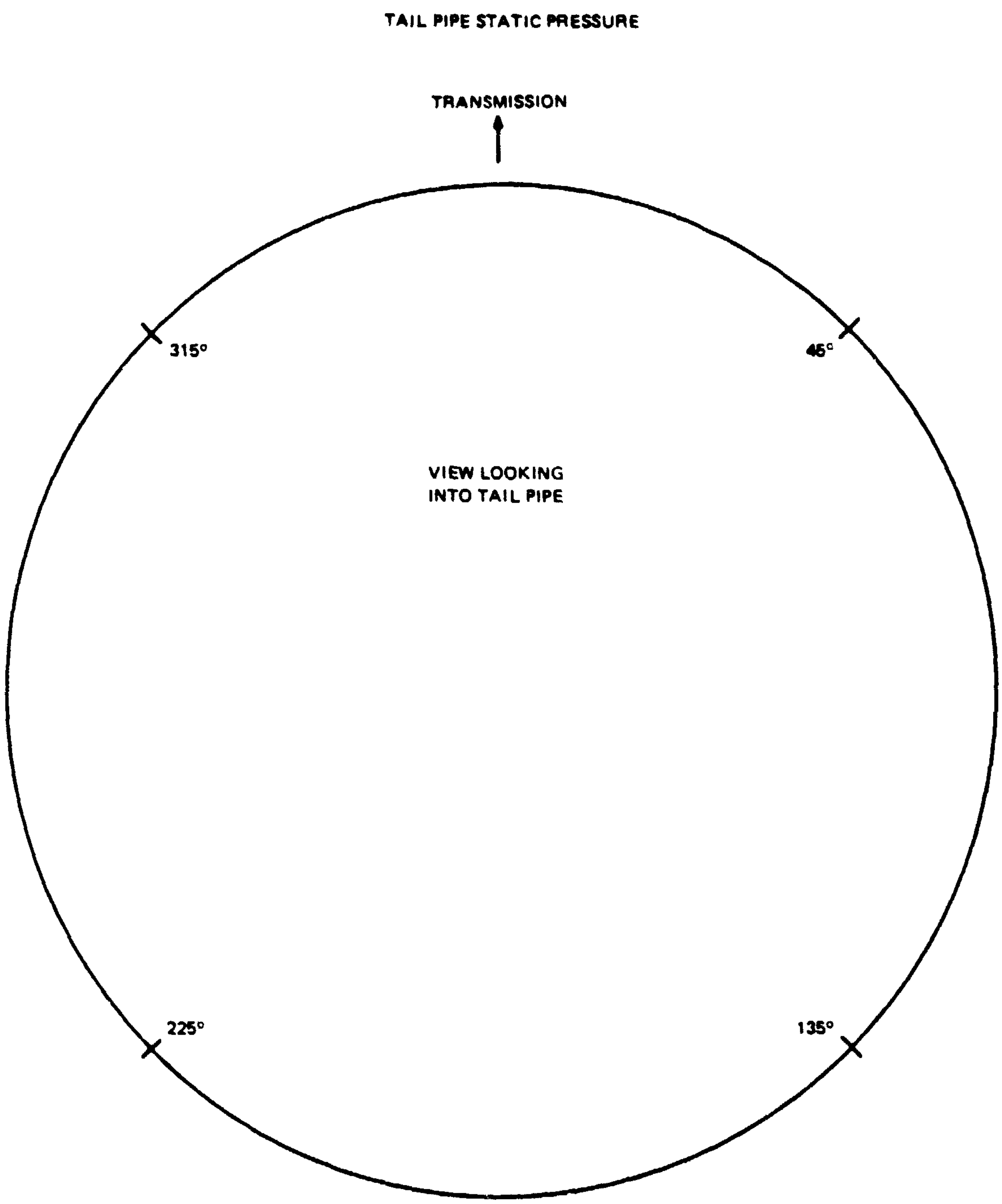

Figure 2-2. Engine tail pipe static pressure port locations

SECTION 3. EQUIPMENT

This section defines the equipment installed for the research instrumentation and data acquisition system. Aircraft inboard profile and basic lines data are included for equipment location and sensor installation reference.

3.1 Contractor Furnished Equipment. Contractor furnished equipment is listed in Table 3-I.

3.2 Government Furnished Equipment. Government furnished equipment is listed in Table 3-II.

3.3 Ships Inventory List. A ships inventory of installed research instrumentation equipment for the XV-15 is given in Volume No. 2 for Aircraft No. 1 and in Volume No. 3 for Aircraft No. 2. The ships inventory lists the item, type, serial number, and calibration interval for each installed sensor and equipment.

3.4 Specification Sheets. Vendor specification sheets for contractor furnished equipment are contained in Volume IV.

3.5 Equipment Location. Location of major research instrumentation equipment is shown in Figure 3-1. An inboard profile of the XV-15 is shown in Figure 3-2 for reference. Basic aircraft lines data is given in Figure 3-3 for reference to the WL, BL, STA coordinate system used to locate aircraft, sensors, and equipment. Research instrumentation equipment is not shown on the inboard profile. This drawing shows location of major aircraft equipment. Aircraft station numbers are shown for reference purposes.

TABLE 3-1 CONTRACTOR FURNISHED EQUIPMENT

Component Description	Model No./Part No	Manufacturer	FSCM	Qty/ Acft	Location
Accelerometer, Engine Vibration	2271A	Endevco	95411	6	LH/RH Engine
Accelerometer, Strain Gage, 05 g	A69TC-05-350	Gould	57187	3	Aircraft C G.
Accelerometer, Strain Gage, 10 g	A69TC-10-350	Gould	57187	4	Pilot & Copilot Seats
Accelerometer, Strain Gage, 25 g	A69TC-25-350	Gould	57187	6	LH/RH Pylon
Accelerometer, Vertical Servo	303TJ6	Sundstrand	97896	1	Aircraft C G.
Amplifier, Charge, Engine Vibration	2647M77	Endevco	95411	6	LH/RH Engine
Antenna, Telemetry	7411003	BHT	97499	2	Fuselage
Cable, Signal	No 8723	Belden	16428	AR	Sensor Disconnect Harness
Cable, Signal	No 8769	Belden	16428	AR	Signal Distribution Cables
Ckt Assy, Data Control Word, C/S 17	SKHD3-20-78-1-17	BHT	97499	1	Active Network Panel-Slot 17
Ckt Assy, Digital Stick Position	SKHD3-20-78-3-11	BHT	97499	1	Active Network Panel-Slot 11
Ckt Assy, Mean/Peak-to-Peak Detector	301ASW220-1	BHT	97499	2	Active Network Panel-Slot 9 & 10
Ckt Assy, Temperature Scanner, C/S 12	SKHD3-20-78-2-12	BHT	97499	1	Active Network Panel-Slot 12
Ckt Assy, Temperature Scanner, C/S 13	SKHD3-20-78-2-13	BHT	97499	1	Active Network Panel-Slot 13
Ckt Assy, Temperature Scanner, C/S 16	SKHD3-20-78-2-16	BHT	97499	1	Active Network Panel-Slot 16
Connector, Bulkhead Pass Thru	KPT8-14-15SP	ITT Cannon Electric	91577	1	Various
Connector, Circular, Box Mount	KPT02-8-3P	ITT Cannon Electric	91577	1	Various
Connector, Circular, Box Mount	KPT02-8-2P	ITT Cannon Electric	91577	1	Various
Connector, Circular, Box Mount	KPT02-8-4S	ITT Cannon Electric	91577	1	Various
Connector, Circular, Box Mount	KPT02-8-4P	ITT Cannon Electric	91577	5	Various
Connector, Circular, Box Mount	KPT02-10-6P	ITT Cannon Electric	91577	258	Various
Connector, Circular, Box Mount	KPT02-1[illegible]P	ITT Cannon Electric	91577	1	Various
Connector, Circular, Box Mount	KPT02-12-10S	ITT Cannon Electric	91577	1	Various
Connector, Circular, Box Mount	KPT02-12-14S	ITT Cannon Electric	91577	1	Various
Connector, Circular, Box Mount	KPT02-14-15S	ITT Cannon Electric	91577	1	Various
Connector, Circular, Box Mount	KPT02-14-19P	ITT Cannon Electric	91577	1	Various
Connector, Circular, Box Mount	KPT02-16-26P	ITT Cannon Electric	91577	[illegible]	Various
Connector, Circular, Box Mount	KPT02-24-61P	ITT Cannon Electric	91577	4	Various
Connector, Circular, Box Mount	KPT02-24-61S	ITT Cannon Electric	91577	27	Various
Connector, Circular, Box Mount	PC06W-8-4S	Bendix	778[illegible]0	7	Various
Connector, Circular, Cable	KPT01-8-3P	ITT Cannon Electric	91[illegible]	1	Various
Connector, Circular, Cable	KPT01-8-4S	ITT Cannon Electric		1	Various
Connector, Circular, Cable	KPT01-12-8S	ITT Cannon Electric			Various

TABLE 3-1 (Continued)

Component Description	Model No./Part No	Manufacturer	FSCM	Qty/ Acft	Location
Connector, Circular, Cable	KPT01-14-18P	ITT Cannon Electric	91577	1	Various
Connector, Circular, Straight Plug	KPT06-8-4S	ITT Cannon Electric	91577	5	Various
Connector, Circular, Straight Plug	KPT06-8-4P	ITT Cannon Electric	91577	63	Various
Connector, Circular, Straight Plug	KPT06-8-2S	ITT Cannon Electric	91577	1	Various
Connector, Circular, Straight Plug	KPT06-8-3S	ITT Cannon Electric	91577	5	Various
Connector, Circular, Straight Plug	KPT06-10-6S	ITT Cannon Electric	91577	258	Various
Connector, Circular, Straight Plug	KPT06-12-8S	ITT Cannon Electric	91577	1	Various
Connector, Circular, Straight Plug	KPT06-12-8P	ITT Cannon Electric	91577	1	Various
Connector, Circular, Straight Plug	KPT06-12-10P	ITT Cannon Electric	91577	1	Various
Connector, Circular, Straight Plug	KPT06-12-10S	ITT Cannon Electric	91577	1	Various
Connector, Circular, Straight Plug	KPT06-12-14P	ITT Cannon Electric	91577	1	Various
Connector, Circular, Straight Plug	KPT06-14-15S	ITT Cannon Electric	91577	1	Various
Connector, Circular, Straight Plug	KPT06-14-15P	ITT Cannon Electric	91577	2	Various
Connector, Circular, Straight Plug	KPT06-14-18S	ITT Cannon Electric	91577	1	Various
Connector, Circular, Straight Plug	KPT06-14-19S	ITT Cannon Electric	91577	1	Various
Connector, Circular, Straight Plug	KPT06-16-8P	ITT Cannon Electric	91577	1	Various
Connector, Circular, Straight Plug	KPT06-16-8S	ITT Cannon Electric	91577	1	Various
Connector, Circular, Straight Plug	KPT06-16-26S	ITT Cannon Electric	91577	1	Various
Connector, Circular, Straight Plug	KPT06-18-32S	ITT Cannon Electric	91577	1	Various
Connector, Circular, Straight Plug	KPT06-22-5SP	ITT Cannon Electric	91577	4	Various
Connector, Circular, Straight Plug	KPT06-24-61S	ITT Cannon Electric	91577	4	Various
Connector, Circular, Straight Plug	KPT06-24-61P	ITT Cannon Electric	91577	27	Various
Connector, Circular, Straight Plug	MS3106-14S-5S	ITT Cannon Electric	91577	7	Various
Connector, Circular, Straight Plug	MS3106-16S-1S	ITT Cannon Electric	91577	4	Various
Connector, Circular, Straight Plug	MS3106-22-14S	ITT Cannon Electric	91577	2	Various
Connector, Circular, Straight Plug	MS3106-24-11S	ITT Cannon Electric	91577	1	Various
Connector, Circular, Straight Plug	WK-4-21C1	ITT Cannon Electric	91577	2	Various
Connector, Printed Circuit	VP5/4CE15	Viking	05574	6	Various
Connector, Printed Circuit	VP3/4CE15	Viking	05574	1	Various
Connector, Retangular, Rack Mount	DB-25S	TRW-Cinch	71785	12	Various
Connector, Retangular, Rack Mount	DC-37P	TRW-Cinch	71785	6	Various
Connector, Retangular, Rack Mount	DC-37S	TRW-Cinch	71785	1	Various
Connector, Retangular, Rack Mount	DE-9S	TRW-Cinch	71785	4	Various

TABLE 3-1. (Continued)

Component Description	Model No./Part No.	Manufacturer	FSCM	Qty/Acft	Location
Connector, Retangular, Rack Mount	DE-9P	TRW-Cinch	71785	3	Various
Control Unit, Scannivalve	SKTASW166-2	BHT	97499	1	L/H Nacelle
Control Unit, Scannivalve	SKTASW166-2	BHT	97499	1	LH Pylon
Control Unit, Synchro Converter	SKWD121476-1	BHT	97499	1	Center Fuselage
Control Unit, Temperature Scanner	SKASW-5479-1	BHT	97499	3	LH/RH Nacelle & Aux Instr Pallet
Converter, Frequency	PI-355-100 Hz	Anadex Inc	14010	4	Various
Converter, Synchro to Linear DC	SLD 214-L-1	Computer Conversions Corp	51086	2	Syn Conv Cont Box
Current Limiter	7235-1-70	Texas Instruments	82647	2	Aft Fuselage
Encoder, Shaft	815-512-IBLP-TTL	Disc	15686	2	LH/RH Rotor
Filter, Premodulation	SKASW-2479-1	BHT	97499	1	Aux Instr Panel
Filter Unit, Fuo Vib	301ASW6780-1	BHT	97499	1	Aux Instr Pallet
Gyro, Attitude	VM02-0110-1	Humphrey	98284	2	Aux Instr Pallet
Gyro, Rate, Axis	402405	Timex	61515	1	Aux Instr Pallet
Indicator, Control Position	301075-20	BHT	97499	1	Cockpit Instr Panel
Indicator, Critical Load	301075-24	BHT	97499	1	Cockpit Instr Panel
Indicator, Data System Control Monitor	301075-25	BHT	97499	1	Cockpit Instr Panel
Indicator, Hub, Flapping	301075-23	BHT	97499	1	Cockpit Instr Panel
Indicator, Temperature Monitor	301075-22	BHT	97499	1	Cockpit Instr Panel
Inverter, Static, 750 VA	PC-17A	Flite-Tronics	07181	1	Aux Instr Pallet
Junction, Temperature Reference	TR34-24PP	Validyne	33107	6	LH/RH Nacelle & Aux Instr Pallet
Potentiometer, Cable	7101-16	Research Inc	09327	6	Ldg Gear Struts & Actuators
Potentiometer, Cable (3.5 in)	4046-3 1/2	Research Inc	09327	4	LH/RH Hub Spring
Potentiometer, Linear (6 in)	Series 950	Spectrol Electronics Corp	02111	4	F/A SCAS (Pitch), LH SCAS (Roll), Rudder (Yaw), Diff Cyc Washout
Potentiometer, Linear, 12-inch	80294-2001941502	Bourns	80294	2	RH/LH Nacelle
Potentiometer, Linear, 6 inch	3,378,805	Bourns	80294	8	Control Surfaces - Various
Potentiometer, Rotary, Single Section (1K)	Series 708	Spectrol Electronics Corp	02111	2	Gimbal Trunnion
Power Supply	CC3D3.5	Abbott	15755	1	Instr Pallet
Power Supply	CC15D1.0	Abbott	15755	1	Instr Pallet
Power Supply	C5D5.0	Abbott	15755	1	Instr Pallet
Power Supply	C28D3.5	Abbott	15755	1	Instr Pallet
Power Supply, DC to DC	2055-28-15	RH Electronics	08450	2	Synchro Control Box

TABLE 3-1 (Concluded)

Component Description	Model No./Part No.	Manufacturer	FSCM	Qty/ Acft	Location
Program Board Receiver	939/0109392	MAC Panel	16654	1	Instr Pallet
Signal Conditioner, OAT	510BF65	Rosemont	04274	1	Lower Belly Panel
Slip Ring Assembly	WB4-100	Wendon	04155	2	LH/RH Rotor
Strain Gage	EA-13 125-350 (typical)	Micro-Measurements	19612	AR	Various
Switch, Pressure Sampling	48J4-1	Scanivalve	22422	1	LH Nacelle
Transducer, Air Pressure	PM6TC-2.5-350	Gould	57187	2	RH Nacelle
Transducer, Airspeed-Altitude	542K2	Rosemont	04274	1	Nose Wheel
Transducer, Displacement	7DCT-1000	Hewlett-Packard	56286	5	Not Installed
Transducer, Oil Pressure (150 psi)	PL722TC-150-350	Gould	57187	4	LH/RH Xmsn
Transducer, Oil Pressure (5000 psi)	PL722TC-5M-350	Gould	57187	3	Hydr Sys PC-1, -2, -3
Transducer, Outside Air Temp	101AN	Rosemont	04274	1	Lower Belly Panel
Transducer, Press Sampling Switch	PM131TC-2.5-350	Gould	57187	1	LH Nacelle

TABLE 3-II. GOVERNMENT FURNISHED EQUIPMENT

Item No.	Component Description	Part Number/ Model Number	Manufacturer	Qty/ Acft	Installed Location
1	Tape Recorder,	MARS 1414 LT3D	Astro Science	1	Instr Pallet
1A	Transport Assy	P/N 95002721		1	
1B	Head Assy	P/N 85006991		1	
1C	Direct Record Cards	P/N 85004861		7	
1D	FM Record Cards	P/N 85006911-3		7	
2	Preamplifier Filter (PAF)	P/N 839716-1	Teledyne	2	Instr Pallet
2A	Power Supply	P/N 839155-1			
2B	PSF-6 Filter Cards	P/N 840648-6			
3	Remote Multiplexer/ Demultiplexer Unit (RMDU)	P/N 838030-1	Teledyne	2	Instr Pallet
3A	Power Supply	P/N 838943-1		2	
3B	SVD Card	P/N 838973-1		1	
3C	DMX Card	P/N 838056-4		2	
3D	DMX Card	P/N 838056-1		2	
3E	AMX Card	P/N 838062-1		10	
3F	ADP Module	P/N 838090-6		2	
3G	SAT-M Module	P/N 840683-1		2	
4	Time Code Generator (TCG)	Model SP 375	Datametrics	1	Instr Pallet
5	R-Cal Box	P/N 838967-1	Teledyne	5	Instr Pallet
6	ILT	P/N 840863	Teledyne	2	Instr Pallet
7	Active Network Panel	Dwg No. A14117-B18, -B19, -B20, -B21	NASA-Ames	1	Instr Pallet
8	Tape Control Card	Dwg No. A14117-D17	NASA-Ames	1	Instr Pallet

TABLE 3-II. (Concluded)

Item No.	Component Description	Part Number/ Model Number	Manufacturer	Qty/ Acft	Installed Location
9	Azimuth Card	Dwg No. A14117-D42	NASA-Ames	2	Instr Pallet (Active Network Panel)
10	Power Supply, Excitation, with Housing and Cooling Fan	Model CC3D3.5 P/N 10806	Abbott	1	Instr Pallet
11	Remote Time Display Unit	Dwg No. A14117-C5.0, -C5.1	NASA-Ames	1	Cockpit Instr Panel
12	Instrumentation Pallet	Dwg No. 301-070-100	BHT	1	Cabin
13	Stepper Position Interface Card (Scannivalve Encoder)	Dwg No. A14117-C24.1, -C24.2, -C24.3	NASA-Ames	1	Instr Pallet (Active Network Panel)
14	Nose Boom Data Head Assembly	100423-1	Space Age Control Inc.	1	Nose Boom
15	Power Supply, Time Display Unit, 5 Vdc	C5D5.0	Abbott	1	Nose

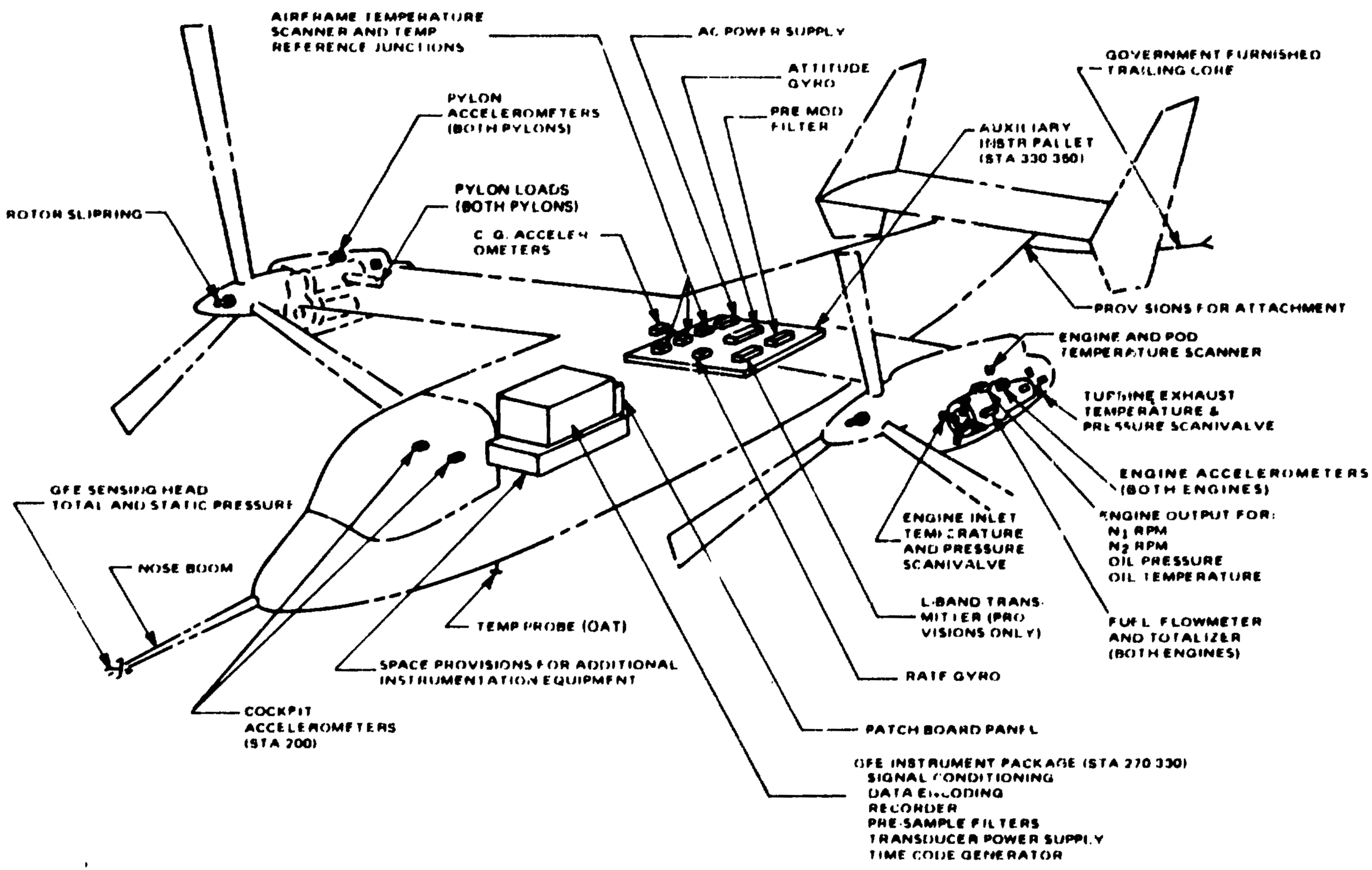

Figure 3-1. Research instrumentation system equipment location

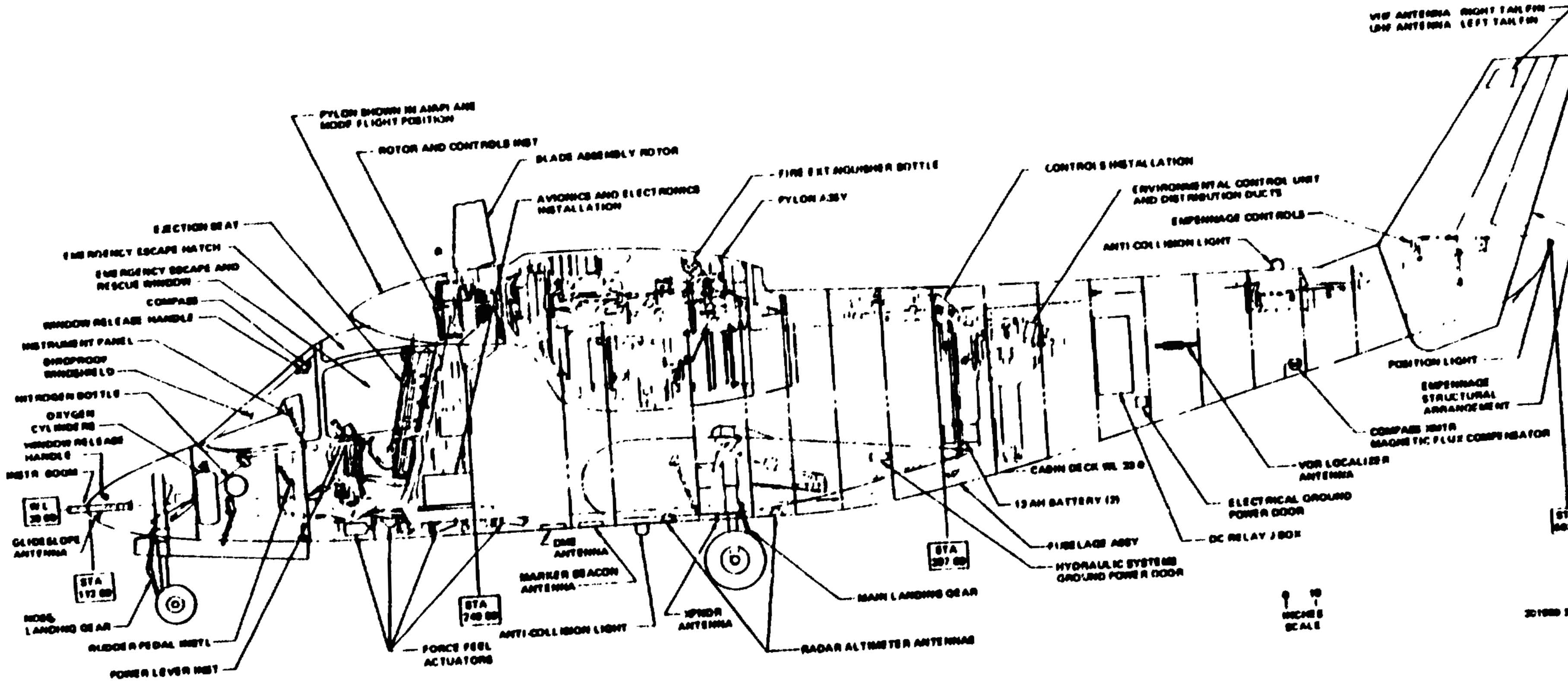

Figure 1-2. XV-15 interior arrangement (sheet 1 of 2)

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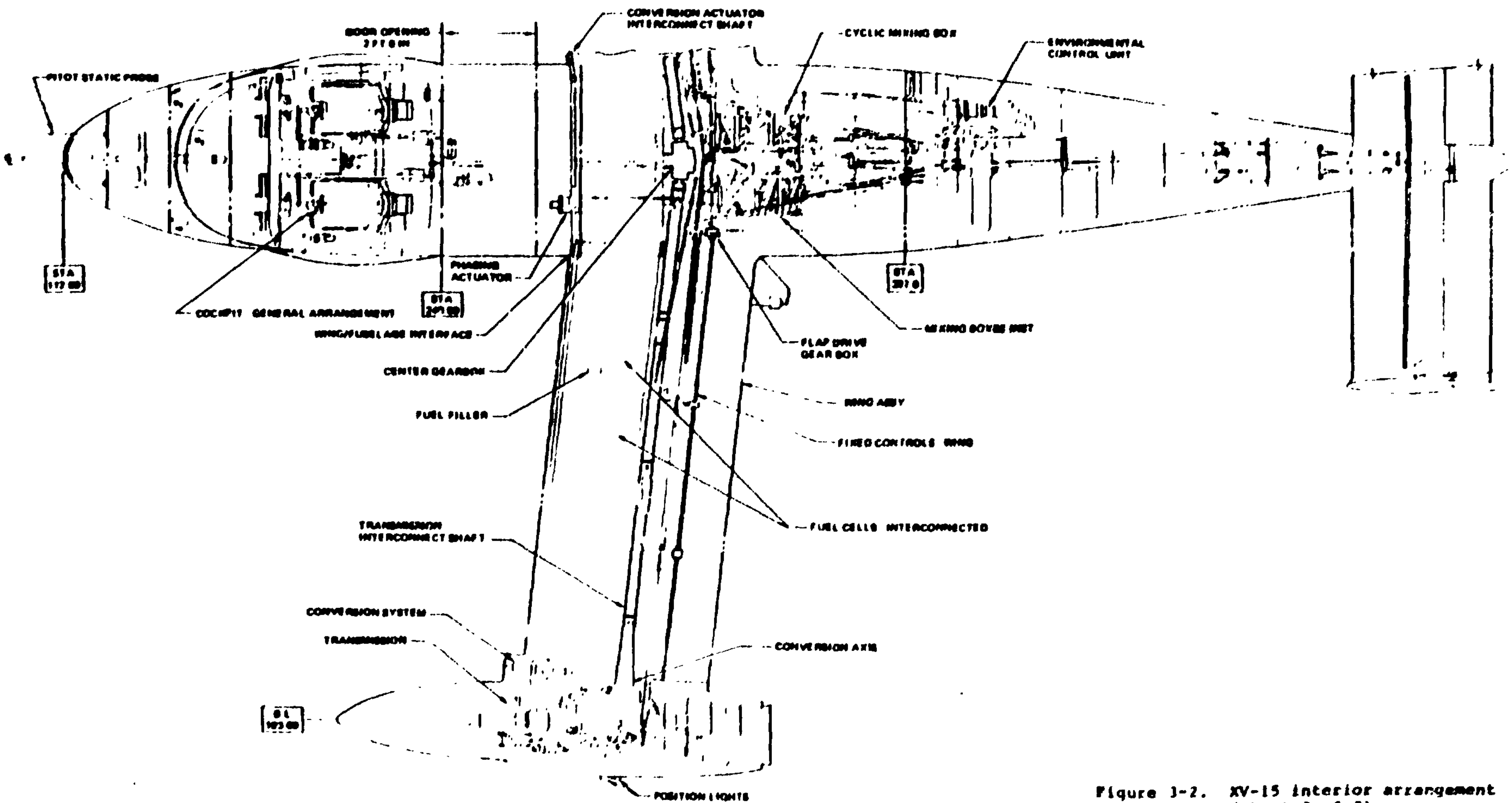

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Figure 3-2. XV-15 interior arrangement (sheet 2 of 2)

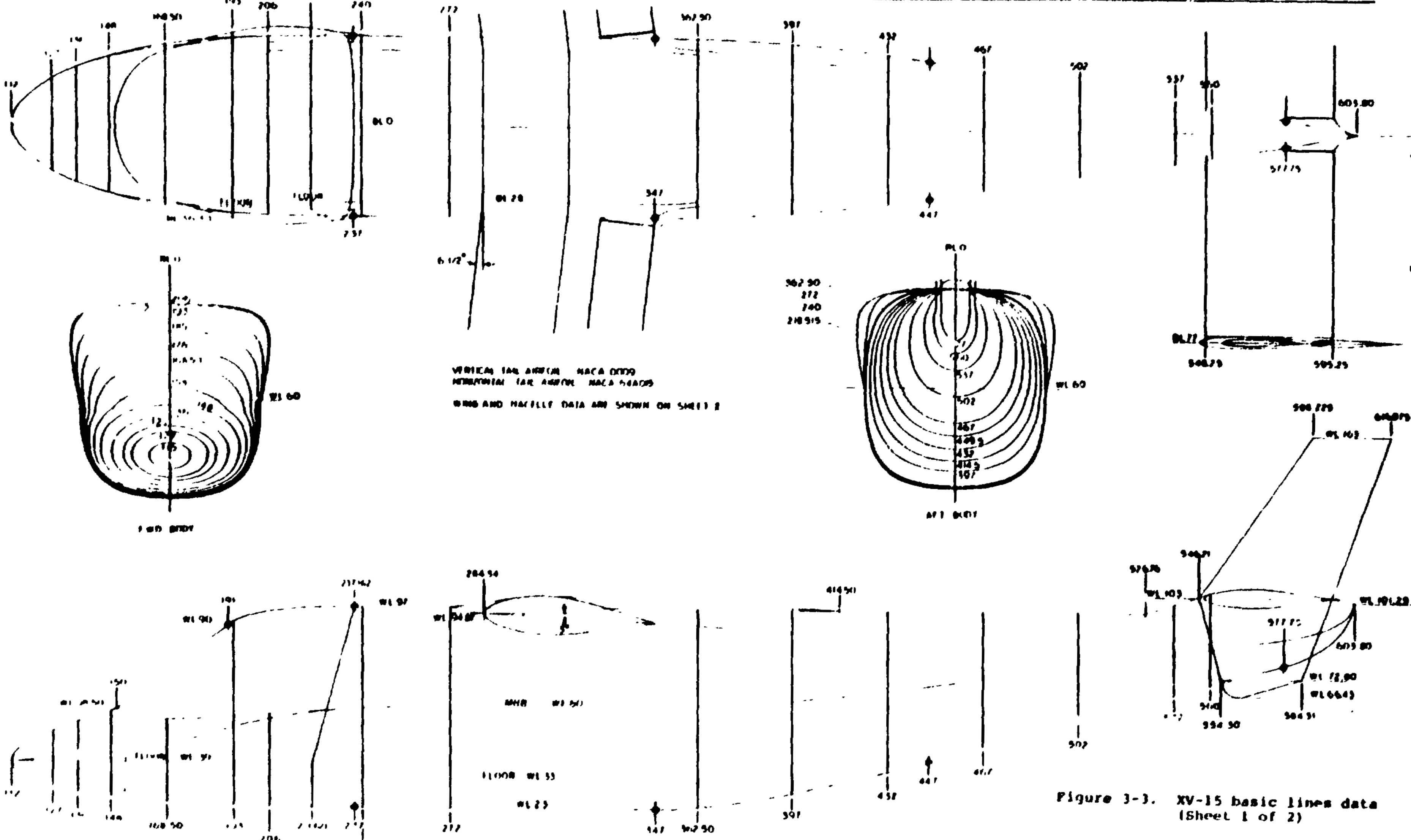
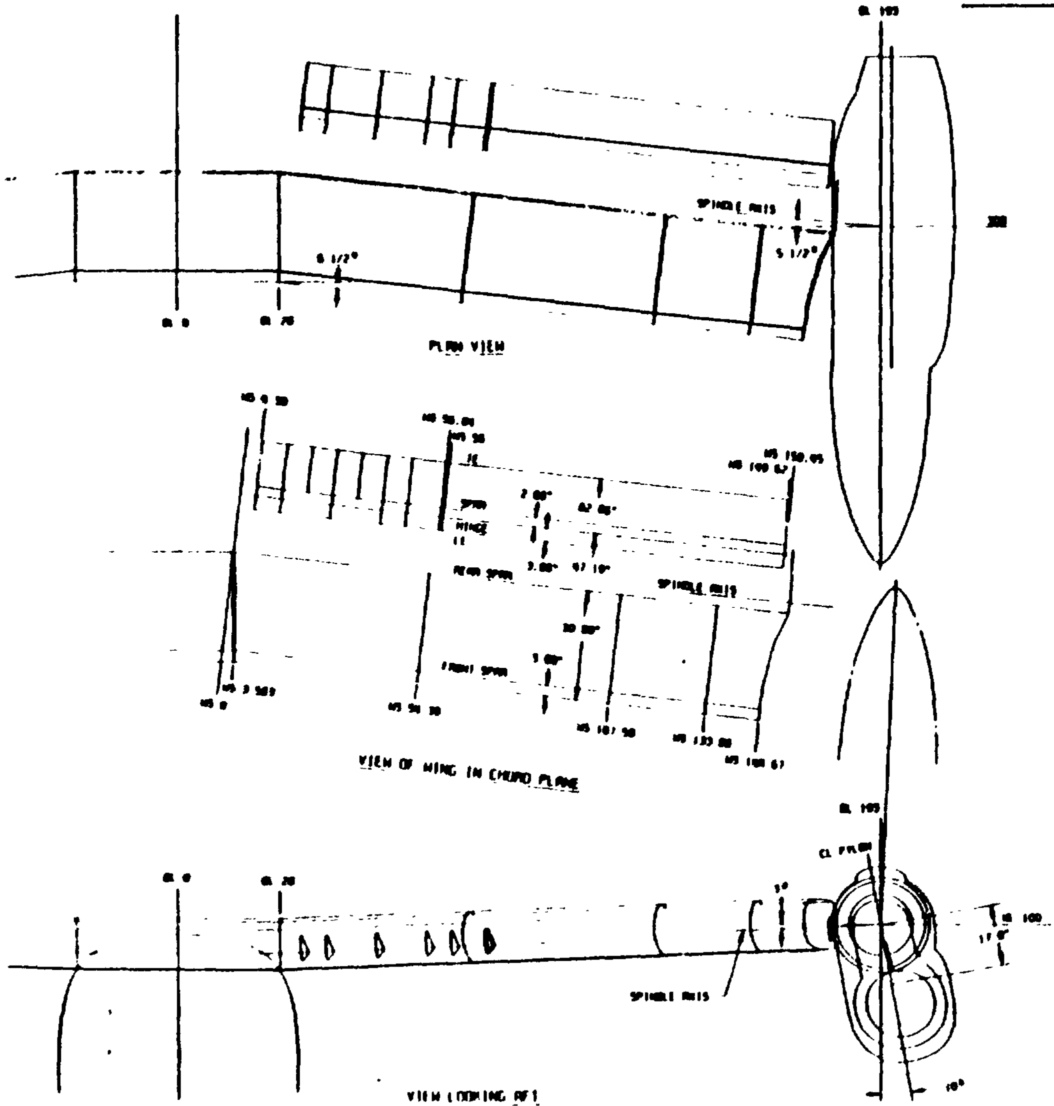


Figure 3-3. XV-15 basic lines data
(Sheet 1 of 2)



WING
AIRFOIL NACA 64A223 MODIFIED
(62.0 CONSTANT CHORD IN BL PLANES)
INCIDENCE 3 DEGREES
DIHEDRAL 1 DEGREE 49.86 MINUTES

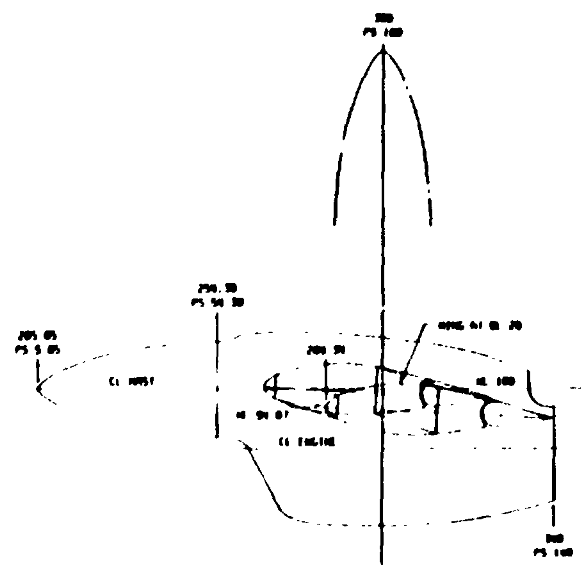


Figure 3-3. XV-15 basic lines data (Sheet 2 of 2)

SECTION 4. POWER AND CONTROL

Electrical power requirements, control signal distribution and control logic for the research instrumentation and data acquisition subsystem are contained in this section. Control logic and wiring for the pressure scanning, thermocouple scanning and telemetry systems are also discussed.

4.1 Power Required. The GFE data acquisition subsystem requires 28 Vdc and 115 Vac, 400 Hz power. Electrical power is supplied by the No. 2 28 Vdc bus and a separate 750 VA, 115 Vac solid state inverter powered by the No. 2 28 Vdc bus. Protection and isolation for the power supply is provided so that the aircraft power system is not affected by failures in the data acquisition subsystem. The data acquisition subsystem is in turn protected from aircraft induced transients by overload sensors, circuit breakers, separate power supplies and DC to DC converters. Aircraft power is connected to the instrumentation pallet and static inverter as shown in Figure 4-1.

4.1.1 DC Power. The 28 Vdc power is furnished to the data system from the aircraft dc bus No. 2 through an 80-amp current sensor and a 50-amp circuit breaker (Figure 4-1). Current in excess of 80 amps will open the overload sensor. The overload fault must be corrected and the sensor reset before power is returned to the system. The overload sensor is installed in the aircraft master power box located on the left side of the rear cabin area behind the auxiliary instrumentation pallet. DC power from the 50-amp circuit breaker panel is routed to the instrumentation pallet through input plugs "C" and "F." DC power is distributed through the circuit breaker panel to the individual instrumentation system components (see Figure 4-2). The following research instrumentation equipment is powered by 28 Vdc.

a. Tape transport deck
b. Attitude gyro, cage-uncage function
c. Rate gyro
d. V_E power supply
e. Program board
f. Telemetry transmitter
g. Active network power supply (±15, +5, +28 Vdc)
h. Data control monitor
i. 750 VA static inverter
j. Temperature reference junctions
k. Time code display panel

4.1.2 AC Power. The 115 Vac, 400 Hz power is furnished to the data acquisition subsystem from a Flite-Tronics Co. PC-17A 750 VA static inverter. The inverter is powered by the No. 2 28 Vdc bus and protected by the 80-amp overload sensor and a 50-amp circuit breaker (see Figure 4-1). AC power from the inverter is connected to the instrumentation pallet through input plugs "C" and "F." The ac power is then distributed through the circuit breaker panel to the individual instrumentation system components (see Figure 4-2). This ac voltage is used to power the following equipment.

a. PAF #A
b. PAF #B
c. RMDU #A
d. RMDU #B
e. Tape deck heaters
f. R-cal box #1
g. R-cal box #2
h. R-cal box #3
i. R-cal box #4
j. R-cal box #5
k. Time code generator
l. Attitude gyro power
m. Flight line tester (FLT)
n. Fan

4.1.3 Circuit Breaker Panel. The circuit breaker panel is installed on the instrumentation pallet. Figure 4-3 shows the layout of the circuit breaker panel.

4.2 System Control Logic. Figure 4-4 shows the basic flow diagram for system control logic. Pressure and temperature scans are initiated by the prime data switch located on the pilot's and copilot's power lever. Instrumentation system status is displayed on the control monitor (Figure 1-7). When the prime data switch is pressed the prime data light on the control monitor will blink indicating that system logic is in prime data mode. When the prime data switch is pressed again, the record number displayed on the control monitor will update and the prime data light will cease blinking.

4.3 Control Signal Distribution. A schematic wiring diagram of the data recorder and control monitor is shown in Figure 4-5. Control signal distribution to the control monitor is shown in Figure 4-6. Control signal input to instrumentation pallet plugs "A" and "B" is shown in Figure 4-7. Control signal wiring for attitude and rate gyro packages is shown on Figure 4-8. Display signal wiring to the pilot's time code generator display is shown in Figure 4-9.

4.4 Pressure Scanning System. A flow diagram for the pressure scanning system control logic is shown in Figure 4-10. Control signal distribution wiring is shown in Figure 4-11. A scannivalve control box, shown schematically in Figure 4-12, is installed to permit manual single step operation of the scannivalve for checkout and maintenance. The scannivalve contains a position encoder which generates a 12-bit word (see Table 4-I) used to identify the pressure ports during the scan mode of operation. Pressure and temperature scanning is synchronized so that the location word (A82-8-1) can be used to identify both pressure port and temperature channel for the temperature scanning system.

4.5 Temperature Scanning System. A flow diagram for the temperature scanning system control logic is shown in Figure 4-13. Control signal distribution wiring is shown in Figure 4-14. Thermocouple signal inputs to the temperature scanner remote unit (typical of three units) is shown in Figure 4-15. Internal wiring for the temperature scanner remote unit is shown in Figure 4-16. The scan mode is initiated automatically when prime data is selected. The scan is terminated at the end of the prime data record or at the end of one complete scan cycle. The temperature monitor (Figure 1-10) contains a FAULT light to indicate that the system is not ready to take data (thermocouple reference junctions not up to temperature or electrical fault) and a CYCLING light to indicate that the system is in the scan mode. The CYCLING light remains illuminated until both pressure and temperature scans are complete. A special circuit card located in the active network panel generates a 12-bit ID code (see Table 4-II) which gives the location of the temperature scanner. This code is generated in either the scan or dial in mode.

4.6 Telemetry System. Control and signal distribution wiring for the L-band telemetry system is shown in Figure 4-17. A schematic of the BHT-fabricated premodulation filter is shown in Figure 4-18.

TABLE 4-I. SCANNIVALVE POSITION ENCODER WORD A82-8-1

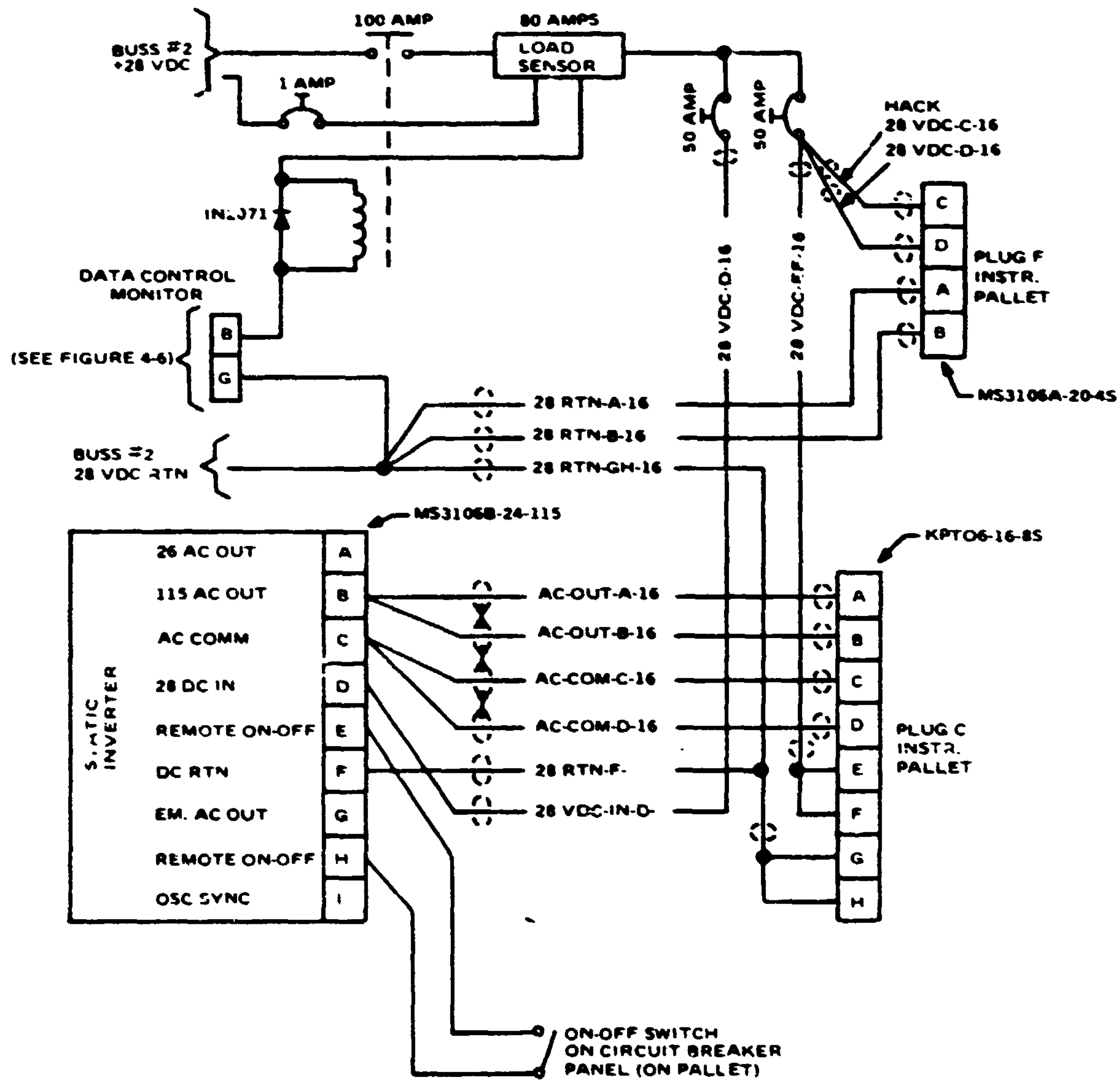
ID Count (Following "000")	Press Port	ID Count (Following "000")	Press Port	
00000010	1	01001010	25	
00000100	2	01001100	26	
00000110	3	01001110	27	
00001000	4	01010000	28	
00001010	5	01010010	29	
00001100	6	01100000	30	
00001110	7	01100010	31	
00010000	8	01100100	32	
00010010	9	01100110	33	
00100000	10	01101000	34	
00100010	11	01101010	35	
00100100	12	01101100	36	
00100110	13	01101110	37	
00101000	14	01110000	38	
00101010	15	01110010	39	
00101100	16	10000000	40	
00101110	17	10000010	41	
00110000	18	10000100	42	
00110010	19	10000110	43	
01000000	20	10001000	44	
01000010	21	10001010	45	
01000100	22	10001100	46	Static
01000110	23	10001110	47	Open
01001000	24	10010000	48	Home

Note: Scan starts at Channel 48 (Home)

TABLE 4-II. TEMPERATURE SCANNER POSITION ENCODER WORD A79-8-7

Temp[1] Chan	ID Count (MSB ... LSB)
0	000000000000
1	000000000001
2	000000000010
3	000000000011
4	000000000100
5	000000000101
6	000000000110
7	000000000111
8	000000001000
9	000000001001
10	000000010000
11	000000010001
12	000000010010
13	000000010011
14	000000010100
15	000000010101
16	000000010110
17	00[illegible]0010111
18	[illegible]0011000
19	000000011001
20	000000100000
21	000000100001
22	000000100010
23	000000100011
24	000000100100
25	000000100101
26	000000100110
27	000000100111
28	000000101000
29[2]	000000101001

[1]Temp Chan refers to ID number set on pilot's panel
[2]This is shorted for reference



1. EQUIPMENT MOUNTED ON AUX. PALLET AT AFT END OF CABIN AREA.

Figure 4-1. Instrumentation power wiring

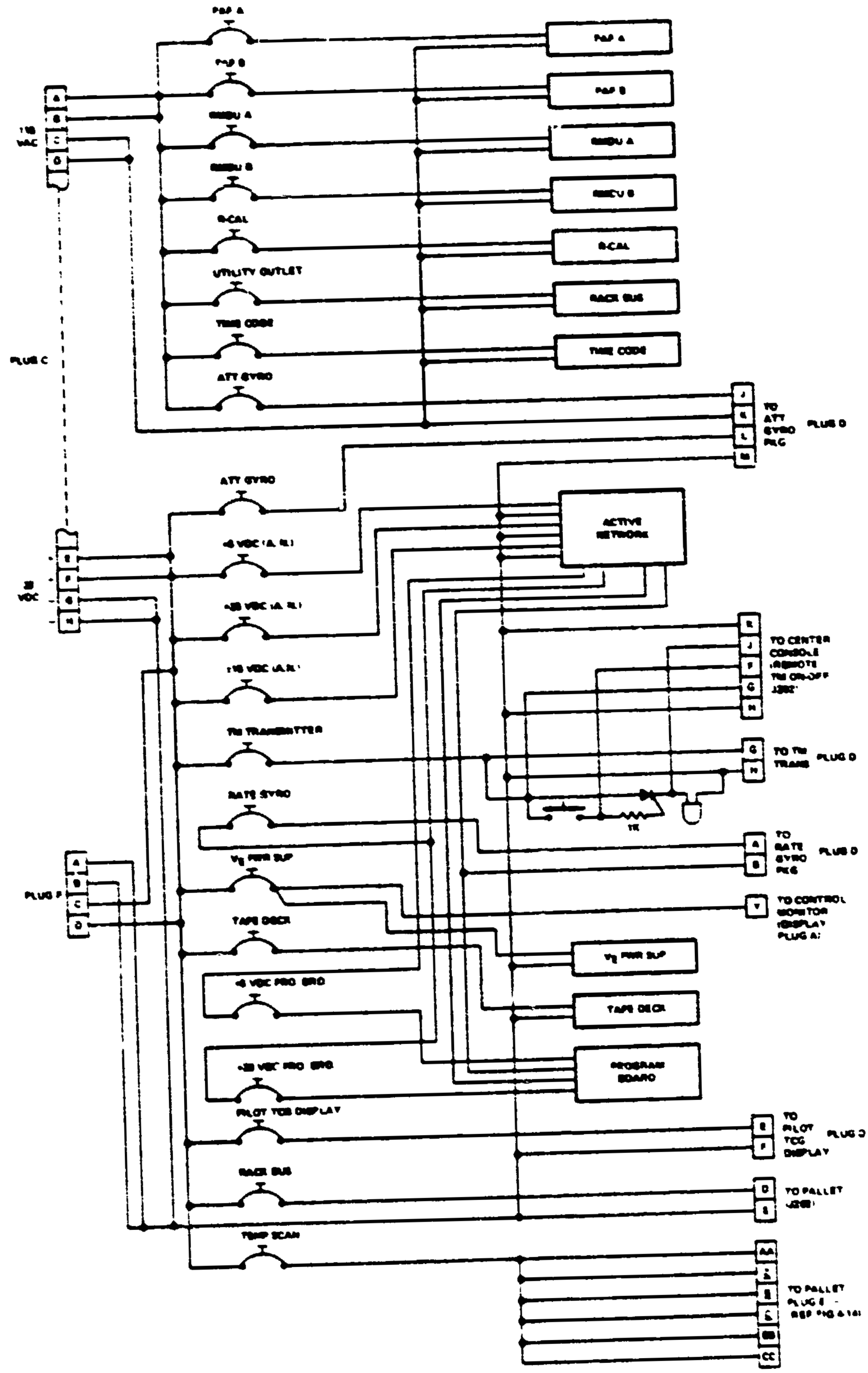


Figure 4-2. Circuit breaker panel wiring

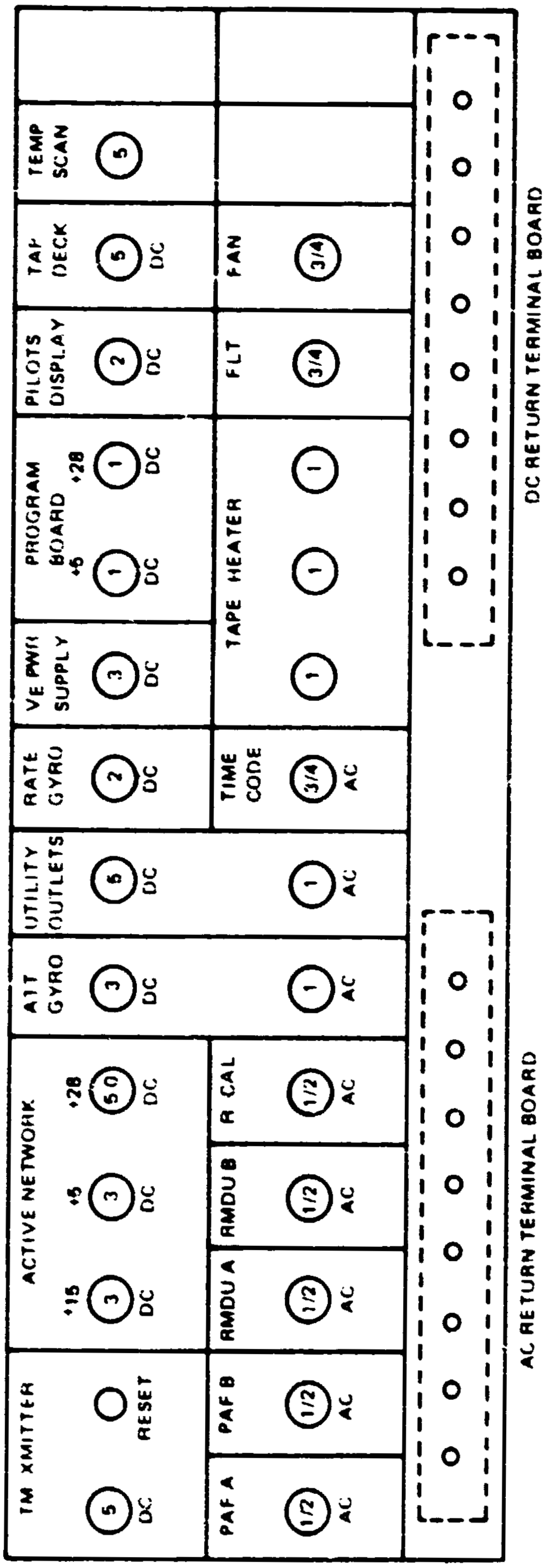
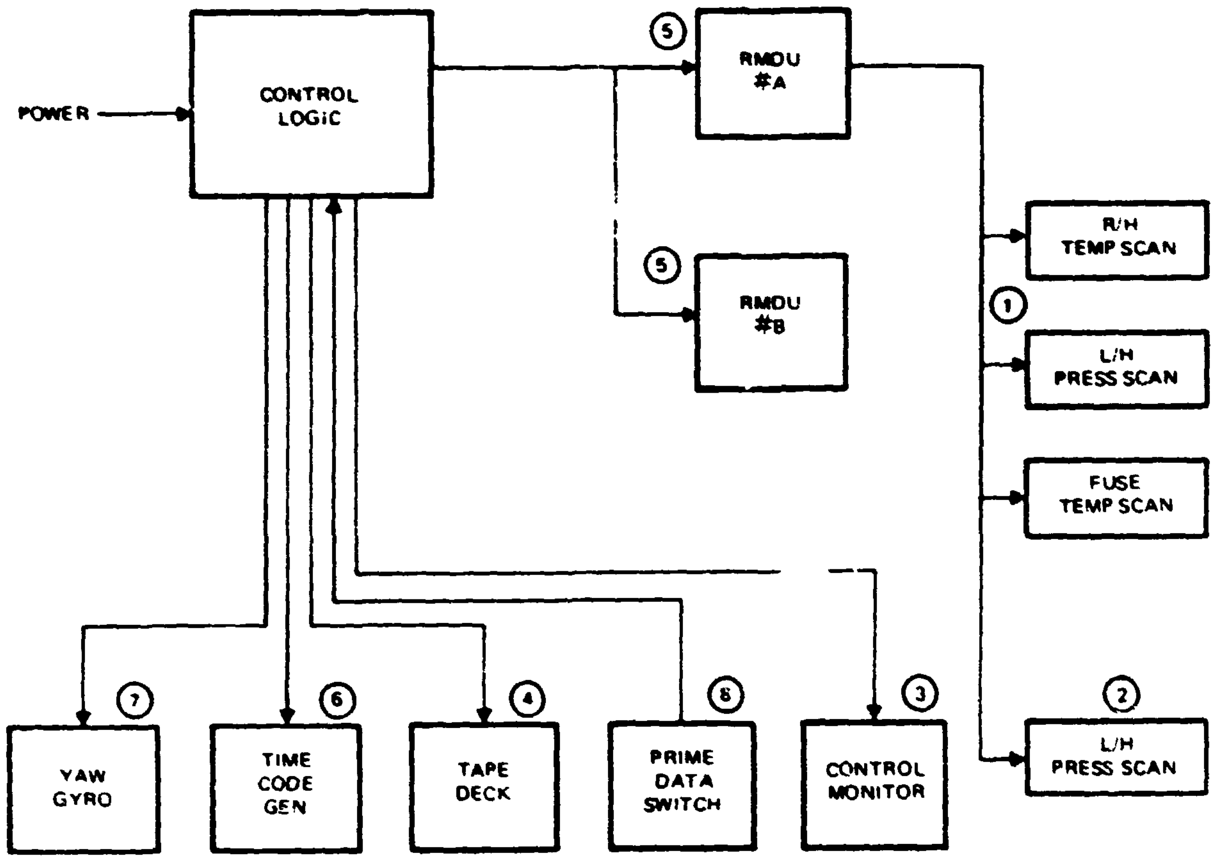


Figure 4-3. Circuit breaker panel layout



(1) Temp Scan – Prime data starts the scan which stops automatically after one full cycle if prime data is still on at the end of scan. The system automatically homes when prime data is terminated

(2) Pressure Scan – Same as Temp. Scan

(3) Control Monitor – Prime data light, Rec # update

(4) Tape Deck – Level code

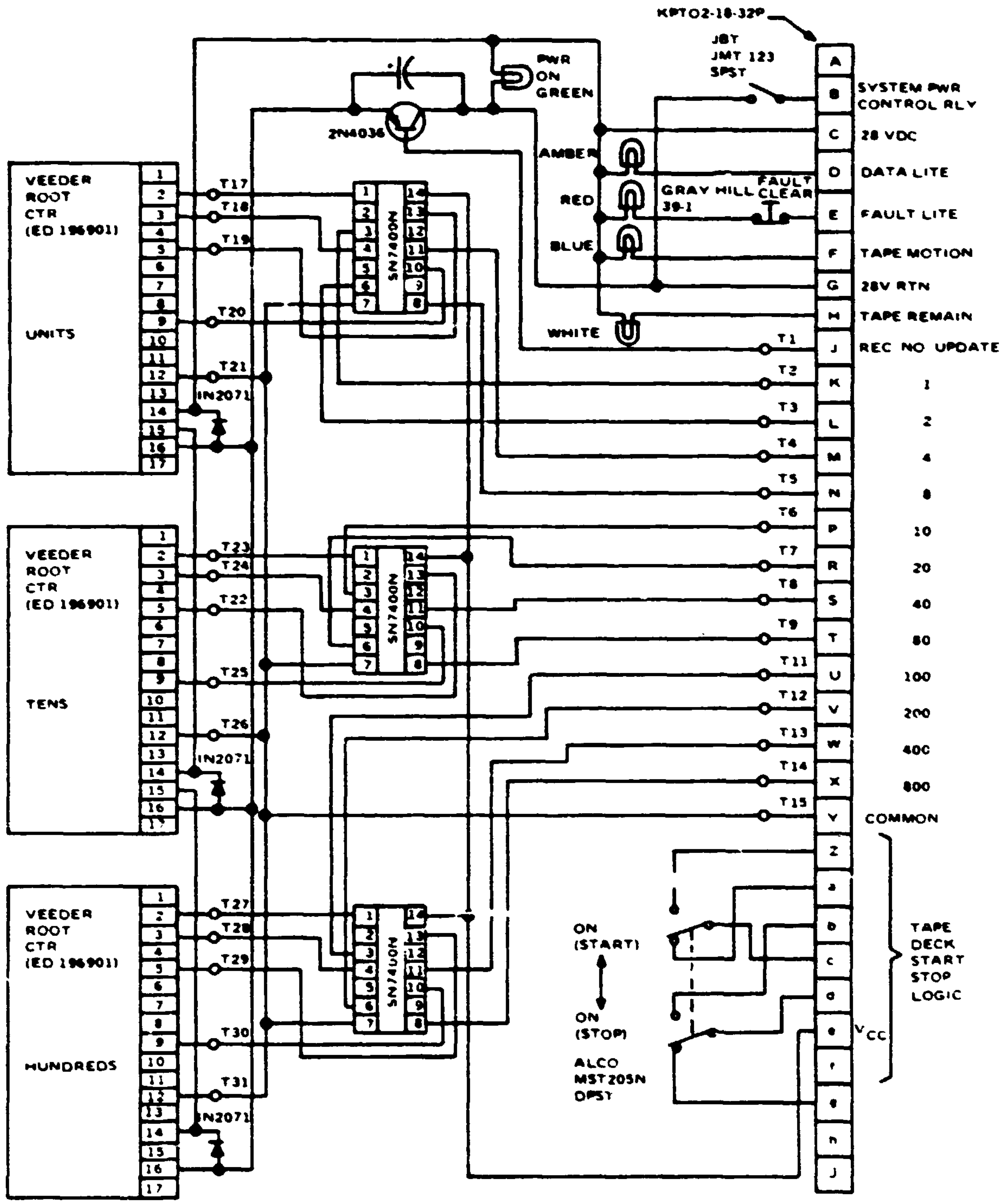
(5) RMDU's (A & B) – Start sample, pressure and temperature scan

(6) Time Code Generator – Receives record number and prime data record bit

(7) Yaw Att Gyro – Cage-uncage circuit

(8) Prime Data Switch – Initiate prime data record

Figure 4-4. Control logic flow diagram



NOTE
ALL LIGHTS ARE DIALITE SERIES
5131-038-303 R - RED C - CLEAR
G - GREEN W - WHITE
A - AMBER B - BLUE

Figure 4-5. Control monitor wiring diagram

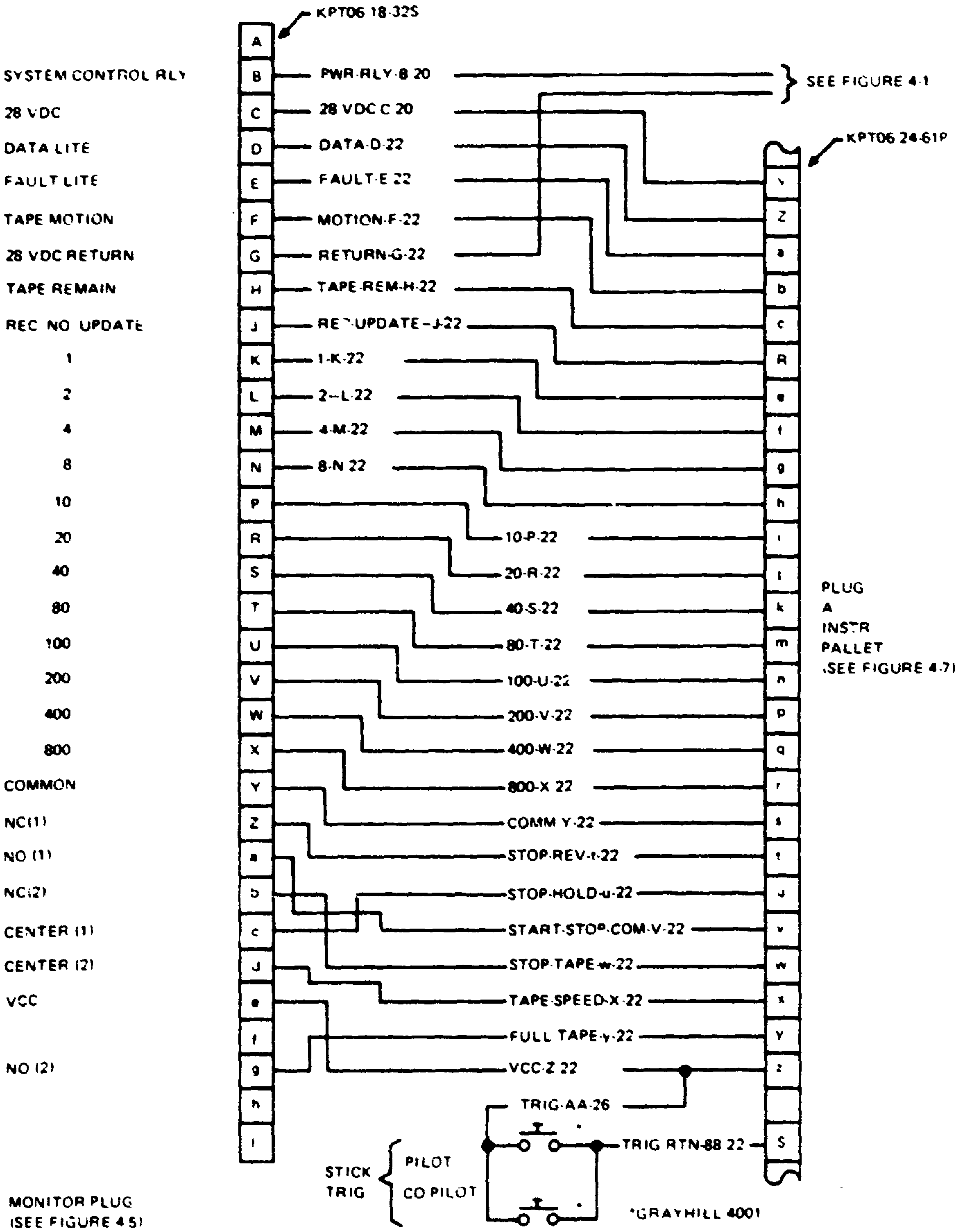


Figure 4-6. Control monitor wiring harness

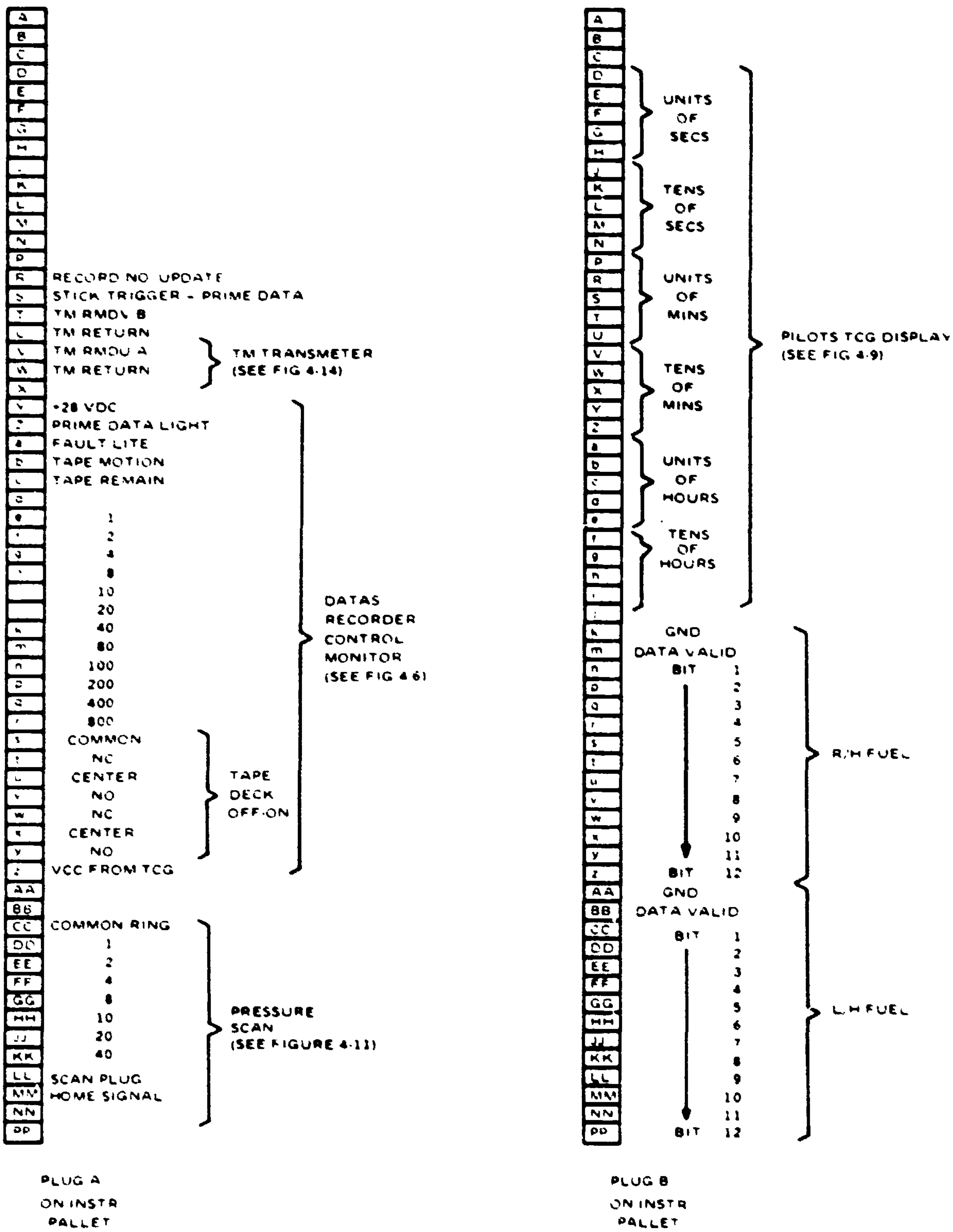
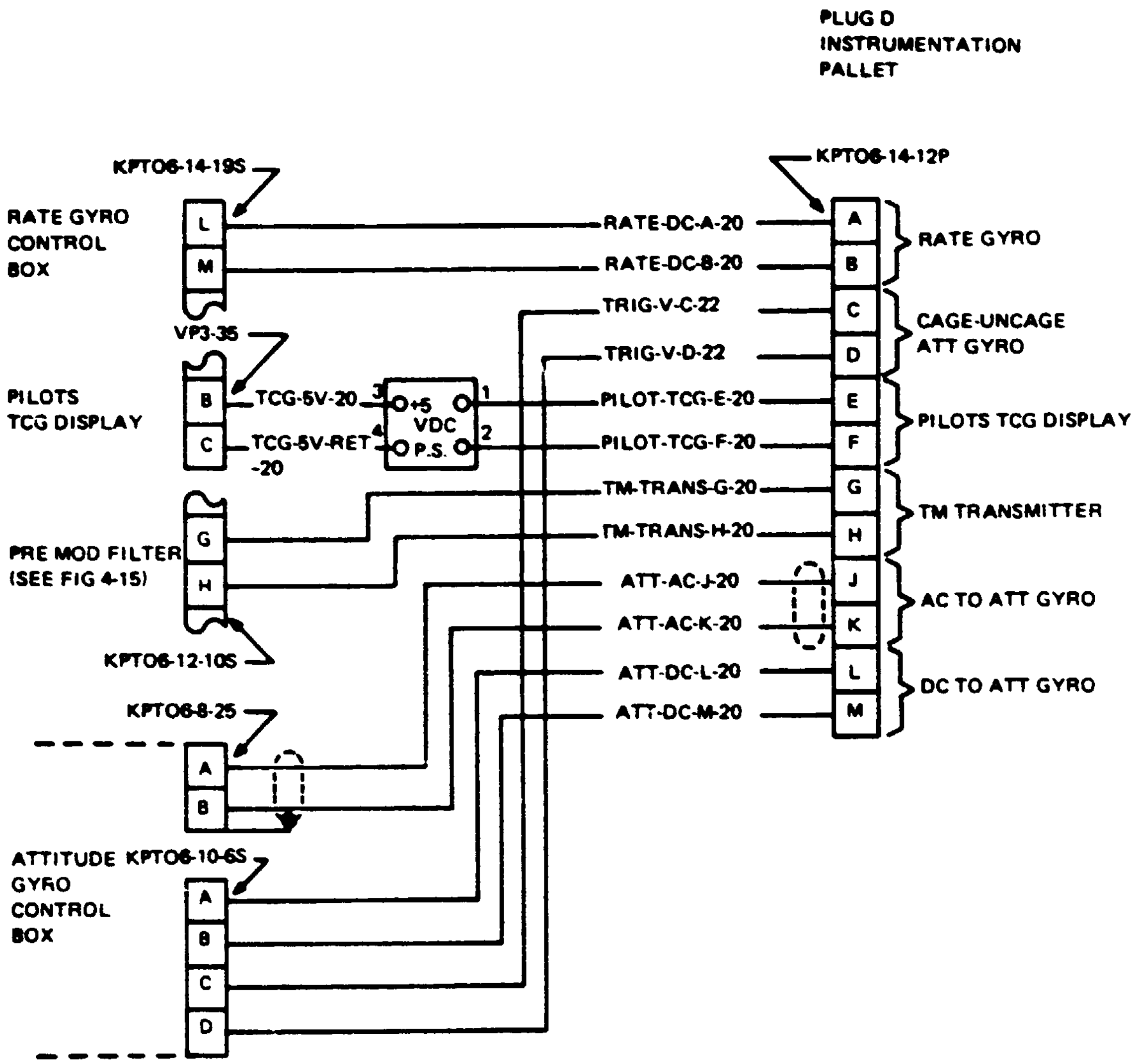


Figure 4-7. Pallet input plugs A and B wiring



1. GYRO CONTROL BOXES MOUNTED ON AUX PALLET AT AFT END OF CABIN AREA.
2. PILOT'S DISPLAY POWER SUPPLY MOUNTED IN COCKPIT AREA.

Figure 4-8. Pallet input plug D wiring (attitude and rate gyro)

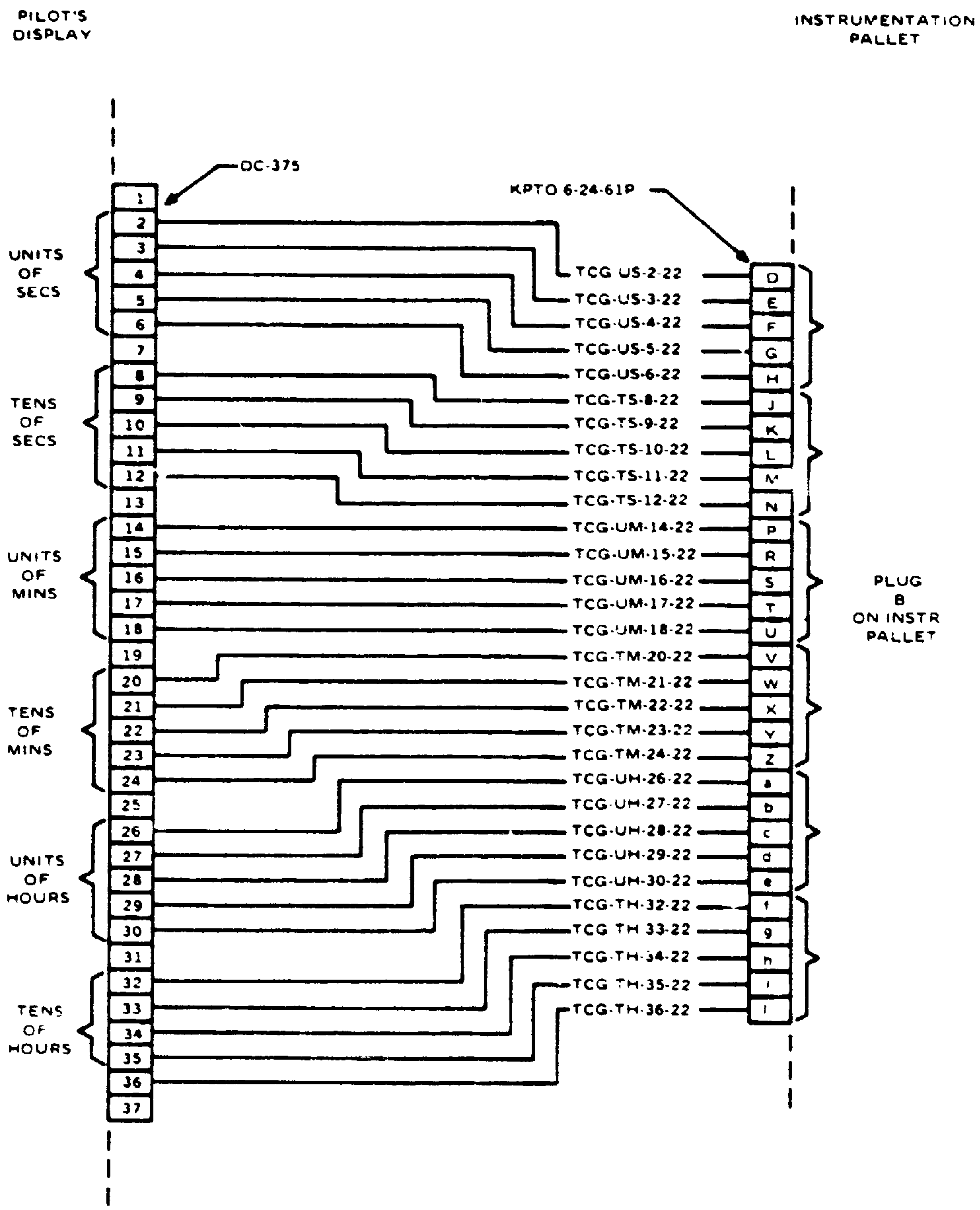


Figure 4-9. Pilot's time code display

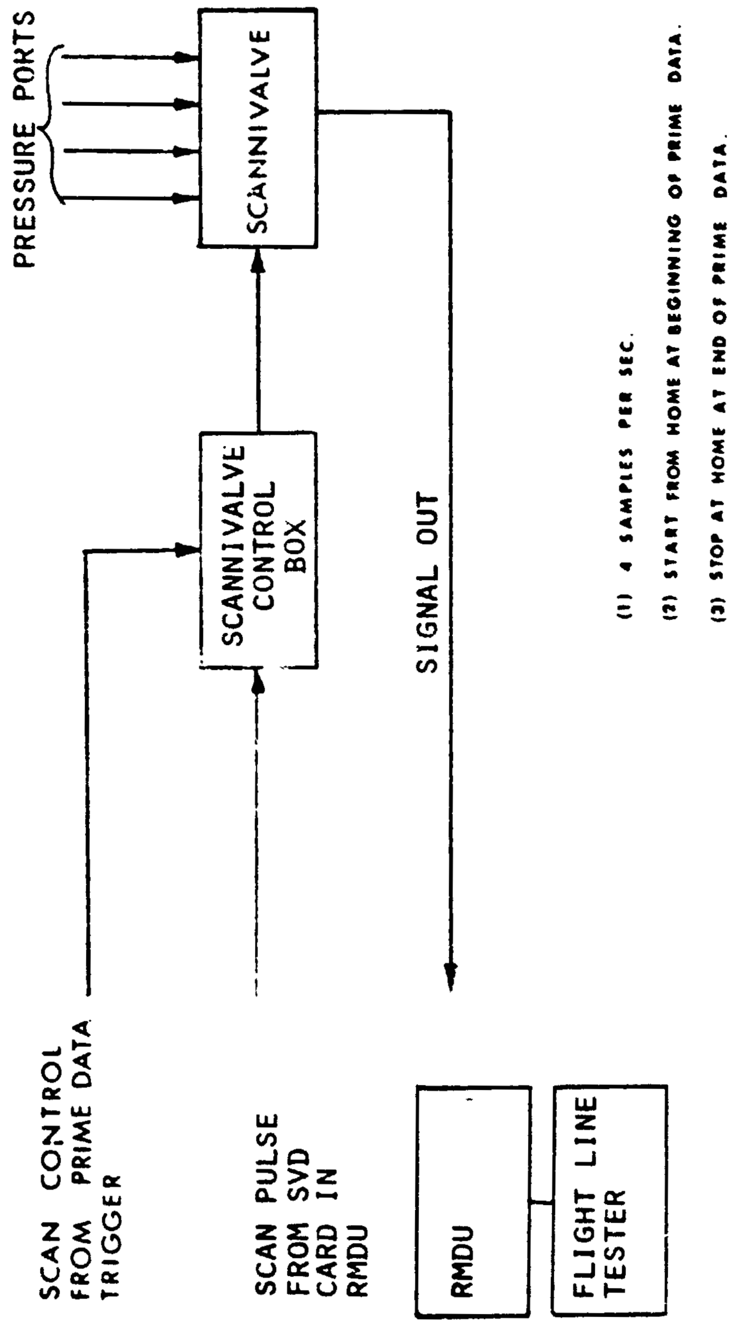
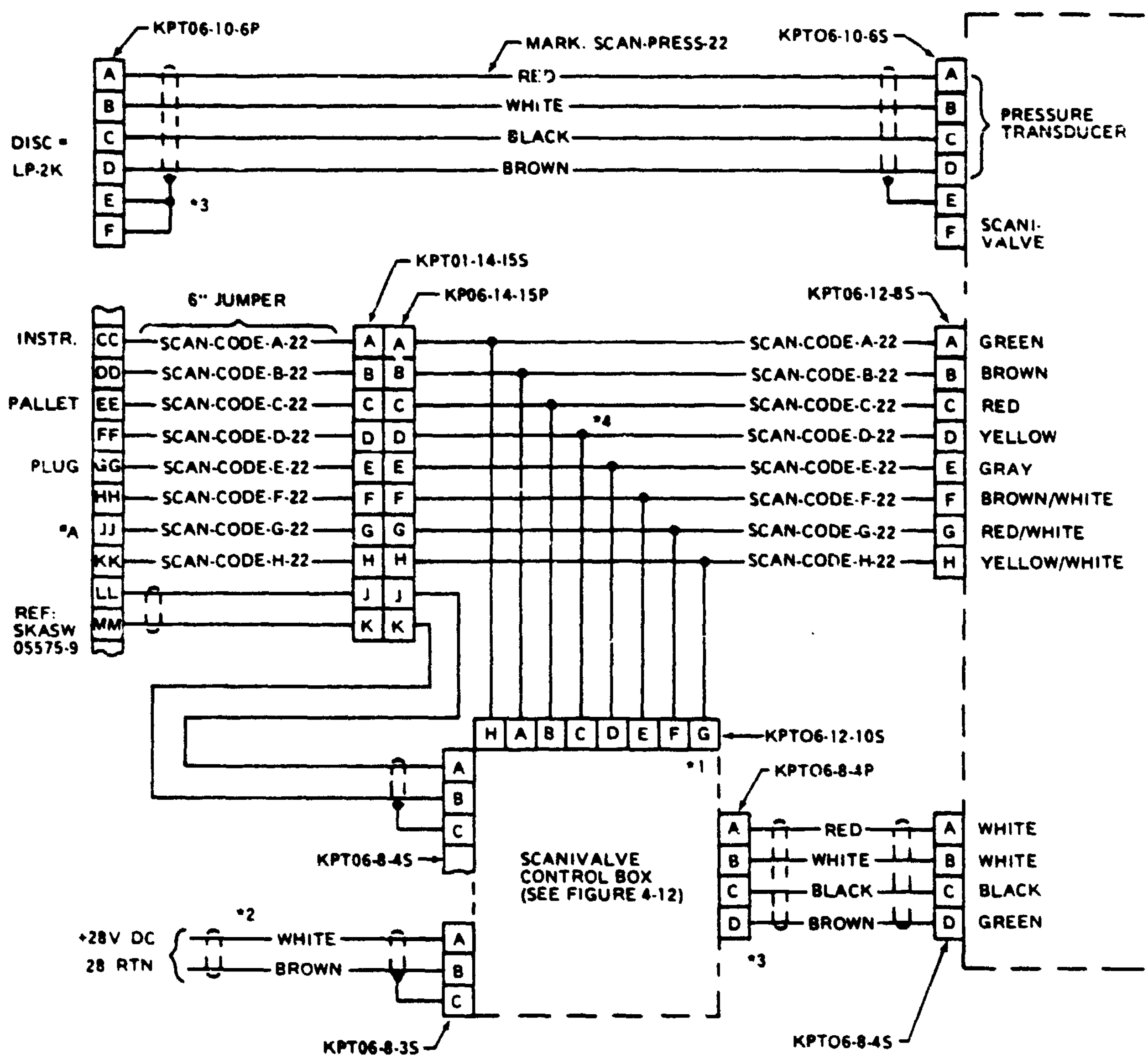


Figure 4-10. Pressure scan flow diagram



*1-CONTROL BOX MOUNTED ON LEFT PYLON
*2-USE 2 CONDUCTOR, 20 GAGE ORANGE WIRE
*3-USE 4 CONDUCTOR, 22 GAGE ORANGE WIRE
*4-MAKE THESE SPLICES AT THE SCANIVALVE CONNECTOR

SCANIVALVE CONTROL WIRING

301099-1?

Figure 4-11. Scannivalve control wiring

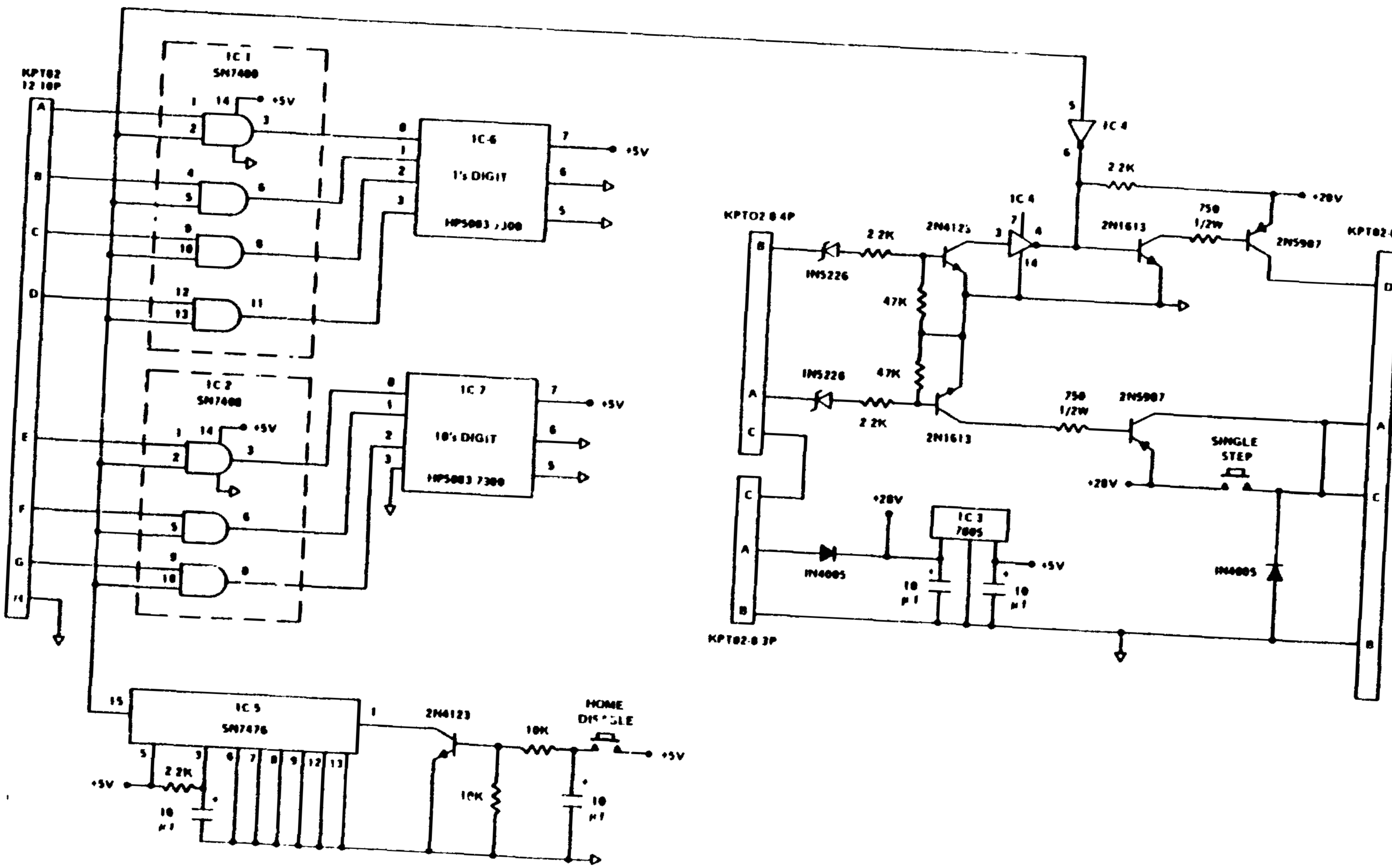


Figure 4-12. Scannivalve control box

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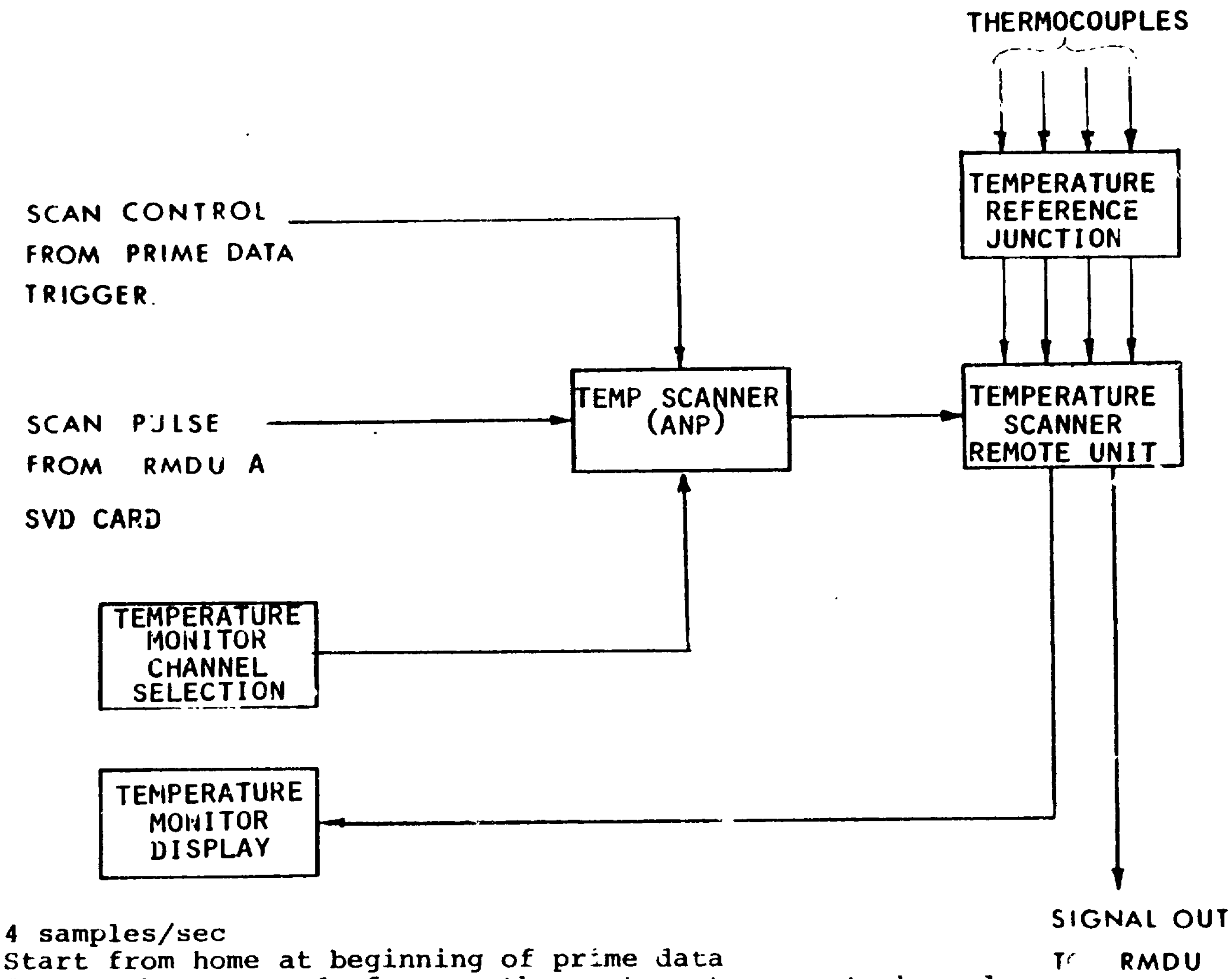


(1) 4 samples/sec
(2) Start from home at beginning of prime data
(3) Stop at home at end of scan, then return to preset channel at end of prime data

Figure 4-13. Temperature scanner flow diagram (typical of 3 remote unit installations)

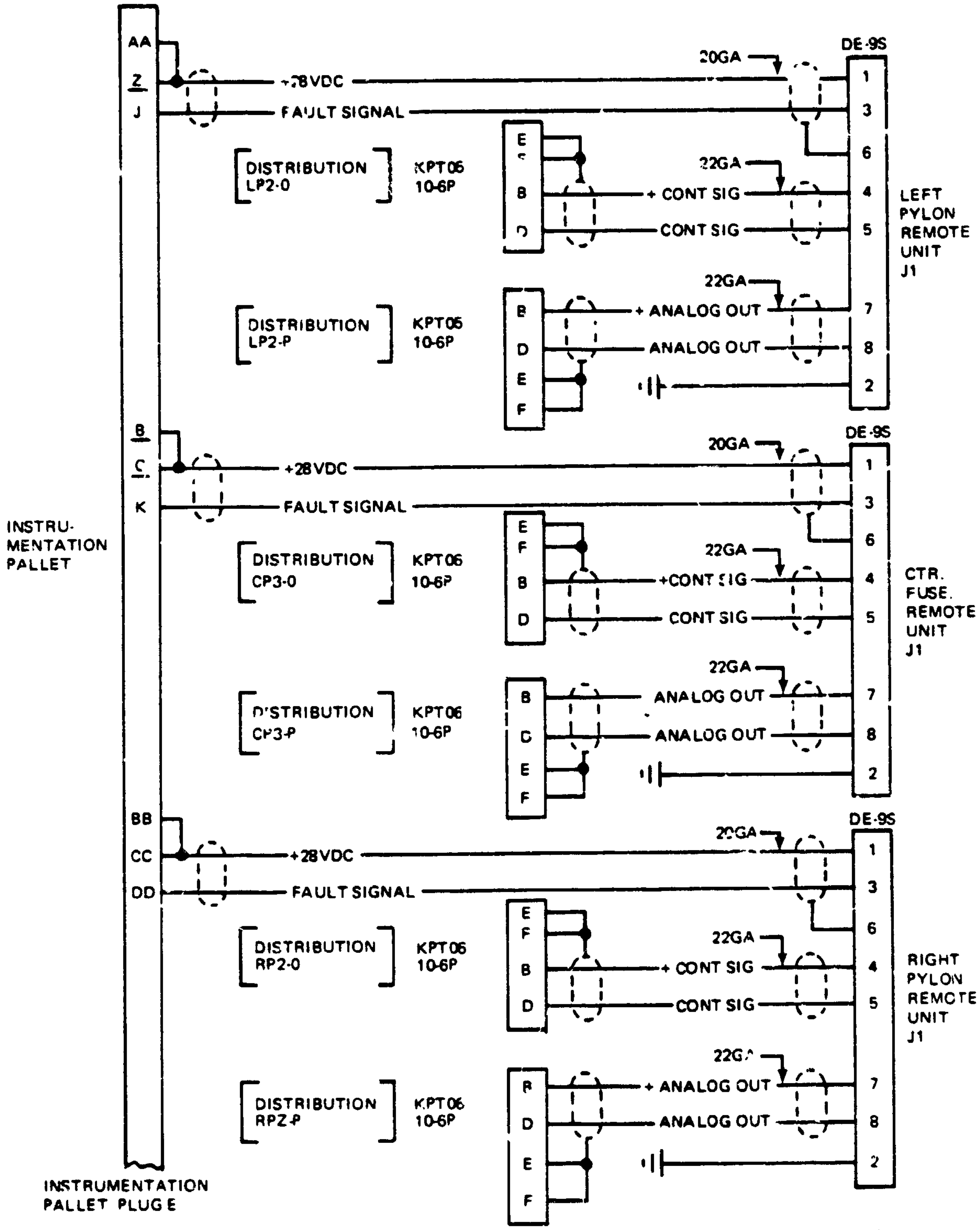


Figure 4-14. Temperature scanner system

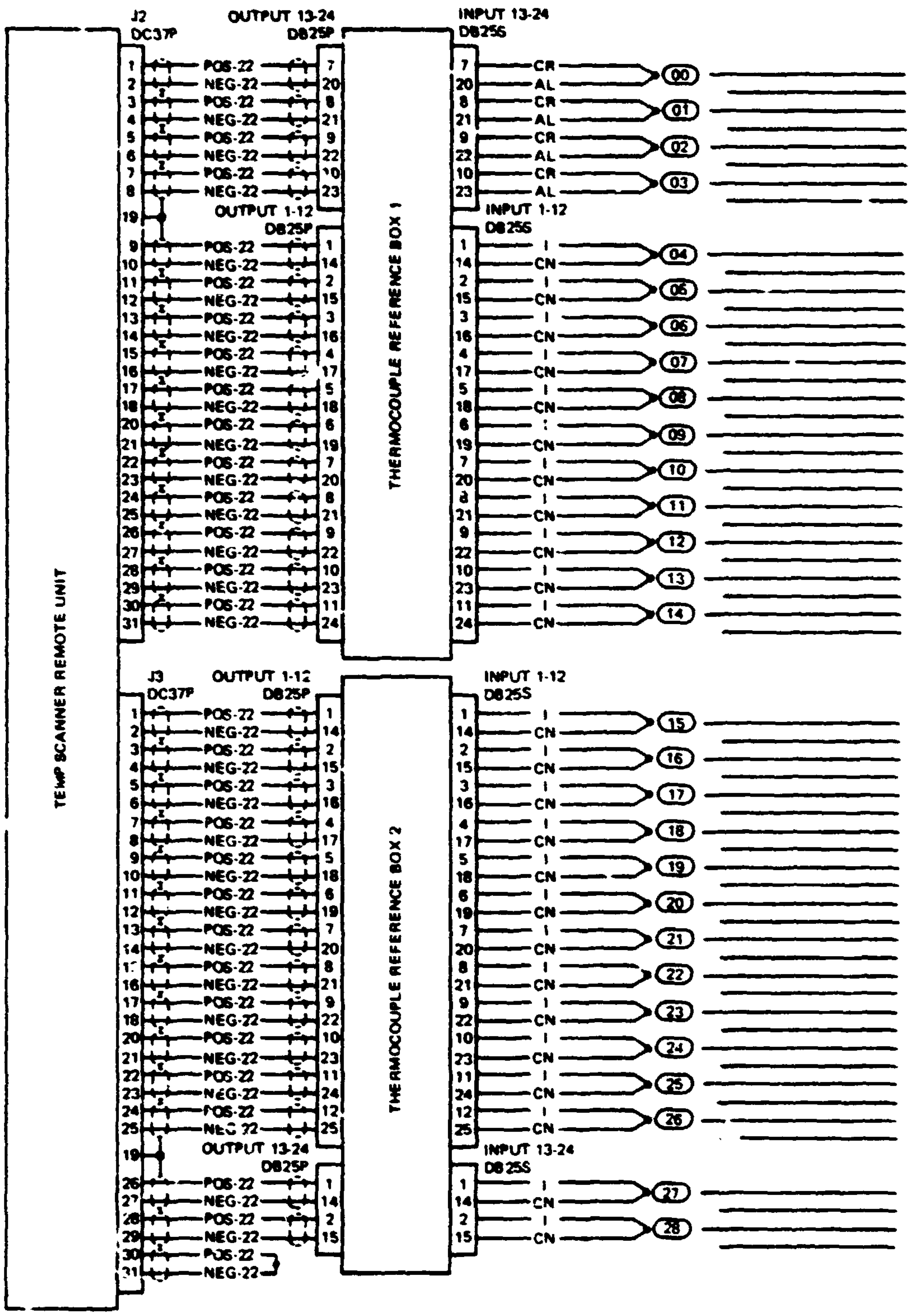


Figure 4-15. Thermocouple system

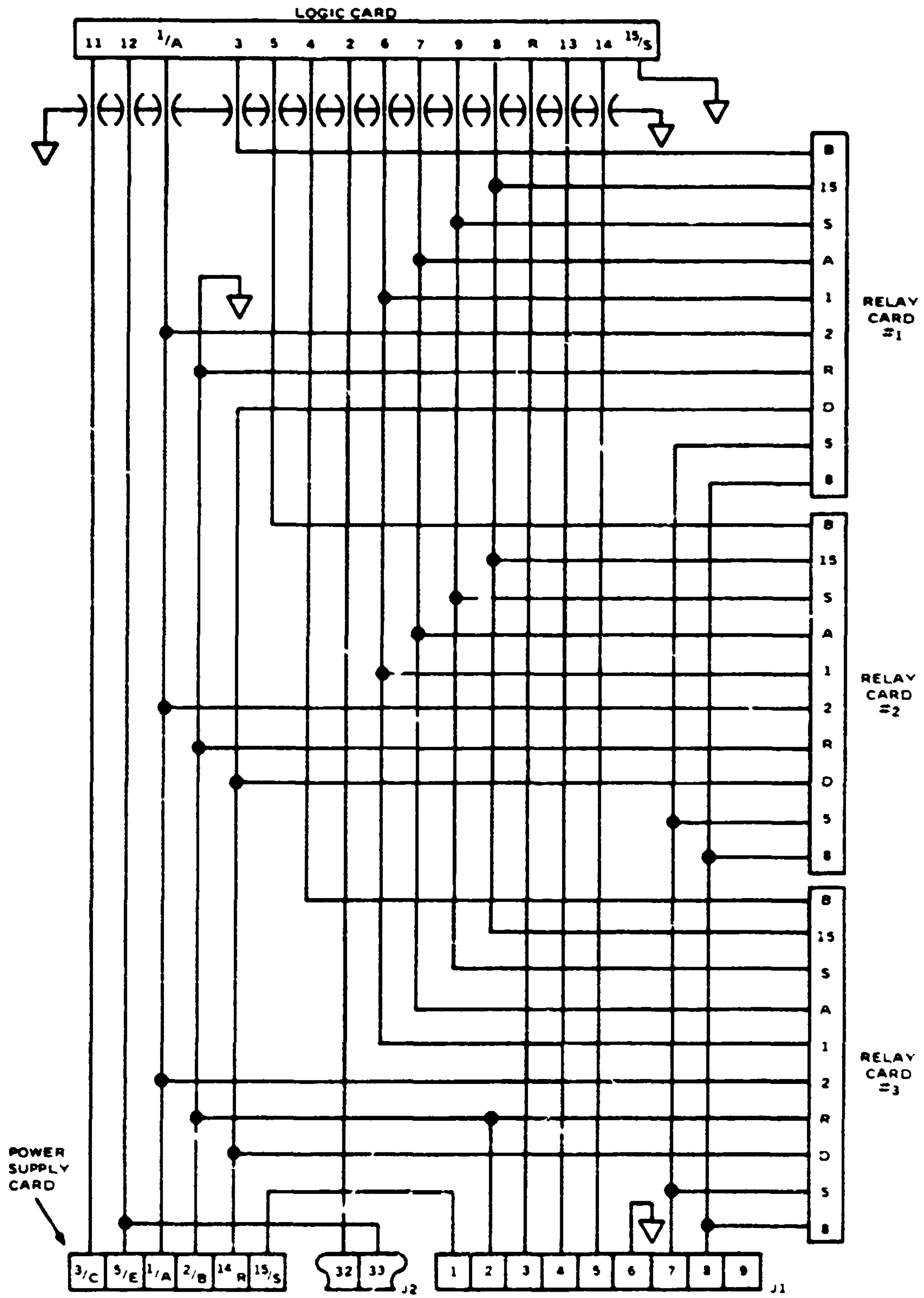


Figure 4-16. Temperature scanner remote unit - internal wiring (sheet 1 of 9)

TEMP SCANNER REMOTE UNIT SIGNAL WIRING

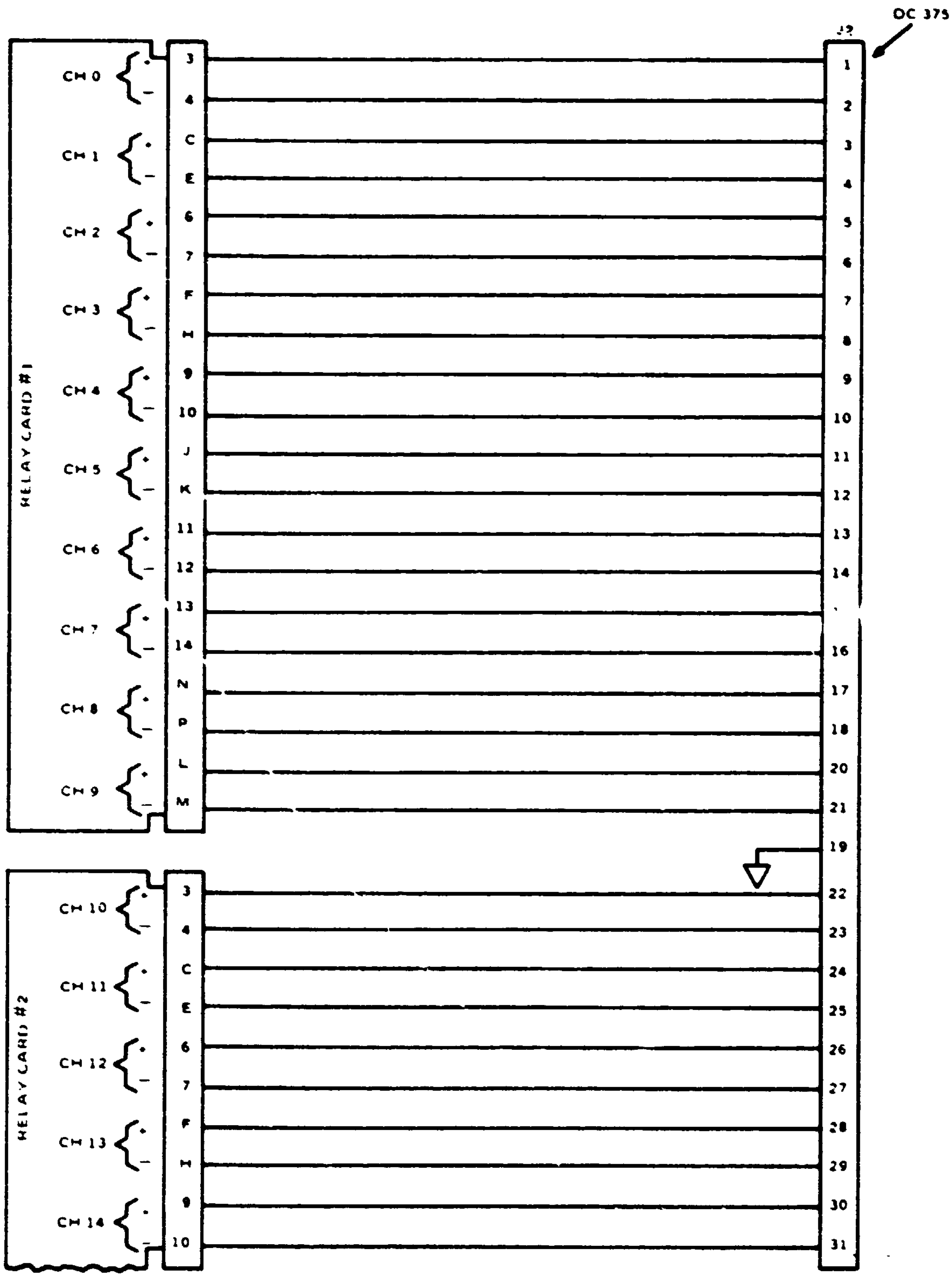


Figure 4-16. Temperature scanner remote unit - internal wiring (sheet 2 of 9)

TEMP SCANNER REMOTE UNIT SIGNAL WIRING

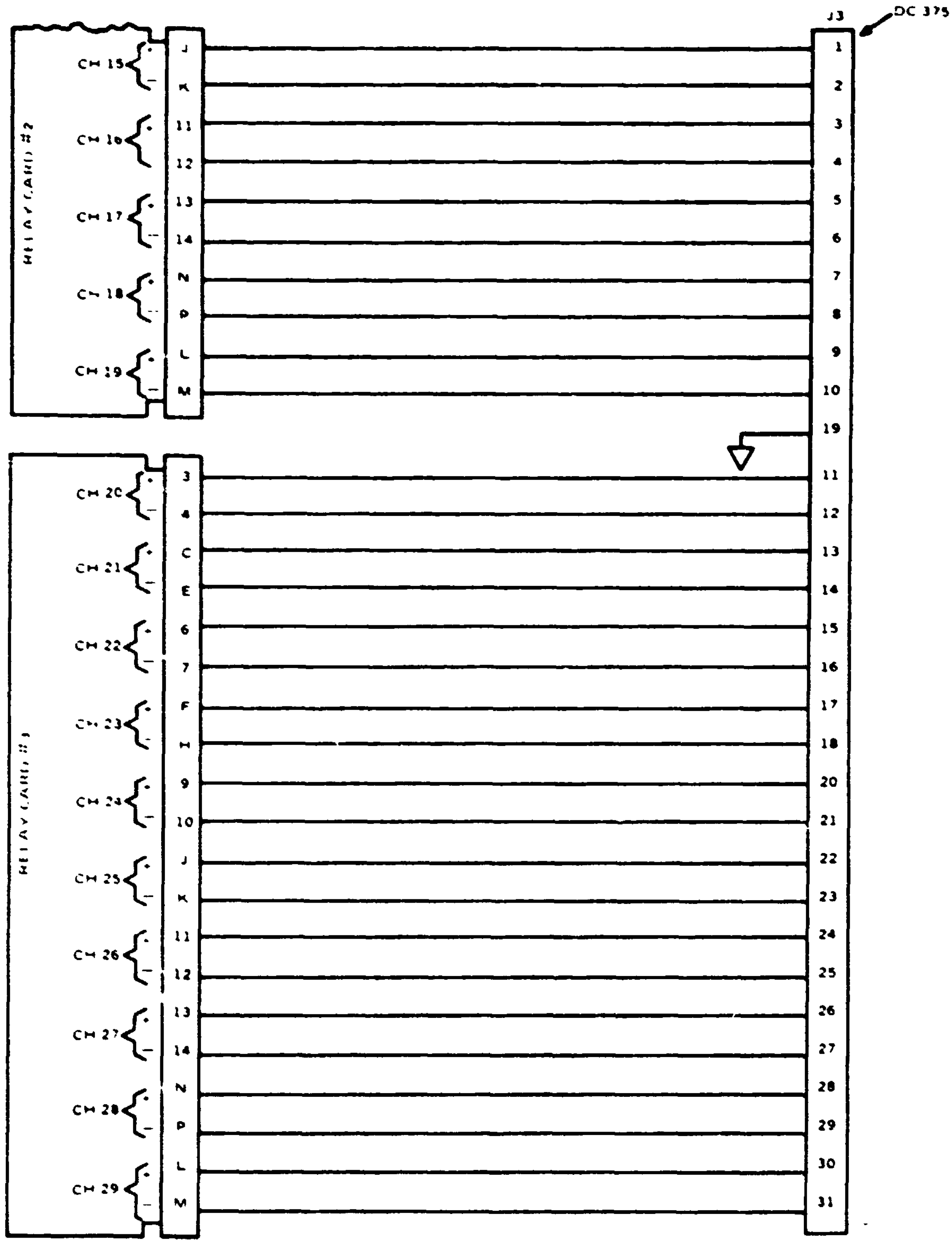


Figure 4-16. Temperature scanner remote unit - internal wiring (sheet 3 of 9)

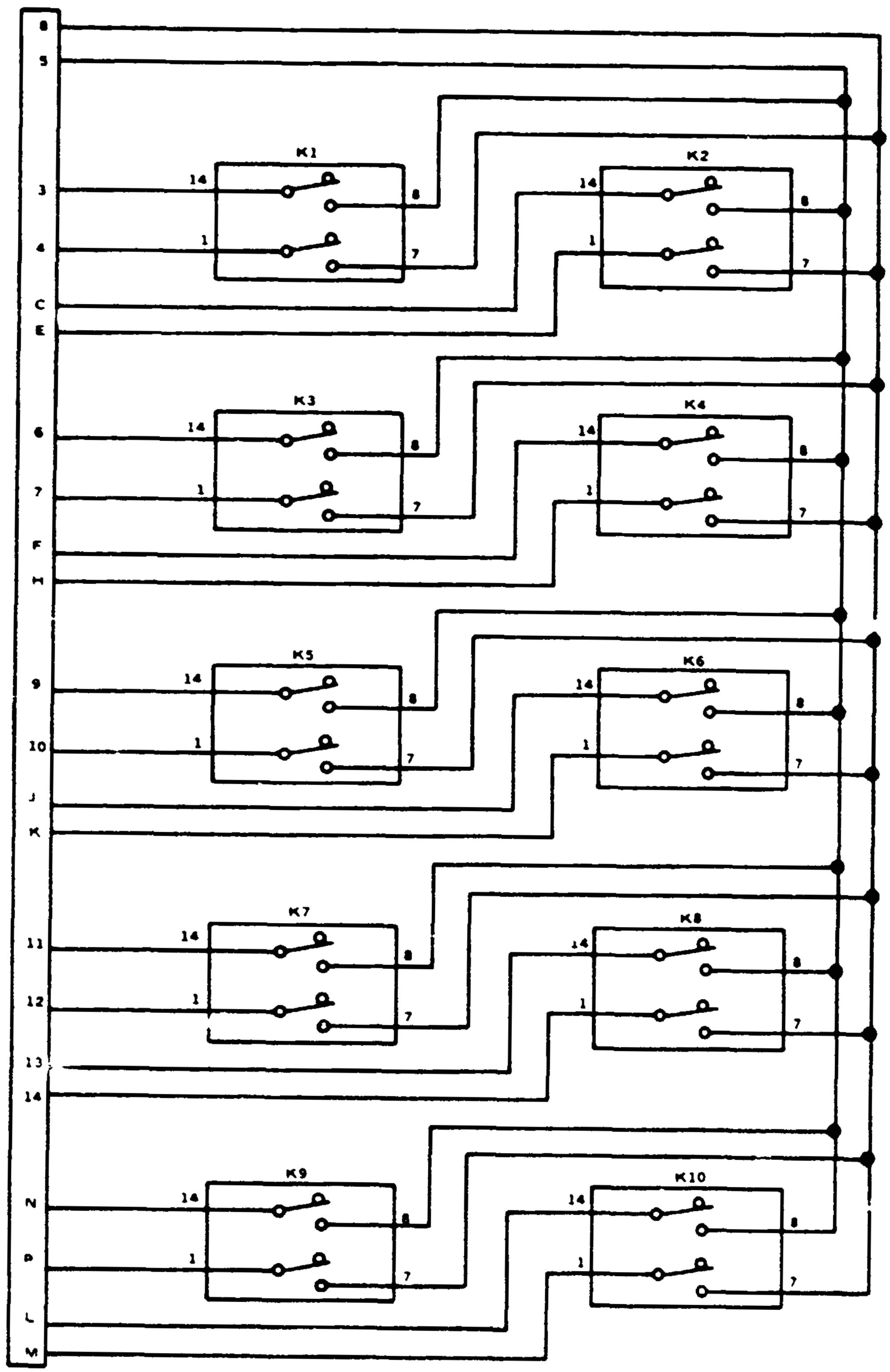


Figure 4-16. Temperature scanner remote unit - relay card schematic (sheet 4 of 9)

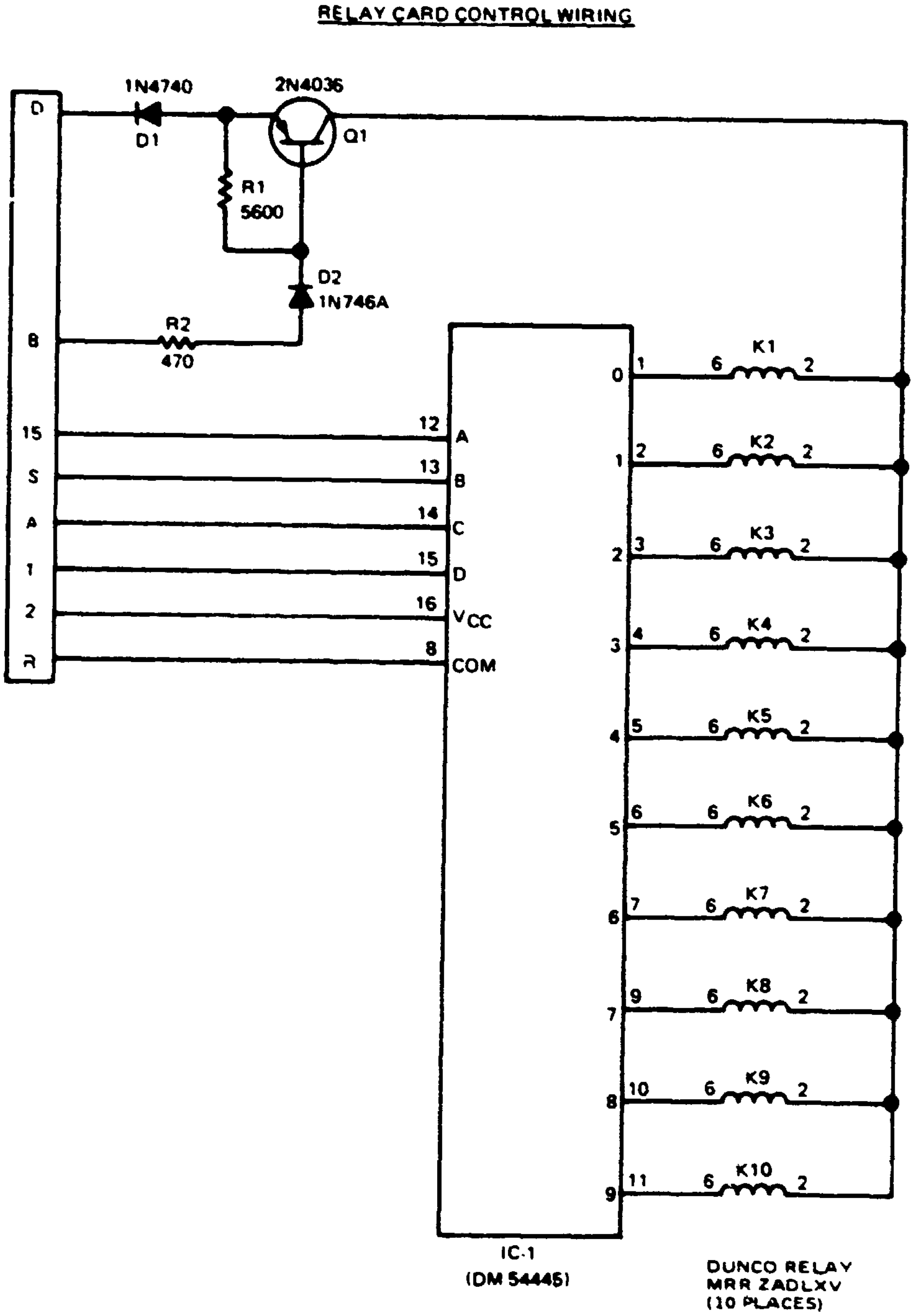


Figure 4-16. Temperature scanner remote unit - relay card schematic (sheet 5 of 9)

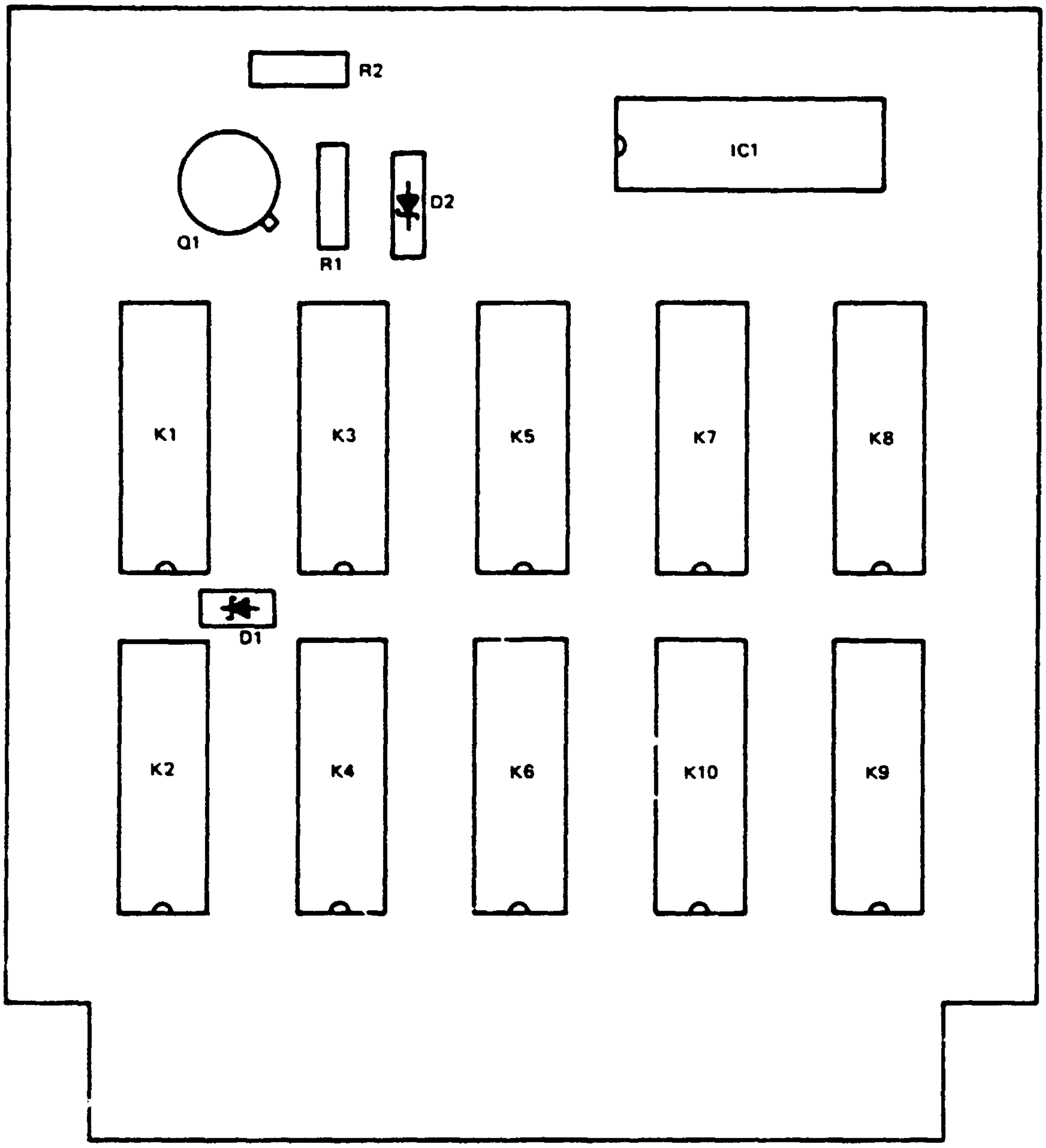


Figure 4-16. Temperature scanner remote unit - relay card layout (sheet 6 of 9)

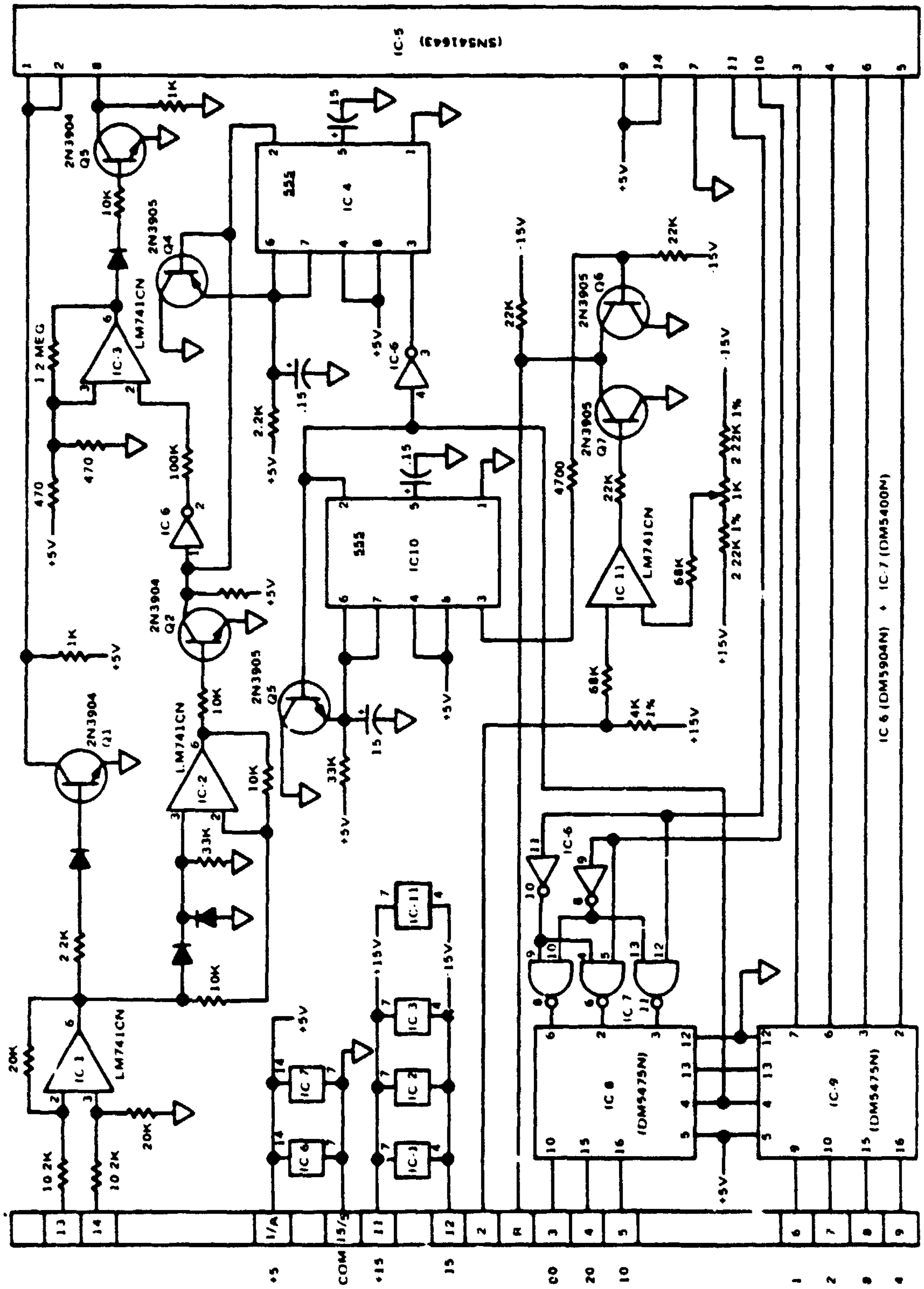


Figure 4-16. Temperature scanner remote unit - logic card schematic (sheet 7 of 9)

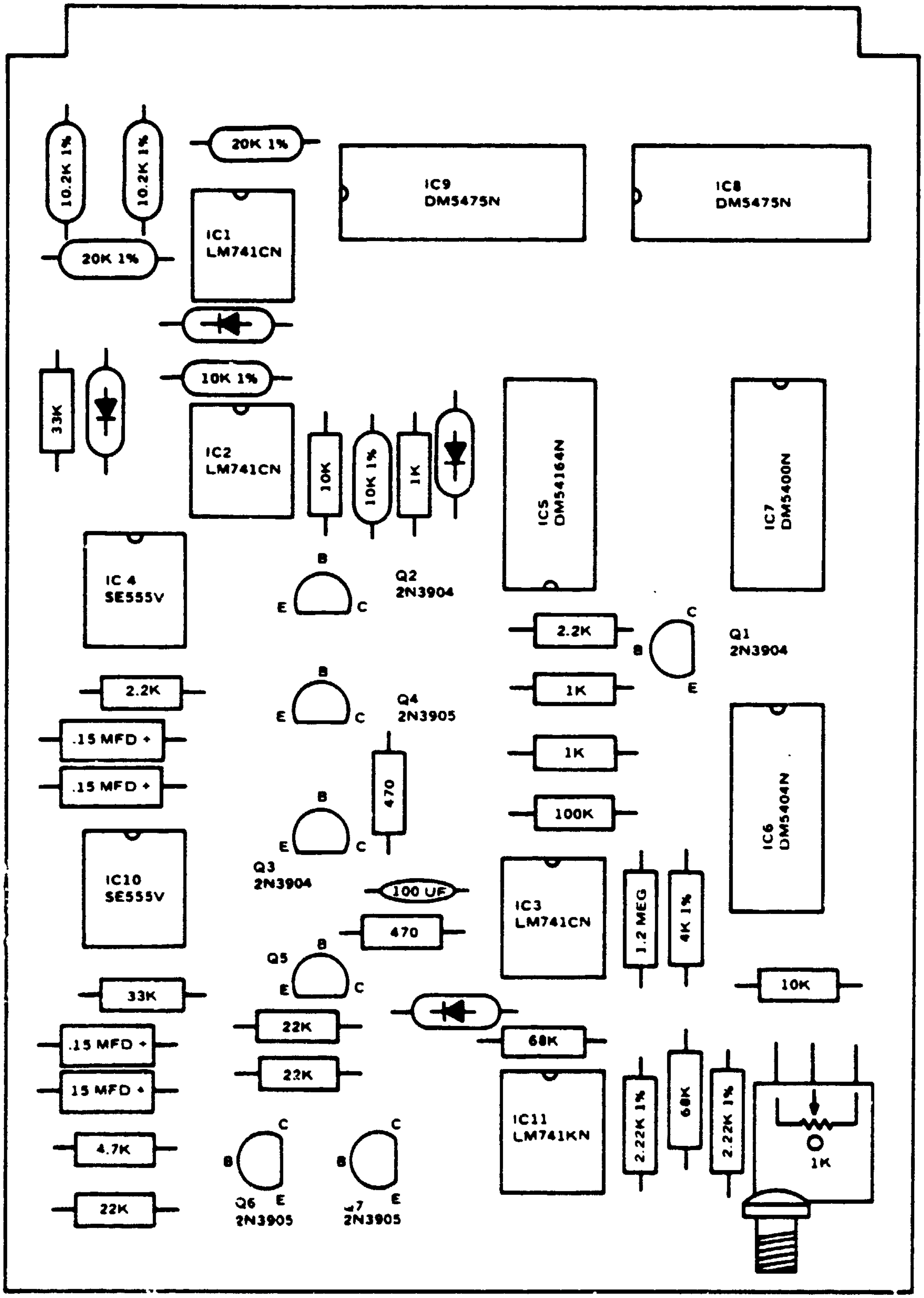


Figure 4-16. Temperature scanner remote unit - logic card layout (sheet 8 of 9)

TEMP SCANNER REMOTE UNIT POWER SUPPLY

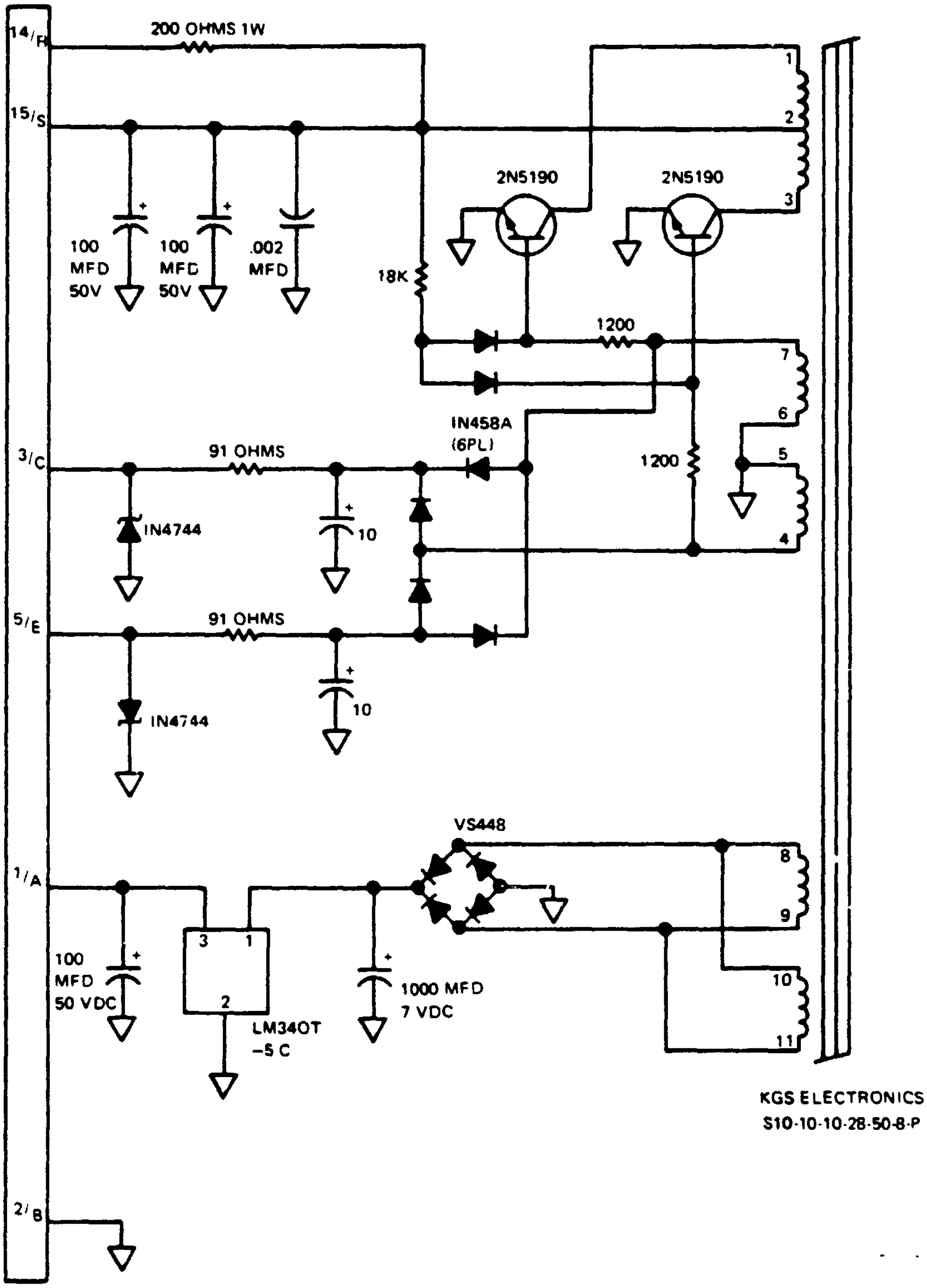
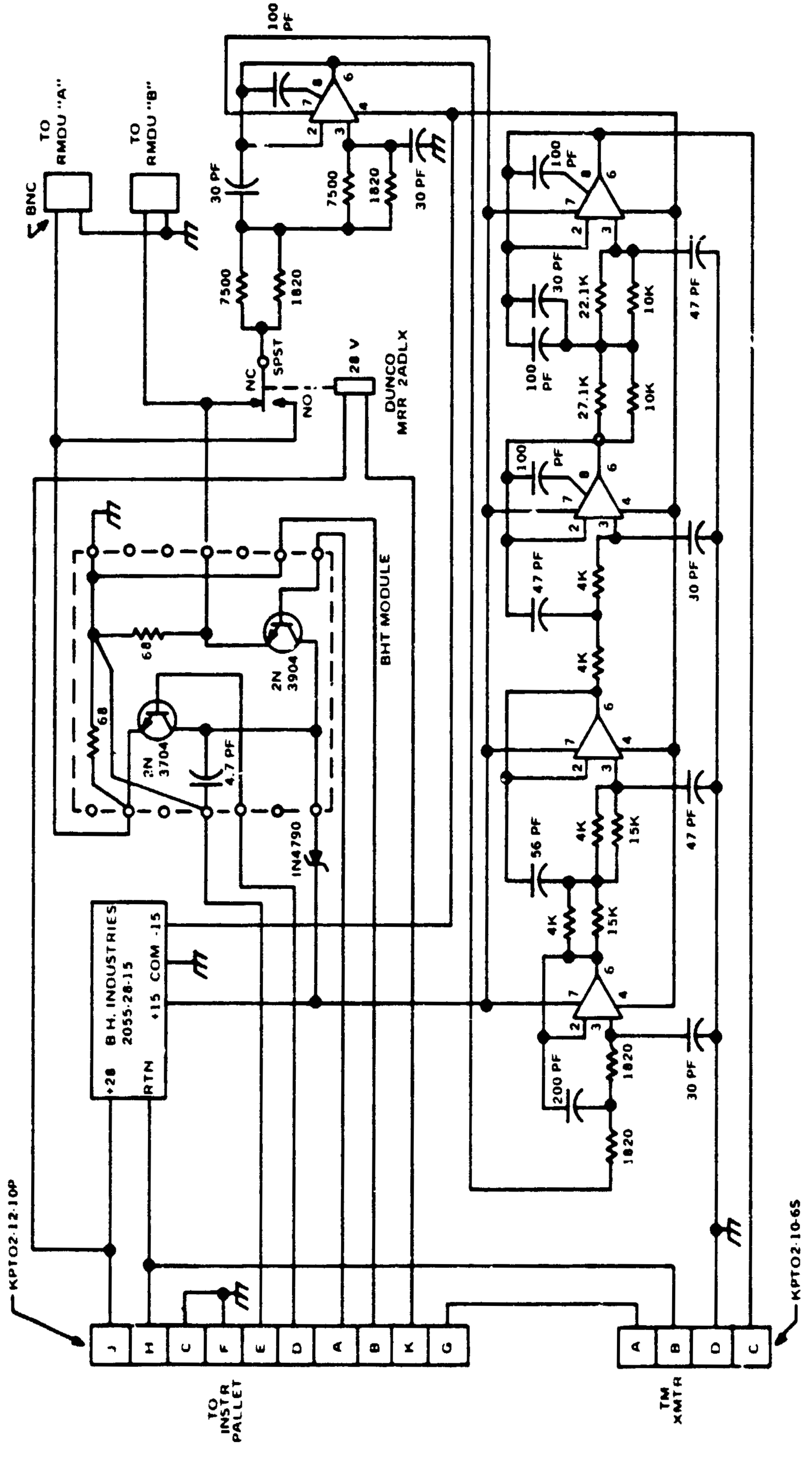


Figure 4-16. Temperature scanner remote unit - power supply card (sheet 9 of 9)



1 ALL RESISTORS ARE 1% UNLESS OTHERWISE NOTED
2 ALL OP AMPS ARE HA2-2525-5 (HARRIS SEMICONDUCTORS)

Figure 4-17. BHT premodulation filter for PCM TM

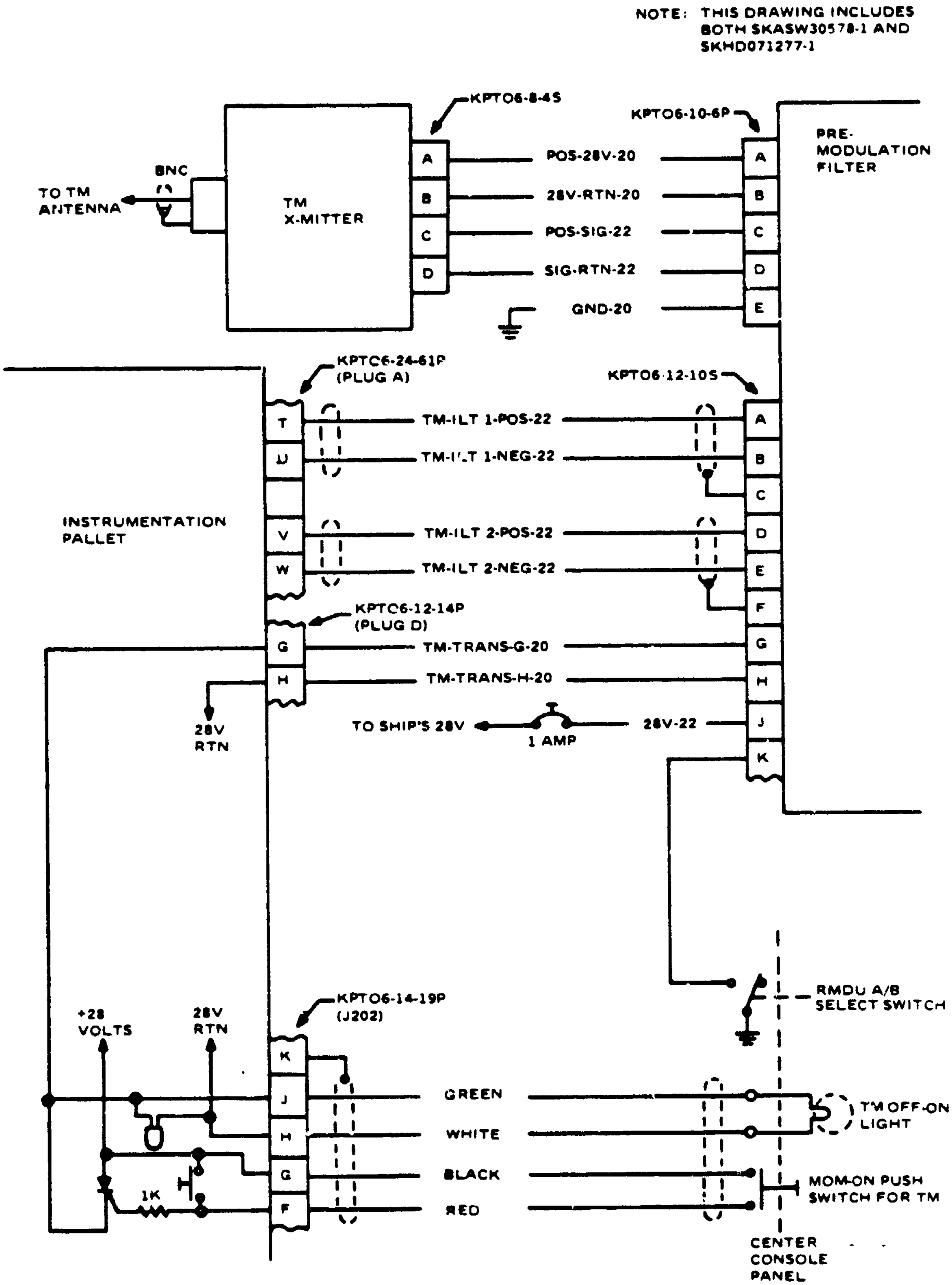


Figure 4-18. TM transmitter wiring

SECTION 5. SENSOR CABLES

This section defines the standard signal distribution cable, sensor disconnect harness, rotor system cables, sensor cable assignments, junction boxes, and patch panel wiring.

5.1 Signal Distribution Cables. The standard signal distribution cables are Beldon No. 8769 consisting of 19 foil shielded twisted pairs of 22-gage stranded wire encased in a gray polypropylene jacket. There are 20 standard signal distribution cables, one for each of the 20 j-box locations distributed throughout the aircraft (see Figure 5-1). Each of the 20 cables terminate in a 61-pin circular connector at the instrumentation pallet, and in 16 six-pin connectors mounted on each remote junction box (j-box). In each 19-pair cable, 16 pairs are used for signals, one pair for positive excitation, one pair for negative excitation, and one pair for excitation sense. Each signal pair is returned as a data channel to a given location on the instrumentation pallet patch panel. All shields are carried through for proper termination at either the transducer or instrumentation pallet. Excitation shields are connected to system common. The distribution cables provide common excitation for each group of 16 signals (parallel at the j-box). This arrangement reduces slipring requirements and minimizes size and weight of the cables. One ±3 Vdc power supply is located in the instrumentation pallet and 20 power distribution cables are wired in parallel to this power supply. A typical signal distribution cable is shown in Figure 5-2. Note that spare pins and excitation wires are located on the outer ring of the 61-pin connector for easy access.

5.2 Sensor Disconnect Harness. All instrumentation sensors are connected to the remote j-box locations with a sensor disconnect harness. The harness consists of a KPT06-10-6P j-box input connector, sensor cable, and sensor connector. The sensor cable is a Beldon No. 8723 consisting of two foil-shielded twisted pairs of 22-gage stranded wire encased in an orange polypropylene jacjet. A schematic diagram of a typical sensor disconnect harness is shown in Figure 5-3 (Form SKASW04375-1). A keyed explanation of the schematic diagram form is contained on Sheet 3 of Figure 5-3. A KPT06-10-6P input connector is used for each of the 320 j-box inputs (16 connectors per j-box x 20 j-box locations). Connectors may be obtained from any of the several approved manufacturers for this type of connector. A disconnect harness for each of the 20 j-box locations is defined on Form SKASW04375-1. These forms are contained in Volume II for Aircraft No. 1 and Volume III for Aircraft No. 2. Figure 5-3 shows the disconnect harness for j-box N-1 as an example. Figure 5-4 shows terminations for the airspeed and altitude sensor cables. Figure 5-5 shows terminations for the nose boom data head.

5.3 Rotor System Cables. Rotor system cables terminate at multi-pin connectors on slip-ring harnesses rather than j-boxes. Signal distribution in the rotating system is provided by "superflex" wire (AWG 26, 60 strands of No. 44) for high fatigue life.

5.4 Sensor Cable Assignment. Table 5-I shows all sensors assigned to the 20 standard signal distribution cables and the item code assigned to each sensor location. Signal pairs (channels) required in each area of the aircraft are summarized in Table 5-II. Spare channels are also tabulated.

5.5 Junction Box. Junction boxes (j-boxes) are installed at critical structural breaks in the aircraft to facilitate maintenance of the sensor installation and cabling. Each remote j-box has excitation and common test points. Figure 5-2 illustrates j-box external configuration and internal wiring. There are 20 j-box locations on the aircraft as shown in Figure 5-1. Each j-box has 16 input connectors identified using the following scheme (RP-1 as an example).

1. RP-1 A
2. RP-1 B
3. RP-1 C
4. RP-1 D
5. RP-1 E
6. RP-1 F
7. RP-1 G
8. RP-1 H
9. RP-1 I
10. RP-1 J
11. RP-1 K
12. RP-1 L
13. RP-1 M
14. RP-1 N
15. RP-1 O
16. RP-1 P

5.6 Patch Panel Wiring. A standard system of signal distribution is used to convey signals from remote j-boxes to the patch panel located on the instrumentation pallet. The standard signal distribution cables (see 5.1) terminate at 61-pin plugs which connect to KPT02-24-61S chassis mount plugs installed on the instrumentation pallet. These plugs are wired to the lower half of the patch panel which contains the removable BHT signal cable program board (reference Figure 1-5). Figures 5-6 through 5-25 show connector wiring to the BHT signal cable program board for each of the 20 j-box connectors. The upper section of the patch panel contains the NASA data acquisition subsystem program board (reference Figure 1-6).

TABLE 5-I. SENSOR CABLE ASSIGNMENT.

DISC	CHANNEL AND LOCATION	ITEM CODE
	Right Rotor, Cable No. 1 (RR-1)	
A	Right Rotor Blade (Red) Bm Bend Sta 22.8 ⚠1	B120
B	Right Rotor Blade (Red) Bm Bend Sta 52.5	B122
C	Right Rotor Blade (Red) Bm Bend Sta 75 ⚠2	B124
D	Right Rotor Blade (Red) Bm Bend Sta 112.5	B126
E	Right Rotor Blade (Red) Ch Bend Sta 52.5	B123
F	Right Rotor Blade (Red) Ch Bend Sta 75	B125
G	Right Rotor Blade (Red) Ch Bend Sta 112.5	B127
H	Right Rotor Blade (Red) Torque Bend Sta 52.5	M129
I	Right Rotor Blade (Red) Torque Bend Sta 112.5	M128
J	Right Rotor Blade (Red) L.E. Stress Sta 9.5 ⚠2	S145
K	Right Rotor Blade (Red) T.E. Stress	S146
L	Right Rotor Blade (Red) Feathering	D111
M	Right Rotor Hub Spindle (Red) Bm Bend ⚠2	B112
N	Right Rotor Hub Spindle (Red) Ch Bend	B113
O	Right Pitch Link (Red)	F103
P		
	Right Rotor, Cable No. 2 (RR-2)	
A	Right Rotor Mast Parallel Bend	B108
B	Right Rotor Mast Perpendicular Bend	B109
C	Right Rotor Mast Torque (02) ⚠3	M107
D	Right Rotor Swashplate Driver	F052
E	Right Rotor Gimbal Flapping	D110
F		
G	Right Rotor Pitch Link (White)	F104
H	Right Rotor Pitch Link (Green)	F053
I	Right Rotor Mast Torque (04) ⚠3	(M107) ⚠3
J		
K	Right Rotor Hub Spindle Bm (White)	B171
L	Right Rotor Hub Spindle Ch (White)	B172
M	Right Rotor Hub Spindle Bm (Green)	B173
N	Right Rotor Hub Spindle Ch (Green)	B174
O	Right Rotor Collective Actuator Pos	D158

Notes: ⚠1 Red blade is instrumented, green and white blades are not.

⚠2 Abbreviations: Bm - beam
Ch - chord
LE - leading edge
TE - trailing edge

⚠3 Multiple gages on one component are identified as 01, 02, 03, 04, etc. Item code does not change for redundant gages.

TABLE 5-1. (CONTINUED)

DISC	CHANNEL AND LOCATION	ITEM CODE
	Right Pylon, Cable No. 1 (RP-1)	
A	R/H Pylon F/A Accel	A150
B	R/H Pylon Lateral Accel	A151
C	R/H Pylon Vertical Accel	A152
D	Right Engine Inlet Case (PCM) (6:30) ⚠1 ⚠2	A500
E	Right Engine Combustion Flange (PCM) (9:00) ⚠1 ⚠2	A501
F	Right Engine Combustion Flange (PCM) (6:00) ⚠1 ⚠2	A502
G	R/H Pylon Hub Spring F/A Motion	D156
H	R/H Pylon Hub Spring Lat Motion	D157
I	Right Fuel Control Lever Pos	D509
J	R/H Pylon Swashplate F/A Motion	D159
K	R/H Pylon Swashplate Lat Motion	D160
L	R/H Pylon Transmission Oil Pressure	P325
M	R/H Pylon Engine Oil Pressure	P323
N	R/H Rotor Power for P/C Encoder	--
O	R/H Rotor 1/Rev	R018
P	R/H Rotor 512/Rev	R053
	Right Pylon, Cable No. 2 (RP-2)	
A	Right F/A Cyclic Boost Actuator Force	F162
B	Right Lateral Cyclic Boost Actuator Force	F163
C	Right Collective Boost Actuator Force	F164
D	Right Engine Inlet Case (FM) (6:30) ⚠1 ⚠2	A525
E	Right Engine Combustion Flange (FM) (9:00) ⚠1 ⚠2	A526
F	Right Engine Combustion Flange (FM) (6:00) ⚠1 ⚠2	A528
G	Right Engine Gas Producer N_1 RPM	R503
H	28 Vdc	--
I	Right Pylon Atmospheric Pressure	P504
J	Right Transmission Compt Static Pressure	P505
K	Right Pylon O.B. Cowl Support Strut	F522
L	Right Pylon I.B. Cowl Support Strut	F523
M	Right Pylon Hydraulic Pressure (System #2)	P153
N		--
O	Right Pylon Temp Scanner Control Signal	T506
P	Right Pylon Temp Scanner Data Signal	

Notes: ⚠1 Transducer radial position shown in parentheses (o'clock)

⚠2 Abbreviations: (PCM) - designated channel is on the PCM track bit system

(FM) - designated channel is on the FM data system

TABLE 5-I. (CONTINUED)

DISC	CHANNEL AND LOCATION	ITEM CODE
	Right Wing, Cable No. 1 (RW-1)	
A	Right Wing Upper Panel BL-0 Outer Skin Stress	S628
B	Right Wing Lower Panel BL-0 Outer Skin Stress	S629
C	Right Wing Upper Panel BL-0 Inner Skin Stress	S609
D	Right Wing Lower Panel BL-0 Inner Skin Stress	S610
E	Right Wing Beam Bend WS 22	B600
F	Right Wing Chord Bend WS 22	B603
G	Right Wing Torque WS 22	M606
H		
I	Right Wing Front Spar Shear Upper WS 66	S630
J	Right Wing Front Spar Shear Lower WS 66	S631
K	Right Wing Rear Spar Shear Upper WS 66	S632
L	Right Wing Rear Spar Shear Lower WS 66	S633
M	Right Flap Drive Tube Torque	M612
N	Right Flap Drive Tube Beam Bend	B613
O		
P		
	Right Wing, Cable No. 2 (RW-2)	
A	Right Flaperon Control Arm Force	F614
B	Right Flaperon Beam Bend Force	B615
C	Right Aileron Pos (Flaperon Actuator)	D645
D	Right Pylon Conversion Act Force	F611
E	Right Pylon Conversion Spindle Beam Bend	B165
F	Right Pylon Conversion Spindle Chord Bend	B166
G	Right Pylon Conversion Pos	D161
H	Left Pylon Conversion Pos	D186
I	Right Wing Front Spar Shear Upper WS 142	S634
J	Right Wing Front Spar Shear Lower WS 142	S635
K	Right Wing Rear Spar Shear Upper WS 142	S636
L	Right Wing Rear Spar Shear Lower WS 142	S637
M		
N		
O		
P	Flap Pos	D617

TABLE 5-I. (CONTINUED)

DISC	CHANNEL AND LOCATION	ITEM CODE
	Right Main Gear, Cable No. 1 (RMG-1)	
A		
B	R/H Main Landing Gear Drag Strut Axial Force (Tension)	F355
C	R/H Main Landing Gear Oleo Strut Lat Bend	B316
D	R/H Main Landing Gear Drag Strut Axial Force (Compression)	F303
E	R/H Main Landing Gear Actuator Pos	D317
F	R/H Main Landing Gear Oleo Extension Pos	D305
G		
H		
I		
J		
K		
L		
M		
N		
O		
P		
	Nose, Cable No. 1 (N-1)	
A		
B		
C	Nose Landing Gear Oleo Strut Lat Bend (Left)	B357
D	Nose Landing Gear Oleo Strut Lat Bend (Right)	B346
E	Nose Landing Gear Drag Strut Axial Force	F347
F	Nose Landing Gear Actuator Pos	D348
G	Nose Landing Gear Oleo Extension Pos	D349
H		
I	Nose Boom Airspeed	P002
J	Nose Boom Altitude	P342
K	28V DC	--
L	Nose Boom Angle of Attack	D008
M	Nose Boom Angle of Sideslip	D007
N		
O		
P		

TABLE 5-I. (CONTINUED)

DISC	CHANNEL AND LOCATION	ITEM CODE
	Cockpit, Cable No. 1 (CP-1)	
A	Pilot F/A Cyclic Stick Force	F330
B	Pilot Lat Cyclic Stick Force	F331
C		
D	Pilot Right Pedal Force	F333
E	Pilot Left Pedal Force	F334
F	Right Fuel Quan	R320
G	Left Fuel Quan	R321
H		
I	Instr Panel OAT	T322
J	28Vdc (OAT)	--
K	Radar Altimeter	D327
L		
M		
N		
O		
P		
	Cockpit, Cable No. 2 (CP-2)	
A	Pilot F/A Cyclic Stick Pos	D021
B	Pilot Lat Cyclic Stick Pos	D022
C	Pilot Power Lever Pos	D023
D	Pilot Rudder Pedal Pos	D024
E	Pilot Flap Lever Pos	D309
F		
G		
H		
I	Pilot Seat Vert Accel	A019
J	Pilot Seat Lat Accel	A302
K	Co-pilot Seat Vert Accel	A320
L	Co-pilot Seat Lat Accel	A304
M		
N		
O		
P		

TABLE 5-I. (CONTINUED)

DISC	CHANNEL AND LOCATION	ITEM CODE
	Cockpit, Cable No. 3 (CP-3)	
A	Right Engine Fuel Flow Rate	R328
B	Left Engine Fuel Flow Rate	R329
C	Right Engine Torque	M335
D	Left Engine Torque	M336
E	Interconnect Shaft Torque	M337
F	Right Engine N_{II} RPM	R338
G	Left Engine N_{II} RPM	R339
H	28Vdc	--
I	Inter-comm	
J	Left Engine Generator Volts	E179
K	Left Engine Generator Amps	E180
L	Right Engine Generator Volts	E154
M	Right Engine Generator Amps	E155
N		
O	Fuselage Temp Scanner Control	--
P	Fuselage Temp Scanner Data Signal	T351
	Cabin, Cable No. 1 (CAB-1)	
A	Cabin Roll Attitude Gyro	D009
B	Cabin Pitch Attitude Gyro	D010
C	Cabin Yaw Attitude Gyro	D011
D	Cabin Roll Rate Gyro	V012
E	Cabin Pitch Rate Gyro	V013
F	Cabin Yaw Rate Gyro	V014
G	Aircraft CG Accel (Servo)	A352
H	28 Vdc Aircraft CG Accel (Servo)	--
I	Aircraft CG Accel Vert	A005
J	Aircraft CG Accel F/A	A301
K	Aircraft CG Accel Lat	A300
L	Diff Cyclic Washout Actuator Pos	D318
M	F/A SCAS Act Pos	D306
N	Lat SCAS Act Pos	D307
O	Dir SCAS Act Pos	D308
P		

TABLE 5-I. (CONTINUED)

DISC	CHANNEL AND LOCATION	ITEM CODE
	Empennage, Cable No. 1 (EMP-1)	
A		
B		
C	R/H Horiz Stab Spar Bm Bend BL 7.7	B262
D	R/H Horiz Stab Spar Bm Bend BL 65	B264
E	R/H Horiz Stab Spar Ch Bend BL 7.7	B263
F		
G	R/H Horiz Stab Spar Torq Bend BL 8	M266
H	L/H Horiz Stab Spar Beam Bend BL 7.7	B259
I		
J	R/H Vert Stab Bm Bend WL 109.95	B270
K	R/H Vert Stab Bm Bend WL 113.94	B258
L		
M		
N		
O	R/H Elevator Drive Tube Torque	M275
P	R/H Elevator Beam Bend	B274
	Empennage, Cable No. 2 (EMP-2)	
A	R/H Rudder Drive Tube Torque	M276
B	R/H Rudder Bm Bend	B278
C	L/H Rudder Drive Tube Torque	M277
D	L/H Rudder Bm Bend	B280
E	L/H Elevator Drive Tube Torque	M279
F	L/H Elevator Bm Bend	B282
G	R/H Elevator Pos	D281
H		
I	R/H Rudder Pos	D284
J		
K	Horizontal Stab Incidence Actuator Force	F286
L		
M		
N		
O		
P		

TABLE 5-I. (CONTINUED)

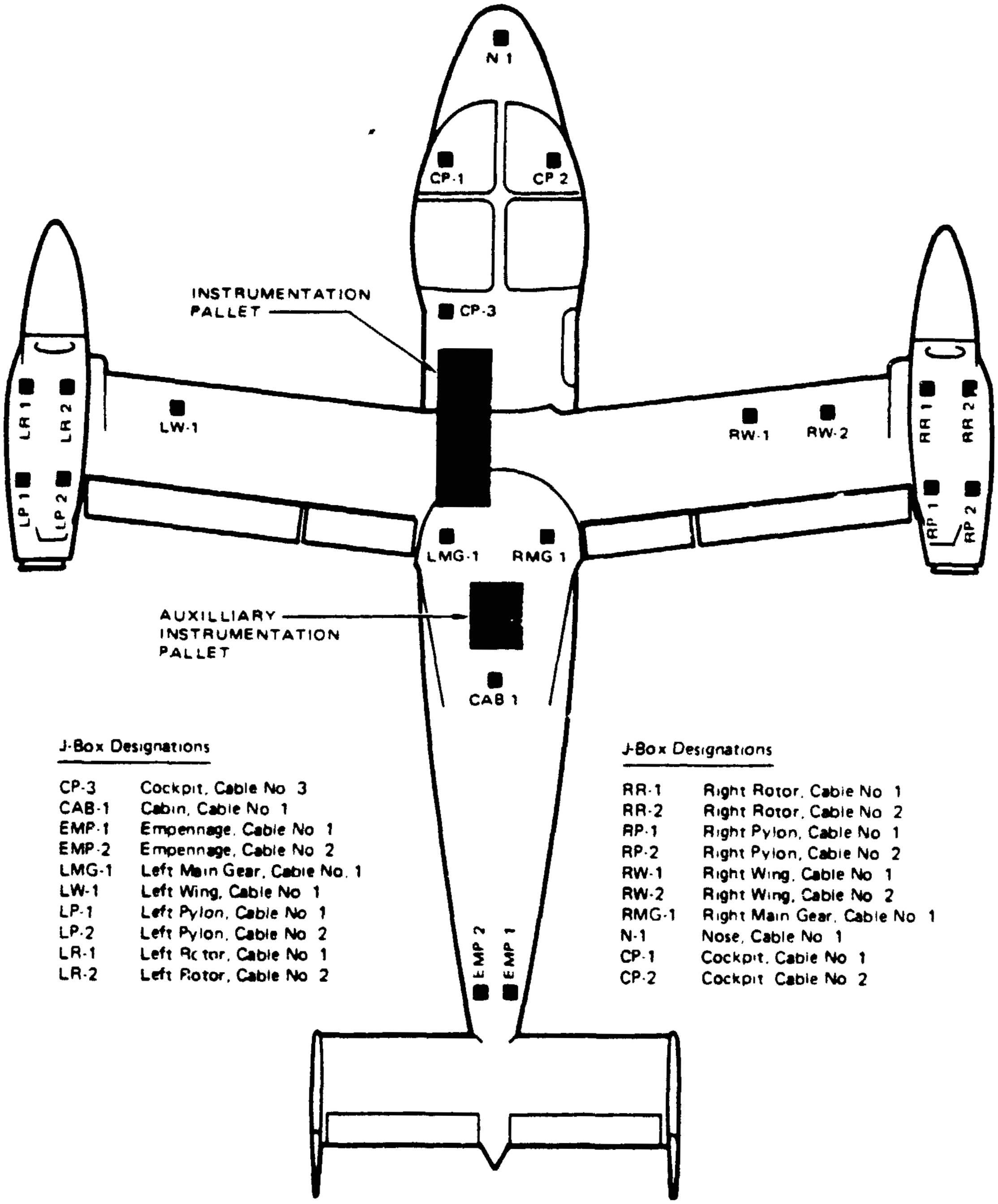
DISC	CHANNEL AND LOCATION	ITEM CODE
	<u>Left Main Gear, Cable No. 1 (LMG-1)</u>	
A		
B	L/H Main Landing Gear Drag Strut Axial Force (Tension)	F356
C	L/H Main Landing Gear Oleo Strut Lat Bend	B312
D	L/H Main Landing Gear Drag Strut Axial Force (Compression)	F313
E	L/H Main Landing Gear Actuator Pos	D314
F	L/H Main Landing Gear Oleo Extension Pos	D315
G		
H		
I		
J		
K		
L		
M		
N		
O		
P		
	<u>Left Wing, Cable No. 1 (LW-1)</u>	
A	L/H Flap Beam Bend	B618
B	L/H Flap Drive Tube Torque	M619
C		
D	L/H Flaperon Control Arm Force	F621
E	L/H Flaperon Beam Bend	B622
F	L/H Aileron Pos (Flaperon Actuator)	D646
G		
H		
I		
J	L/H Pylon Conversion Spindle Beam Bend	B190
K	L/H Pylon Conversion Spindle Chord Bend	B191
L	L/H Pylon Conversion Actuator Force	F638
M		
N		
O		
P		

TABLE 5-I. (CONCLUDED)

DISC	CHANNEL AND LOCATION	ITEM CODE
	<u>Left Rotor, Cable No. 1 (LR-1)</u>	
A	Left Rotor Blade (Red) Bm Bend Sta 22.8	B130
B	Left Rotor Blade (Red) Bm Bend Sta 52.5	B132
C	Left Rotor Blade (Red) Bm Bend Sta 75	B134
D	Left Rotor Blade (Red) Bm Bend Sta 112.5	B136
E	Left Rotor Blade (Red) Ch Bend Sta 52.5	B133
F	Left Rotor Blade (Red) Ch Bend Sta 75	B135
G	Left Rotor Blade (Red) Ch Bend Sta 112.5	B137
H	Left Rotor Blade (Red) Torque Sta 52.5	M139
I	Left Rotor Blade (Red) Torque Sta 112.5	M138
J	Left Rotor Blade (Red) Stress L.E. Sta 9.5	S147
K	Left Rotor Blade (Red) Stress T.E. Sta 9.5	S148
L	Left Rotor Blade (Red) Feathering Pos	D066
M	Left Rotor Hub Spindle (Red) Bm Bend	B114
N	Left Rotor Hub Spindle (Red) Ch Bend	B115
O	Left Pitch Link (Red)	F060
P		
	<u>Left Rotor, Cable No. 2 (LR-2)</u>	
A	Left Rotor Mast Parallel Bend	B140
B	Left Rotor Mast Perpendicular Bend	B141
C	Left Rotor Mast Torque (02)	M143
D	Left Rotor Swashplate Driver	F142
E	Left Rotor Gimbal Flapping Pos	D144
F		
G	Left Pitch Link (White)	F061
H	Left Pitch Link (Green)	F062
I	Left Rotor Mast Torque (04)	(M143)
J		
K	Left Rotor Hub Spindle Beam Bend (White)	B192
L	Left Rotor Hub Spindle Ch Bend (White)	B193
M	Left Rotor Hub Spindle Beam Bend (Green)	B194
N	Left Rotor Hub Spindle Ch Bend (Green)	B193
O	Left Rotor Collective Act Pos	D183
P		

TABLE 5-II. CABLE DISTRIBUTION SUMMARY.

	No. of Cables	Signal Pairs		
		Available	Required	Spare
Right Rotor	2	32	28	4
Left Rotor	2	32	28	4
Right Pylon	2	32	31	1
Left Pylon	2	32	32	0
Right Wing	2	32	26	6
Left Wing	1	16	8	8
Empennage	2	32	18	14
Cockpit	3	48	32	16
Nose	1	16	10	6
Right Main Gear	1	16	5	11
Left Main Gear	1	16	5	11
Cabin	1	16	15	1
Total	20	320	238	82



J-Box Designations

CP-3	Cockpit, Cable No 3
CAB-1	Cabin, Cable No 1
EMP-1	Empennage, Cable No 1
EMP-2	Empennage, Cable No 2
LMG-1	Left Main Gear, Cable No. 1
LW-1	Left Wing, Cable No 1
LP-1	Left Pylon, Cable No 1
LP-2	Left Pylon, Cable No 2
LR-1	Left Rotor, Cable No 1
LR-2	Left Rotor, Cable No 2

J-Box Designations

RR-1	Right Rotor, Cable No 1
RR-2	Right Rotor, Cable No 2
RP-1	Right Pylon, Cable No 1
RP-2	Right Pylon, Cable No 2
RW-1	Right Wing, Cable No 1
RW-2	Right Wing, Cable No 2
RMG-1	Right Main Gear, Cable No 1
N-1	Nose, Cable No 1
CP-1	Cockpit, Cable No 1
CP-2	Cockpit Cable No 2

Figure 5-1. Instrumentation J-box location

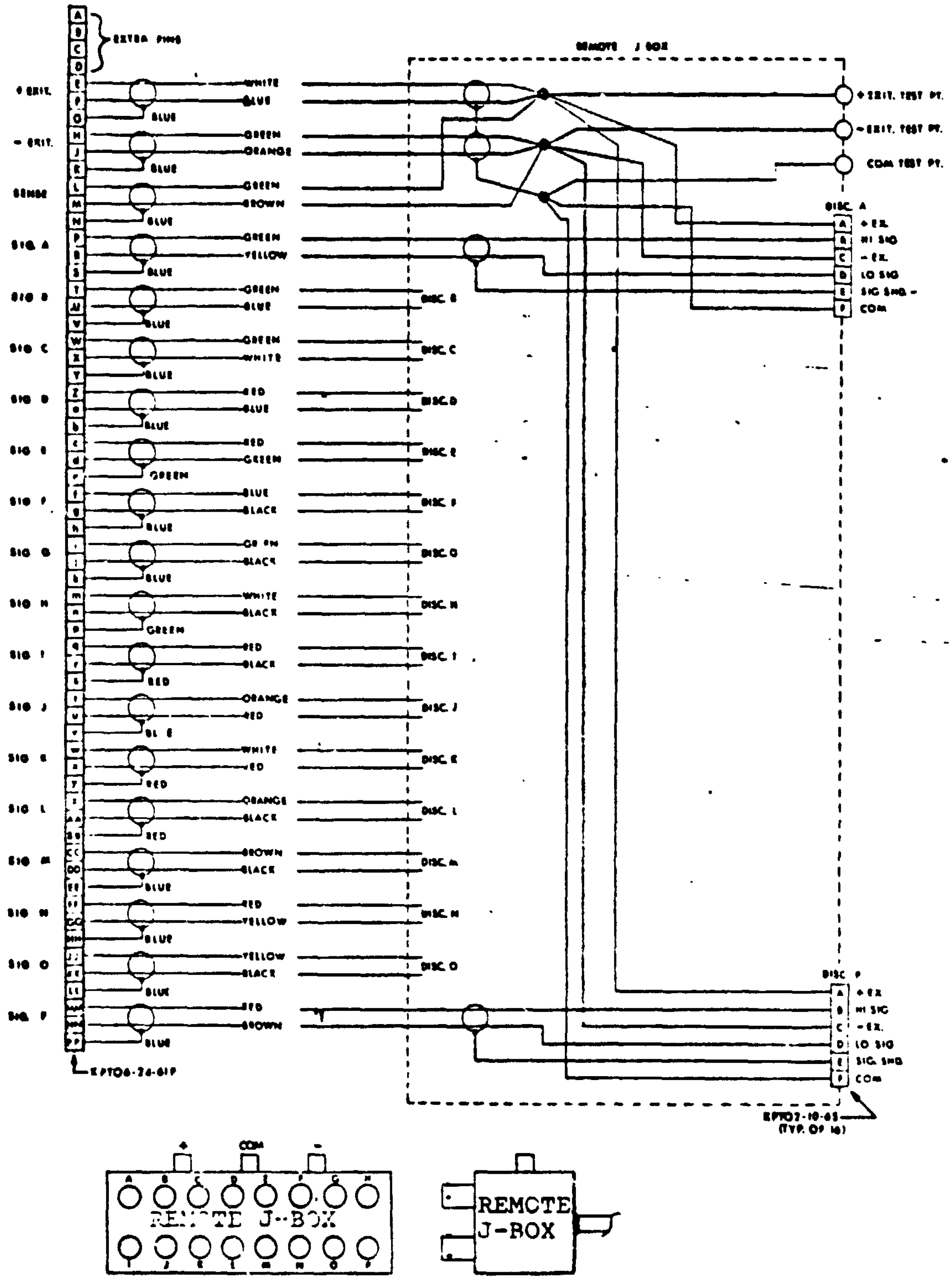
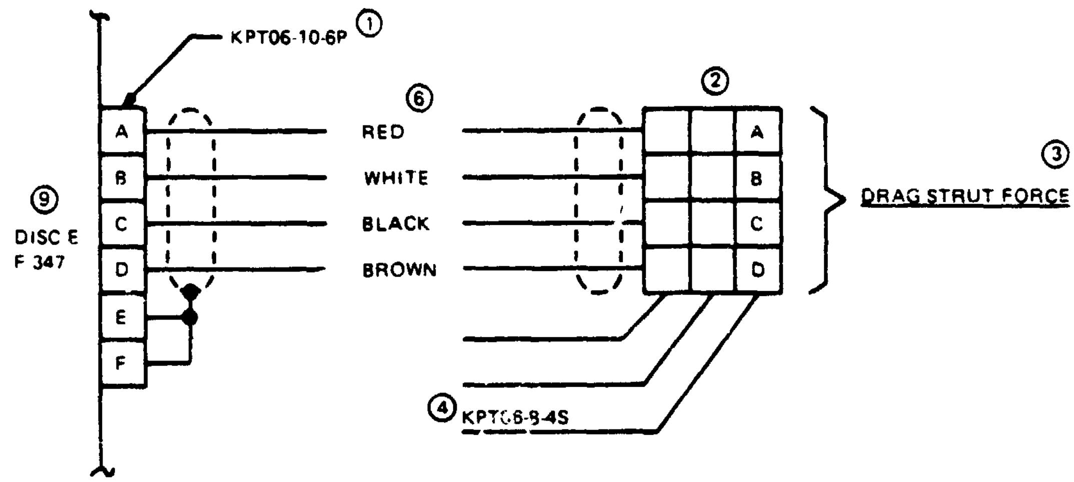


Figure 5-2. Typical instrumentation distribution cable and J-box.

DISCONNECT HARNESS SCHEMATIC–KEYED EXPLANATION



NOTES

① WIRING OF THE KPT06-10-6P INPUT PLUG (TYPICAL FOR ALL INPUTS).

② SENSOR PLUGS ARE DRAWN AS A 3 BY 4 MATRIX SO THAT THE SAME FORMAT MAY BE USED TO SHOW ANY 3 OR 4-PIN PLUG

③ SENSOR CHANNELS ARE DESIGNATED FOR EACH J-BOX INPUT

④ SENSOR CONNECTORS ARE IDENTIFIED BY LINES TO THE 3-WIDE MATRIX.

⑤ SENSOR CONNECTORS WHICH ARE CIRCLED (SEE SHEET 2 OF FIGURE 5-3) REFER TO AN ADDITIONAL DRAWING INSERTED AFTER THE BASIC J-BOX PRINT. FIGURES 5-4 AND 5-5 ARE EXAMPLES OF ADDENDUMS TO THE BASIC PRINT

⑥ THE COLOR CODE IS DEFINED FOR THE INPUT SIGNAL CABLE. THE SHIELD IS CARRIED FROM THE VOLTAGE INPUT

PIN	COLOR CODE
A	RED
B	WHITE
C	BLACK
D	BROWN

⑦ FIGURE 5-3 (SHEETS 1 AND 2) SHOWS SHORTING OF PIN D TO CARRY BRIDGE VOLTAGE BACK TO LOW SIDE OF AMX CARD INPUT FOR POTENTIOMETER CHANNELS

8 SENSOR CONNECTIONS WHICH SHOW NO CONNECTOR NUMBER OR CONNECTOR PIN CALLOUTS ARE TERMINATED AT THE SENSOR TERMINAL BOARD WITH NO INTERMEDIATE SENSOR JUMPER CABLE INSTALLED. IN THIS CASE, PIN A OF THE INPUT CABLE IS CONNECTED TO PIN A OF THE TERMINAL BOARD, B TO B, ETC

⑨ J-BOX CONNECTORS ARE IDENTIFIED BY PLUG LETTER AND ITEM CODE

Figure 5-3. Disconnect harness for J-box location N-1
(sheet 1 of 3)

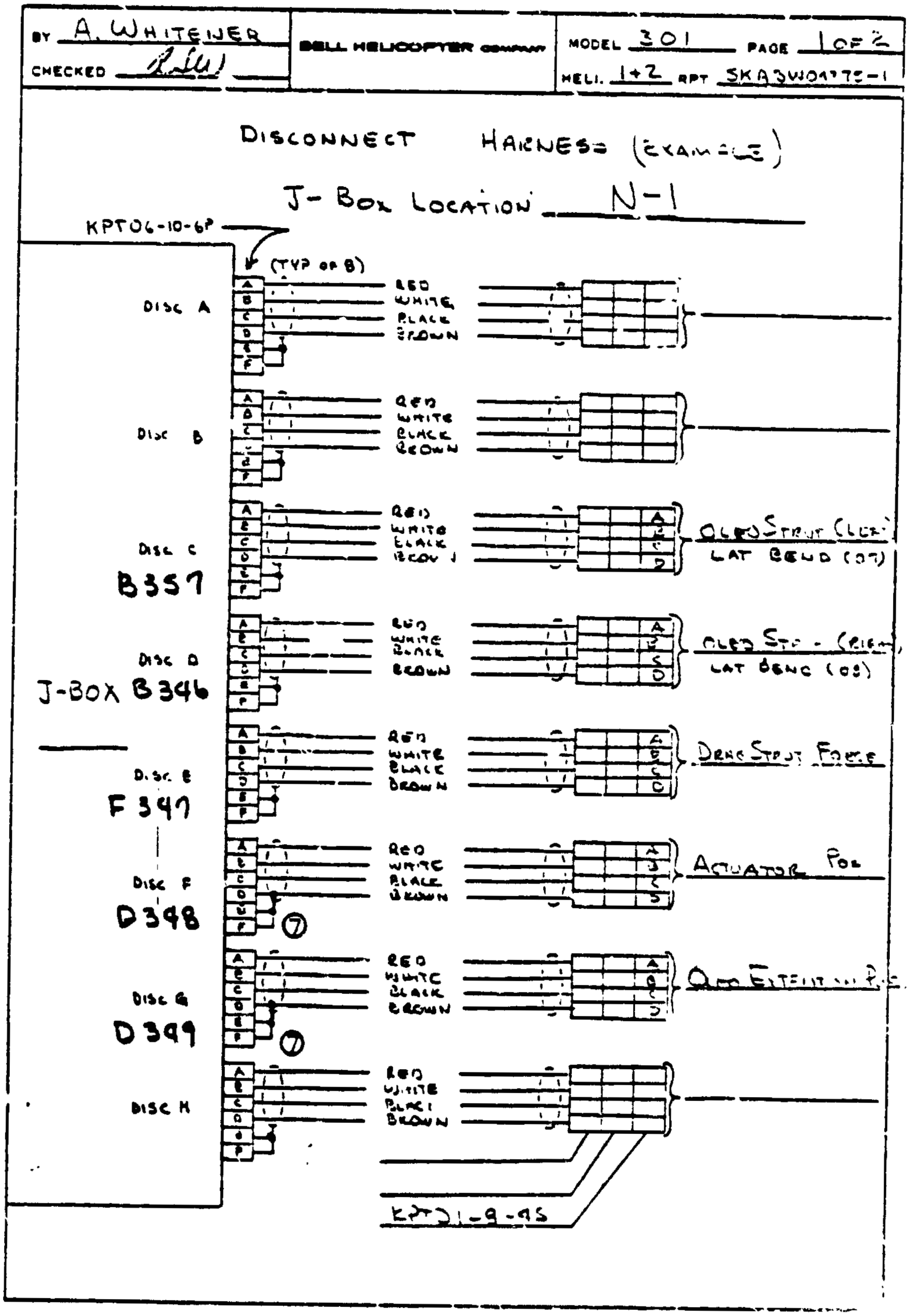


Figure 5-3. Disconnect harness for J-box location N-1.
(Sheet 2 of 3)

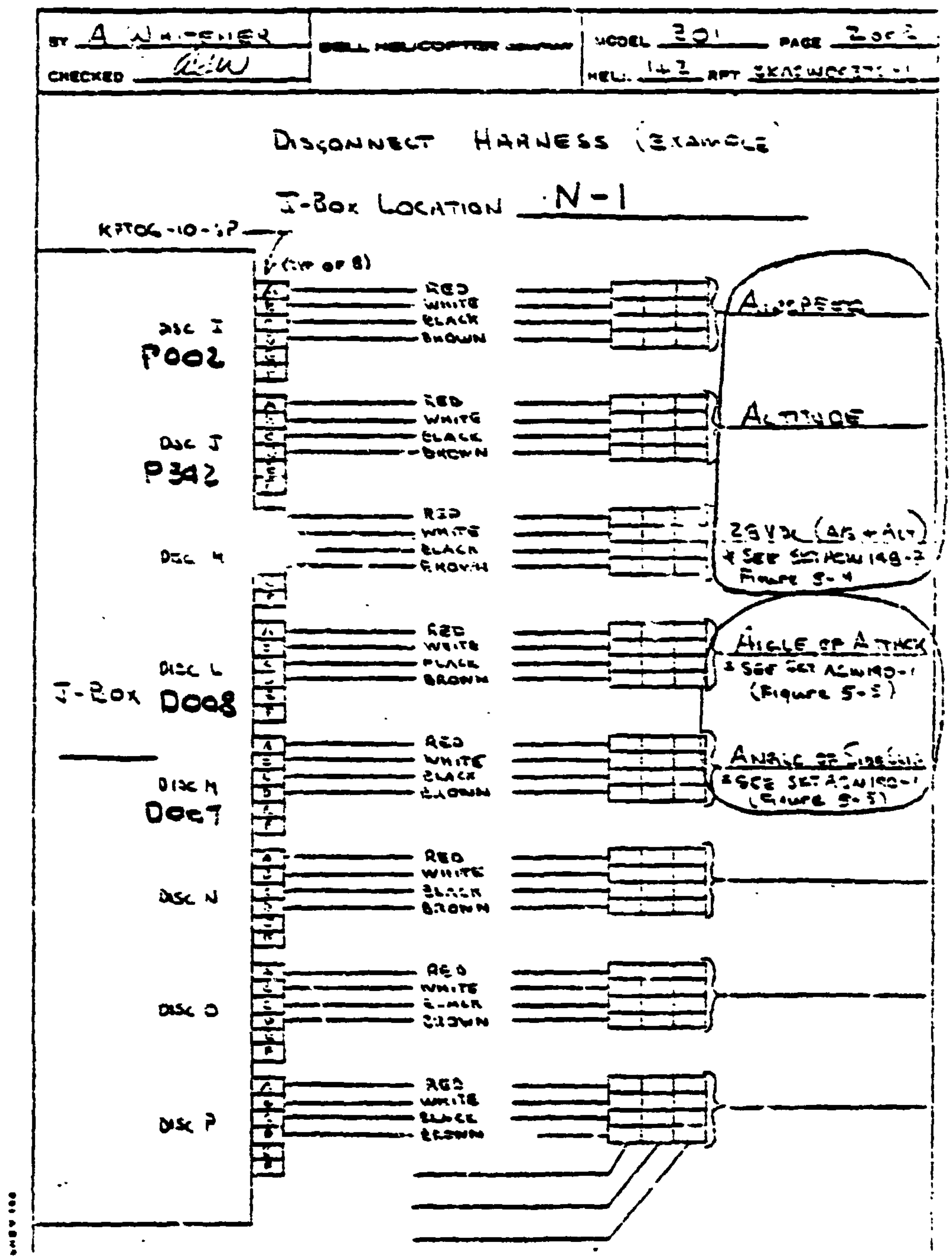


Figure 5-3. Disconnect harness for J-box location N-1 (Sheet 3 of 3)

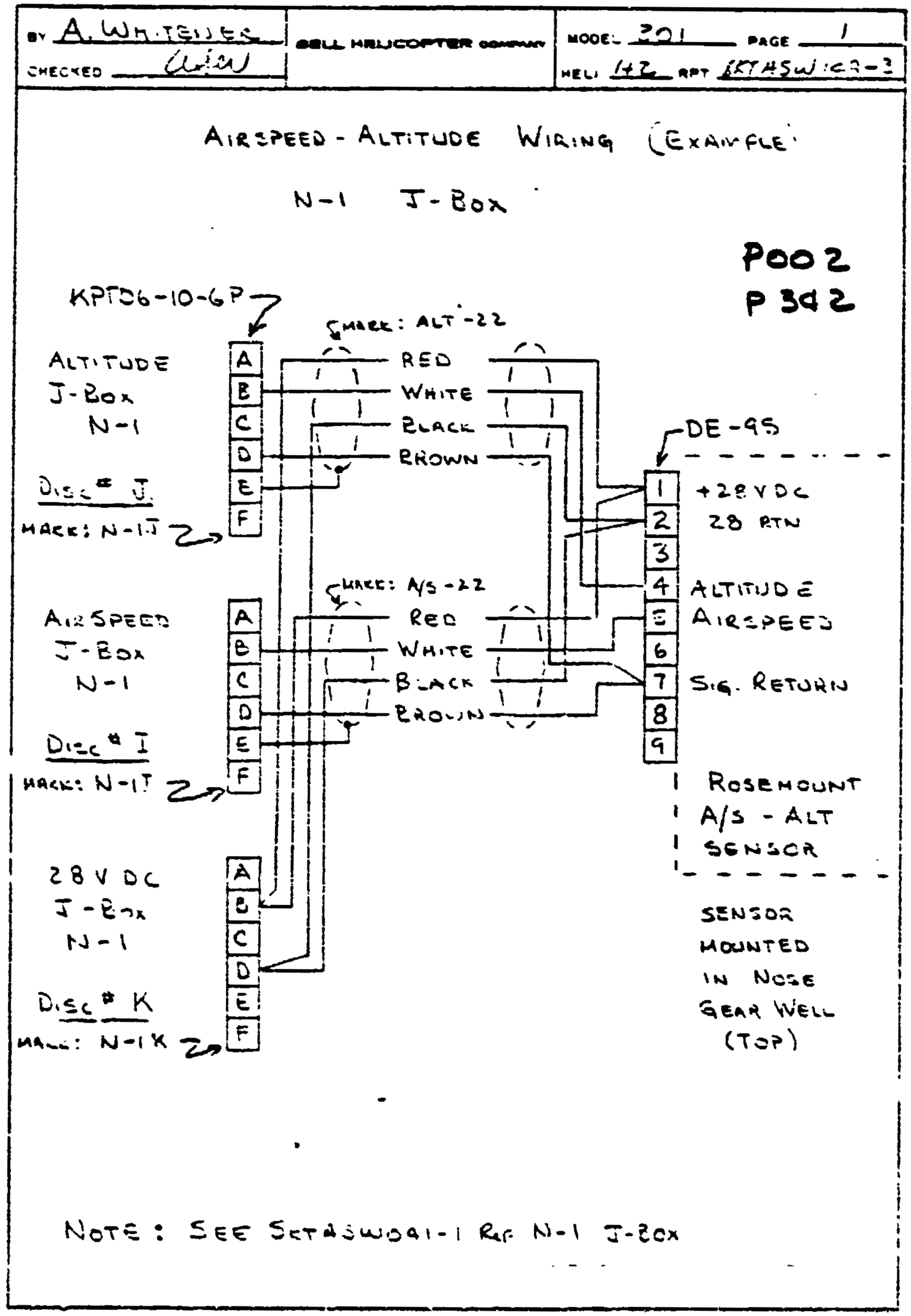


Figure 5-4. Airspeed-altitude sensor wiring (example)

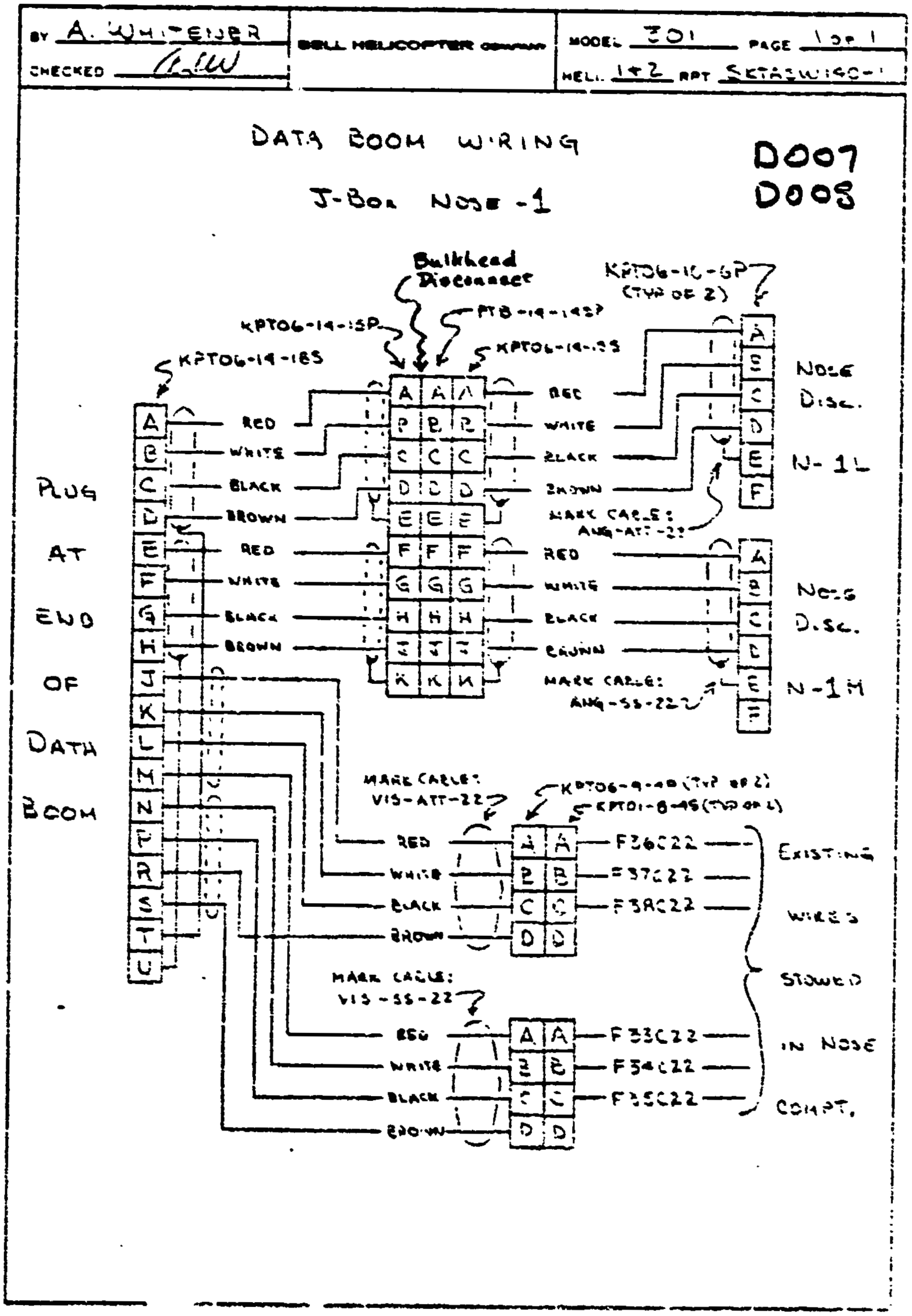


Figure 5-5. Data boom wiring (example).

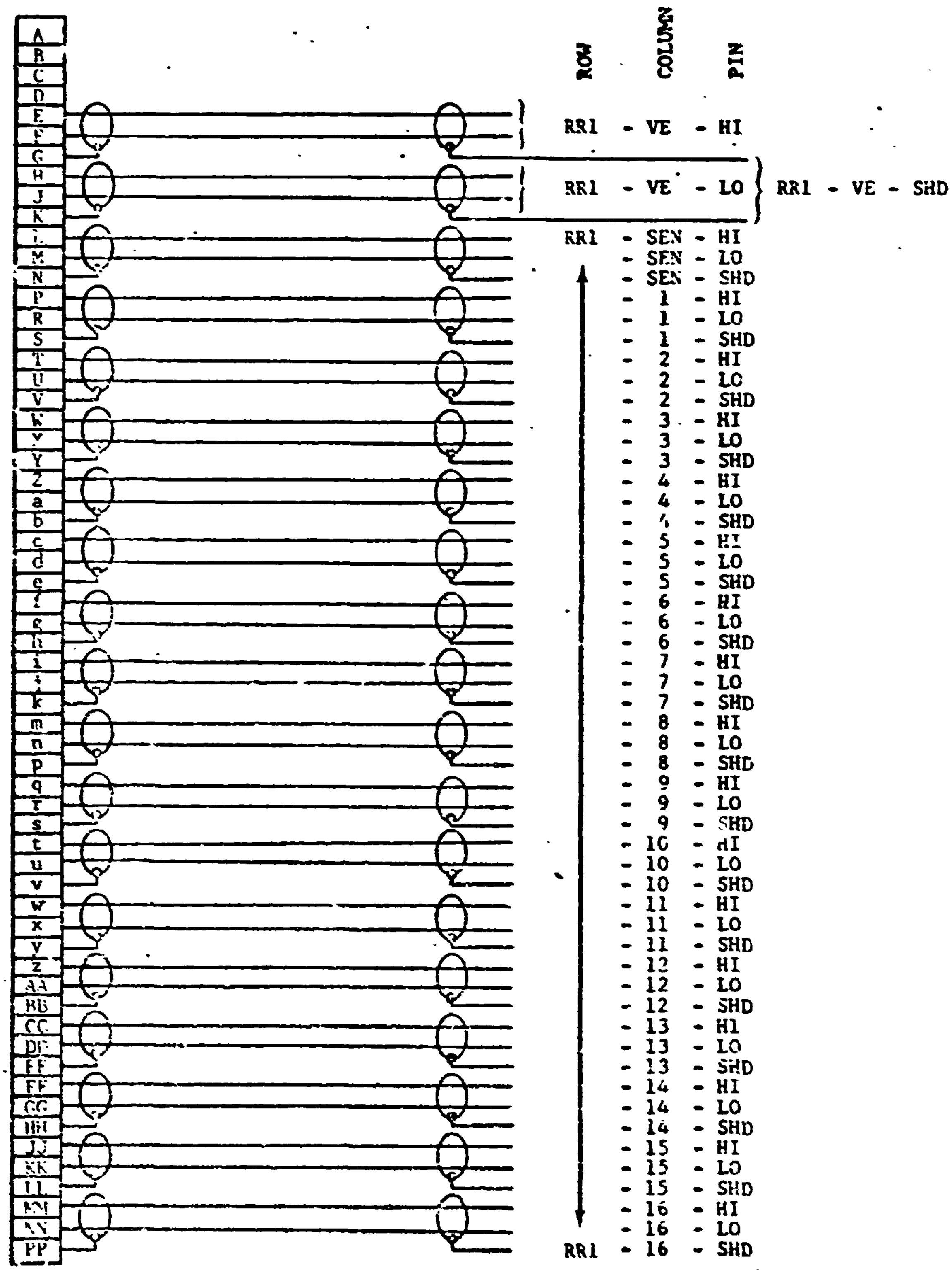


Figure 5-6. BHT program board signal input wires disconnect RR1.

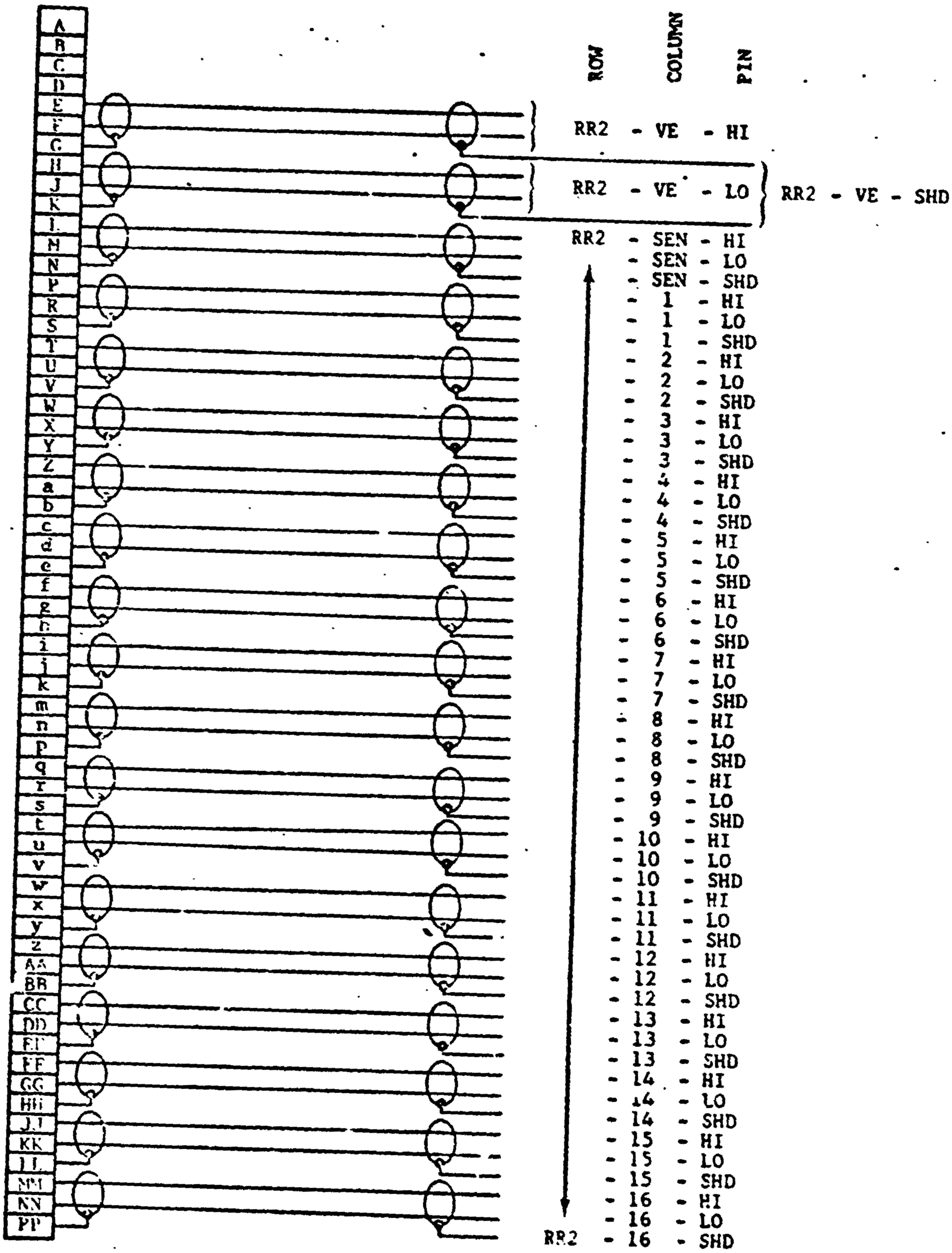


Figure 5-7. BHT program board signal input wires disconnect #RR2.

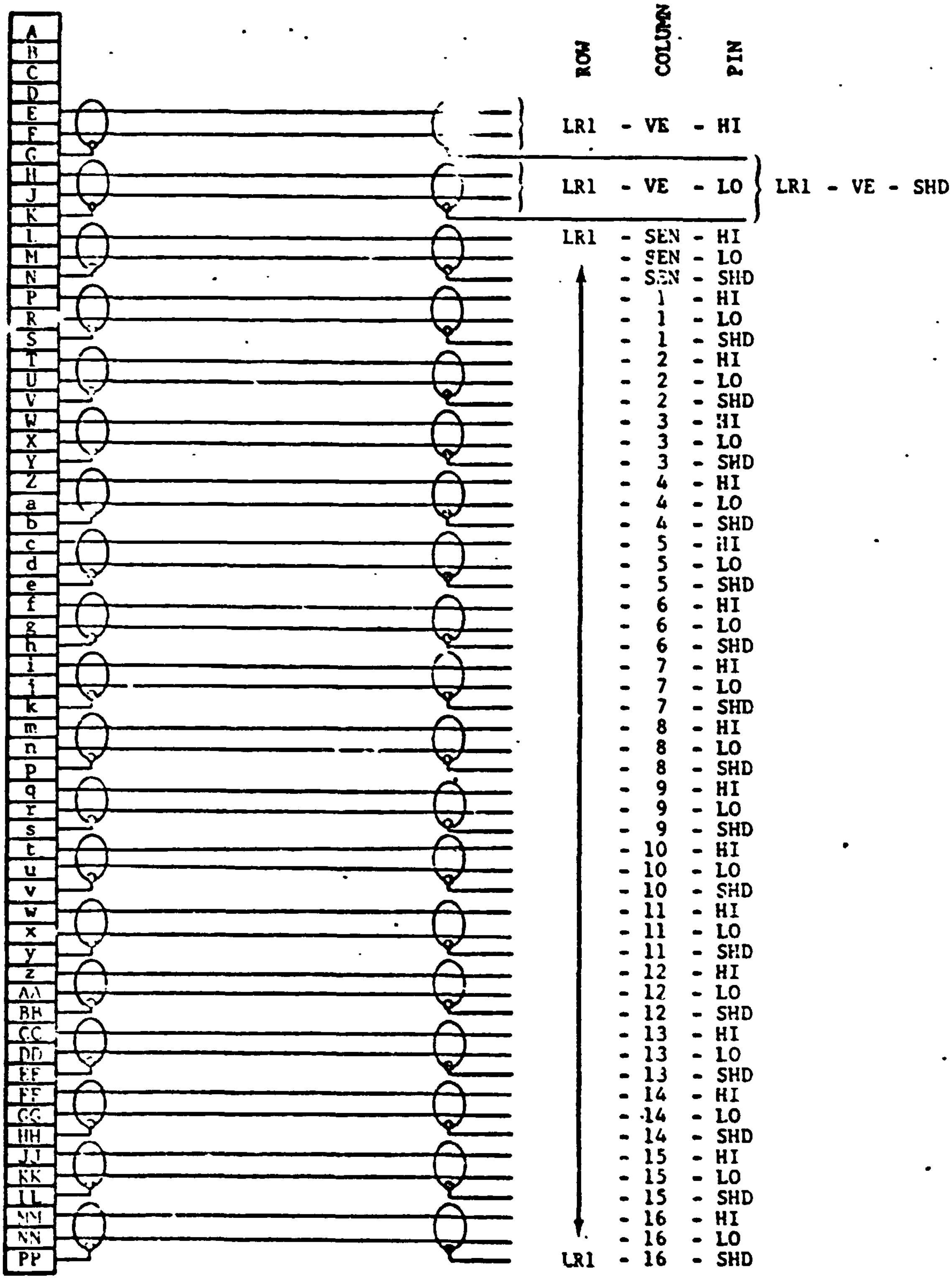


Figure 5-8. BHT program board signal input wires disconnect #LR1.

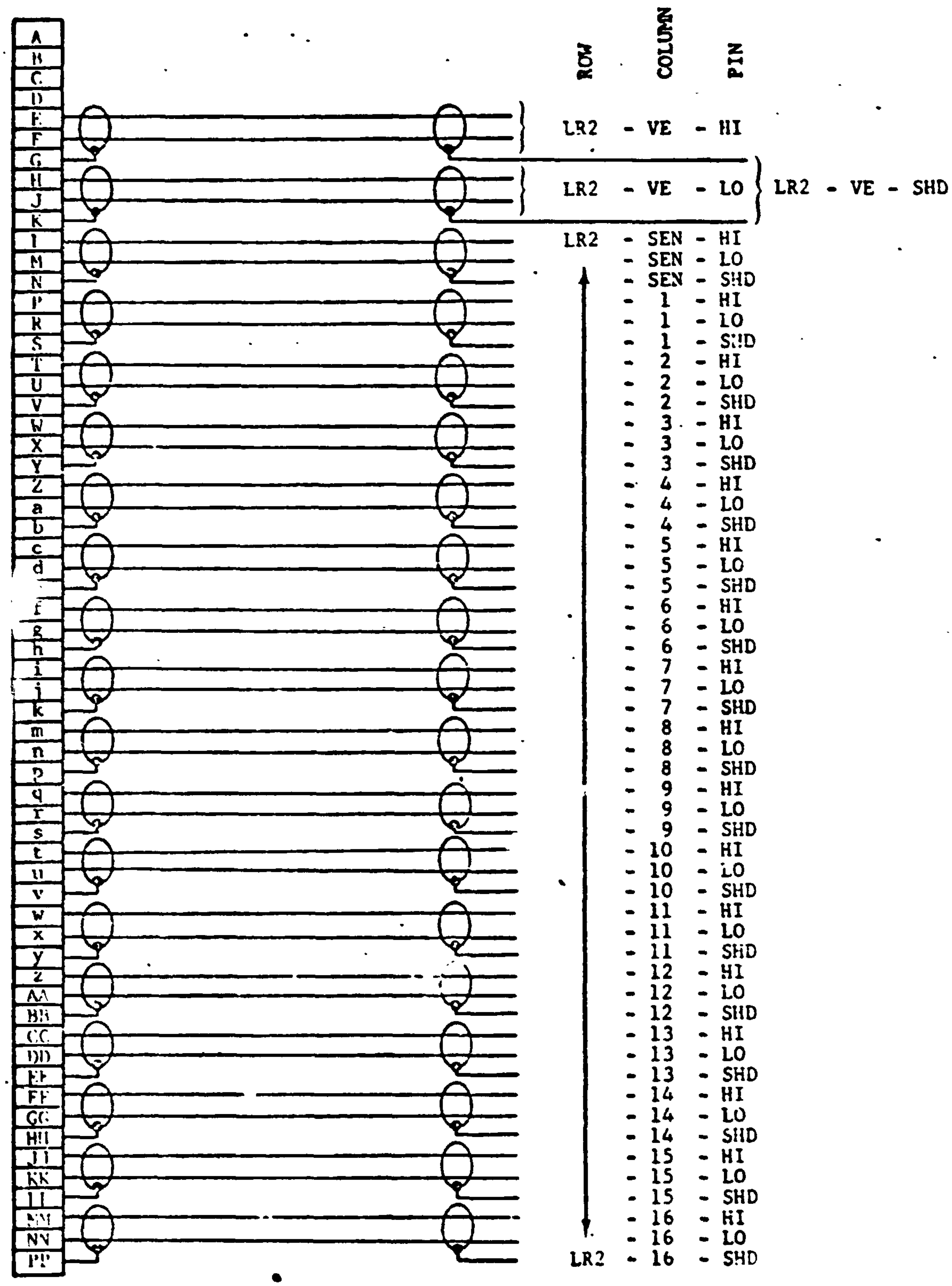


Figure 5-9. BHT program board signal input wires disconnect #LR2.

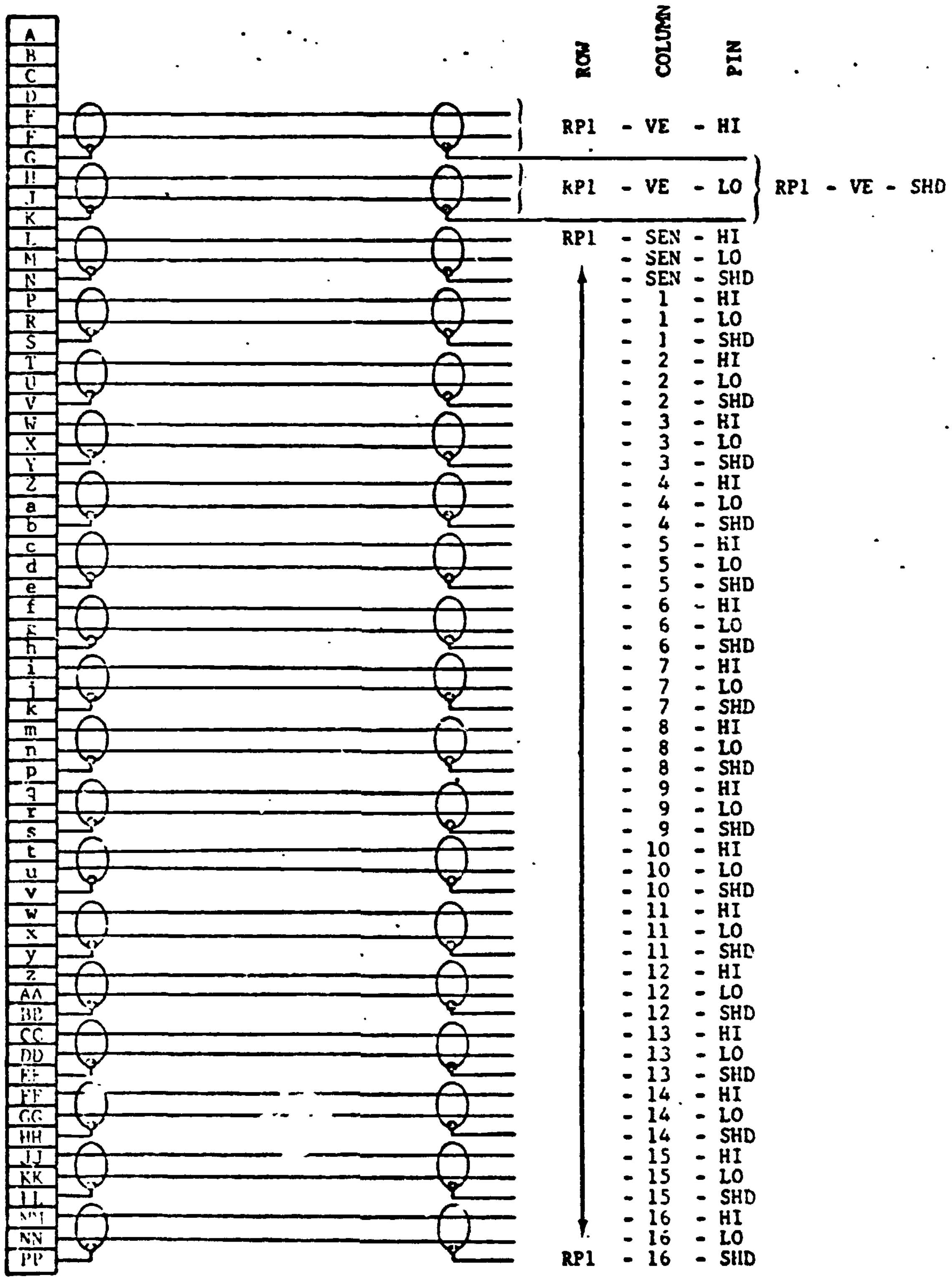


Figure 5-10. BHT program board signal input wires disconnect #RP1.

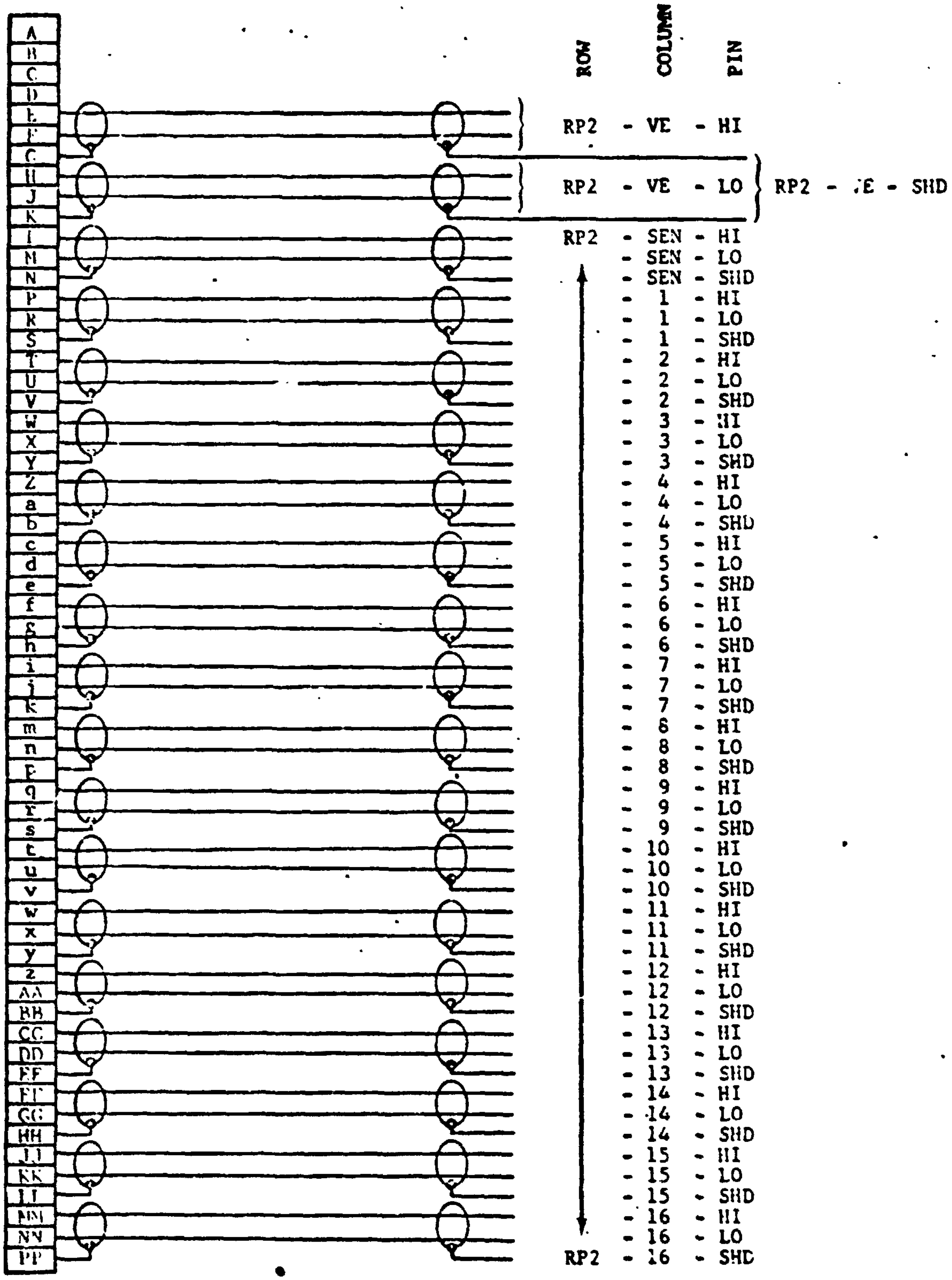


Figure 5-11. BHT program board signal input wires disconnect #RP2.

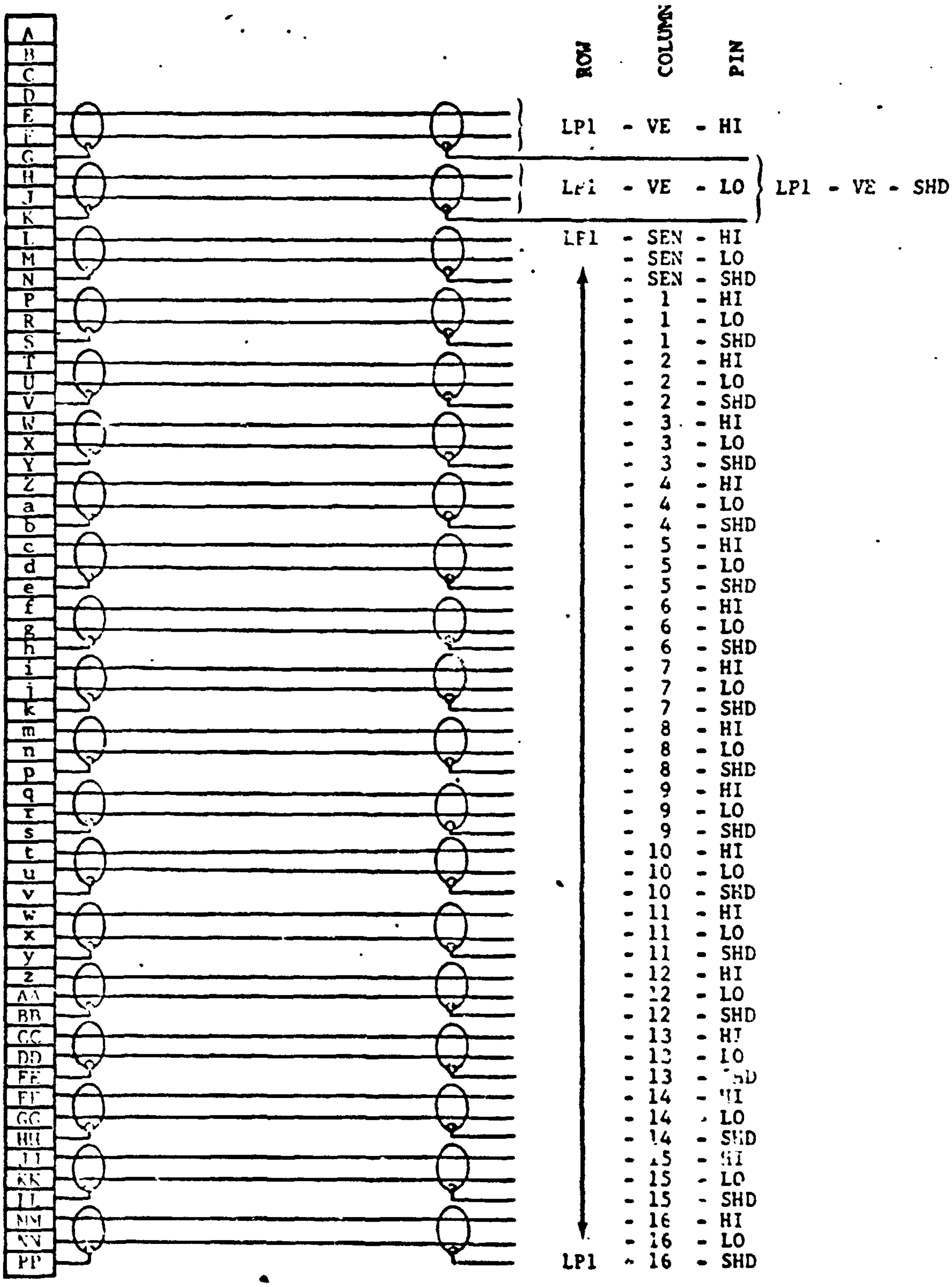


Figure 5-12. BHT program board signal input wires disconnect #LP1.

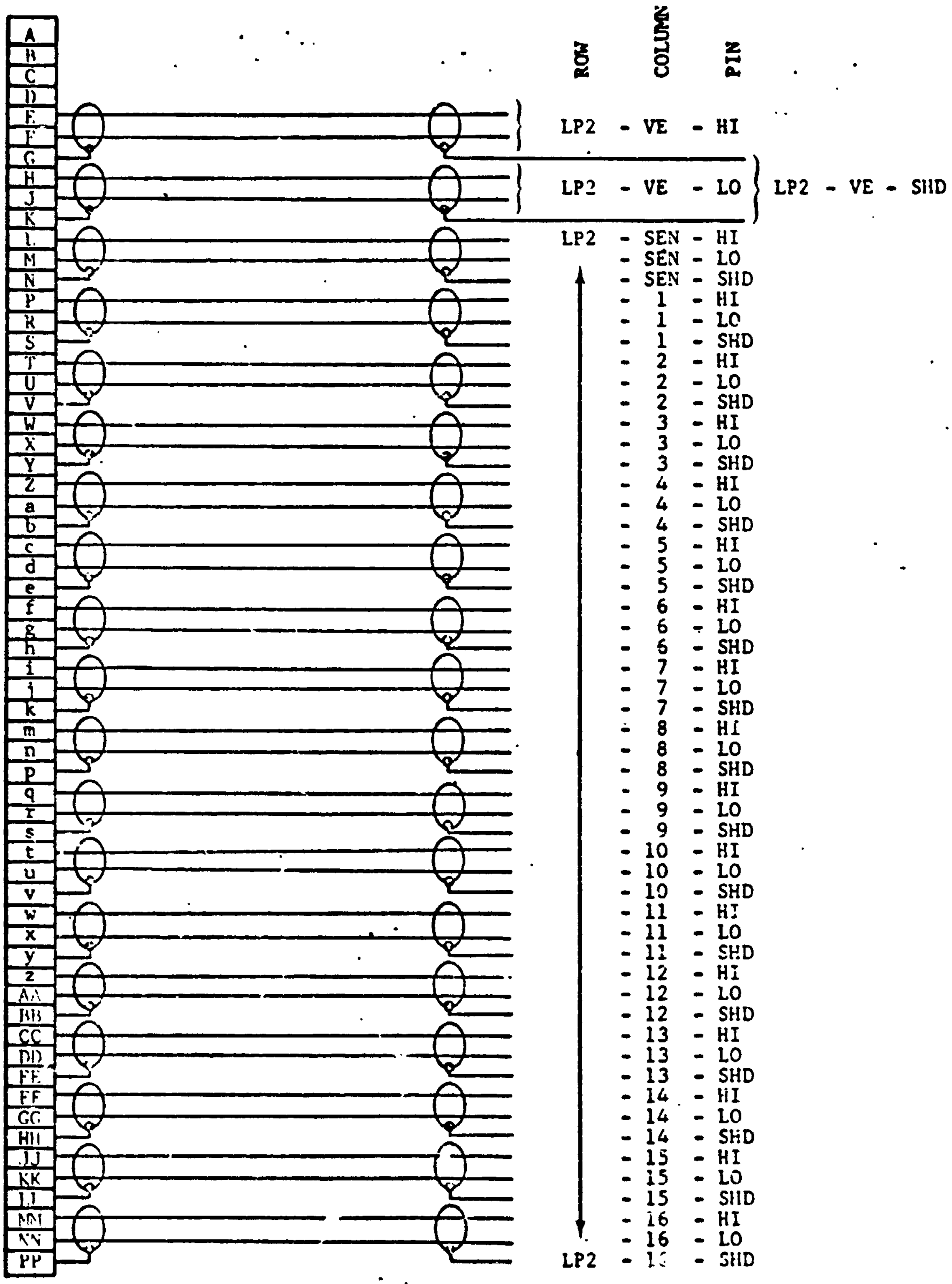


Figure 5-13. BHT program board signal input wires disconnect #LP2.

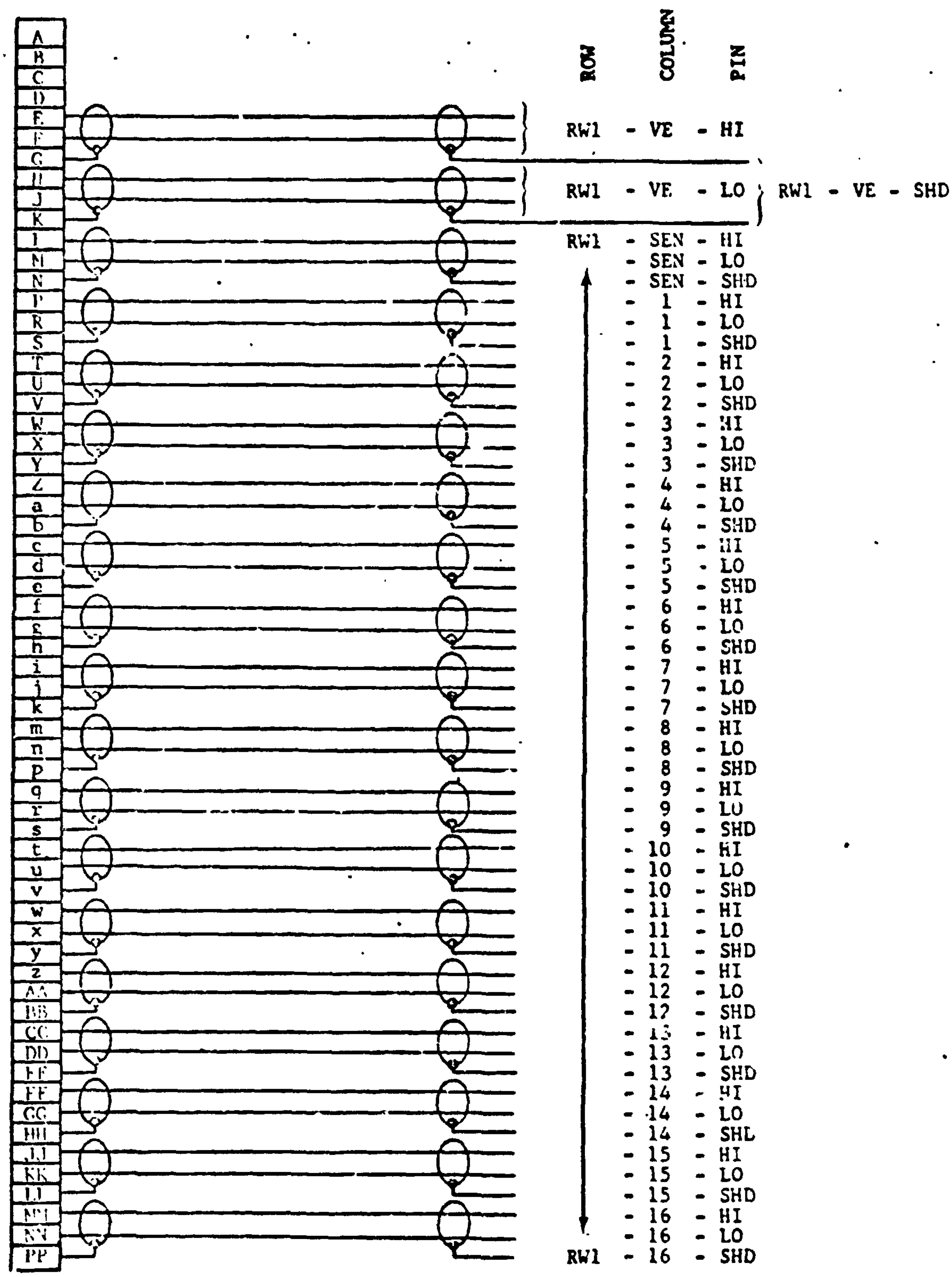


Figure 5-14. BHT program board signal input wires disconnect #RW1.

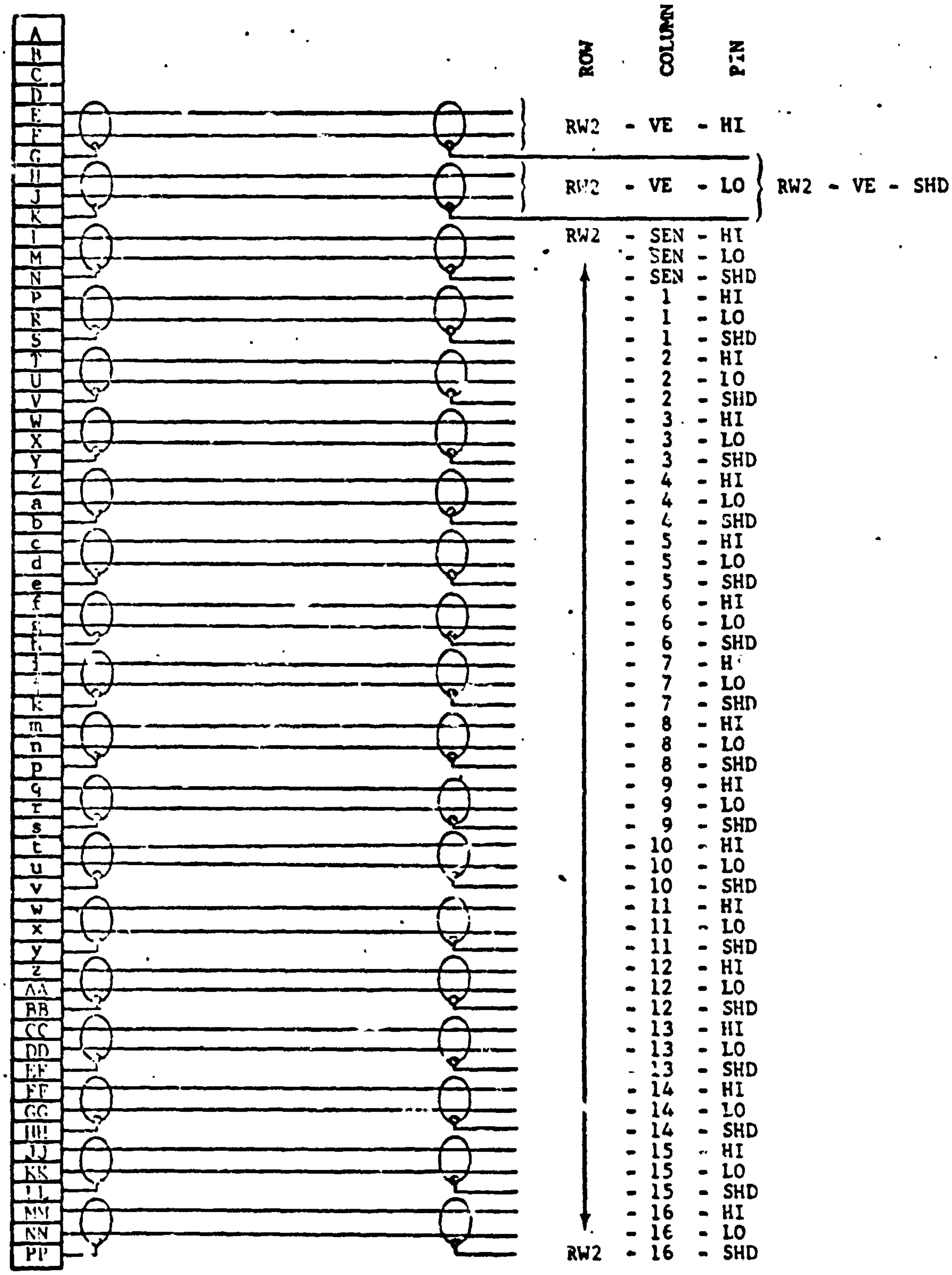


Figure 5-15. BHT program board signal input wires disconnect #RW2.

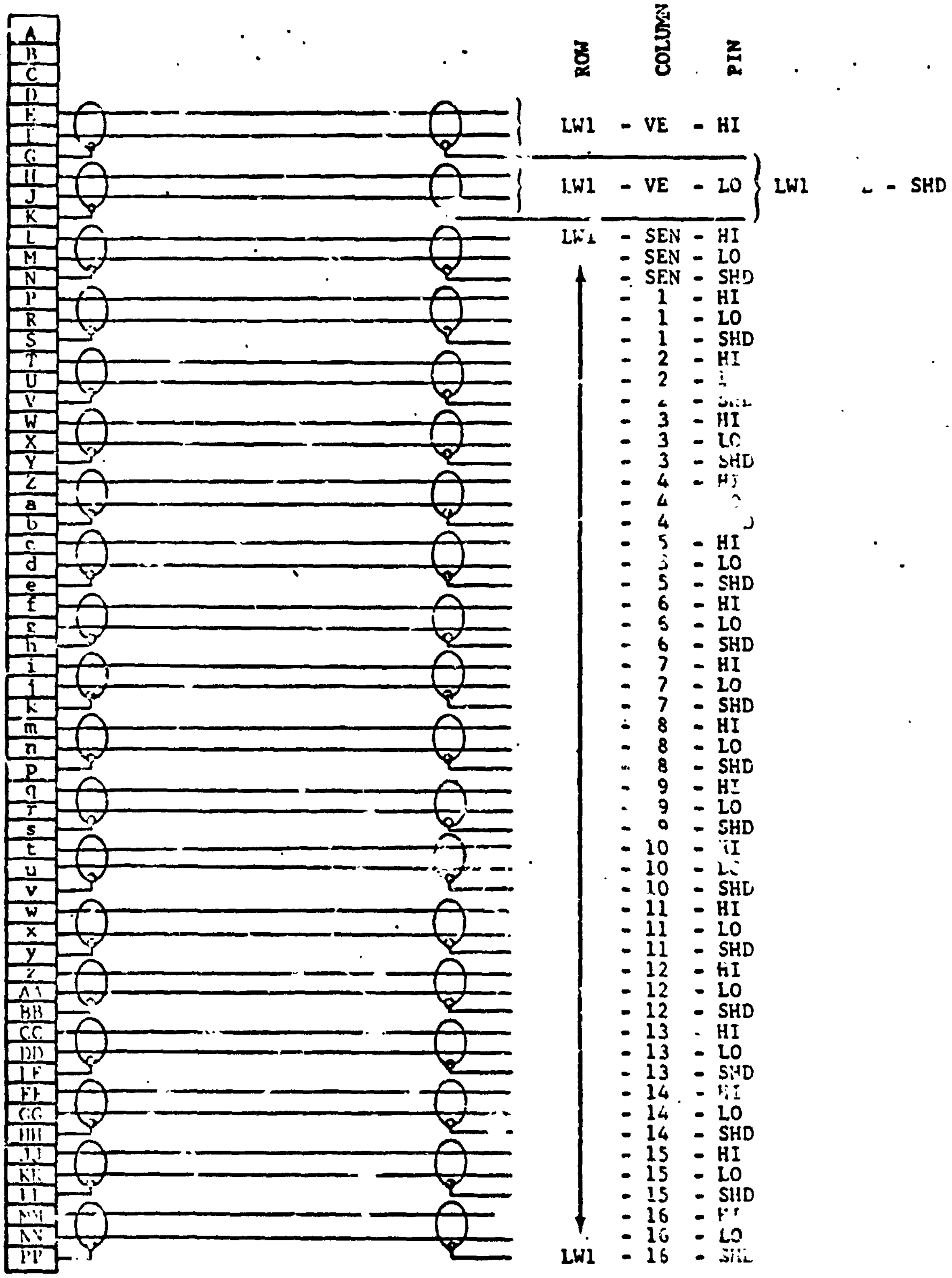


Figure 5-16. BHT program board signal input wire disconnect #1.

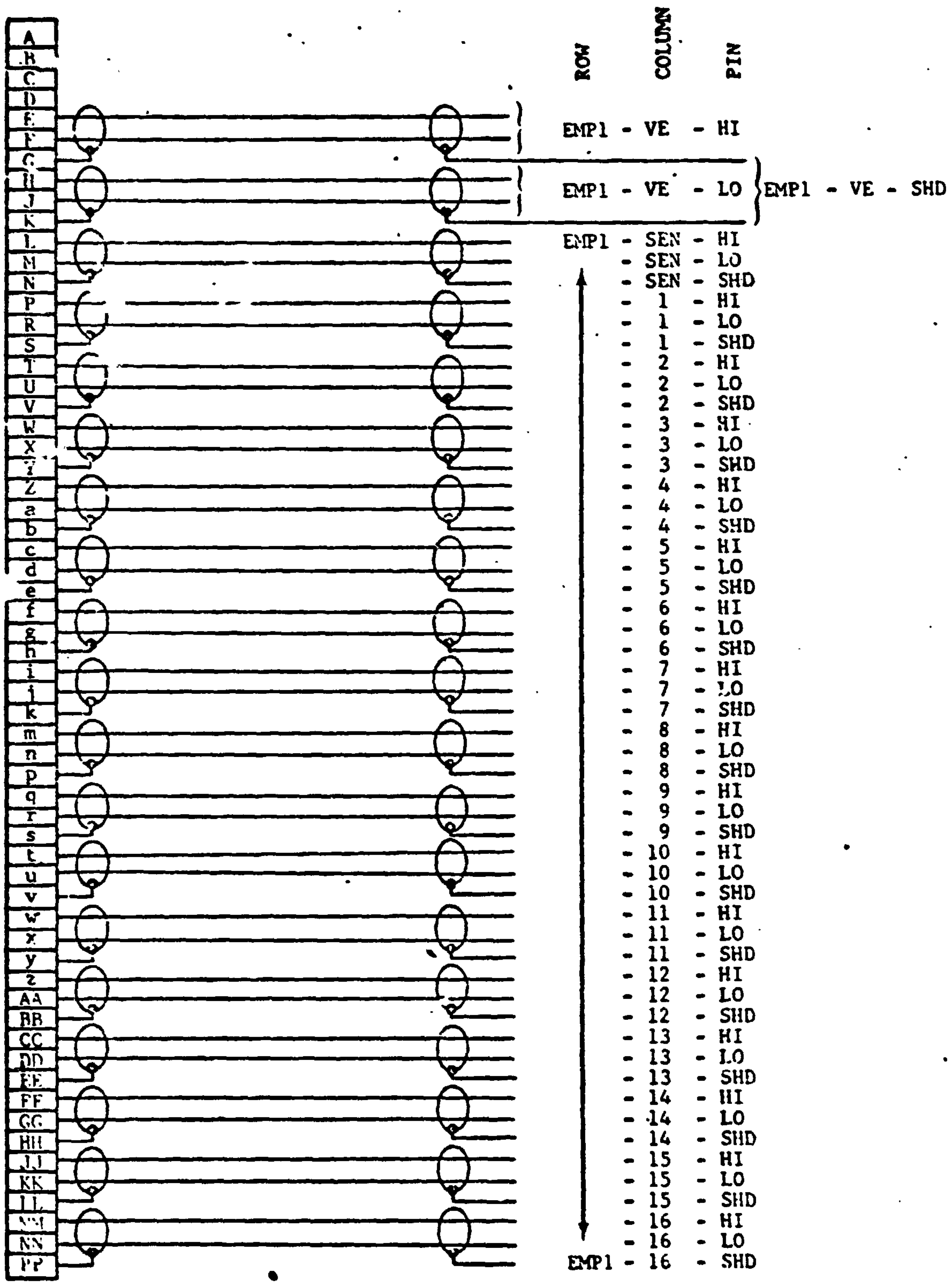


Figure 5-17. BHT program board signal input wires disconnect #EMP1.

C-3

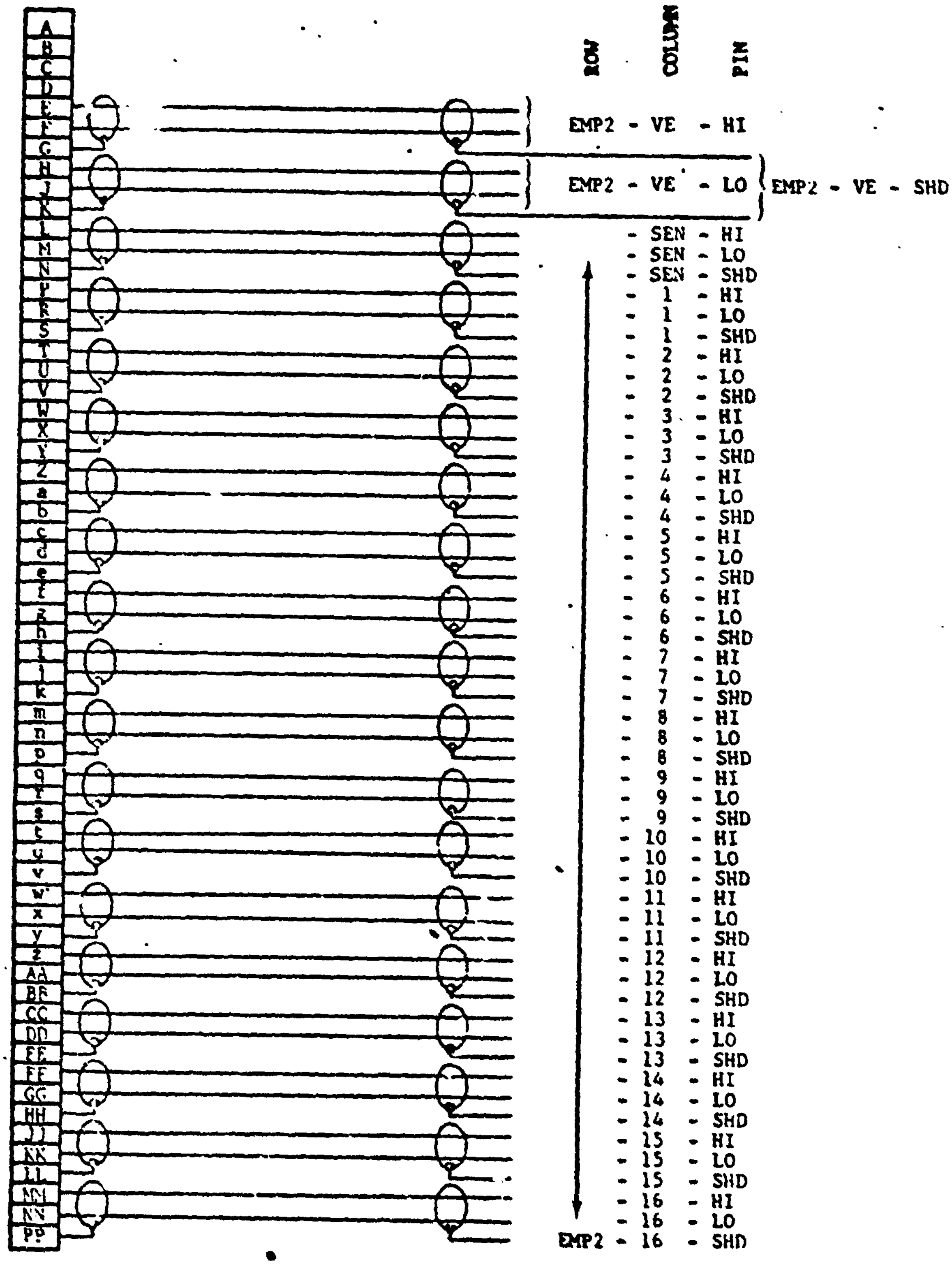


Figure 5-18. BHT program board signal input wires disconnect #EMP2.

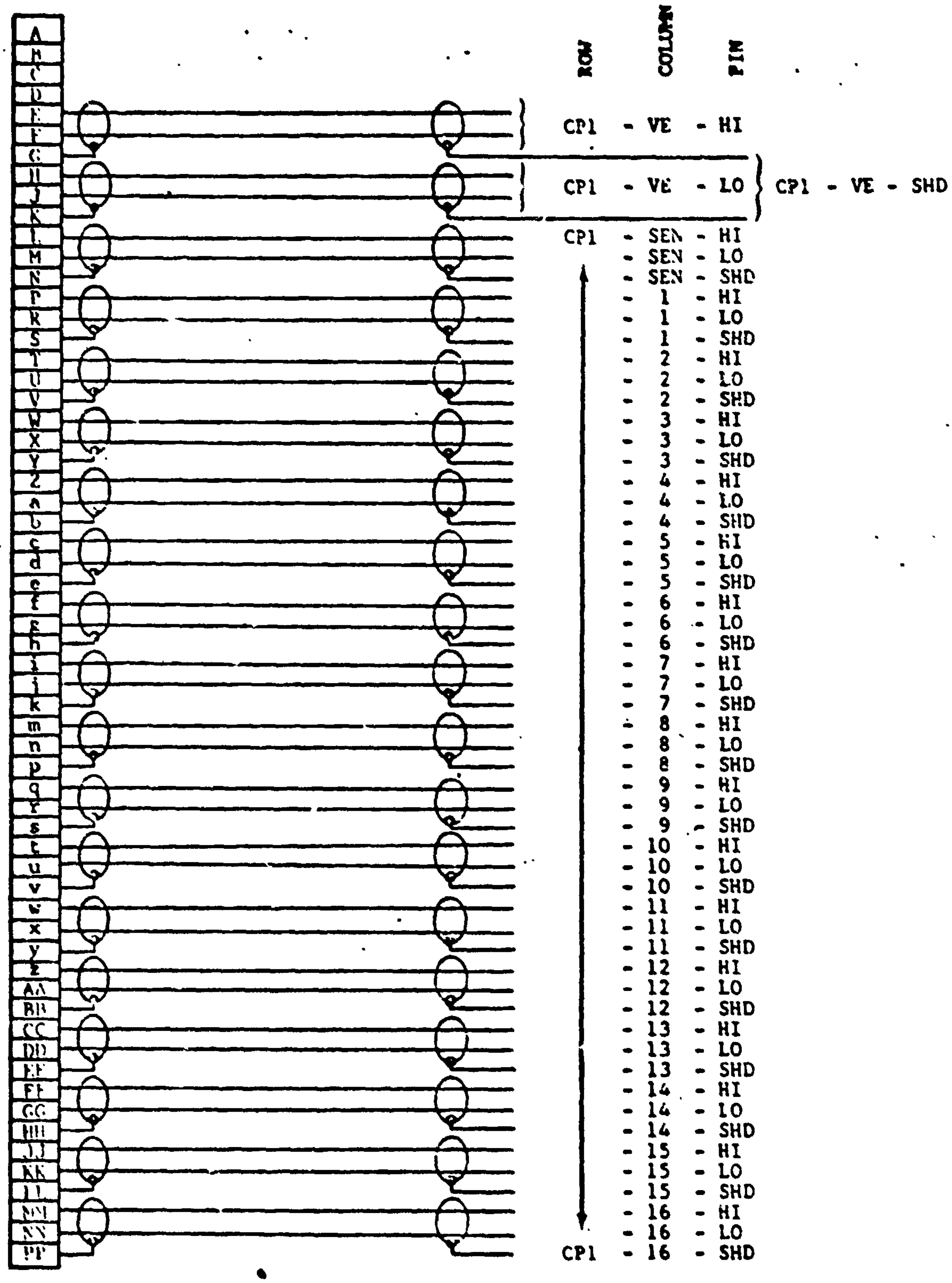


Figure 5-19. BHT program board signal input wires disconnect #CP1.

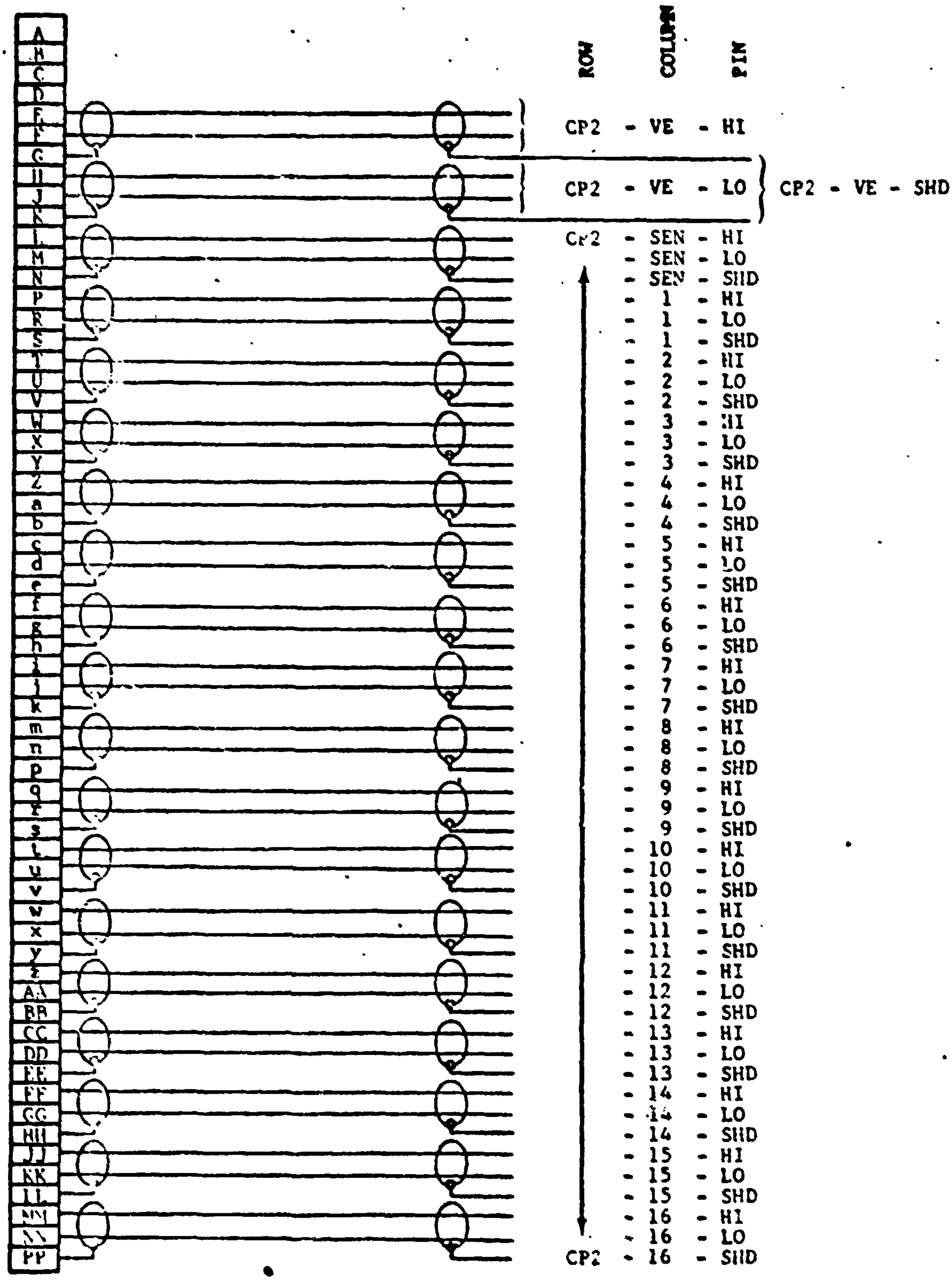


Figure 5-20. BHT program board signal input wires disconnect #CP2.

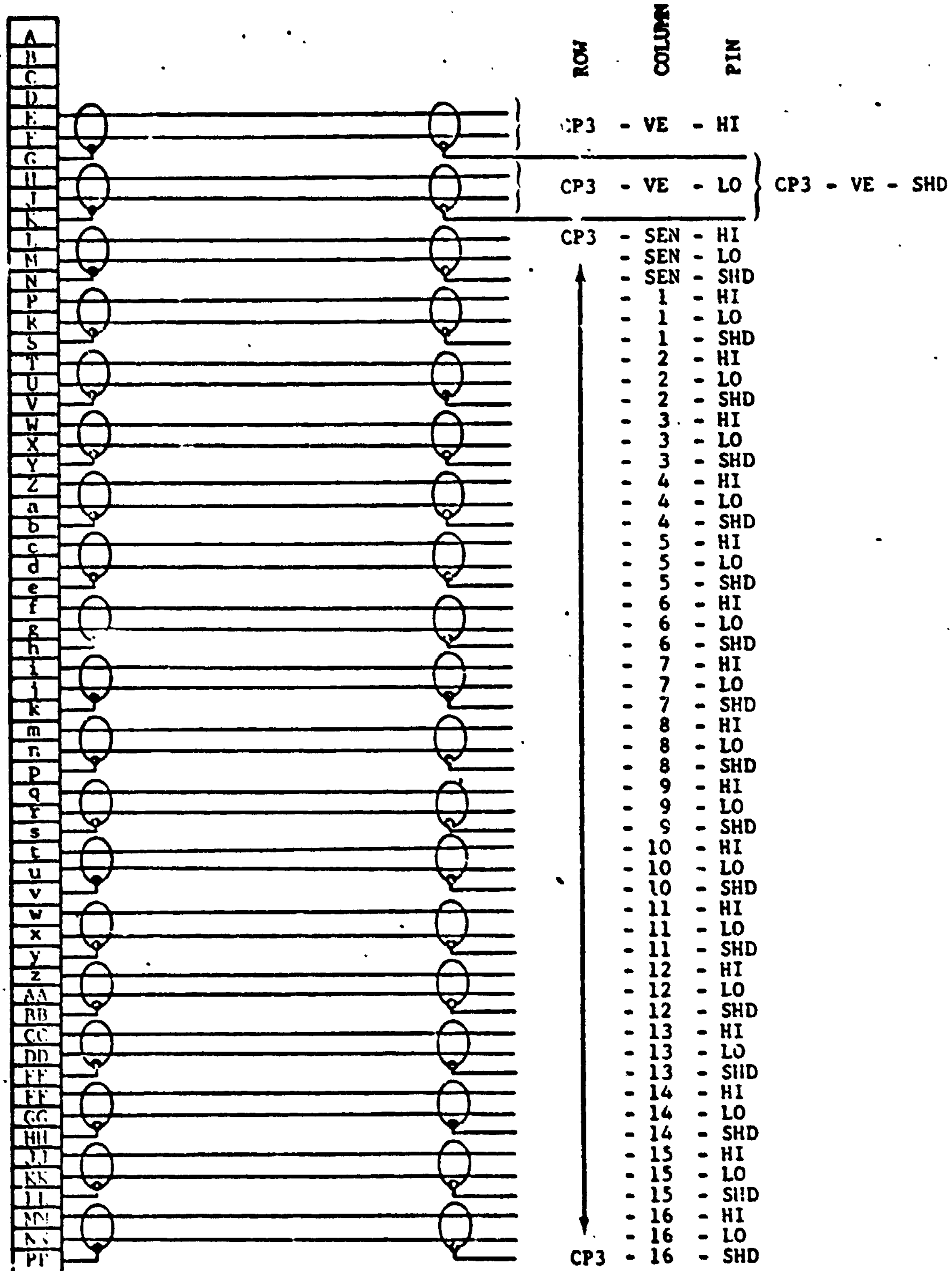


Figure 5-21. BHT program board signal input wires disconnect #CP3.

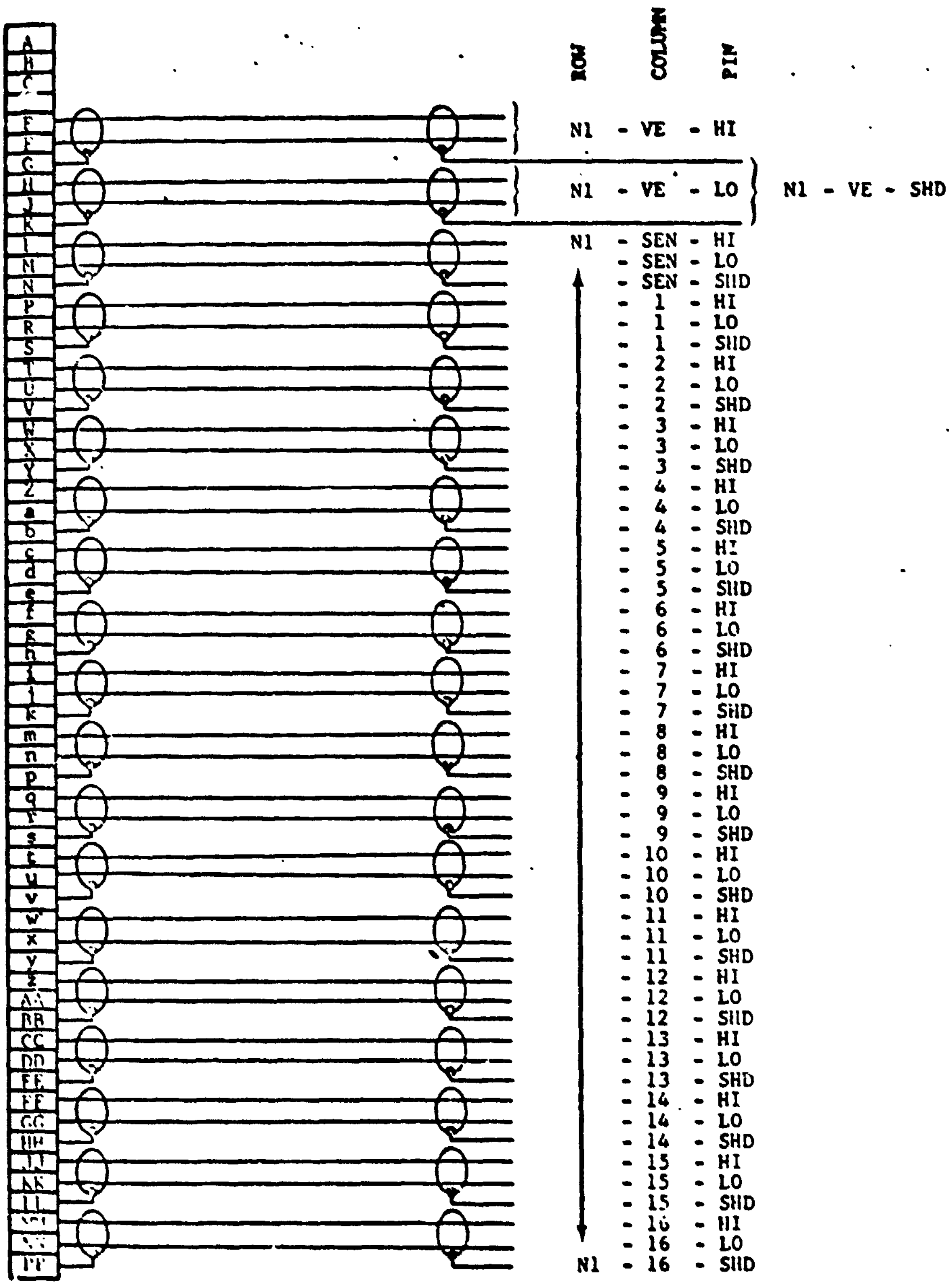


Figure 5-22. BHT program board signal input wires disconnect #N1.

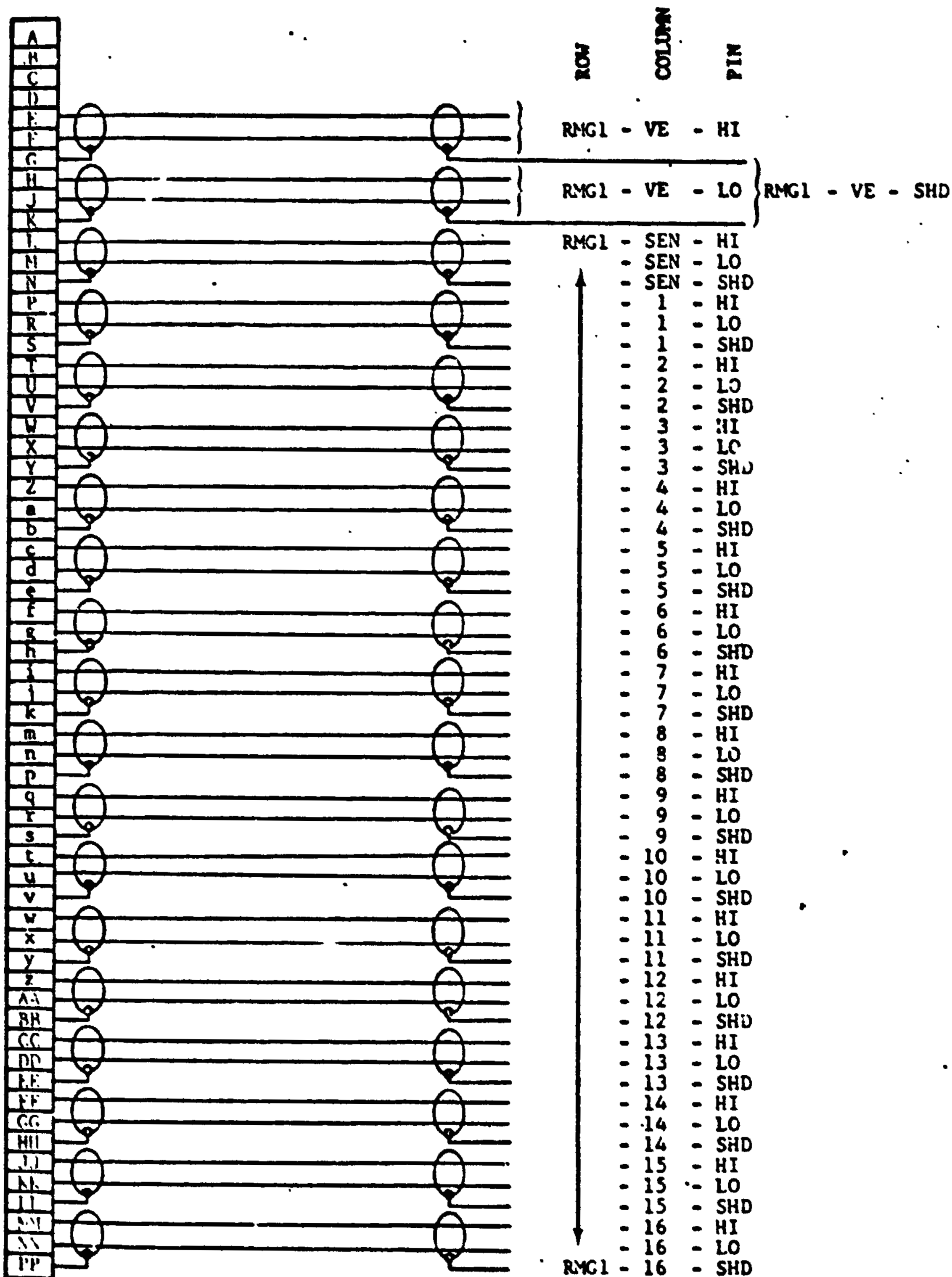


Figure 5-23. BHT program board signal input wires disconnect #RMG1.

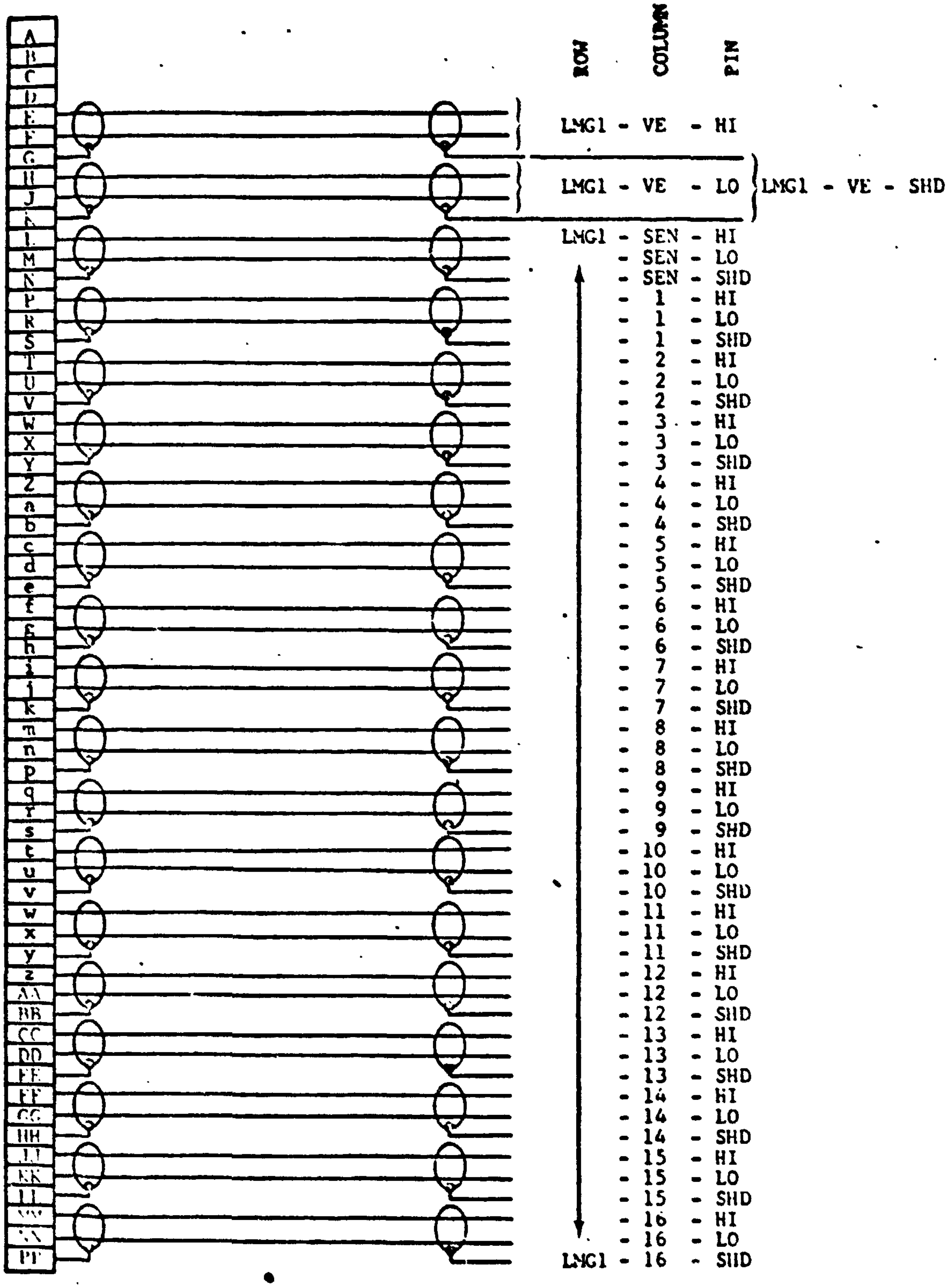


Figure 5-24. BHT program board signal input wires disconnect #LMG1.

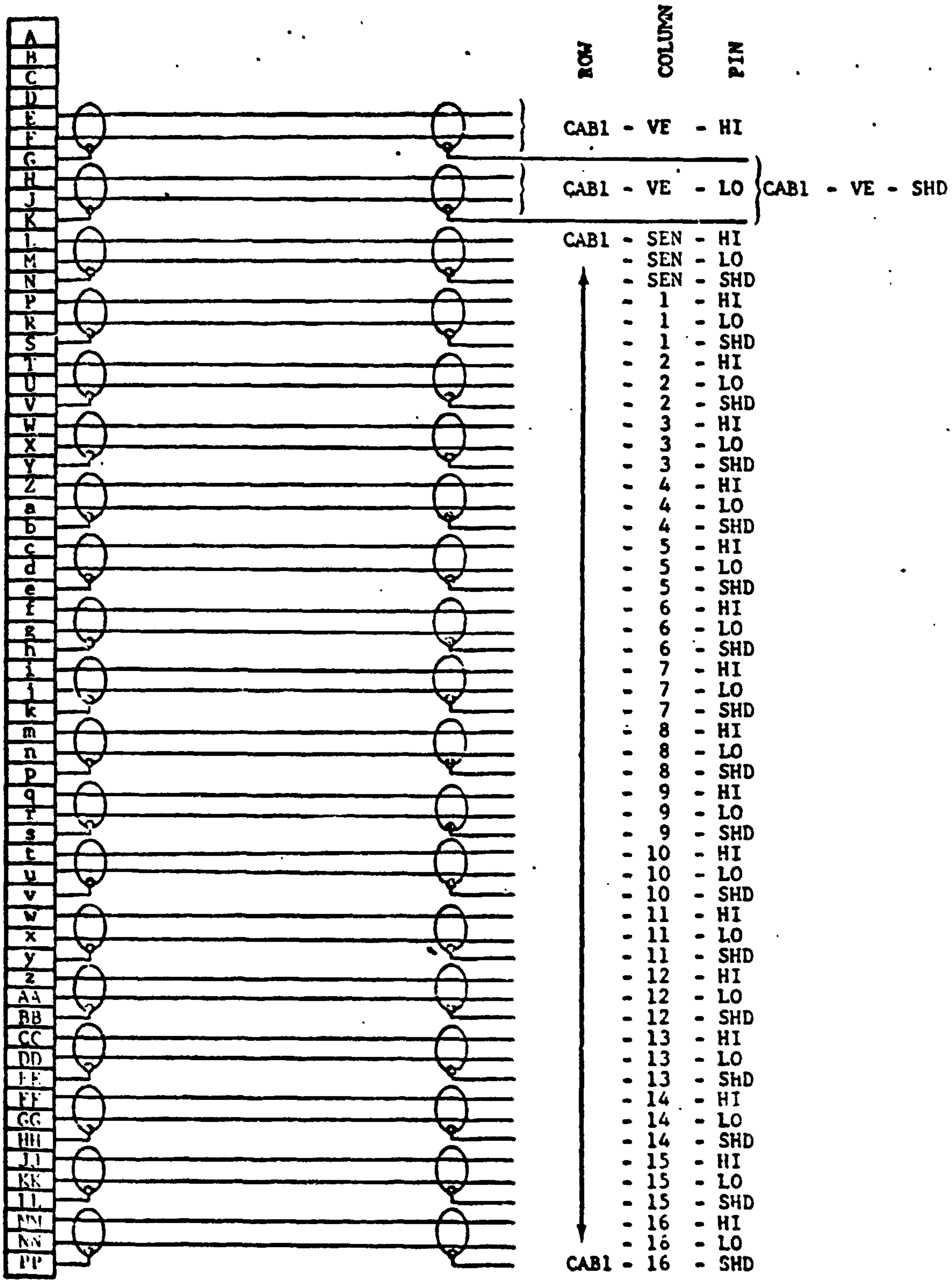


Figure 5-25. BHT program board signal input wires disconnect #CAB1.

SECTION 6. SENSOR INSTALLATION

This section defines the installation of the research instrumentation transducers.

6.1 Transducer Installation Worksheets. The installation of each research instrumentation transducer is covered by a lab worksheet or engineering sketch. The worksheet defines the transducer type and location, installatio procedure, lead terminations, and illustrates the instrumented component. Figures 6-1 through 6-7 show the transducer installation worksheets for all sensors associated with j-box N-1 which is the example used in Section 5. A complete set of worksheets for transducers installed in Aircraft No. 1 is found in Volume II. Worksheets for Aircraft No. 2 are found in Volume III. A keyed description of information contained on the standard BHT instrumentation laboratory worksheet is found in Figure 6-1. Bell Helicopter Textron Operating Procedure No. 13-OP-0401 (see reference 1) describes worksheets and documentation procedures for strain gaging of structural parts.

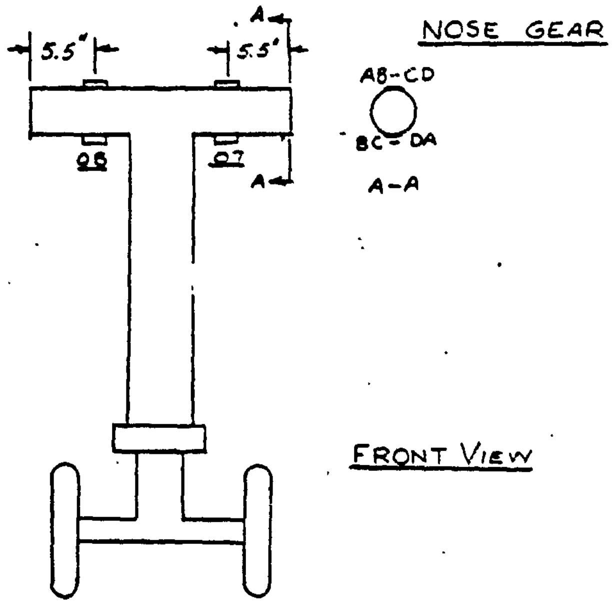
6.2 Strain Gage Application. Procedures used to apply strain gages to structural parts are described in BHT Engineering Laboratory Operating Procedure No. 80-13-004 and 13-OP-0402 (see reference 2 and 3).

INSTRUMENTATION LABORATORY WORK SHEET

MODEL NO 301 (1)	GAGE TYPE (2) EA-06-250MQ-350	(3) 688512
EWA NO A427-118 (4)	RESISTANCE 350 ± 0.4 % (5)	LAB. NO 11348A (6)
WK ORDER A427 (7)	GAGE FACTOR 2.13 ± 0.5 % (8)	PART NO 21800-200 (9)
REQUESTED BY A. WHITENER (10)	LOT NO. Q-A1BAF56 (11)	SERIAL NO (12)

TITLE OF TEST (13) 301 FLIGHT TEST

SKETCH: (14)



REMARKS: (15)

INSTALL BENDING BRIDGES AS SHOWN. USE EASTMAN 910 CEMENT. MAKE BRIDGE AT FLAT TERMINAL AS INDICATED. COVER WITH SHELL 9309. ATTACH FOUR TEN INCH SUPRENANT LEADS. ENCASE LEADS IN VINYL SLEEVING AND TERMINATE WITH KPT-06-8-4P PLUG.

(26)

	B357 07	B396 08						
(16) BRIDGE	BENDING	BENDING						
(17) BALANCE TICKS	420	413						
(18) RES TO GROUND								

DATE ASSIGNED (19)	TECHNICIAN CCW- WVF (20)	EST HRS (21)	APPROVED BY (25)
DATE COMPLETED 11-18-76 (22)	ENGINEER (23)	ACT. HRS (24)	

Figure 6-1. Instrumentation laboratory worksheet - keyed description (Sheet 1 of 3)

NOTES

Block 1 - MODEL NO. - Model number of the aircraft on which the instrumented part or component will be used.

Block 2 - GAGE TYPE - Part number, type or catalog number of the gage installed on the part.

Block 3 - DLN - Daily Labor Number assigned for direct engineering labor cost.

Block 4 - EWA NO. - Engineering Work Authorization number applicable to this job.

Block 5 - RESISTANCE - Resistance of the gages used on the subject part.

Block 6 - LAB NUMBER - The sequentially assigned alpha-numeric designation which identifies the lab sheet.

Block 7 - WORK ORDER - Work Order against which all labor and materials are charged.

Block 8 - GAGE FACTOR - Index of strain sensitivity of the installed gage.

Block 9 - PART NO. - Part number of the part or component instrumented.

Block 10 - REQUESTED BY - Engineering requesting the instrumentation.

Block 11 - LOT NO. - The manufacturing lot number of the installed gage. This number is assigned by the gage manufacturer.

Block 12 - SERIAL NO. - The manufacturer's serial number assigned to the part or component being instrumented. This block is applicable only to serialized parts.

Block 13 - TITLE OF TEST - The type of test that the part will be used in (e.g., flight test, fatigue test, bench test).

Block 14 - SKETCH - A schematic representation of the part which illustrates the gage location, orientation and designation (e.g., 01, 02, etc.).

Figure 6-1. Instrumentation laboratory worksheet - keyed description (Sheet 2 of 3)

NOTES (Concluded)

Block 15 - REMARKS - Verbal description of work to be done including any special instructions.

Block 16 - BRIDGE - Type of bridge (e.g., bending, torsion, stress, axial) and bridge designation (e.g., 07, 08).

Block 17 - BALANCE - Indication of the bridge balance network on a scale of 0-1000 (500 is a perfect balance).

Block 18 - RES TO GROUND - The resistance (usually in megohms) from the bridge terminal to a conducting surface of the part.

Block 19 - DATE ASSIGNED - The date the part is assigned to be gaged.

Block 20 - TECHNICIAN - The technician responsible for application of instrumentation.

Block 21 - EST HOURS - The amount of labor in manhours estimated to gage the part.

Block 22 - DATE COMPLETED - The date that gaging of the part is complete.

Block 23 - ENGINEER - The engineer responsible for the gaging.

Block 24 - ACT HRS - Actual manhours used to complete the gage installation.

Block 25 - APPROVED BY - The individual responsible for approving the materials and procedures used to gage the part.

Note 26 - ITEM CODE - The measurement item code is usually noted on the lab work sheet for each bridge.

Figure 6-1. Instrumentation laboratory worksheet - keyed description (Sheet 3 of 3)

INSTRUMENTATION LABORATORY WORK SHEET

MODEL NO 301	GAGE TYPE EA-06-125TB-350	693941
EWA NO A435-34	RESISTANCE 350.0 ± 0.4 %	LAB NO 11349A
ORDER A435	GAGE FACTOR 2.12 ± 0.5%	PART NO [illegible]
REQUESTED BY: A. WHITENER	LOT NO Q-[illegible]	SERIAL NO

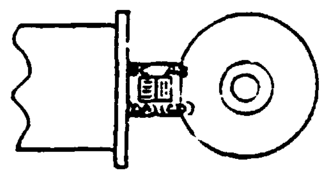
TITLE OF TEST: 301 FLIGHT TEST

SKETCH:

ROD END-HYD. ACT[illegible]

NOSE GEAR

F547



REMARKS: INSTALL AXIAL BRIDGE AS SHOWN. USE ~~EASTMAN 910~~ MB-[illegible] CEMENT. MAKE BRIDGE AT FLAT TERMINAL AS IN DETAIL. COVER WITH SHELL 9307. ATTACH FOUR WIRE TEN INCH [illegible] LEADS. ENCASE LEADS IN VINYL SLEEVING AND TE[illegible] WITH KPT-06-8-4P PLUG.

Figure 6-2. Nose gear actuator force.

BRIDGE	C9 AXIAL								
[illegible]CE	-0.14								
[illegible]ES TO GROUND	10KM								

DATE ASSIGNED	TECHNICIAN CCV, -MH	EST HRS	APPROVED BY
DATE COMPLETED 1-12-78	ENGINEER	ACT HRS	

BY A. WHITEHIER
CHECKED
Bell Helicopter TEXTRON
MODEL 301 PAGE 1
RPT ASW5377-2

NOSE + MAIN LANDING GEAR
ACT POS

P398

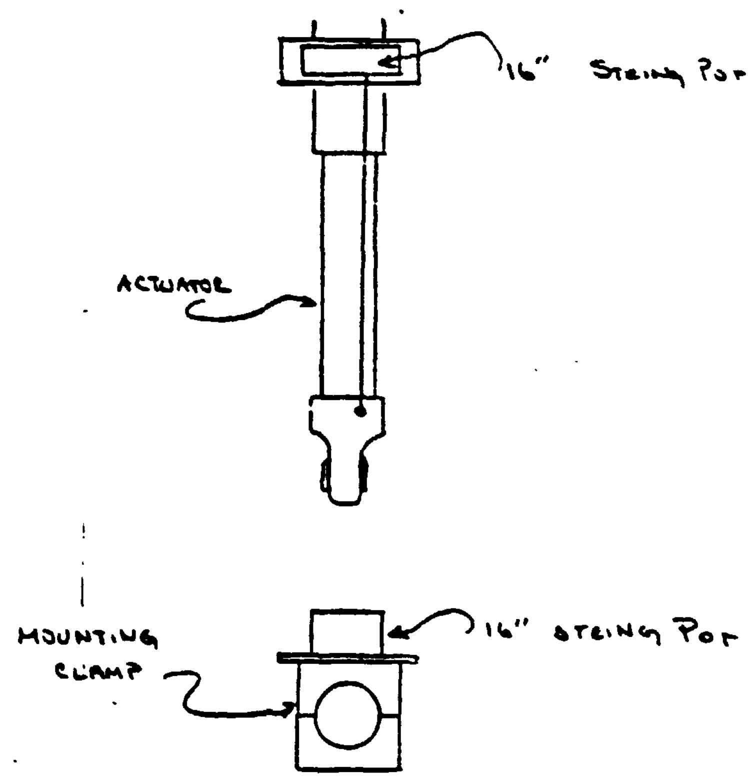


Figure 6-3. Nose and main landing gear actuator position.

BY A. WHITENER	Bell Helicopter TEXTRON	MODEL 301 PAGE 1
CHECKED		RPT ASW 5377-2

Nose Landing Gear

Oleo Extention Pos

D 349

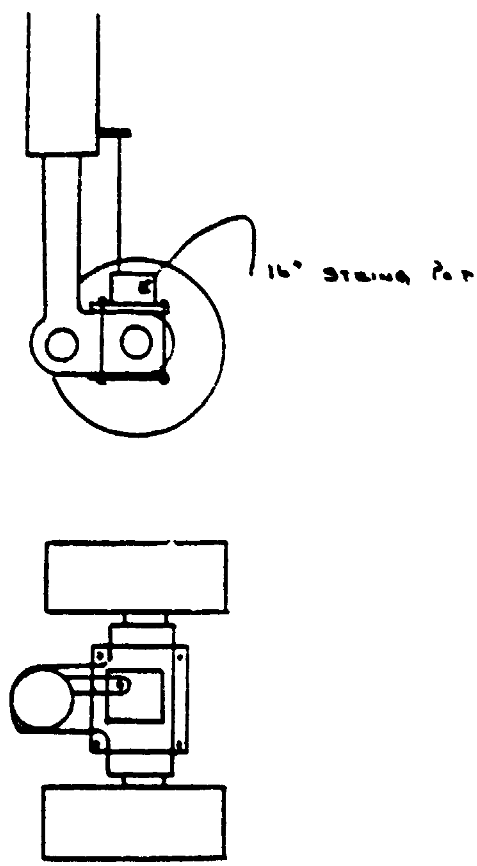
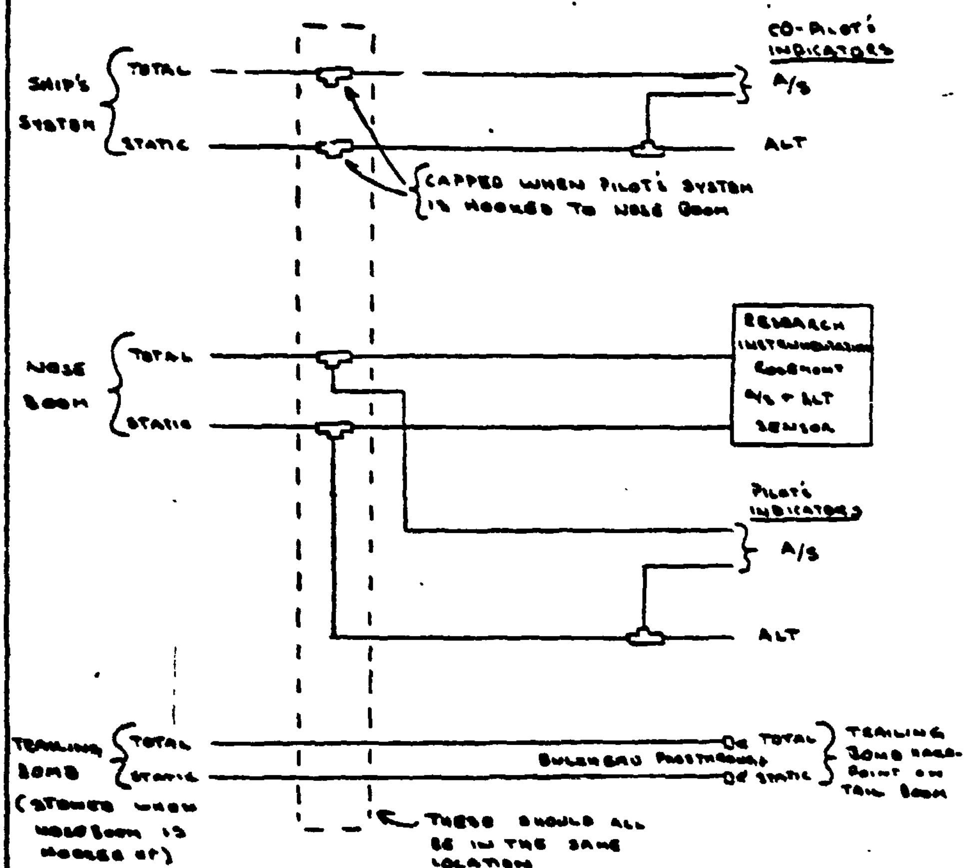


Figure 6-4. Nose landing gear oleo extension.

BY A. Whitenel	BELL HELICOPTER COMPANY	MODEL 301 PAGE 1 of 1
CHECKED		HELI. RPT SKASW 33576-1

SHIP'S A/S + ALT. CONNECTIONS

P002
P542



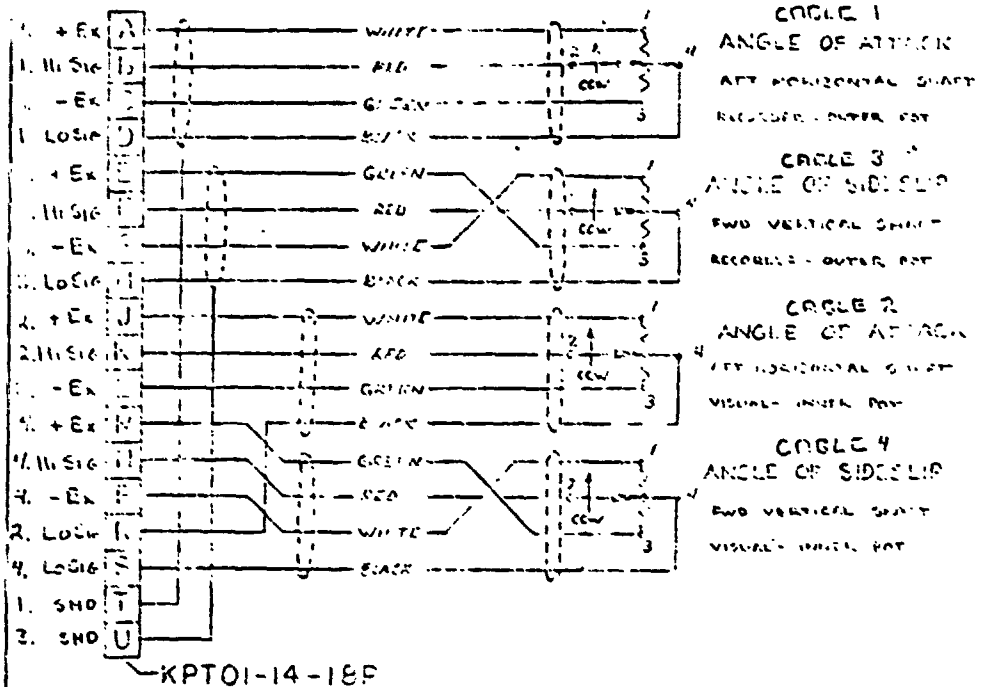
1. Nose Boom and Trailing Bomb inputs will be exchanged (or can be exchanged) at various time during tests.

2. All tubes will be Red (Total) + Yellow (Static) ¼" Polyflow Tubing

3. Pilot's system can be connected to either Nose Boom, Trailing Bomb or Ship's System

Figure 6-5. A/S and altitude sensors.

DATA BOOM WIRING P/N 100510-1
SPACE AGE CONTROLS
SWIVEL NOSE



1. SIGN CONVENTION - UPSCALE, POSITIVE VOLTAGE
   ANGLE OF ATTACK - NOSE OF HORIZONTAL VANE MOVES DOWN
   ANGLE OF SIDESLIP - NOSE OF VERTICAL VANE MOVES RIGHT

2. MECHANICAL ROTATION - 360°

3. ELECTRICAL ROTATION - ± 170° ± 5° FROM CENTER TAP

4. ?? - VANE ASSEMBLIES INSTALLED WITH 3 POT TERMINALS AFT

Figure 6-6. Data boom wiring.

BELL HELICOPTER COMPANY

ENGINEERING ORDER

FSCM IDENT NO. 97499	☐ CHANGE	E.O. NO. 301 HEC 03
AUTHORITY FOR CHANGE	☐ RELEASE ☐ TEST	SHEET 1 OF 5
R.C.A. NO.	☐ PROCESS ☒ YES	ENG'R'G WORK ORDER
L.E.T.A.R. NO.		

REASON: YAW AND PITCH ADAPTER

DRAWINGS AFFECTED	DRAWING CHANGE LTR.	DRAWING TITLE

0008
0007

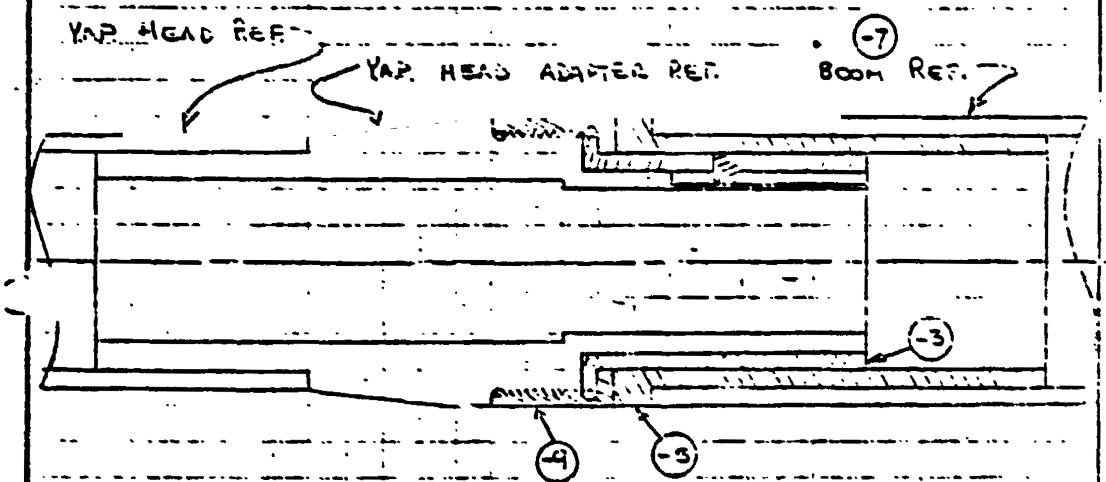


Figure 6-7. Yaw and pitch head adapter installation

(-1) ASS'Y (FINAL ASSY ON A/C INSTALLATION)

MAKE 2 EACH (-1) ASSEMBLIES PER THIS E.O.
DELIVER TO A. WHEELER (4582) ITO PLANT #6

STATUS	PART/ASSY NO	ADD.	REV.	CHG.	ENGINEERING DISPOSITION

SIGNATURE	DATE	SIGNATURE	DATE	SIGNATURE	DATE
PREPARED BY		STRUCTURES		LIST. DES.	
ENGR		CUSTOMER		WEIGHTS	
CHECKED BY		Q.E.R.		PROJ. ENG	

MANUFACTURING EFFECTIVITY	ENGINEERING EFFECTIVITY
NONE	NONE

REL. INFORMATION | CHANGE CONTROL | SPARES | ...

SECTION 7. SENSOR CALIBRATION

This section establishes calibration requirements, procedures, re-calibration intervals, and documentation requirements for XV-15 research instrumentation sensors.

7.1 Sensor Installation and Calibration. Sensors are installed in the aircraft during assembly. All strain-gaged components are calibrated prior to installation on the aircraft except where this is not practical (e.g., wing and landing gear strain gages). Position sensors are calibrated after installation on the aircraft and after completion of positive identification and sign convention checks (see Section 9). Accelerometer and pressure sensors are calibrated prior to aircraft installation using laboratory procedures. With the aircraft level, the attitude gyros will be installed and shimmed to give zero output between caged and uncaged positions for pitch and roll attitudes. When all sensors have been calibrated, installed on the aircraft and all signal cables have been connected to the data package, checkout of each data channel can begin (see Section 9 for checkout procedures).

7.2 Calibration Requirements. Calibration requirements for research instrumentation shall be in accordance with MIL-C-45662. All transducers are to be calibrated by applying increasing and decreasing stimuli in both negative and positive directions. This process will provide linearity and hysteresis data over full scale range. Data from digital readout equipment will then be computer processed to provide best straight line fit to all points and these deviations will become the basis for acceptance or rejection of the calibration. Total error (deviation from straight line) is not to exceed ±3 percent of full scale. If deviations greater than ±3 percent cannot be avoided, then special considerations must be taken. The best straight line calibration data will be published as "Engineering Units/100K Step."

7.2.1 Strain Gages. Strain gaged structural parts are calibrated in accordance with BHT Procedure No. 80-13-005 (reference 4). Strain gage transducers installed on the XV-15 are of the foil bonded type. These gages are applied under controlled conditions with BR600 cement, baked out and then covered with Shell 956.3 covering. Large parts, such as main rotor blades and the empennage, which cannot be oven-baked, use Eastman 910 cement and the same Shell 956.3 covering. All gages ar configured as four active arm bridges of approximately 350Ω resistance. Calibration is performed by application of actual working loads using appropriate laboratory test fixtures. These loads are related to a standard load by using calibrated pressure gages and hydraulic cylinders. Gage output is recorded with a calibration computer, printing digital voltmeter, and scanner. Every effort shall be made to match cylinder and gage size to required full-scale calibration load. Acquisition of calibration data for strain gaged parts is covered by BHT Procedure No. 13-OP-0501 (reference 5). The following list relates full-scale accuracies of load applying devices:

a.	Hydraulic cylinder (friction, dimensions)	±1% Full Scale
b.	Pressure gages (hysteresis, linearity)	±1% Full Scale
c.	Digital printing system Total error at room temperature	±0.5% Full Scale
d.	Human error reading Pressure gage	±1% Full Scale

Calibration RMS Error = ±1.8% Full Scale

When multiple gage parts are calibrated (rotor blades, etc.), all channels are monitored during load application in each direction (beam and chord). These data provide cross talk information. If cross talk is greater than ±5 percent of full scale, the regaging is generally performed to reduce cross talk. Data are available that can be used to correct cross talk if desired. Calibration documentation and records are in accordance with BHT Procedure No. 13-OP-503 (reference 6).

7.2.2 Position Transducers - Linear and Rotary. All position transducers are calibrated on the test vehicle after electrical displacement has been optimized for maximum mechanical displacement by adjusting the amplifier gain. A clinometer and protractor are used to calibrate rotary potentiometers, and a dial indicator and 12 inch scale are used for linear potentiometers and LVDT's. Transducer output is recorded at the output of the flight line tester in bit count.

Calibration accuracies for position transducers are as follows:

a. Clinometer ±1 minute = ±0.009 percent (full scale = 180 degrees)

b. Dial indicator ±0.002 inch = ±0.13 percent (full scale = 1.5 inches)

c. Human reading error = ±0.5 percent

Calibration TMS error = 0.50 percent clinometer
= 0.52 percent dial indicator

7.2.3 Accelerometers and Gyros. All accelerometers shall be calibrated in the laboratory by the Standards and Calibration Group. An Unholtz-Dickie Model MA-351 accelerometer calibration system is used to obtain a calibration accuracy of ±2 percent. Standard plots are made to show frequency response characteristics at a known G-level.

Rate gyros are calibrated on a turntable whose speed is known to within ±0.1 percent of reading. Attitude gyros may be calibrated either in the laboratory or on the aircraft. Attitude gyros are calibrated on a tilt table whose accuracy is known to be within ±1 minute.

7.2.4 Pressure Transducers. These transducers are calibrated by applying stimulus under laboratory conditions. Standard pressure is placed on transducers and millivolt output is recorded from a digital voltmeter. Data are tabulated through full scale range of the transducer.

7.2.5 Thermocouples. All thermocouples are indicated on a digital display designed and built by BHT. The total system error (reference junction, system noise, BHT circuitry) is ±6°F. The wire is specified as (iron-constantan J type) (32° to 530°F) ±4°F, (530 to 1400 degrees) ±3/4 percent of reading. Each roll is sampled by the Standards Laboratory and a correction is published to be applied to the data. Data going directly into the data system will only have reference junction error associated with it, ±2°F.

7.2.6 Panel Instruments. These units are calibrated by applying stimulus under laboratory conditions. The criterion of using a standard 10 times more accurate than the test instrument is applied. Data are tabulated as deviation from standard through full-scale range of the unit. Accuracy of applied stimulus is listed below:

a. Airspeed ±0.015 percent of reading

b. Attitude ±0.015 percent of reading

c. Rate of climb ±0.1 percent of reading

d. Tachometers ±0.1 percent of reading

e. Fluid pressure ±0.2 psi

7.3 Calibration Intervals. Recommended calibration intervals for XV-15 research instrumentation are specified in BHT IOM 86:ASW:mc-3710 (reference 7).

7.4 Calibration Sheets. Calibration of each sensor is documented by a calibration data sheet. Figure 7-1 through 7-8 show the calibration sheets for all sensors associated with j-box N-1 which is the example used in Section 5. A complete set of calibration sheets for all sensors installed in Aircraft No. 1 is found in Volume II. Calibration sheets for Aircraft No. 2 are found in Volume III.

CALIBRATION DATA SHEET

Date 3-7-[illegible]
Lab. No. [illegible]
Project Nose Landing Gear
Serial No. [illegible]
Model [illegible]
Title [illegible]
Part No. [illegible]
L. T. R.
EWA
Engineer [illegible]

Technician	Lab. Notebook No.	Instruments	Serial No.	Res.	Galvo.
[illegible]		DVM			

Volts	6.06			6.06					
Gage Type									
Gage Fac.									
Gage Res.									
Lot. No.									
Act. Arm									
Chan.	[illegible]			[illegible]					
Bridge	08			07					
Config.									
Cal. Res.	100 K			100 K					
Lever Arm									
Load	Output			HB					
0	-2.[illegible]	0		~~[illegible]~~	0				
[illegible]	+.572	2.63		~~[illegible]~~	2.624				
0	-2.059	0		+2.15[illegible]	0				
450 PSI	-1.290	.799		+1.41[illegible]	-.75				
900	-.45[illegible]	1.609		+.609	-1.557				
1350	+.310	2.399		-.201	-2.367				
1800	+1.122	3.211		-1.002	-3.168		Ck RGJ 3-15-78		
2250 PSI	+1.905	3.994		-1.812	-3.978				
1350	+.392	2.451		-.205	-2.372				
450 PSI	-1.227	.832		+1.421	-.745				
0	-2.065	.024		+2.169	+.003				

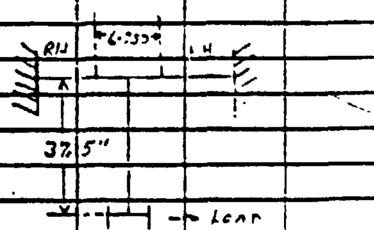


Figure 7-1. Nose gear strut bending.
(Sheet 1 of 3)

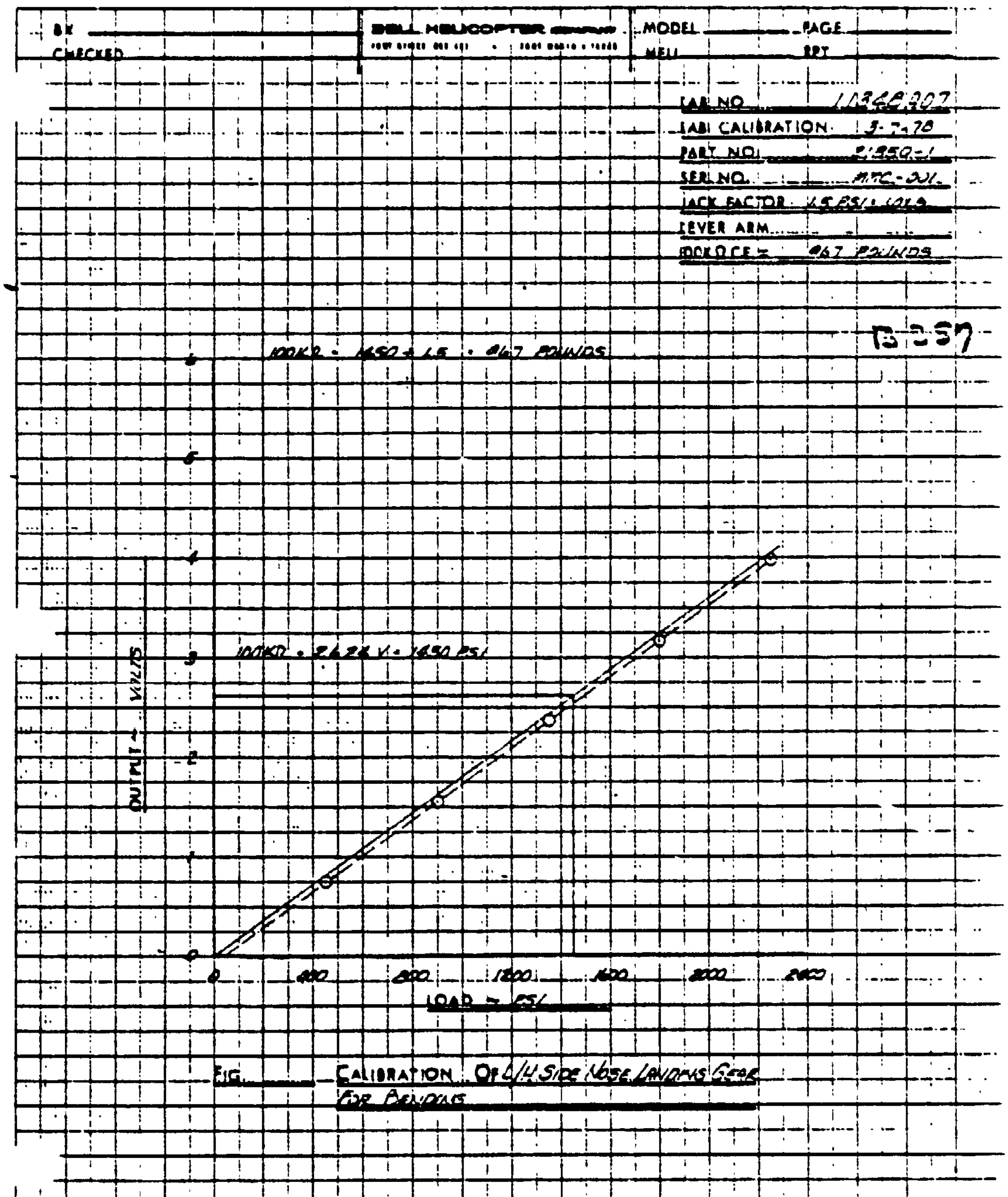


Figure 7-1. Nose gear strut bending.
(Sheet 2 of 3)

7862 57624

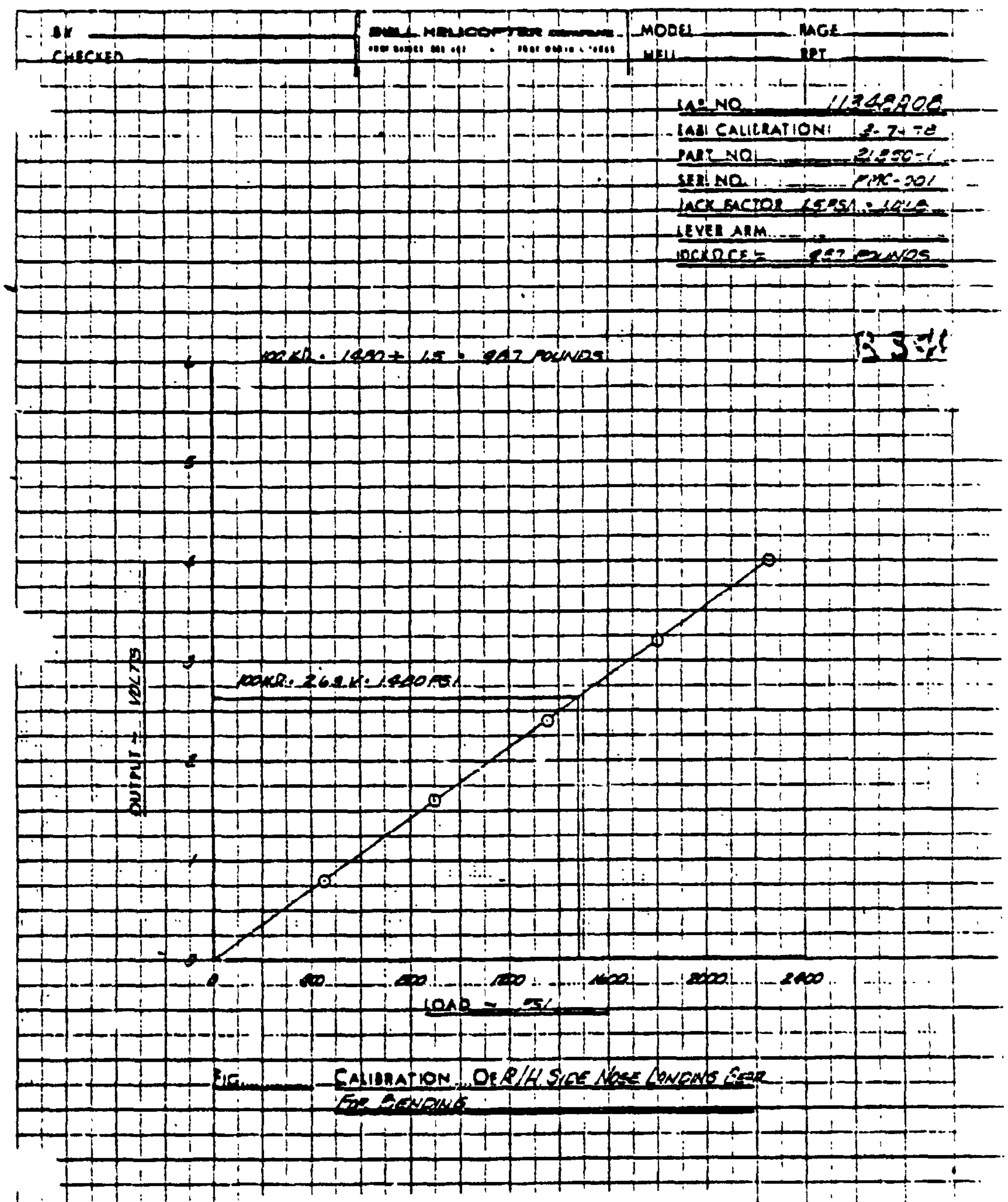


Figure 7-1. Nose gear strut bending.
(Sheet 3 of 3)

7862 57624

(1) (2) CALIBRATION SHEET
(3) LAB ENGINEER: WHITENER
DATA ANALYST: MARY LOU WRIGHT
(4) LAB TECHNICIAN: ANDERSON

(6) LAB NO. : 11349A.1
(7) CAL DATE: 1-10-73
(8) SERIAL NO: NONE
(9) P/N: NONE

(5) PROJECT: 301 FLIGHT TEST.

(10) F 547 3

(11) PART NAME: ROD END
(12) CHANNEL: 03 - POS AXIAL LOADING

****

(13) CALIBRATE EQUIVALENT: 100K = 25159 POUNDS
UNIT CAL = 28535 POUNDS/MV/V

****

(14) BRIDGE RES. : 350.00
(15) GAGE FACTOR : 2.120
(16) BRIDGE VOLT.: 6.00
(17) PRE CAL. : 5.29
(18) POST CAL. : 5.29

(19) JACK FAC. : 0.0018 PSI/LB
(20) LEVER ARM : NONE
(21) CAL RES. : 100

LOADS-STD-MV (22)	LOADS-POUNDS (23)	OUTPUT-MV (24)	VARIATION FROM MEAN LINE MILLIVOLTS (25)	VARIATION FROM MEAN LINE POUNDS (26)
0	0	0.000	-0.006	-29
0.00	0.00	0.000	0.006	29
1.85	1016.12	0.210	0.002	10
3.41	1876.64	0.380	-0.008	-40
5.62	3092.07	0.640	-0.004	-20
7.44	4094.48	0.850	-0.005	-22
9.31	5123.60	1.080	0.009	42

(27) MAXIMUM CALIBRATION LOAD: 5124 POUNDS

(28) BHC PROGRAM FCCR33 - RUN DATE: 02-03-7

****************************** END OF JOB ******************************

****************************** END OF JOB ******************************

****************************** END OF JOB ******************************

Figure 7-2. Nose gear drag strut force.
(Sheet 1 of 4)

CALIBRATION SHEET
LAB ENGINEER: WHITENER
DATA ANALYST: MARY LOU WRIGHT
LAB TECHNICIAN: ANDERSON

LAB NO.: 11349A01
CAL DATE: 1-16-79
SERIAL NO: NONE
P/N: NONE

PROJECT: 301 FLIGHT TEST

F347

PART NAME: ROD END

CHANNEL: 03 - NES AXIAL LOADING

****

CALIBRATE EQUIVALENT: 100K = 19616 POUNDS
UNIT CAL = 22259 POUNDS/MV/V

****

BRIDGE RES. : 350.00
GAGE FACTOR : 2.120
BRIDGE VOLT.: 6.00
PRE CAL. : 5.29
POST CAL. : 5.28

JACK FAC. : NONE
LEVER ARM : NONE

CAL RES. : 100

LOADS-POUNDS	LOADS-POUNDS	OUTPUT-MV	VARIATION FROM MEAN LINE MILLIVOLTS	POUNDS
0	0	0.000	0.005	10
0.00	0.00	0.000	-0.005	-10
1000.00	1000.00	0.270	0.005	22
2000.00	2000.00	0.540	-0.004	-13
3000.00	3000.00	0.820	0.007	25
4000.00	4000.00	1.050	-0.002	-9
5000.00	5000.00	1.350	-0.002	-7

MAXIMUM CALIBRATION LOAD: 5000 POUNDS

BHC PROGRAM FCC233 - RUN DATE: 02-02-7

Figure 7-2. Nose gear drag strut force.
(Sheet 2 of 4)

DEFINITIONS

1. Calibration Sheet - Identification of printout as a calibration sheet

2. Lab Engineer: Whitener - The individual responsible for the measurement data when the part is installed on aircraft

3. Data Analyst: Mary Lou Wright - The individual who checks data and puts it in the computer for calibration number

4. Lab Technician: Anderson - The individual who records data during calibration

5. Project: 301 Flight Test - Project that will use the part

6. Lab No.: 11349A01 - Number assigned to this part when it is sent to lab for gaging and calibration
   11349 - Number assigned to part
   A - Number of times the part has been calibrated (A-1st, B-2nd, C-3rd, etc.)
   01 - If there is more than one (1) gage on the part, this number identifies the gage

7. Cal. Date: 1-16-78 - The date the part was calibrated

8. Serial No.: None - This is BHT serial number for this part (if serialized)

9. P/N: None - BHT part number for this part

10. Item Code: F347 - This is item code number assigned to part/gage for data acquisition

11. Part Name: Rod End - General name for part

12. Channel: 03 - Pos Axial Loading - Channel number of the calibration data system (pos axial loading - what type load was applied)

13. Calibrate Equivalent:
    100K = 25159 Pounds - Cal step equivalent (used on XV-15)
    Unit Cal = 28536 Pounds/MV/V - Cal step equivalent (used on BHT FM system)

Figure 7-2. Nose gear drag strut force.
(Sheet 3 of 4)

Definitions (Cont'd.)

14. Bridge Res.: 350.00 - Resistance of bridge

15. Gage Factor: 2.120 - Gage factor for this set of gages taken from spec sheet with gage package

16. Bridge Volts: 6.00 - Actual voltage applied to gage during calibration

17. Pre. Cal.: 5.29 - Mv output obtained by placing a 100K resistor across the CD leg of bridge before calibration loading begins

18. Post Cal.: 5.29 - Same as Item 17 except done after completion of calibration

19. Jack Fac.: 0.0018 PSI/LB - The conversion factor from psi to lbs for the particular hydraulic cylinder use on the calibration

20. Lever Arm: None - Distance between place where load is applied and gage location

21. Cal. Res.: 100K - The precision (1%) resistor that is placed across the CD leg of the bridge to get calibration equivalent

22. Loads-Std-Mv - Standard load applied to part before jack factor correction

23. Load-Pounds - Load applied to part after jack factor correction

24. Output-MV - Output in Mv from gage

25. & 26. Variation from Mean Line - Millivolts / Pounds - These are how far off the best straight line that each of these points fall off in millivolts and pounds

27. Maximum Calibration Load: 8124 - Max load used in calibration of the part

28. BHC Program FCCR33 - Run Date: 02-03-7 - The BHT computer program number used for this calibration

Figure 7-2. Nose gear drag strut force.
(Sheet 4 of 4)

CALIBRATION DATA SHEET

Date [illegible]
Lab. No.
Serial No.
Part No.
Engineer [illegible]

Project [illegible]
Title [illegible]
W. O. 301 #2
L. T. R. EWA

Technician	Lab. Notebook No.	Instruments	Serial No.	Res.	Calve.
[illegible]					
[illegible]					

Volts	5.[illegible]
Gage Type	
Gage Fac	
Gage Res.	
Loc. No.	
Act. Arm	
Chan.	[illegible] "A" - 73-2-1
Bridge	[illegible]
Config.	
Cal. Res.	N/A
Lever Arm	

~~Load~~ Deflection (Inches)	~~Output~~ Output (Volts)
0	-615
1	-549
2	-475
3	-400
4	-329
5	-255
6	-186
7	-115
8	-045
9	+036
10	99
11	170
12	244
13	319
12	244
10	100
8	-032
6	-185
4	-330
2	-475
0	-615

[illegible] = [illegible]
[illegible] = [illegible]
Use [illegible] from [illegible]

Figure 7-3. Nose gear actuator position.
(Sheet 1 of 2)

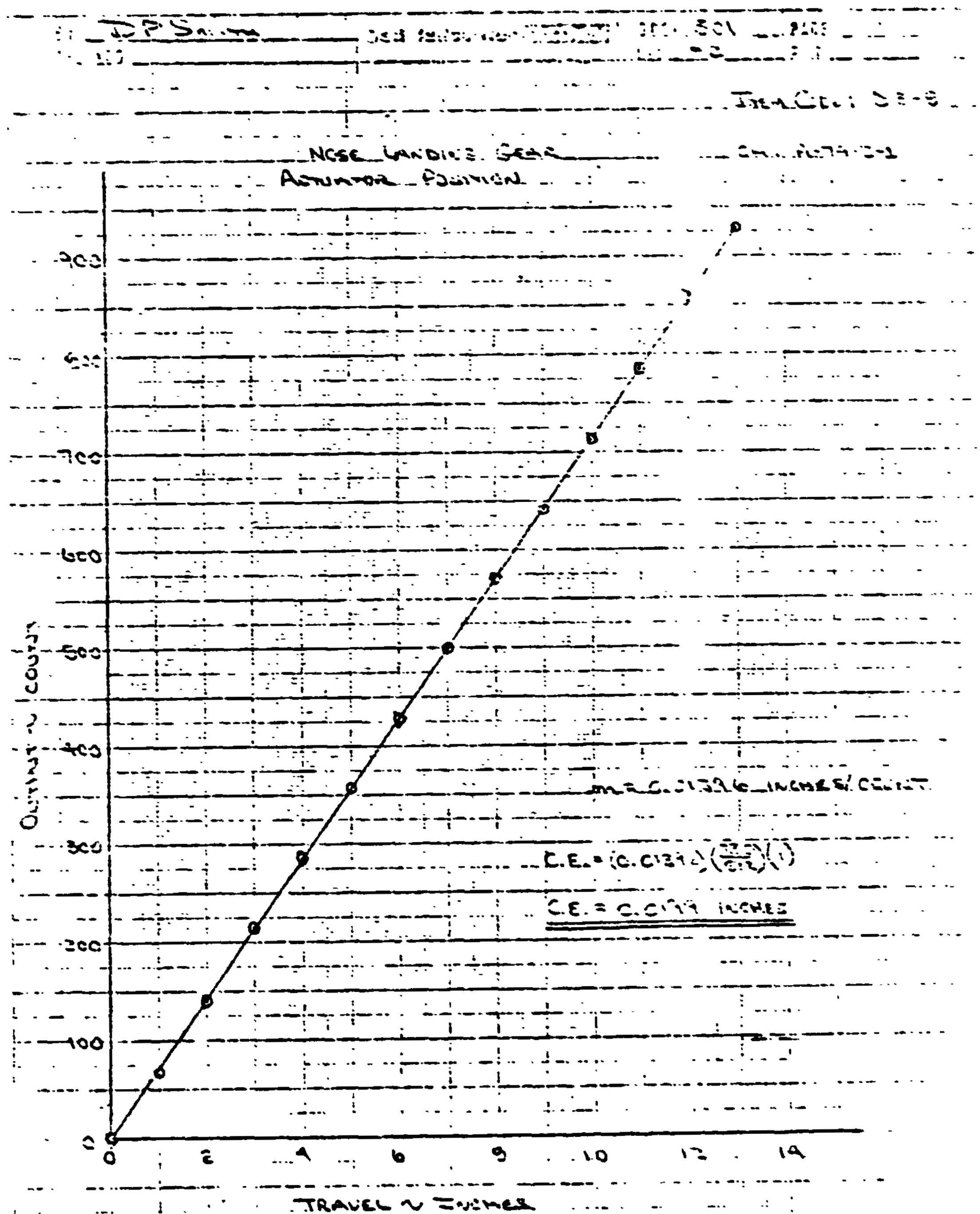


Figure 7-3. Nose gear actuator position.
(Sheet 2 of 2)

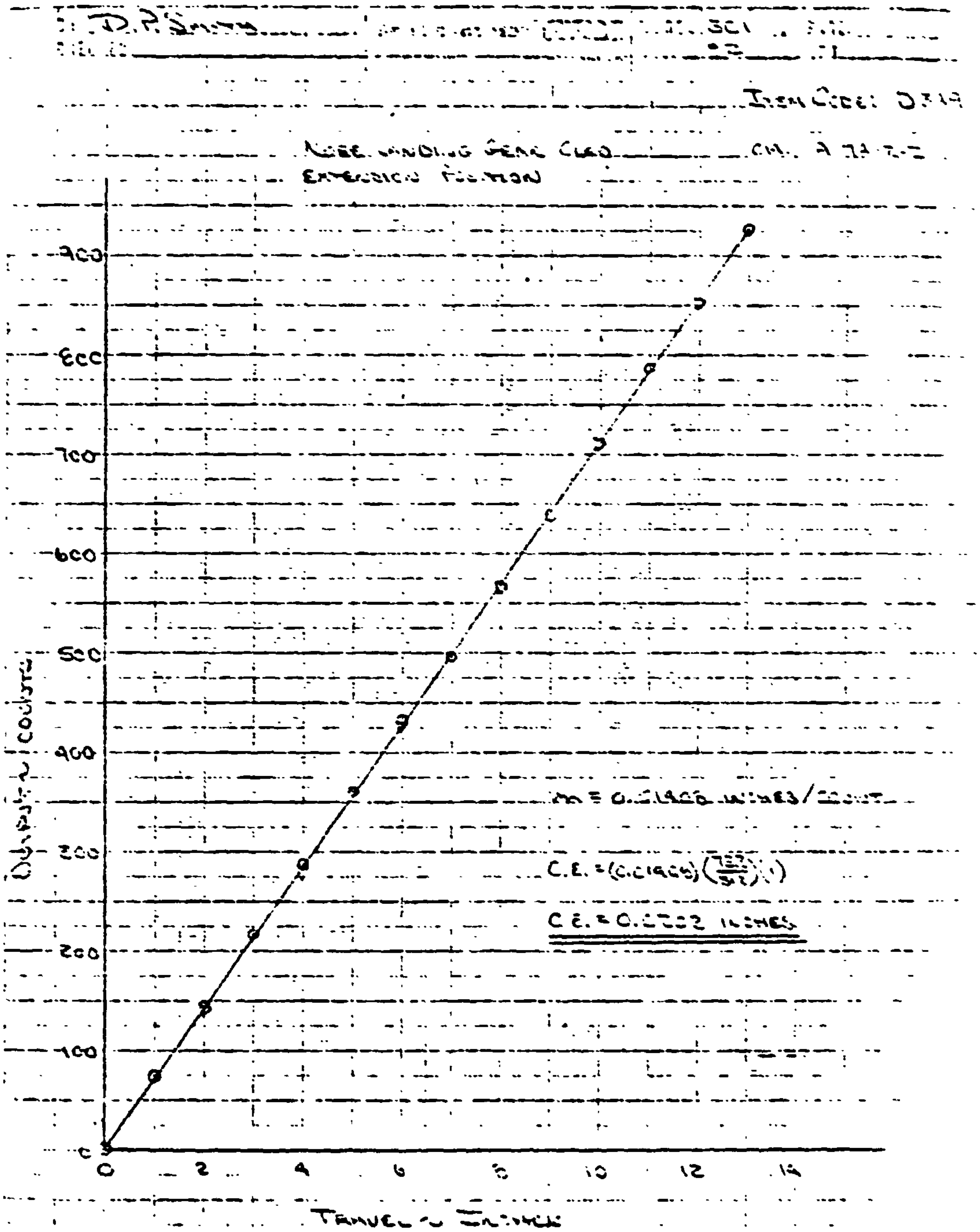


Figure 7-4. Nose gear strut extension.
(Sheet 2 of 2)

ENGINEERING LABORATORIES
Calibration Data Sheet

POOR

Description [illegible] AIR SPEED	Date Calibrated: 5-27-79
Model/Type 542K2	
Range 75 TO 350 KIAS	Calibration Period: 6 MO
Mfg. ROSEMOUNT INC.	
Serial No. 29	LCP No. [illegible]
Lab No.	Calibrated by: T. G[illegible]SKI
Remarks: O.M. BASED ON MASTER CALIBRATION 11-28-77	

O.M.	STD. KNOTS	OUTPUT VOLTS	OUTPUT VOLTS		
.979	75	+1.497	—		
.954	80	+1.599	1.611		
1.208	90	+1.798	—		
1.492	100	1.994	2.010		
1.769	110	2.192	—		
2.156	120	2.390	2.408		
2.574	130	2.587	—		
2.943	140	2.784	2.801		
3.384	150	2.982	—		
3.857	160	3.179	3.201		
4.362	170	3.376	—		
4.900	180	3.574	3.505		
5.471	190	3.772	—		
6.075	200	3.969	3.992	m = 50.5157	
6.714	210	4.166	—	b = -1.1	
7.388	220	4.365	4.395		
[illegible]	230	[illegible]	—		
[illegible]	240	4.762	4.774		
[illegible]	250	4.961	—		

781 411 Rev

Figure 7-5. Airspeed. (Sheet 1 of 2)

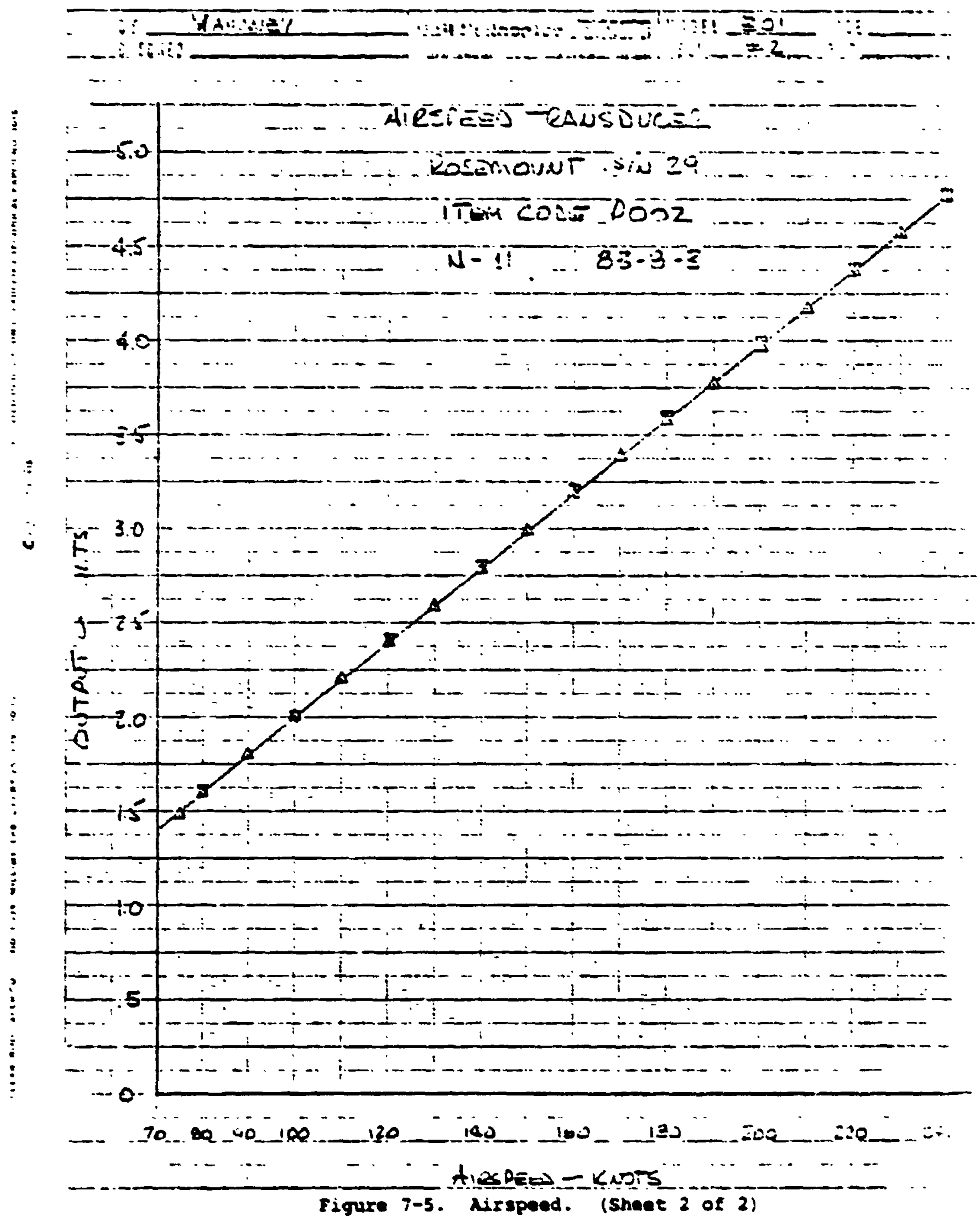


Figure 7-5. Airspeed. (Sheet 2 of 2)

ENGINEERING LABORATORIES
Calibration Data Sheet

P342

Description: [illegible]	Date Calibrated: 5-23-78
Model/Type: 542K-2	
Range: -1000 TO [illegible] FT.	Calibration Period: 6 MO
Mfg.: ROSEMOUNT INC.	
Serial No.: 29	~~ECP No.~~ [illegible]
Lab No.	Calibrated by: T. G. [illegible]
Remarks: O.M.-BASED ON [illegible] CALIBRATION [illegible]	

O.M.	STD. FT.	OUTPUT VOLTS	OUTPUT VOLTS		
93.817	0	+.199	+.200		
92.121	500	+.297	—		
90.366	1000	+.398	+.390		
88.650	1500	+.499	—		
86.986	2000	+.599	+.600		
85.364	2500	+.699	—		
83.900	3000	+.799	+.800		
82.267	3500	+.900	—		
80.776	4000	+1.000	+1.001		
79.307	4500	+1.110	—		
77.853	5000	+1.200	+1.201		
76.421	5500	+1.301	—		
74.907	6000	+1.402	+1.403	[illegible]	
69.510	8000	+1.800	—	[illegible]	
64.326	10 000	+2.197	+2.198		
[illegible]	12000	+2.[illegible]	—		
54.951	14000	+2.[illegible]	+2.[illegible]		
50.684	16000	+3.[illegible]	—		
[illegible]	18 000	+3.[illegible]	+3.[illegible]		
[illegible]	[illegible]	[illegible]	—		

Figure 7-6. Altitude. (Sheet 1 of 2)

786-411 Rev6.

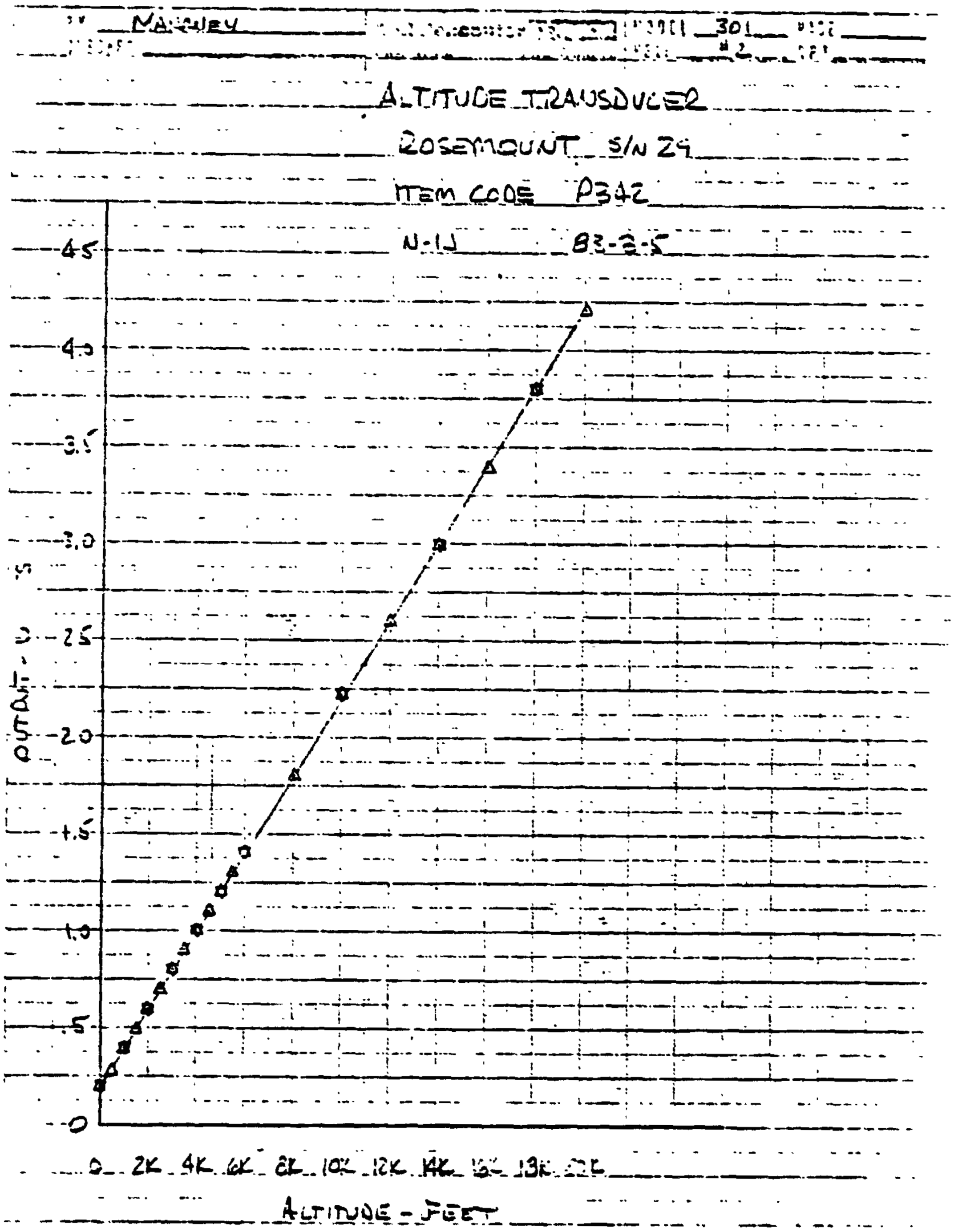


Figure 7-6. Altitude. (Sheet 2 of 2)

Use or disclosure of data on this page is subject to the restriction on the title page

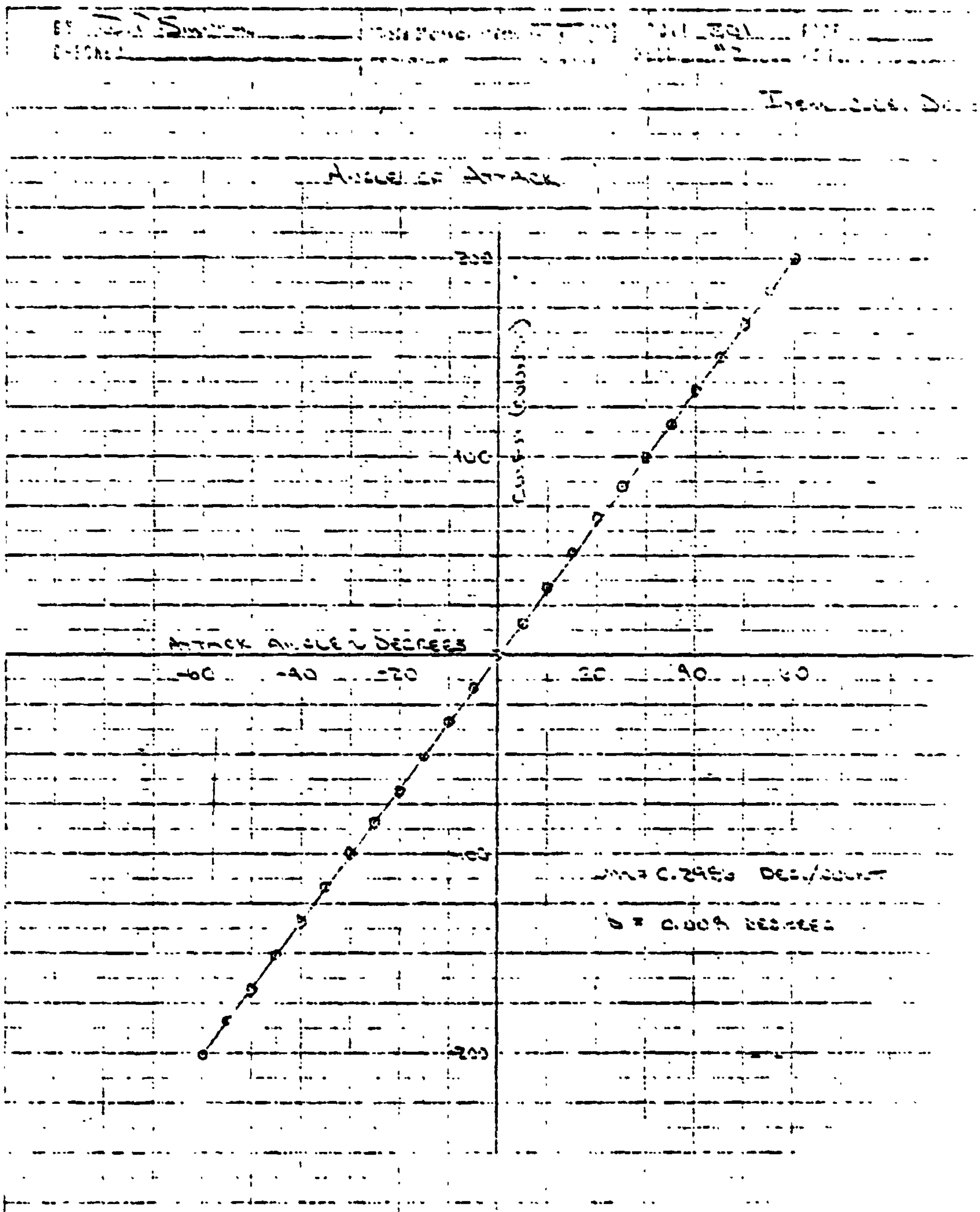


Figure 7-7. Angle of attack. (Sheet 1 of 2)

CALIBRATION DATA SHEET

Date [illegible]

Lot. No.

Serial No.

Part No.

Engineer [illegible]

Project [illegible]

Title [illegible] of Attack ([illegible])

W. O.

L. T. R.

EWA

[illegible]

Technician	Lab. Notebook No.	Instruments	Serial No.	Res.	Galvo.
[illegible]					

Volts									
Gage Type									
Gage Fac.									
Gage Res.									
Lot. No.									
Act. Arm									
Chan.	[illegible]								
Bridge	[illegible]								
Config.									
Cal. Res.	[illegible]								
Lever Arm									

~~Load~~ α Attack (Degrees)	~~Output~~ Output (Counts)		α Att. (Deg)	Counts
0	-005		-15	-56
5	11		-20	-72
10	29		-25	-89
15	47		-30	-105
20	63		-35	-122
25	[illegible]		-40	-139
30	95		-45	-156
35	111		-50	-173
40	129		-55	-189
45	145		-60	-206
50	162		-50	-173
55	[illegible]		-40	-139
60	195		-30	-105
50	162		-20	-72
40	129		-10	-39
30	95		0	-5
20	63			
10	30		GPA₀ ([illegible]) =	-7
0	-005		[illegible] (43-8.7) =	7.3
-5	-22			
-10	[illegible]			

Figure 7-7. Angle of attack. (Sheet 2 of 2)

Bell Helicopter TEXTRON
Division of Textron Inc

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CALIBRATION DATA SHEET

Date [illegible]
Lab. No.
Project [illegible]
Serial No.
301 #2 Title Angle of Sideslip [illegible]
Part No.
W. O. L. T. R. EWA
Engineer [illegible]

Technician	Lab. Notebook No.	Instruments	Serial No.	Res.	Galva.
[illegible]					

Volts									
Gage Type									
Gage Fac.									
Gage Res.									
Lot. No.									
Act. Arm									
Chan.	[illegible]								
Bridge	[illegible]								
Config.									
Cal. Res.	N/A								
Lever Arm									

~~Load~~ Angle of side slip (deg)	~~Output~~ Output (cnts)	ΔSS (deg)	Output (cnts)
0	1	-15	-51
5	16	-20	-69
10	33	-25	-85
15	50	-30	-102
20	68	-35	-119
25	84	-40	-135
30	101	-45	-152
35	119	-50	-169
40	135	-55	-187
45	152	-60	-203
50	169	-50	-169
55	184	-40	-135
60	202	-30	-101
50	169	-20	-67
40	135	-10	-35
20	101	0	1
[illegible]	50		
10	33		
0	0	CAL (62.6-?) = -6	
-5	-16	LLC (62.6-?) = 793	
-10	-33		

Figure 7-8. Angle of side slip.
(Sheet 1 of 2)

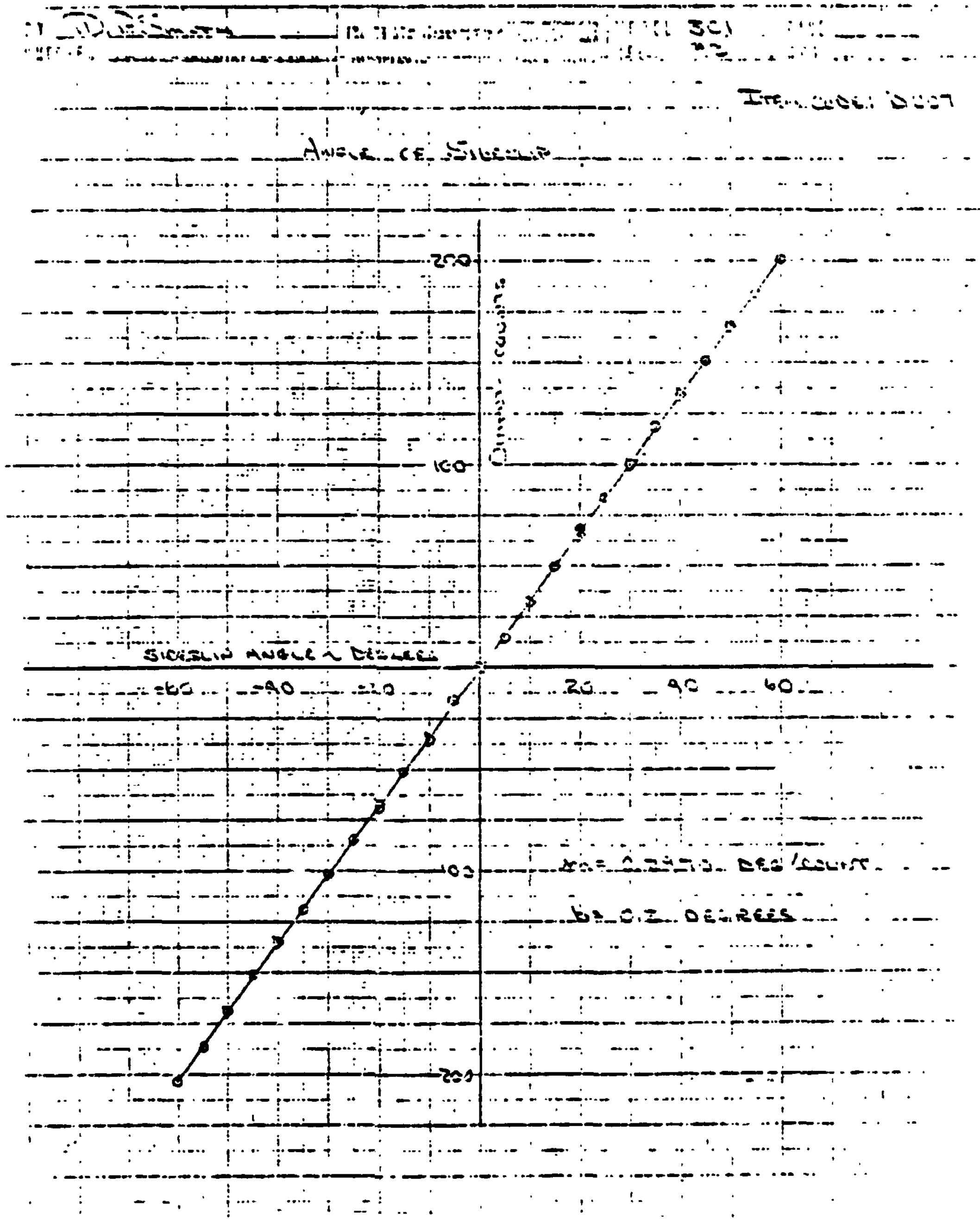

Figure 7-8. Angle of side slip.
(Sheet 2 of 2)

SECTION 8. SPECIAL CIRCUITS

This section describes the special circuits developed for the Active Network Panel (ANP). Active network circuits are installed to provide special processing for transducer signals which are not compatible with the RMDU and for other special purpose instrumentation requirements.

8.1 Active Network Panel. The active network panel is installed on the instrumentation pallet. The panel contains 23 card slots for special purpose circuits. Table 8-I identifies the special circuit cards currently in use in the active network panel.

8.2 Mean/Peak-to-Peak Detector (Card Slots 9 and 10). Card No. 301ASW220-1 is a mean/peak-to-peak detector card used to condition signals for the critical function monitors (Figures 1-8 and 1-9). The two research instrumentation chanels selected for cockpit display are blade beam bending at Station 52.5 (card slot 9) and F/A hub flapping (card slot 10). Figure 8-1 shows an electrical schematic of the mean/peak-to-peak detector card No. 301ASW220-1.

8.2.1 Signal Flow. Figure 8-2 shows the signal flow from the strain gage to the critical load meter display (blade beam bending). Figure 8-3 shows the signal flow from the transducer to the hub spring flapping indicator. The signal flows from transducer to the program board where it is patched to the correct PSF channel in the RMDU. The RMDU places the signal in the assigned location of the PCM format. A buffered output from the PSF card is brought back to the program board and patched into the assigned card slot in the active network panel.

8.2.2 Mean/Peak-to-Peak Card Setup. Card No. 301ASW220-1 contains a MEAN/P-P switch, zero, and gain adjustments located as shown on Figure 8-4. The mean detector circuit contains zero and gain adjustments. The peak-to-peak detection circuit is a simple rectifier circuit with a gain adjustment only. These gain adjustments allow various signal input levels to the conditioned for compatibility with the 0-100 micro-amp meter used as the display.

8.3 Digital Stick Position (Card No. 11). The digital stick position control card located in card slot 11 of the active network panel contains all the circuitry to drive the control position indicator display (Figure 1-12) as well as gain and balance adjustments to set up the zero and 100 percent positions for each control. Adjustment potentiometer locations are shown on Figure 8-5 for each of the four control position displays.

A schematic wiring diagram of the digital stick position control card (card No. 11) is shown on BHT drawing SKHD3-20-78-3 (Figure

8-6). The drawing also shows the card electrical interface with the active network panel. Interface between the active network panel and control position indicator and position potentiometers is through plug "E" on the instrumentation pallet (see Figure 8-7).

8.4 Temperature Scan Control (Card No. 12). The temperature scan control card contains the circuitry to produce a serial code which controls the three remote temperature scanner units. During normal operation this serial code directs a given temperature scanner to read one of thirty thermocouple signals manually selected by a crew member at the temperature monitor (Figure 1-10). When the prime data is selected the scan mode of operation is automatically initiated and is terminated when prime data is turned off or at the end of one complete scan cycle (thirty thermocouples). The control card also monitors the temperature reference junctions, checks for the presence of a readable serial code, checks for proper power supply operation, and generates a fault signal if a system malfunction is detected.

A schematic wiring diagram for the temperature scanning system control card is shown in BHT drawing SKHD3-20-78-2 (Figure 8-8). The drawing also shows control card interface with the active network panel. Interface between the active network panel and the temperature monitor and remote switching units is through plug "E" on the instrumentation pallet (see Figure 8-7). Location of adjustment controls and test points is shown on Figure 8-9. Setup procedures for the temperature scanning system are covered in Section 9.

8.5 Temperature Scanner ADC (Card No. 13). The temperature scanner analog-to-digital converter card contains the circuitry to convert the conditioned analog temperature signal to digital format for the temperature monitor cockpit display. The circuit card is illustrated in Figure 8-10. An electrical schematic for the card is shown on BHT drawing SKHD3-20-78-2 (Figure 8-8). The card is installed in card slot No. 13 of the ANP. Interface between the ANP and temperature monitor is through plug "E" on the instrumentation pallet (see Figure 8-7).

8.6 Rotor Azimuth Circuit Card. The rotor azimuth circuit card P/N A14117-D42 is a GFE circuit card installed in ANP card slots 14 and 15. This circuit contains a buffer amplifier which provides isolation for the rotor azimuth encoder circuitry.

8.7 Temperature Scanner (Card No. 16). Temperature scanner card No. 16 provides signal conditioning for the temperature display. A schematic wiring diagram for circuit card No. 16 is shown on BHT drawing SKHD3-20-78-2 (Figure 8-8). The drawing also shows card interface with the active network panel. Location of controls and adjustments is shown on Figure 8-11.

8.8 Data Control Word (Card No. 17). A twelve-bit data control word is generated by card No. 17 in the active network panel. The control word is located in the PCM bit stream directly after the subframe ID counter and contains information used both in data reduction and prflight checkout. Bits one through six are used to drive computer interrupts in the data reduction process. Bits seven through twelve can be monitored either during flight or preflight checkout in order to control system faults.

8.8.1 Wiring Diagram. A schematic wiring diagram of the data control word card No. 17 is shown in BHT drawing SKHD3-20-78-1 (Figure 8-12). This drawing also shows the electrical interface between the card and the active network panel. Figure 8-13 shows the location of test points and adjustment potentiometers.

8.8.2 Data Control Word Bit Designation. The data control word bit designation is shown in Figure 8-14. The following list describes the function of each bit of the control word.

BIT #1 (R/H AZIMUTH) - This bit goes high for at least one mainframe each time the R/H red blade passes the 0 degree position (red blade aft). The bit may stay high for more than one mainframe.

BIT #2 (L/H AZIMUTH) - This bit goes high for at least one mainframe each time the L/H red blade passes the 0 degree position (red blade aft). The bit may stay high for more than one mainframe.

BIT #3 (FAULT LIGHT) - This bit goes high whenever the fault light on the instrumentation control panel comes on and stays on until the copilot resets the fault light by pressing the reset button on the control panel. The fault light is turned on by either a bridge voltage error, a loss of either rotor azimuth, the loss of either PCM bit stream or a fault detected by the tape deck internal fault logic.

BIT #4 (R-CAL) - This bit goes high one quarter second after the R-CAL button is pushed and goes low immediately when the button is released. The one quarter second delay is to allow the data to settle before signalling the computer to read the R-Cal values.

BIT #5 (PRIME DATA) - This bit is high during prime data and low during non-prime data.

BIT #6 (DATA) - This bit is low during prime data and high during non-prime data.

BIT #7 (TAPE LOW) - This bit goes high when the tape low light on the instrumentation control panel comes on. This occurs approximately five minutes before the end of the tape.

BIT #8 (NO TAPE MOTION) - This bit goes high when the tape deck is stopped.

BIT #9 (EXCITATION FAULT) - This bit goes high when the bridge voltage goes lower than 5.7v or higher than 6.3v at the power supply. A fault detected by this circuit will also turn on the fault light and the fault bit (#3). The excitation fault bit goes low when the fault is cleared. It does not stay high until the fault light is reset.

BIT #10 (IDENTIFICATION BIT) - This bit is low for RMDU "A" and high for RMDU "B."

BIT #11 (AZIMUTH FAULT) - This bit goes high when either azimuth circuit goes more than one second without producing an azimuth pulse. A fault detected by this circuit will normally turn on the fault light and the fault bit (#3), but a switch is provided on card No. 17 of the active network panel to disable this link for ground checkout and ground run, where data is often taken without the rotors turning. This bit is only high when a fault exists; it does not stay high until the fault light is reset.

BIT #12 (TAPE DECK FAULT) - This bit goes high when the tape fault logic in the Astro Science tape deck signals a fault. A tape deck fault also turns on the fault light and the fault bit (#3). This bit is high only when a tape fault is signaled.

8.9 Stepper Position Interface (Card No. 18). The stepper position interface card, P/N A14117-C24, is a GFE card which provides signal distribution for the scannivalve encoder function. Figure 8-15 shows the location of test points provided on the stepper position interface card.

8.10 Fuel Quantity Jumper (Card No. 19 and 20). The fuel quantity jumper cards (P/N 301ASW19 and 301ASW20) provide signal distribution for the left and right fuel quantity measurement channels. These cards are installed in ANP card slots 19 and 20. Figure 8-16 shows the location of test points provided on the fuel quantity jumper card.

8.11 Record Number Jumper (Card No. 21 and 22). The record number jumper cards (P/N 301ASW21 and 301ASW22) provide signal distribution for the record number function. These circuit cards are installed in ANP card slots 21 and 22. Figure 8-17 shows the location of test points provided on the record number jumper card.

8.12 Tape Speed Control (Card No. 23). The tape speed control card (P/N A14117-D17) is a GFE circuit card installed in ANP card slot No. 23. This card provides the tape transport speed control function. Figure 8-18 shows location of adjustments, controls, and indicator lights provided on this circuit card.

TABLE 8-I. ACTIVE NETWORK PANEL

Card Slot	Active Network	Circuit Card Part No.	Reference Drawing
1	(Open)		
2	(Open)		
3	(Open)		
4	(Open)		
5	(Open)		
6	(Open)		
7	(Open)		
8	(Open)		
9	Mean/Peak-to-Peak Detector (Blade Beam)	301ASW220-1	See Fig. 8-2
10	Mean/Peak-to-Peak Detector (Hub Flapping)	301ASW220-1	See Fig. 8-3
11	Digital Stick Position Card	SKHD3-20-78-3	See Fig. 8-6
12	Temperature Scanner Control Card	SKHD3-20-78-2	See Fig. 8-8
13	Temperature Scanner ADC Card	SKHD3-20-78-2	See Fig. 8-8
14	Left Rotor Azimuth (GFE)	A14117-D41	A14117-D42
15	Right Rotor Azimuth (GFE)	A14117-D41	A14117-D42
16	Temperature Scanner Card	SKHD3-20-78-2	See Fig. 8-8
17	Data Control Word Card	SKHD3-20-78-1	See Fig. 8-12
18	Stepper Position Interface (Scannivalve Encoder)	A14117-C24.1	A14117-C24.1 A14117-C24.2 A14117-C24.3
19	Fuel Quantity Jumper Card - RT Fuel	301ASW-19	A14117-C23.1
20	Fuel Quantity Jumper Card - LT Fuel	301ASW-20	A14117-C23.2
21	Record Number Jumper Card	301ASW-21	A14117-C22.1
22	Record Number Jumper Card	301ASW-22	A14117-C22.1
23	Tape Speed Control Card (GFE)	A14117-D17	

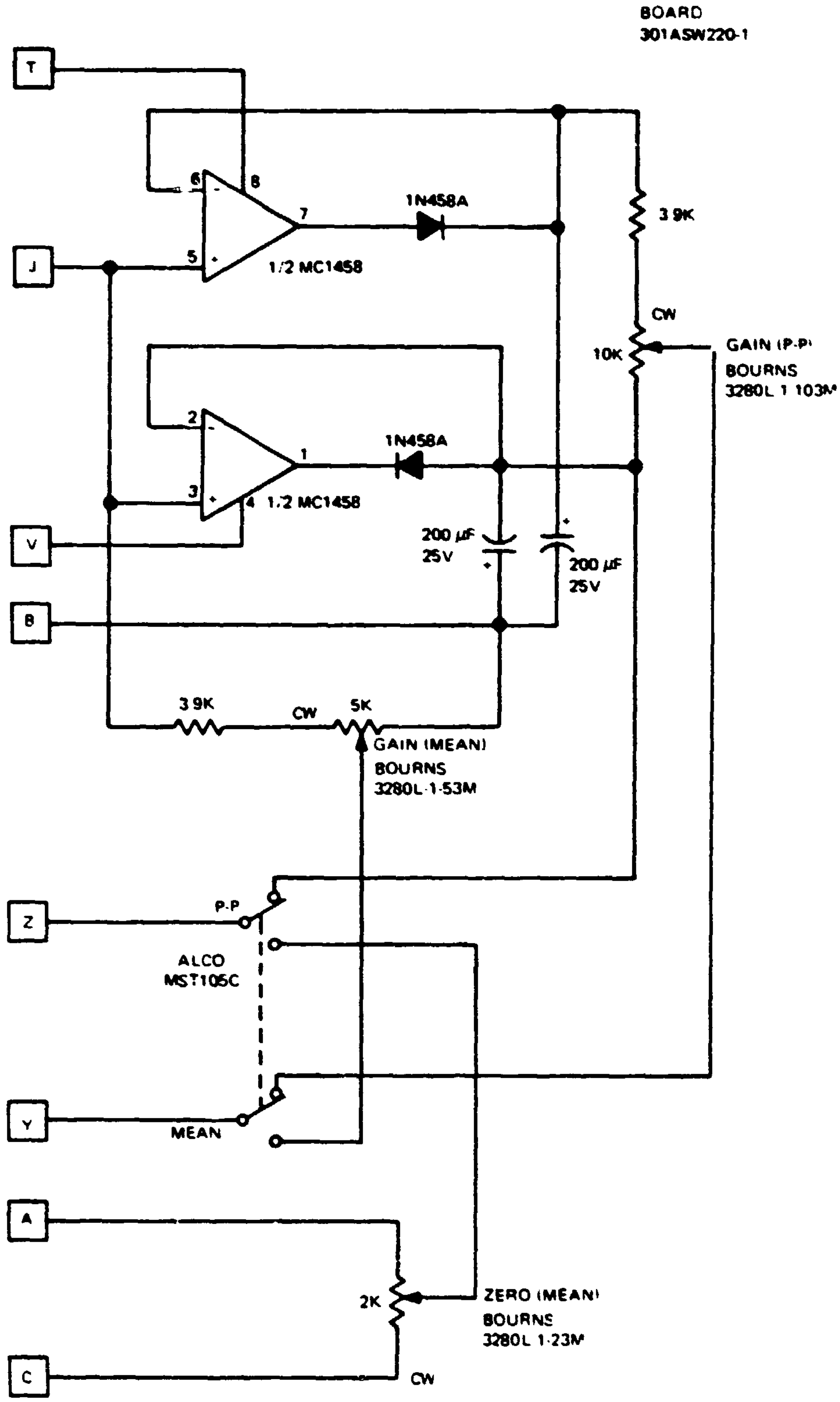

Figure 8-1. Mean/peak-to-peak detector card
(ANP card slots 9 and 10)

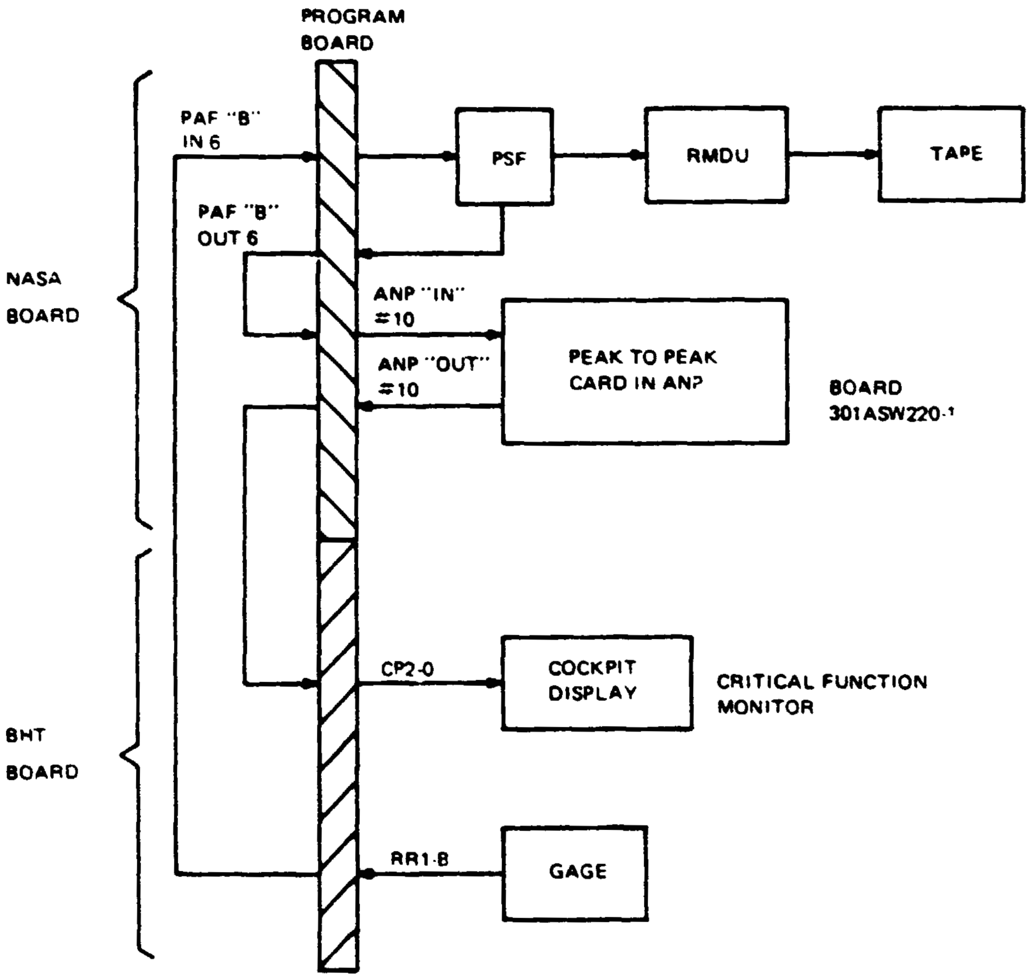

Figure 8-2. Flow diagram for critical load meter display (RT (red) rotor blade beam bend Sta 52.5)

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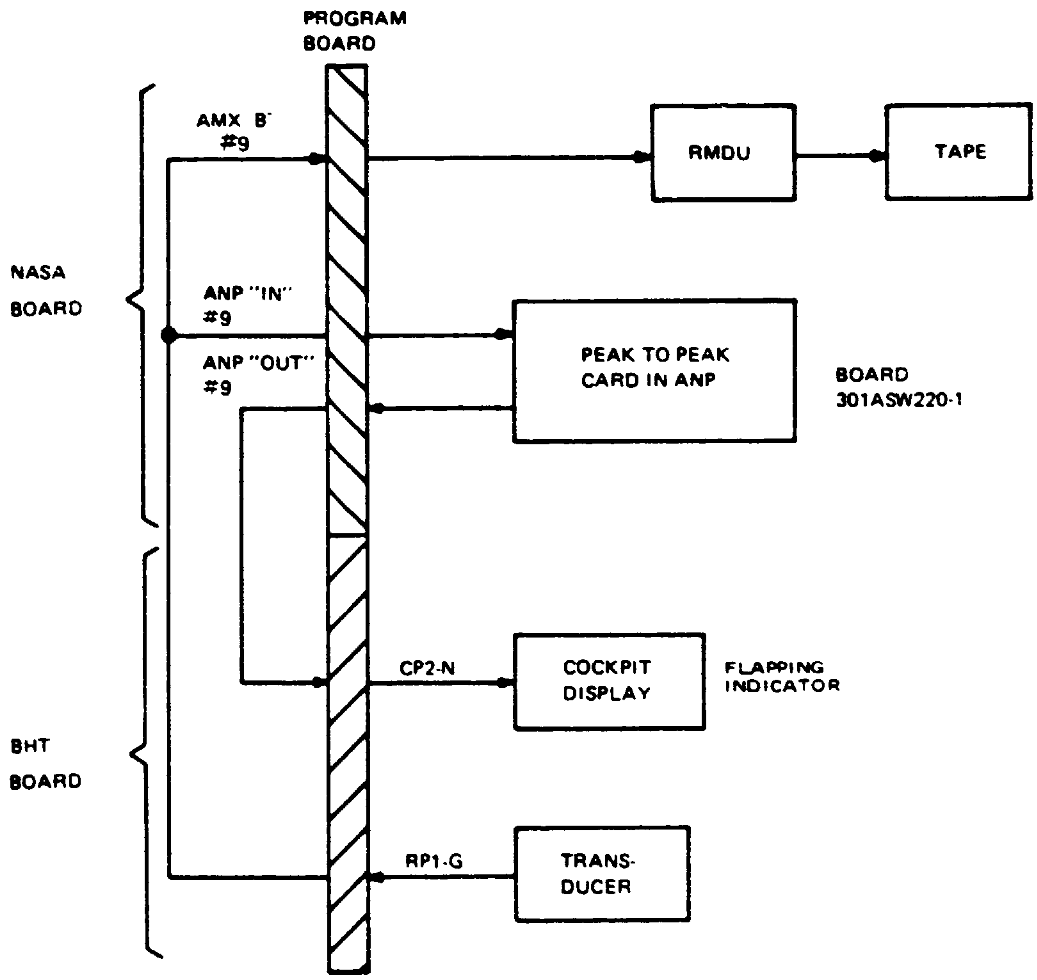


Figure 8-3. Flow diagram for hub spring flapping indicator

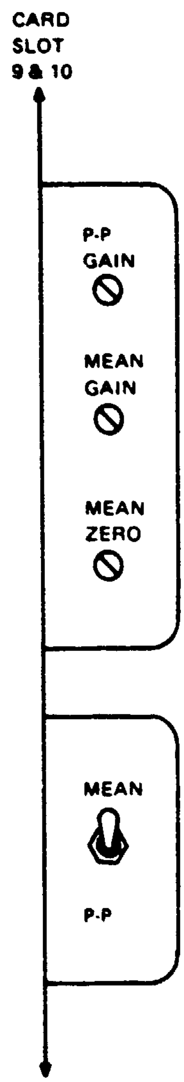


Figure 8-4. Mean/peak-to-peak detector card controls and adjustments

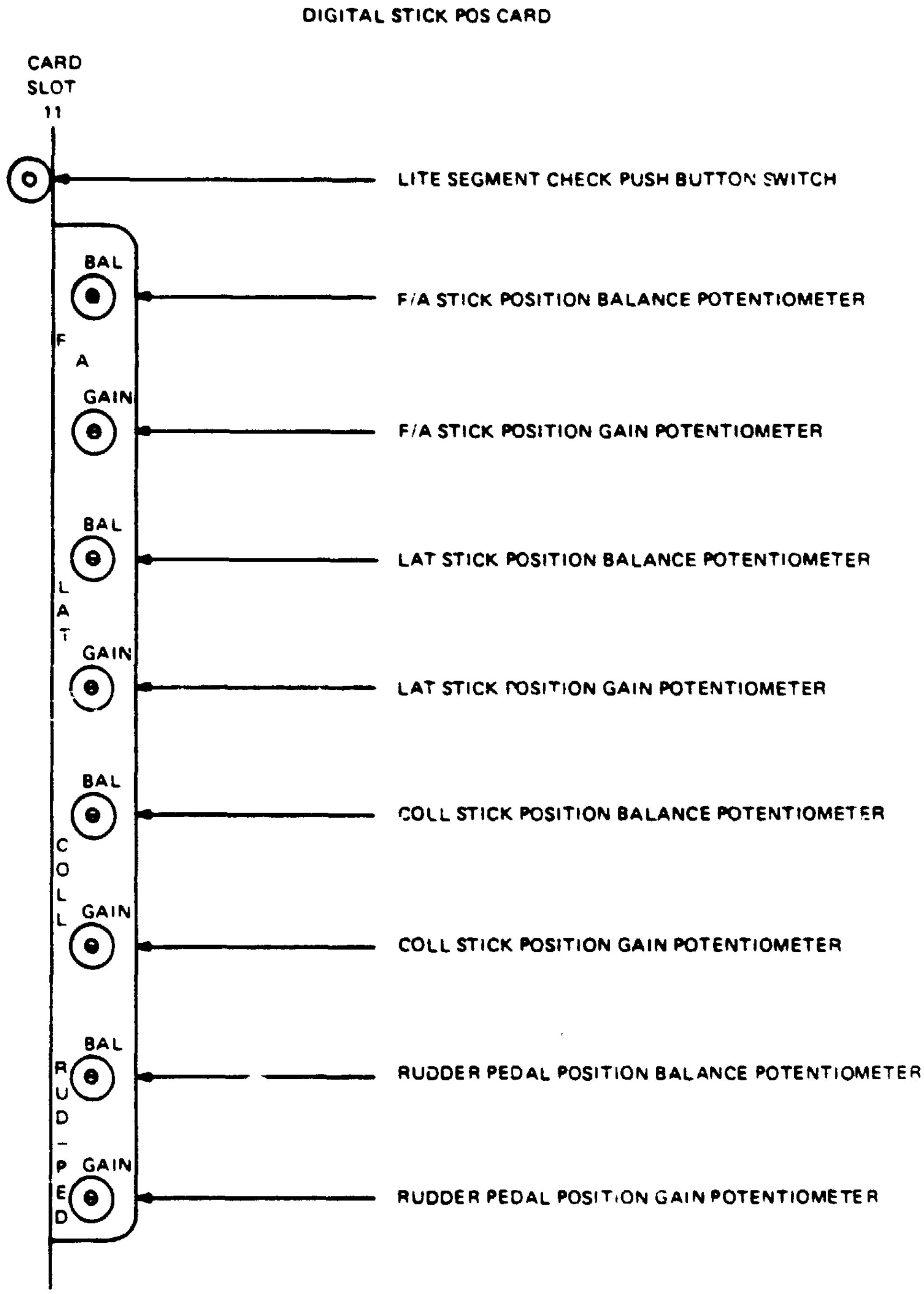


Figure 8-5. Digital stick position card
(ANP card slot 11)

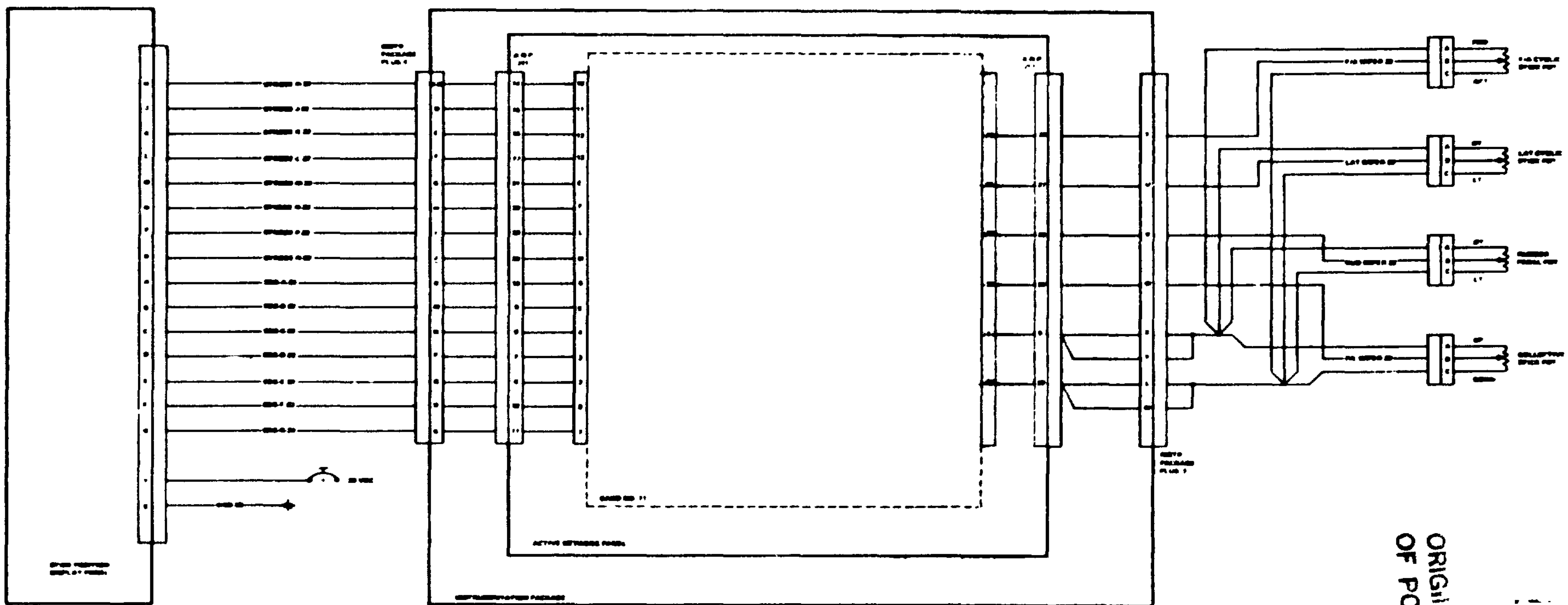
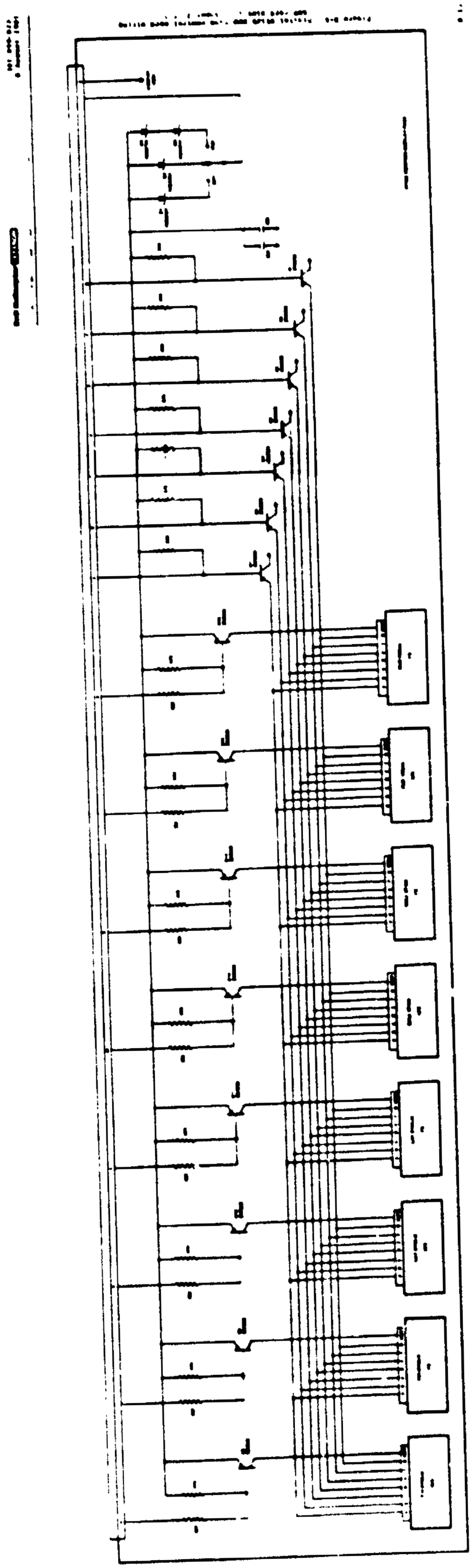


Figure 8-8. Digital stick position control card wiring
(ANP card slot 11) (Sheet 1 of 3)



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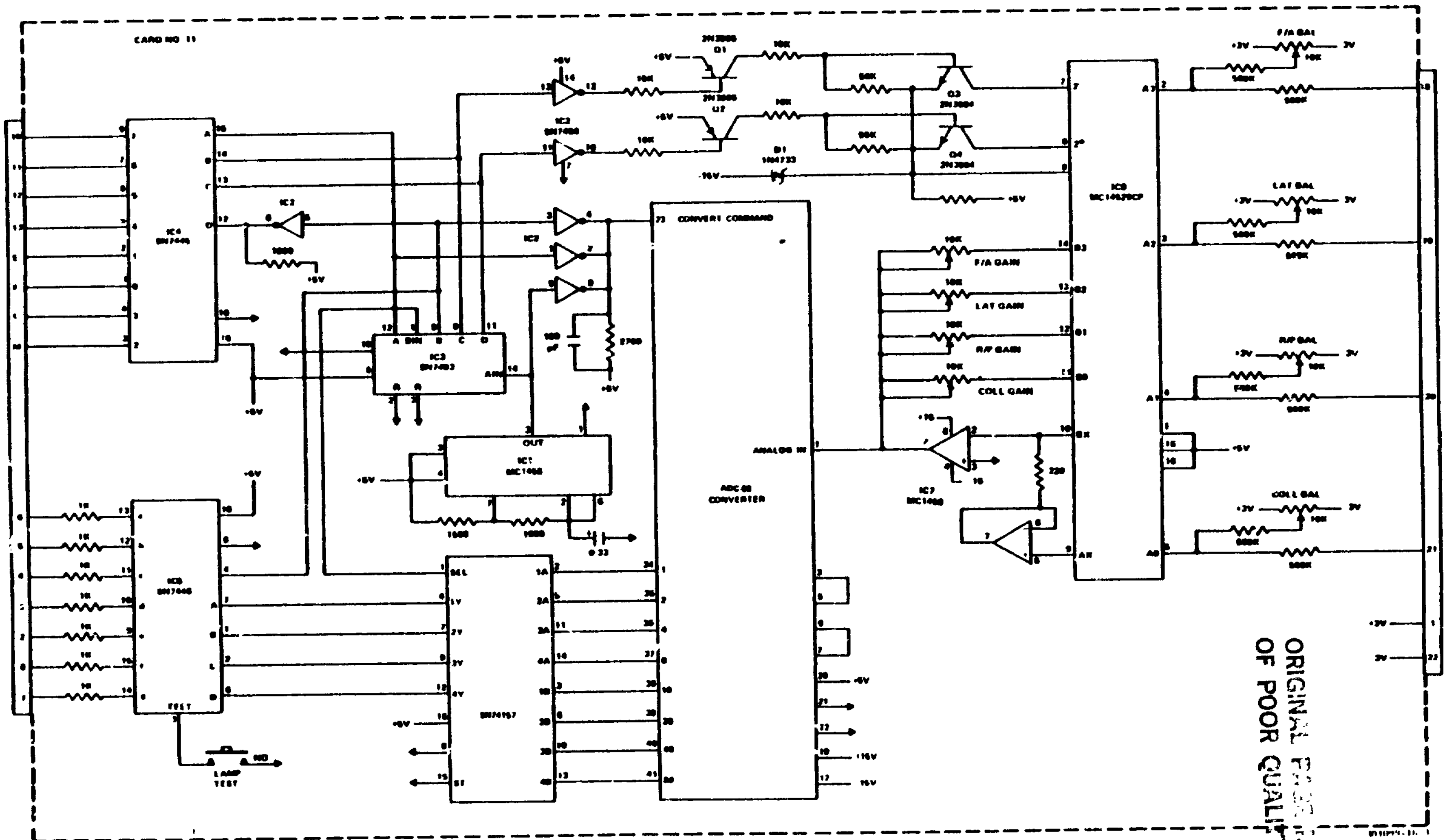

Figure 8-6. Digital stick position control card wiring
(ANP card slot 11) (Sheet 3 of 3)

Pin	Signal	Group
A	CHAN SEL "1"	
B	CHAN SEL "2"	
C	CHAN SEL "4"	
D	CHAN SEL "8"	
E	CHAN SEL "10"	TEMP SCAN
F	CHAN SEL "20"	
G	NOT READY LIGHT	
H	SER COMP LIGHT	
J	L/W FAULT SIG	
K	C/W FAULT SIG	
L, M	(-) EXCITATION	STICK POS
N	C/F SELECT	
P	R/W SELECT	
R	1000's STROBE	
S	100's STROBE	
T	10's STROBE	
U	1's STROBE	
V	SEGMENT "a"	TEMP SCAN
W	SEGMENT "b"	
X	SEGMENT "c"	
Y	SEGMENT "d"	
Z	SEGMENT "e"	
A	SEGMENT "f"	
B, C	+28Vdc	
D	F/A CYCLIC 1's	
E	LAT CYCLIC 10's	
F	LAT CYCLIC 1's	
G	RUD PED 10's	
H	RUD PED 1's	
I	POWER LEVER 10's	
J	POWER LEVER 1's	
K	SEGMENT "a"	
M	SEGMENT "b"	
N	SEGMENT "c"	STICK POS
P	SEGMENT "d"	
Q	SEGMENT "e"	
R	SEGMENT "f"	
S	SEGMENT "g"	
T	F/A CYCLIC POT WIPER	
U	LAT CYCLIC POT WIPER	
V	RUD PED POT WIPER	
W	POWER LEVER POT WIPER	
X, Y	(+) EXCITATION	
Z	+28Vdc	
AA	+28Vdc	
BB	+28Vdc	
CC	+28Vdc	
DD	R/W FAULT SIG	
EE	SPARE	TEMP SCAN
FF	L/W SELECT	
GG	SPARE	
HH	SEGMENT "g"	
JJ	SPARE	
KK	F/A CYCLIC 10's	
LL	SPARE	STICK POS
MM	COMMON	
NN	COMMON	TEMP SCAN
PP	SHIELD FOR COMMON	

Figure 8-7. Instrumentation pallet plug "E"

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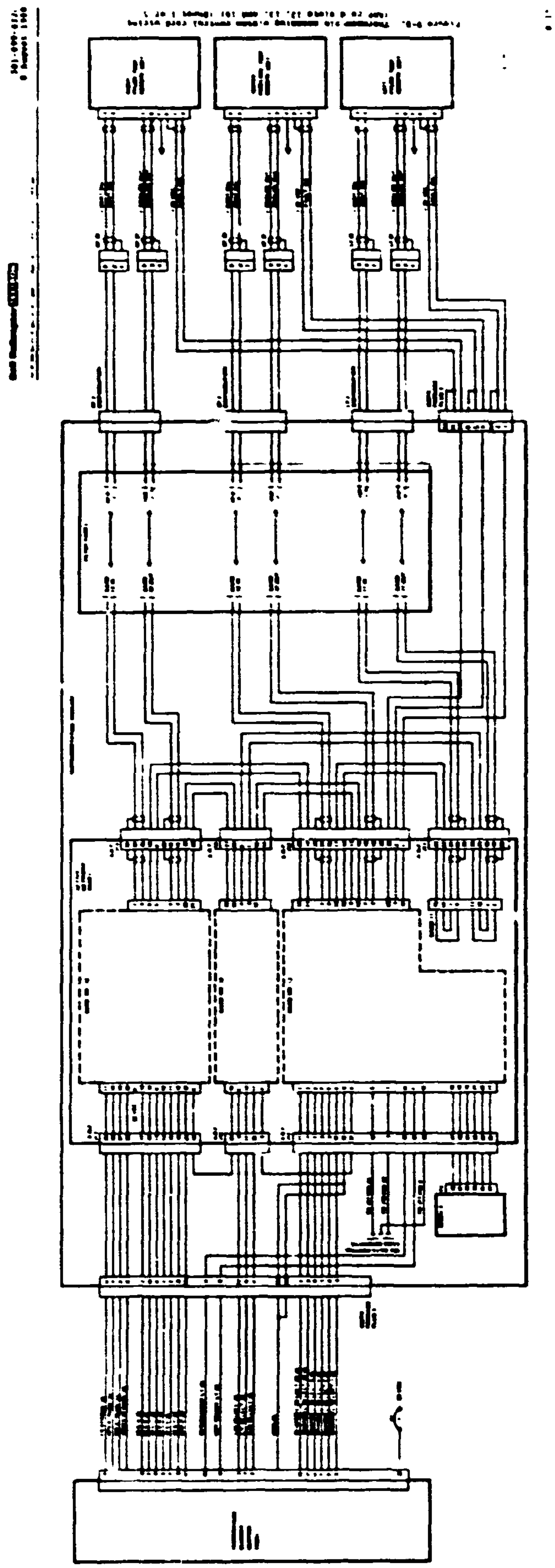

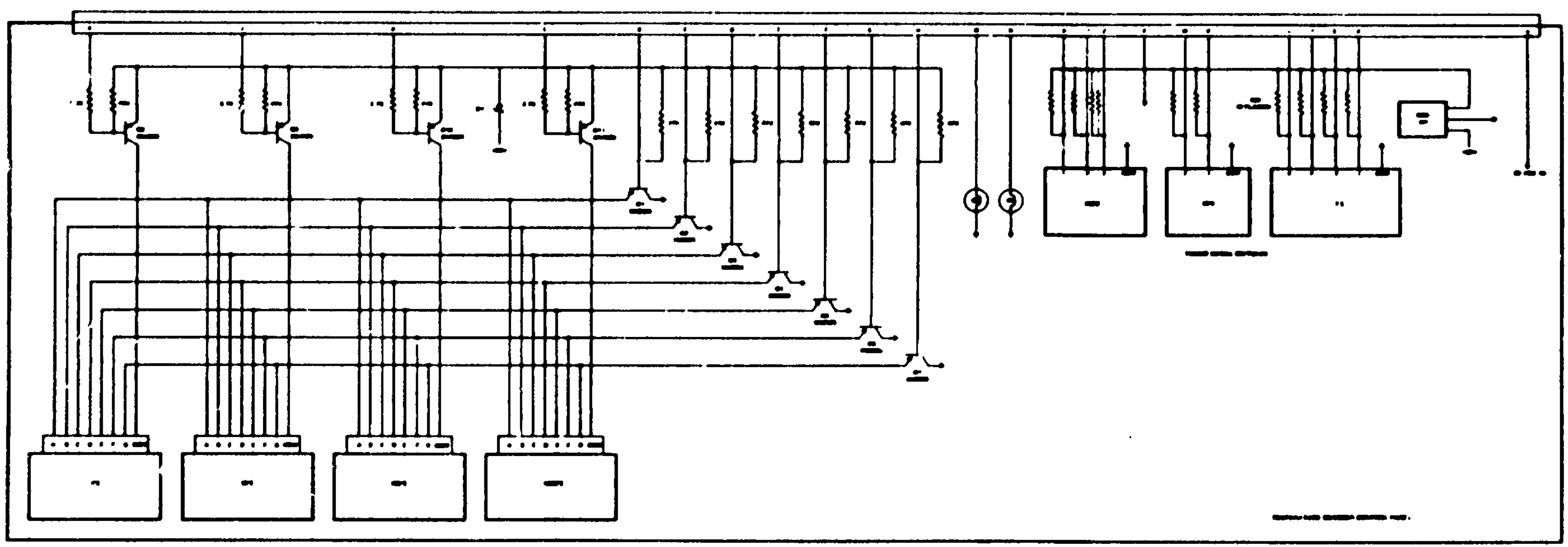

Figure 8-8. Thermocouple scanning system control card wiring (A&T card slots 12, 13, and 10) (Sheet 2 of 3)

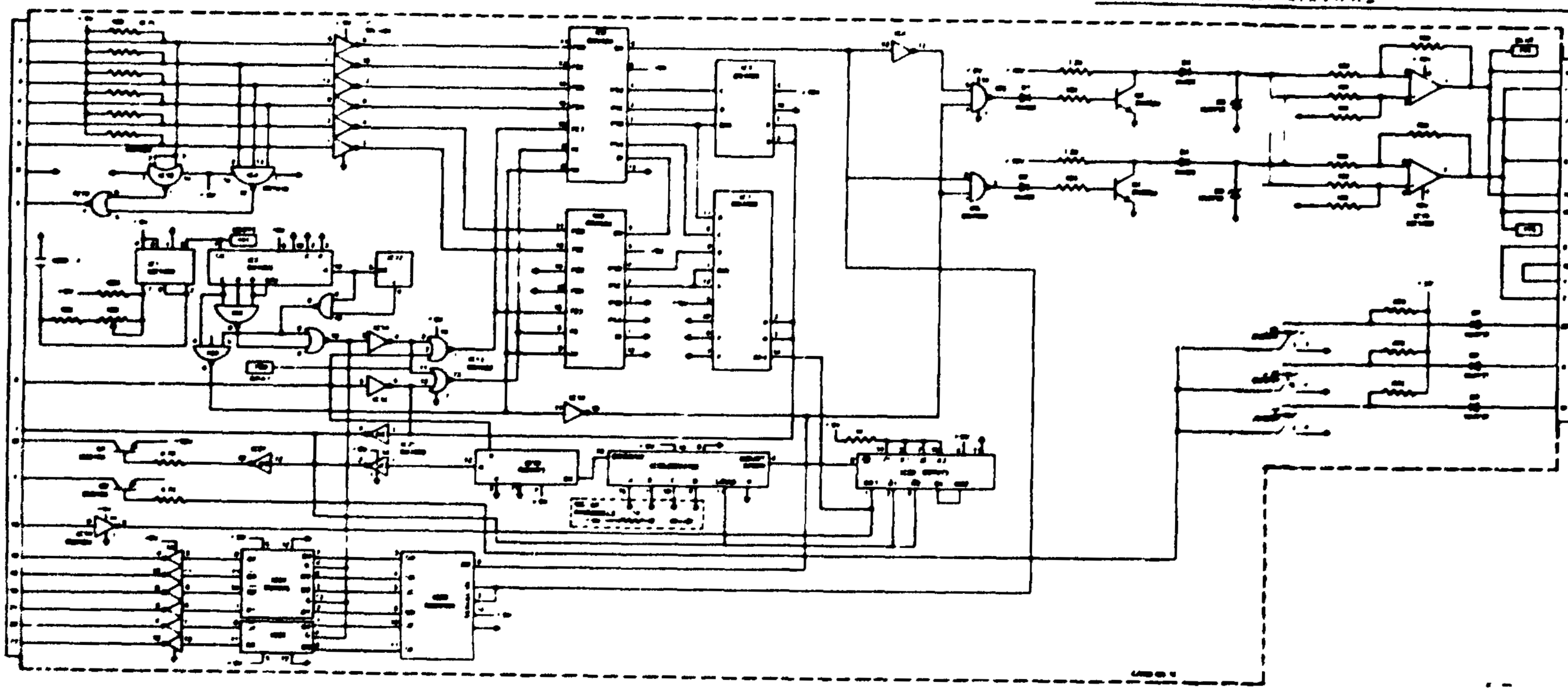

Figure 8-8. Thermocouple scanning system control card wiring (A&M and slots 12, 11, and 18) (Sheet 3 of 3)

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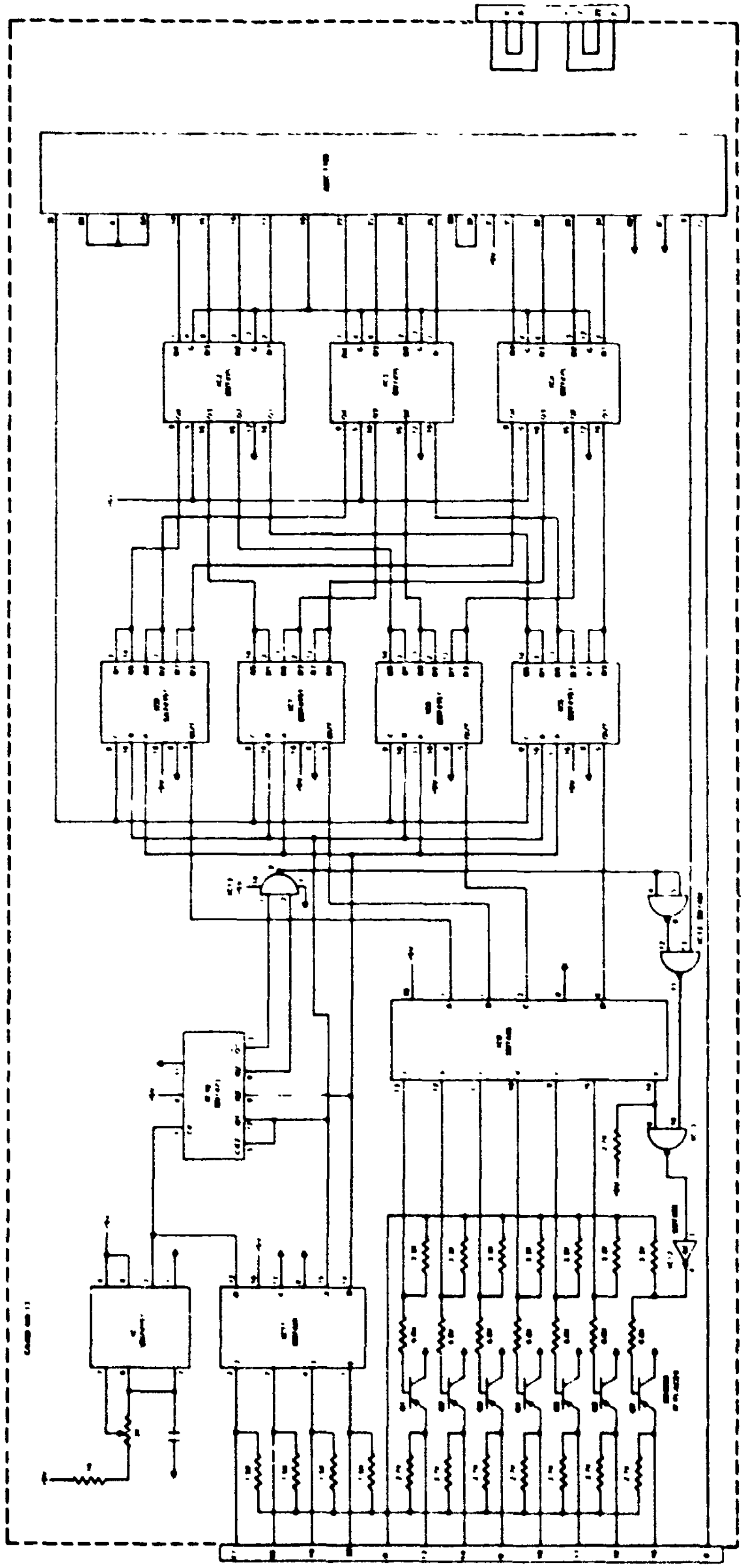

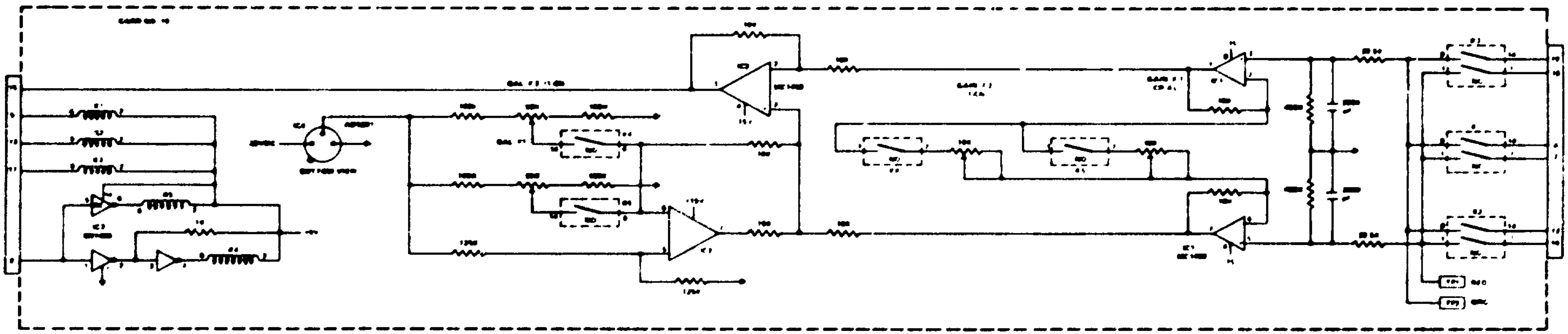

Figure 8-8. Thermocouple scanning system control card wiring
(ANP [illegible] 12, 13, and 14) [illegible]

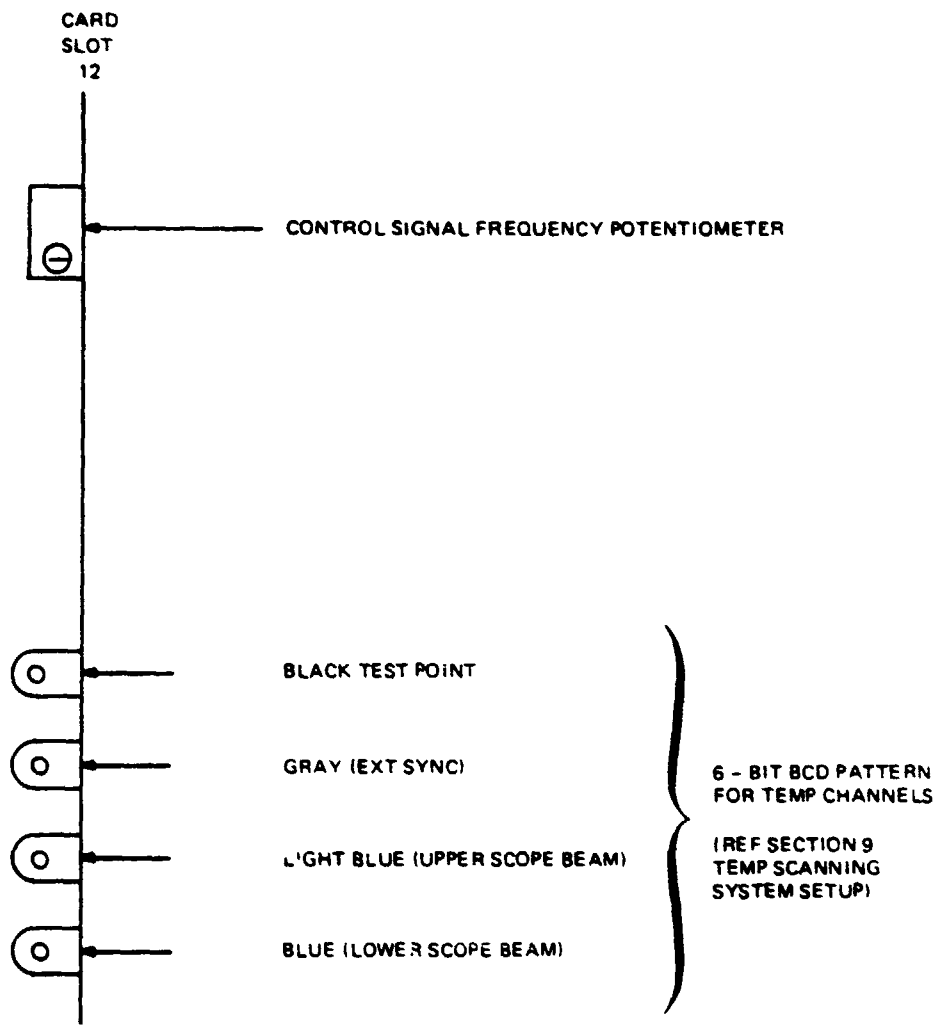

Figure 8-9. Temperature scanner control card
(ANP card slot 12)

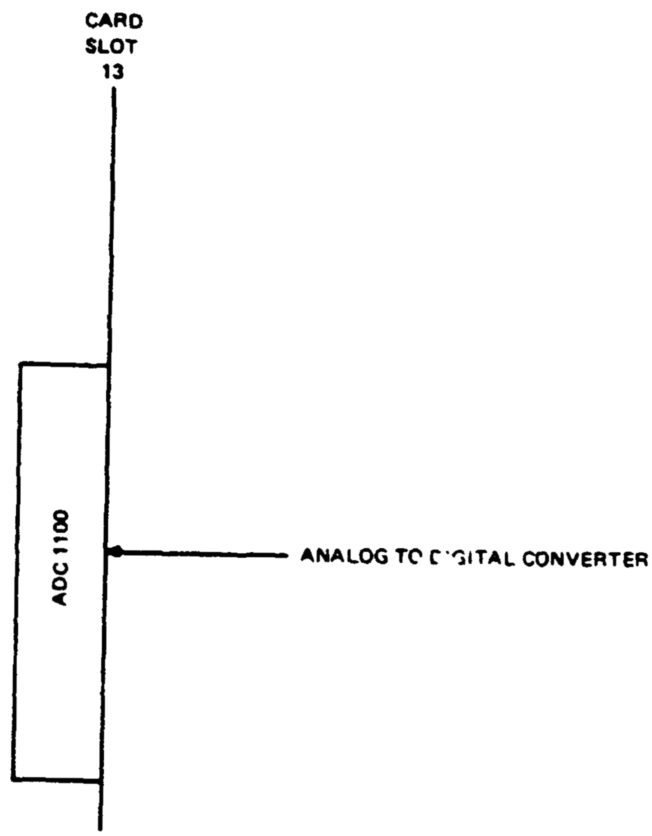

Figure 8-10. Temperature scanner ADC
(ANP card slot 13)

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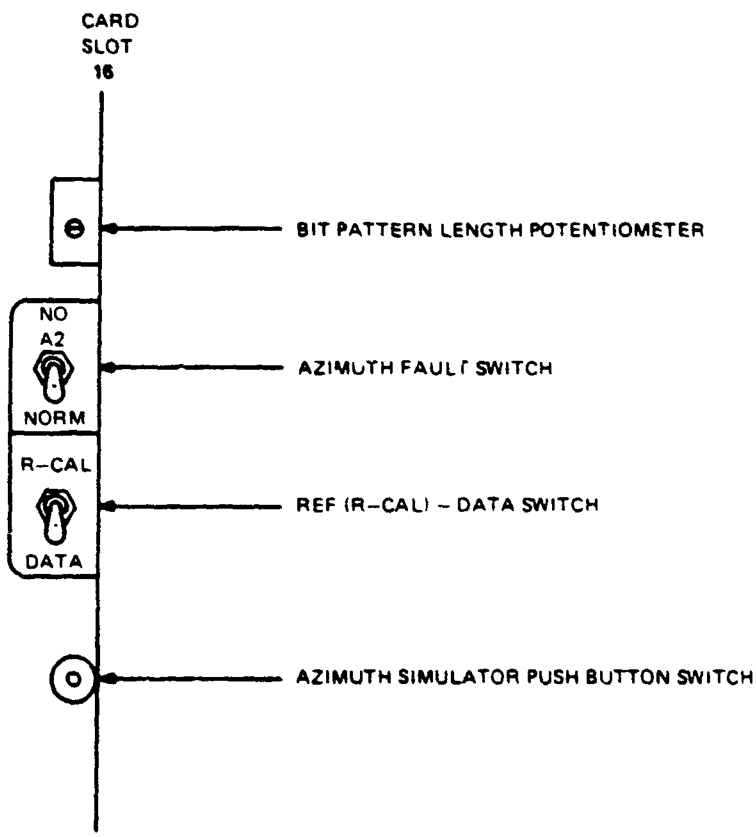
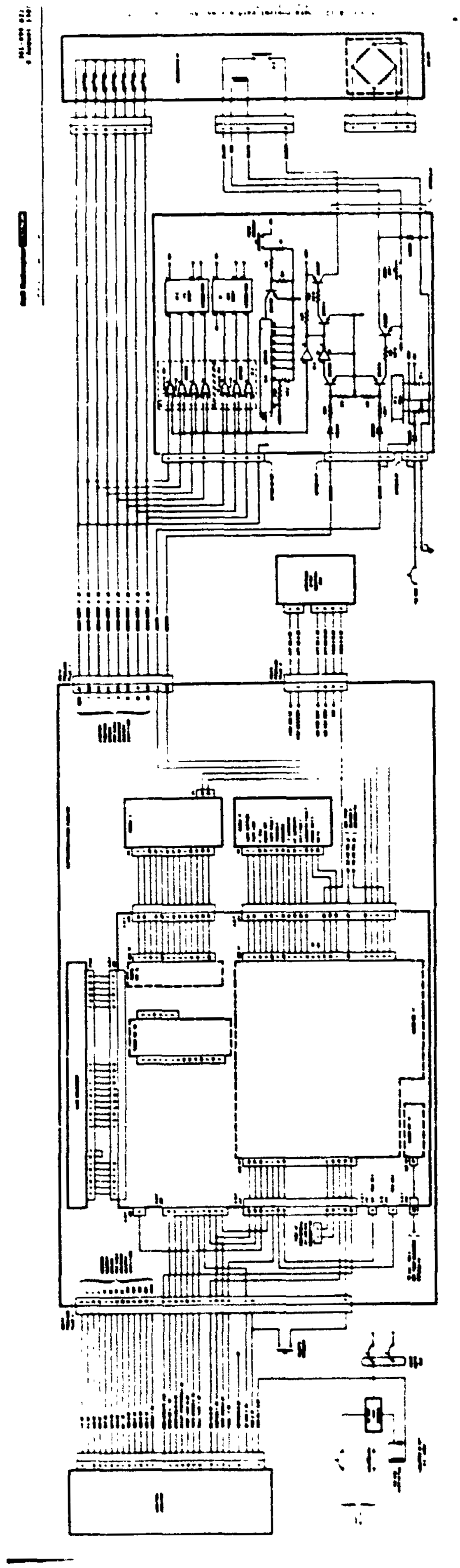


Figure 8-11. Temperature scanner card (ANP card slot 16)



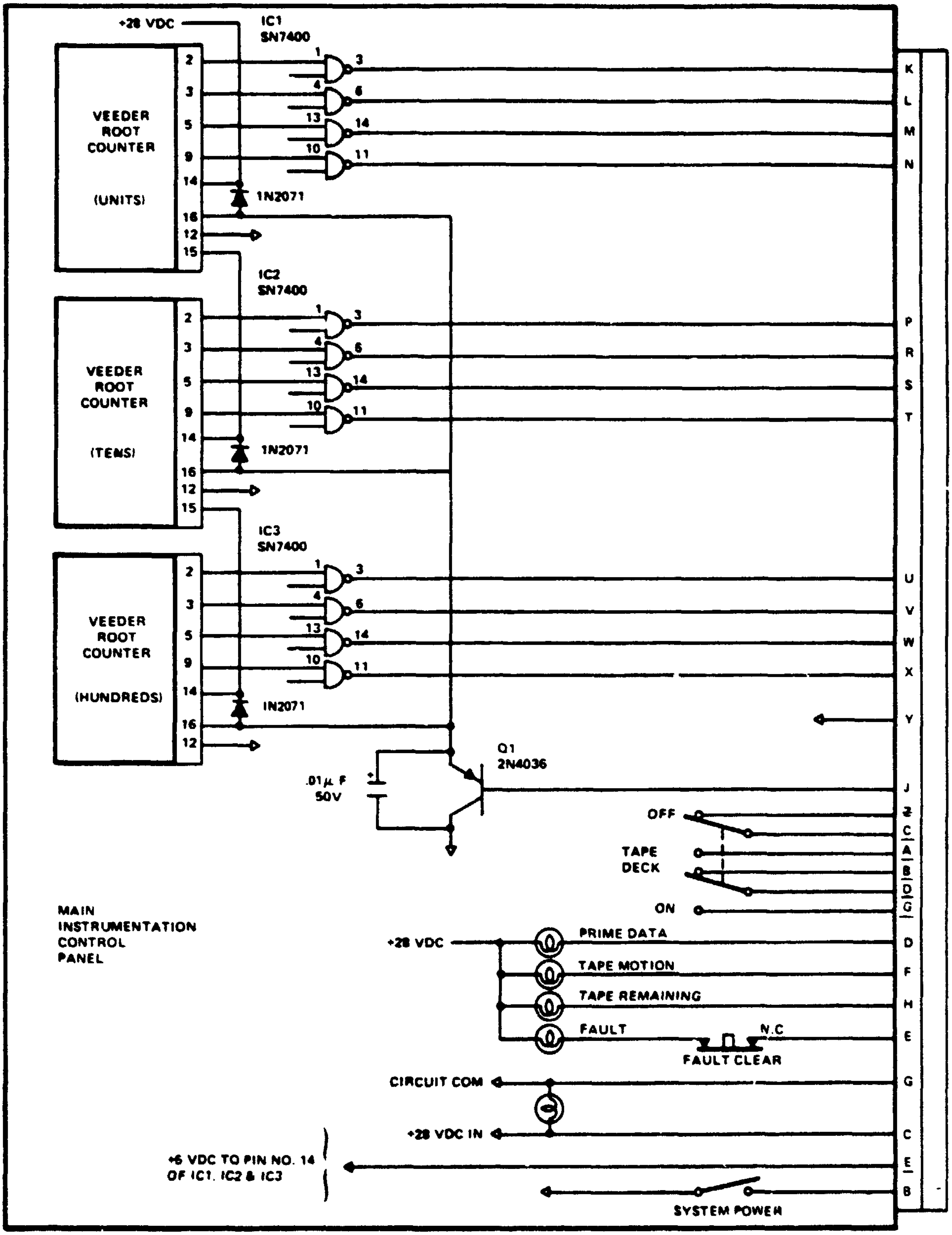
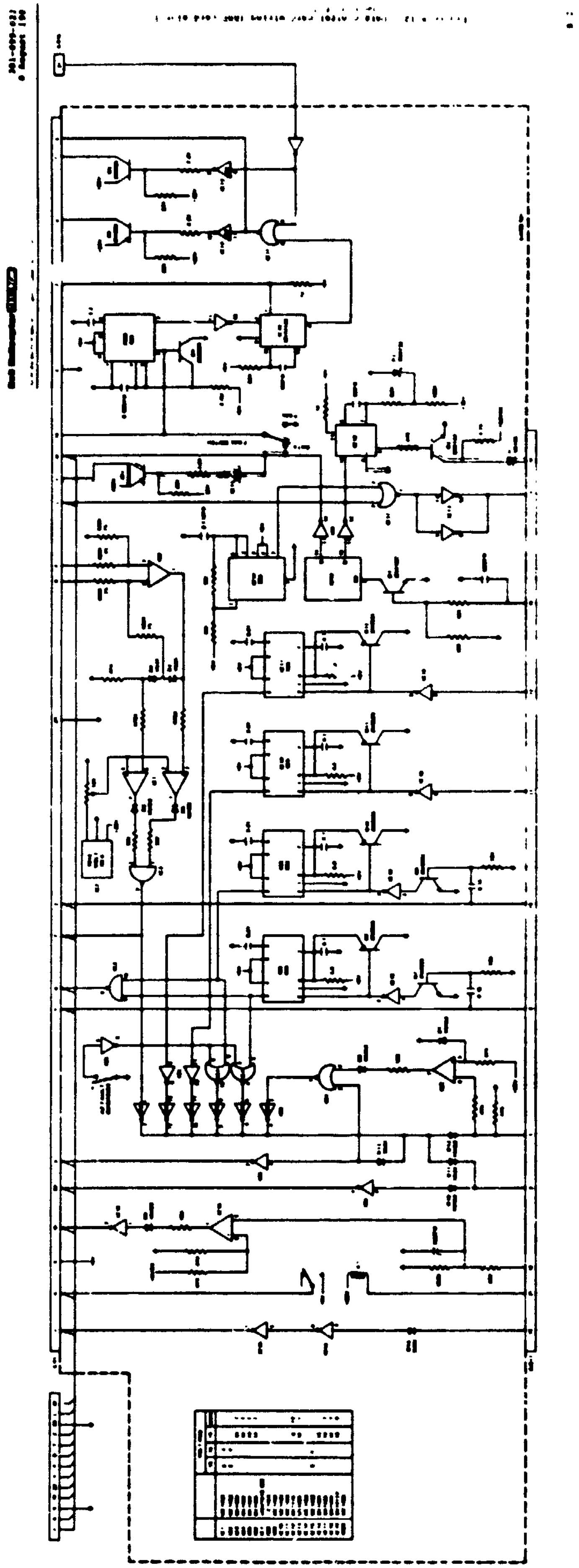


Figure 8-12. Data control card wiring (ANP card slot 17)
(.heet 2 of 7)



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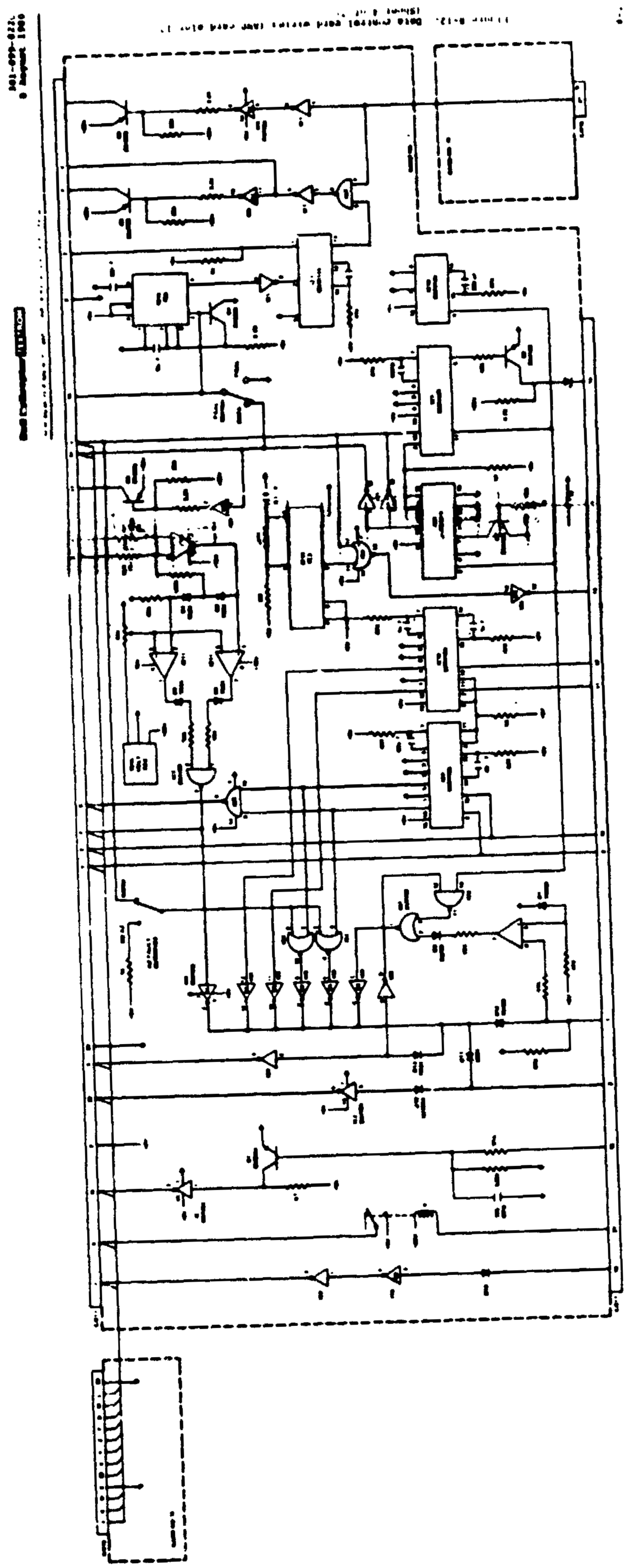

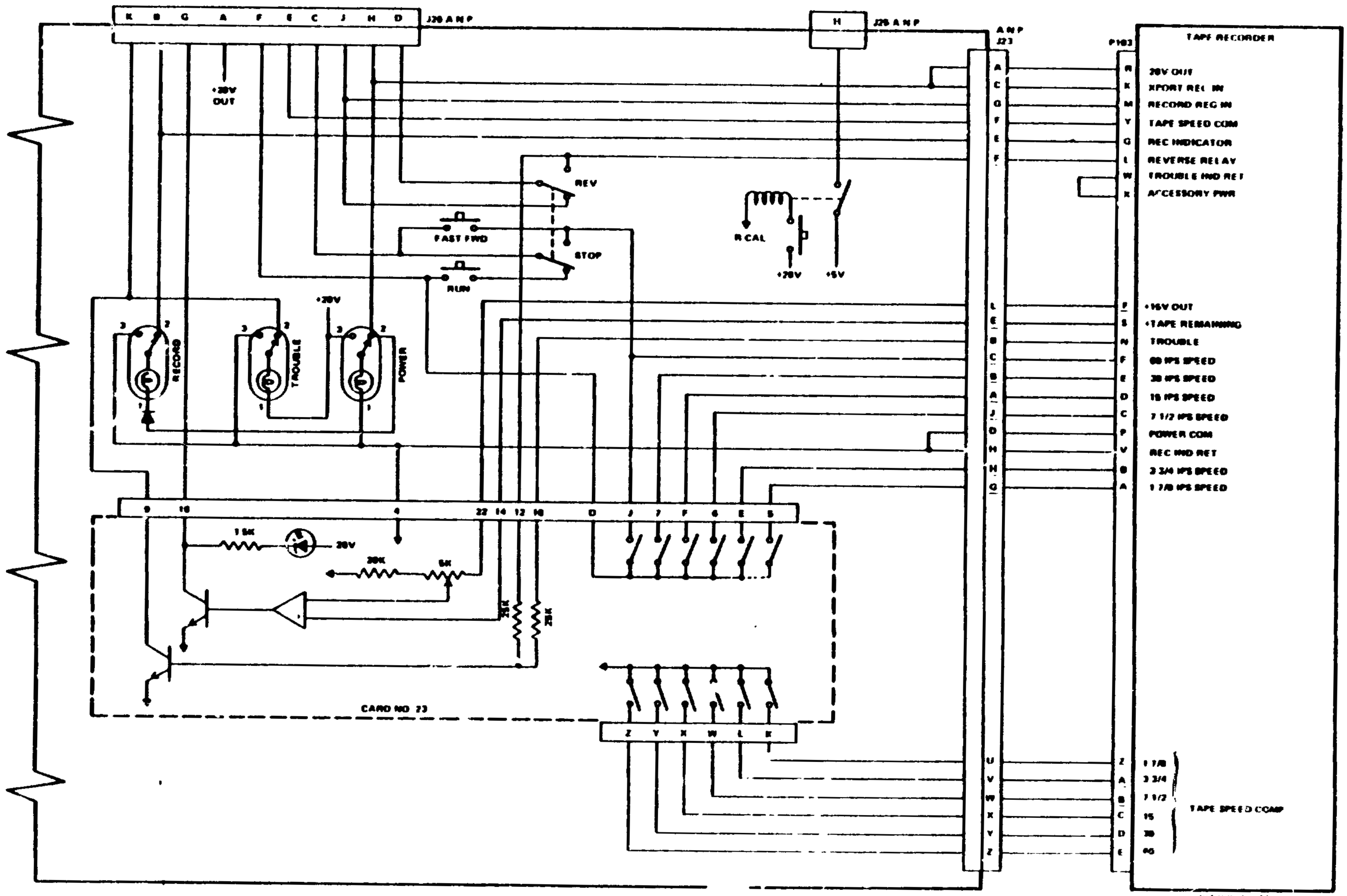

Figure 8-12. Data control card wiring (ANP card slot 17)
(Sheet 5 of 7)

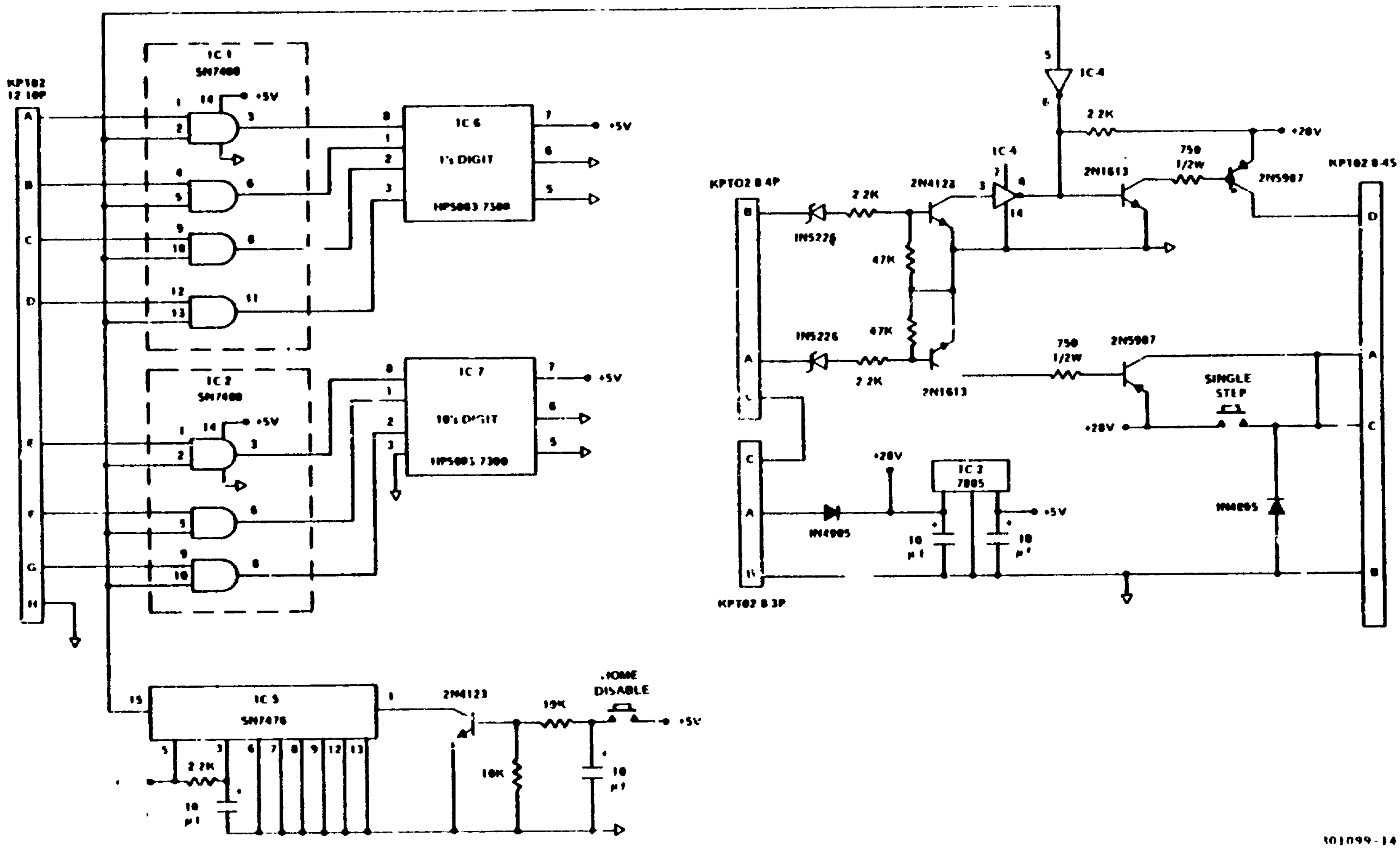

Figure 8-12. Data control card wiring (ANP card slot 1)
(Sheet 6 of 7)

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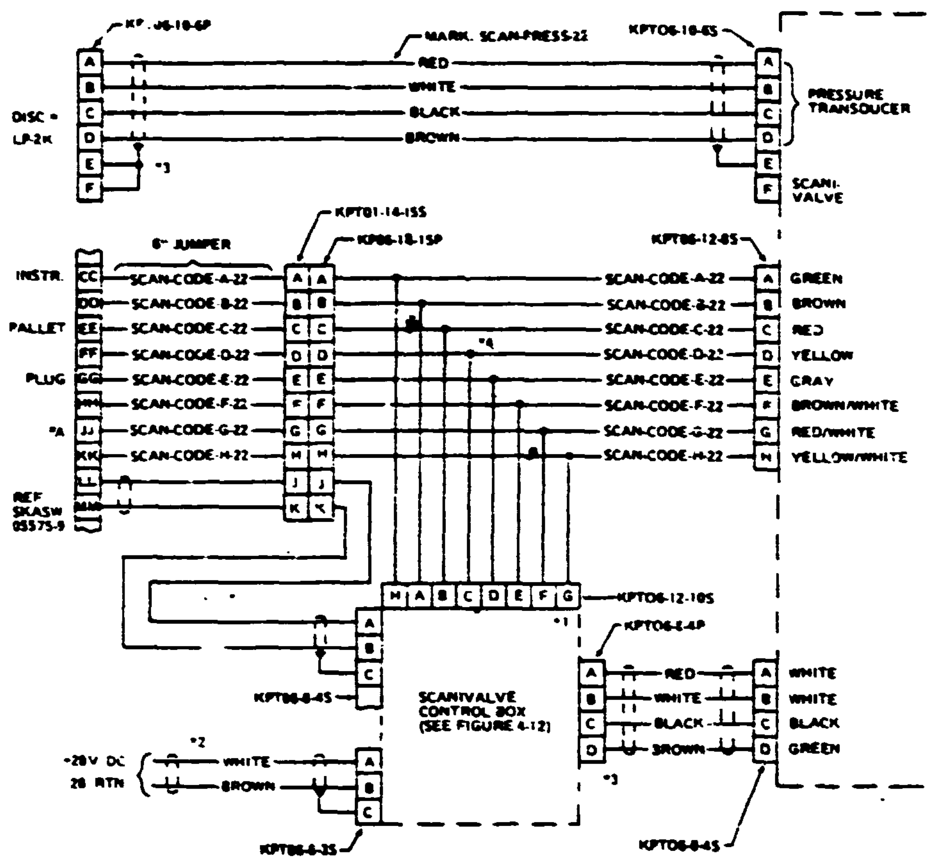

*1-CONTROL BOX MOUNTED ON LEFT PYLON
*2-USE 2 CONDUCTOR 20 GAGE ORANGE WIRE
*3-USE 4 CONDUCTOR 22 GAGE ORANGE WIRE
*4-MAKE THESE SPLICES AT THE SCANIVALVE CONNECTOR

SCANIVALVE CONTROL WIRING

301099-13

Figure 8-12. Data control card wiring (ANP card slot 17)
(Sheet 7 of 7)

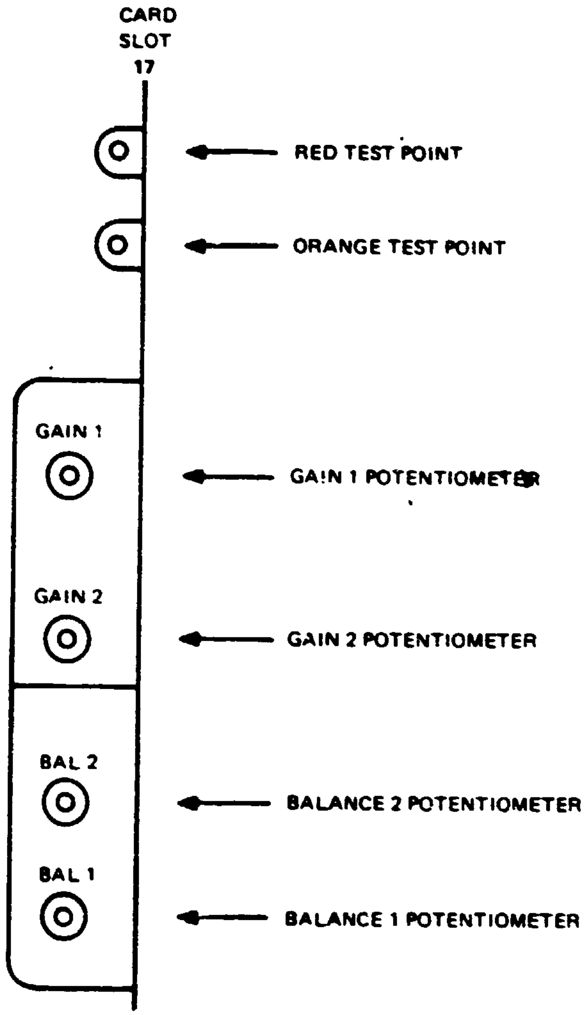

Figure 8-13. Data control word card
(ANP card slot 17)

1. RH AZIMUTH
2. LH AZIMUTH
3. FAULT LIGHT
4. R CAL
5. PRIME DATA
6. DATA
7. TAPE LOW
8. NO TAPE MOTION
9. EXCITATION FAULT
10. IDENTIFICATION BIT
11. AZIMUTH FAULT
12. TAPE DECK FAULT

Figure 8-14. Control word bit designation.

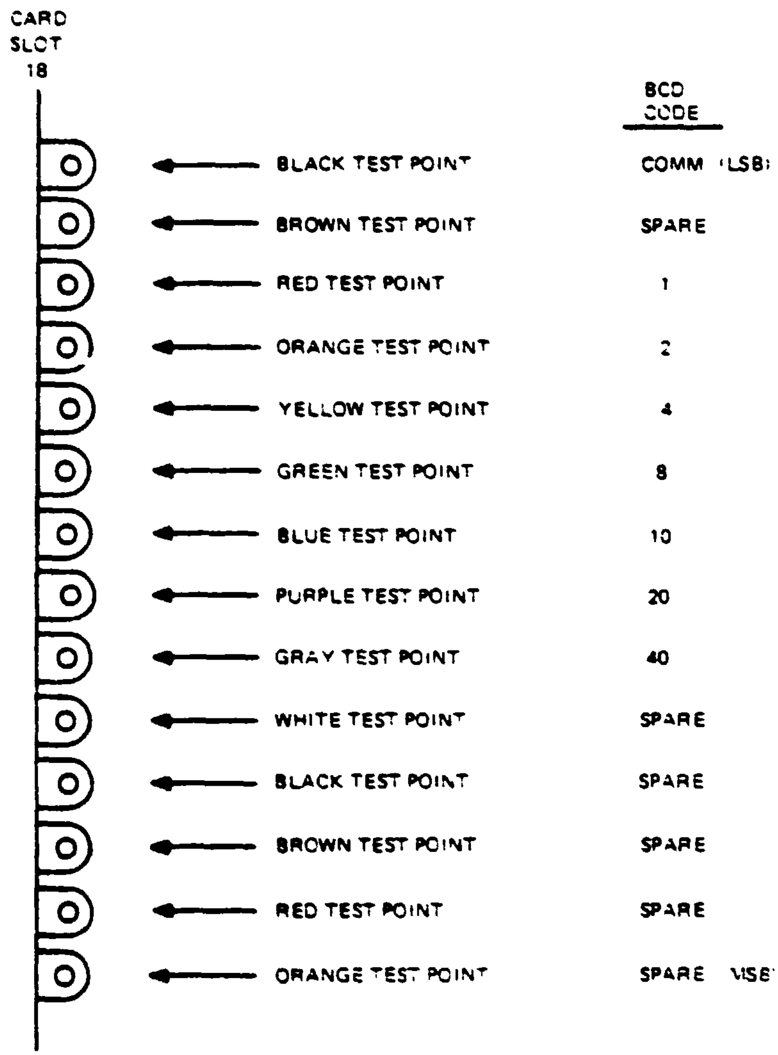

Figure 8-15. Scannivalve stepper position interface card (ANP card slot 18)

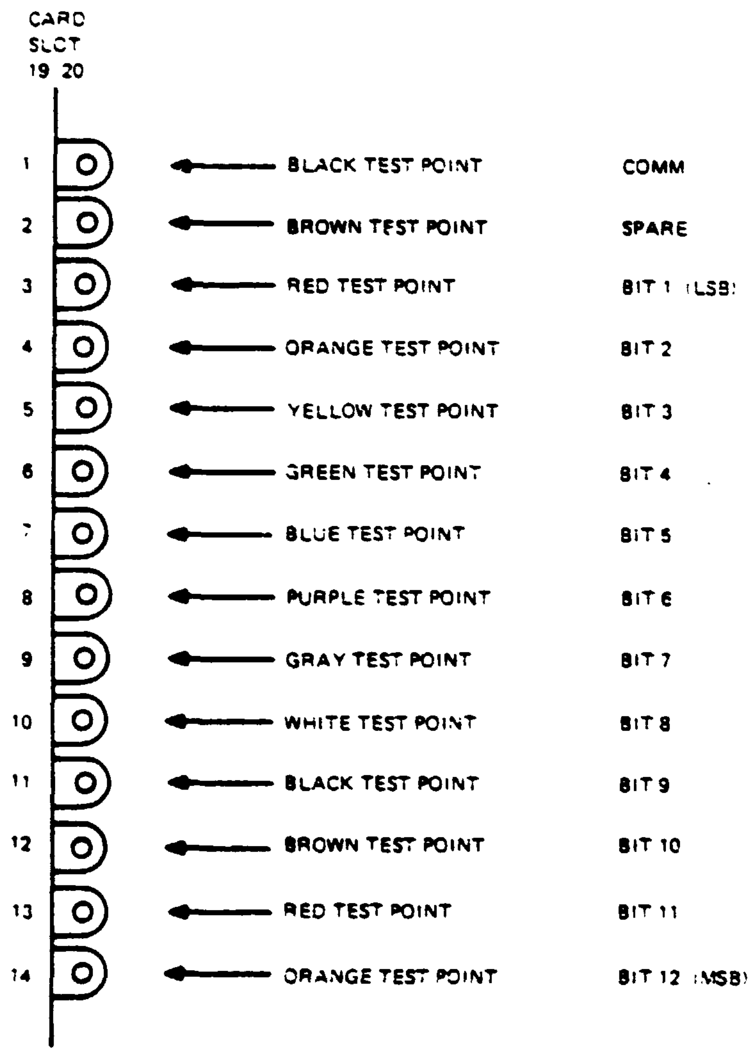

Figure 8-16. Fuel quantity jumper card (ANP card slots 19 and 20)

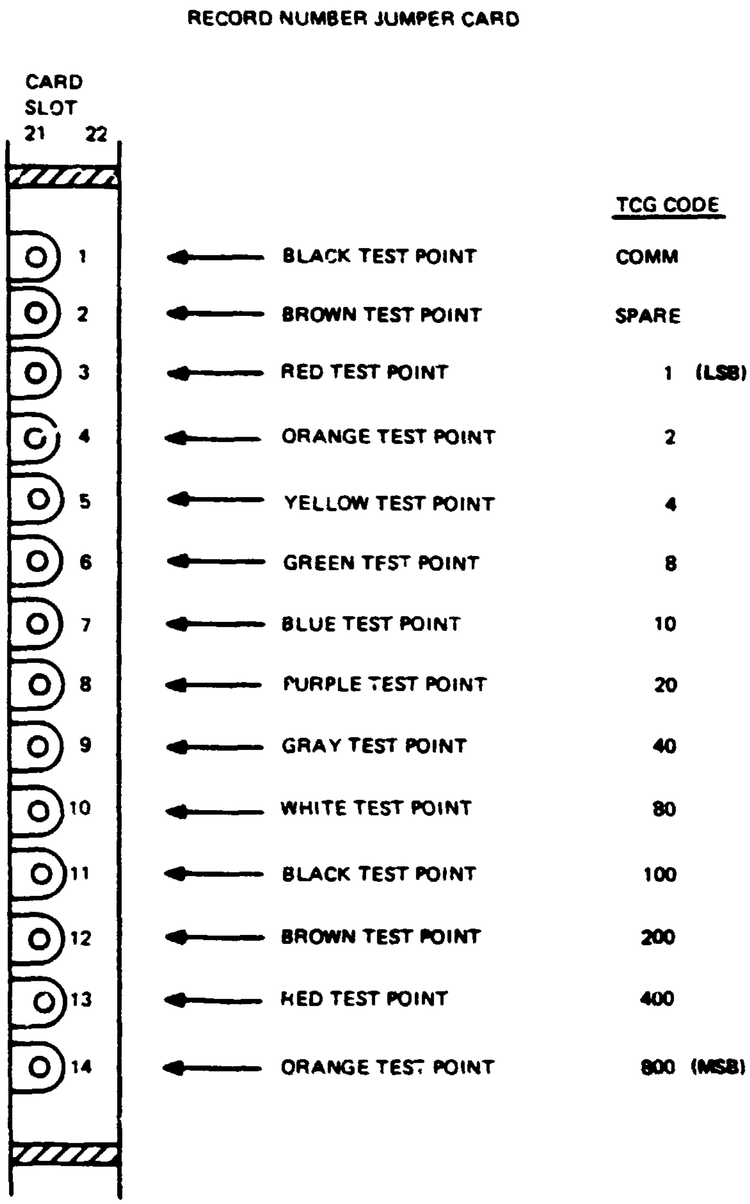

Figure 8-17. Record number jumper card
(ANP card slots 21 and 22)

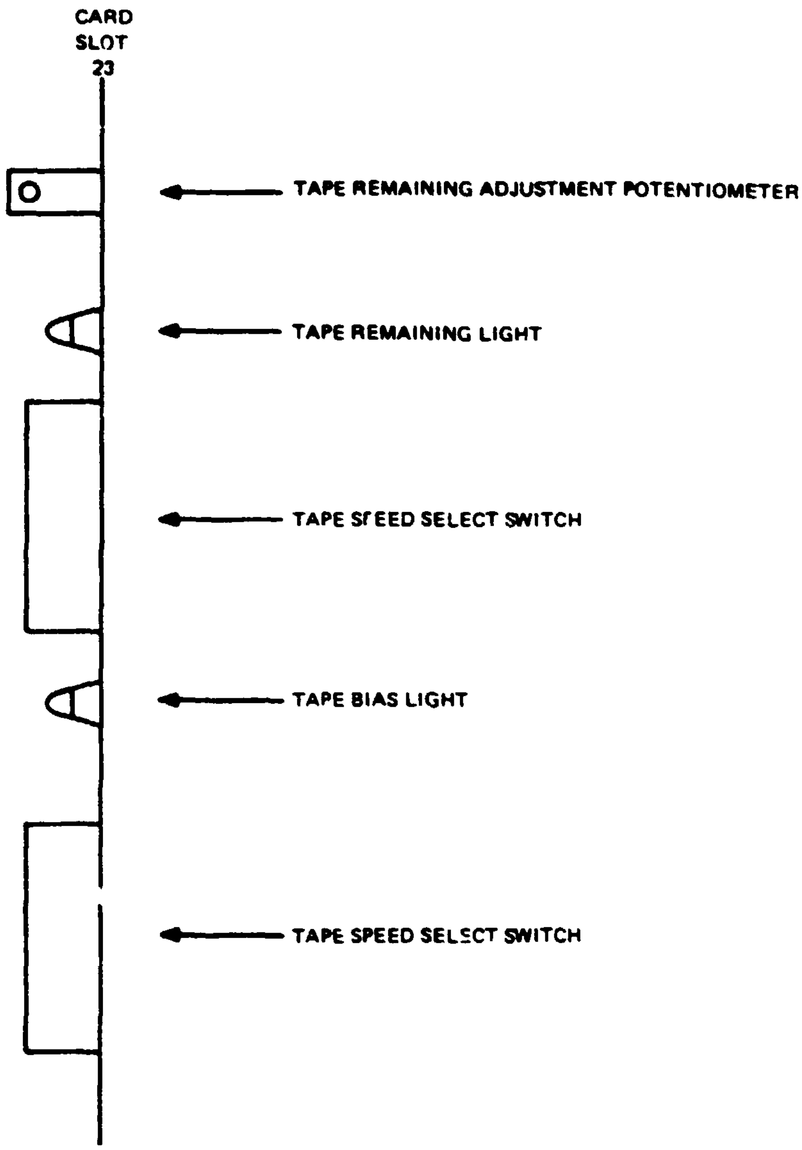

Figure 8-13. Tape speed control card (ANP card slot 23)

SECTION 9. OPERATING TECHNIQUES AND CHECKOUT PROCEDURES

This section establishes the techniques and procedures to be used for operation and checkout of the XV-15 research instrumentation system. These procedures include system power and control checkout, sensor setup, and preflight checkout of the research instrumentation system.

9.1 System Power and Control Checkout. The sample check list shown in Table 9-I may be used while performing the following checks.

9.1.1 Initial Power Application. After instrumentation pallet installation, all power, control, and signal cables shall be connected and power applied to the system. For initial power applications, all circuit breakers should be open and power control switches placed in the OFF position.

a. Energize the aircraft 28 Vdc bus No. 2 and close the two 50-amp instrumentation circuit breakers located in the aircraft's master power distribution box. Position the power switch on the control monitor (Figure 1-7) to the PWR ON position. This will supply 28 Vdc power to plugs "C" and "F" on the instrumentation pallet and 28 Vdc input power to the 115 Vac 400 Hz static inverter.

b. Check for correct 28 Vdc power distribution to the static inverter by measuring the voltage at the inverter connector. See Figure 4-1 for connector pin numbers.

c. Check for correct 115 Vac, 400 Hz power distribution to the instrumentation pallet by measuring the voltage at plug "C." Check for correct 28 Vdc power distribution to the instrumentation pallet by measuring the voltage at plugs "C" and "F." See Figure 4-1 for connector pin numbers.

d. Energize research instrumentation equipment individually by closing the associated circuit breaker located on the instrumentation pallet circuit breaker panel (see Figure 4-3).

9.1.2 Control Function Checkout. When input power has been determined to be correct, close all circuit breakers. Load a reel of tape on the tape transport and check the following control functions.

a. Tape start - stop - the tape start-stop switch on the control monitor will be turned on and off while watching the tape deck to see if it starts and stops correctly.

b. Tape motion light - while the tape start-stop switch is in the start position and the tape deck is running, observe the tape motion light to ensure that it is on.

c. Prime data light - with the tape running, push the pilot's stick prime data trigger and see if the prime data light comes on, push the pilot's stick trigger again to ensure it goes off. Repeat this procedure with copilot's stick prime data trigger and data package trigger to ensure that these triggers perform correctly.

d. Fault light - momentarily short out the bridge voltage and check that the fault light comes on.

e. Fault reset switch - push in the fault reset switch to see if the fault light goes out.

f. Tape remaining light - run the tape deck to the point that approximately 5 minutes of tape remains and check that the tape remaining light comes on.

g. Record number update - push the pilot and copilot prime data stick triggers on and off. Observe that the record number updates each time prime data is turned off. Check to ensure that the control monitor and the time code generator display the same record number.

h. Check pilot's time code display to ensure that it is functioning properly and that both display and time code generator show the same time.

9.2 Sensor Setup. A sensor setup configuration shall be determined for the PCM format. A sample PCM system sensor setup form is given in Table 9-II. Table 9-III (RMDU A) and 9-IV (RMDU B) show a sample PCM format location and gain for each sensor item code (see PCM setup sheets for latest configuration). When a final setup configuration has been determined, the program board will be patched in and its checkout will run concurrently with the checkout of the data channels. Any incorrect patches will be revealed and corrected during this checkout phase. The sensor setup sheet (Table 9-II) can be used as the sensor pass/fail checkout sheet. When all channels have been checked to ensure that a data channel is in each location as designated by the setup sheet, tests will be performed to positively identify and establish sign conventions for each channel.

9.2.1 Positive Identification. Positive identification of a channel is a means of ensuring that the designated parameter shown on the setup sheet is truly in that position in the data system. By using the flight line tester, each data channel can be dialed up and monitored while it is being checked. The following means of positive identification may be used for positive identification of each type of sensor:

a. Accelerometers - with the accelerometer unbolted, it is given a "2.g" turnover (turning it 180 degrees on its active axis). This gives 2 g's worth of sensor output at the monitor.

b. Strain gages - using a 100K probe as a simulated load, probe across one leg of the bridge at the terminal board for the particular channel. This will give an output at the monitoring equipment.

c. Position potentiometers - with the wiper arm free to move, rotate the wiper arm which produces a simulated motion of the part under consideration which produces an output at the monitoring equipment.

d. Pressure - pressure is applied to the open port of the sensor and this load produces output at the monitoring equipment.

e. Gyros - with the gyro base free to rotate, the gyro is rotated in the desired axis and this simulated aircraft motion produces output at the monitoring equipment.

f. Temperature - with the temperature scanner set to the desired location, the thermocouple is heated with some heat source (soldering iron, heat gun, etc.) and the output is monitored.

g. Rotor azimuth - output of the encoder (1/rev or 512/rev) is monitored on the oscilloscope while the rotor is being rotated.

9.2.2 Sign Convention After all channels have been properly identified using the procedure of 9.2.1, any discrepancies such as faulty wiring or incorrect patching shall be corrected. Channel sign conventions will then be checked using the procedure of dialing up each individual channel with the flight line tester and monitoring the electrical output signal for a given mechanical input load. To minimize confusion, all sign conventions will be taken with the aircraft in helicopter mode. For conversion and airplane mode operation, all sign conventions will be with reference to the helicopter mode. Table 9-V is a list of standard sign conventions which will be used except as otherwise noted on the aircraft setup sheet. General rules for sign convention are as follows:

Trace moves upscale when:

a. Tension loads increase

b. Motions occur to right, forward or up

c Temperatures, pressures, flows, etc. increase

d. For stress bridges, tension occurs in CD leg of bridge

e. Displacement or velocity at a transducer is forward, right or up

f. For unoriented bending bridges, tension occurs in the CD leg of bridge

9.2.3 Noise Level. Noise level for each channel should not exceed ±20 counts (±2 percent of full scale) on the flight line tester.

9.3 Temperature Scanning System Setup Procedure. A flow diagram for the temperature scanning system is shown in Section 4. Schematic diagrams of system components are contained in Volume IV. The thermocouple scanning system is set up using the setup sheets shown in Table 9-VI and the following procedures.

9.3.1 Control Signal Checkout. The following procedure shall be used to test the random access thermocouple channel selection function.

a. Using a dual beam oscilloscope, connect the upper beam to blue terminal No. 1 of Card No. 12, logic card in the active network panel. Connect the lower beam to blue terminal No. 2, common to the black terminal, and Ext Sync to the gray terminal of the same card (see Figure 8-9). A pattern six bits long should be present. The pattern will be centered about common on both traces and the lower beam will be the exact inverse of the upper beam. Set the potentiometer on card No. 16 for a bit pattern 20 msec in length from first bit to first bit.

b. With the instrumentation system in the non-prime data mode, select channels 100 through 129 on the control display panel. Check the scope as each number is dialed to see that the six bit code corresponds to the number dialed in binary coded decimal (BCD).

9.3.2 Reference Junction Monitors. Set the adjustment potentiometer located in the rear of the remote temperature scanner logic box (P/N SKASW-5479-1) to the full counterclockwise position. If the thermocouple reference junctions have not had 30 minutes to reach operating temperatures, allow sufficient time for them to heat. The fault light on the control monitor should now be off. Starting with any remote switching unit, turn the potentiometer clockwise until the fault light comes on, then back counterclockwise 1/2 turn. Repeat this procedure for each remote temperature scanner logic box.

9.3.3 Temperature Monitor. The following procedure shall be used to calibrate the temperature monitor (Figure 1-10).

a. Select channel 000 on the temperature monitor. Connect a short piece of wire between the orange and red test terminals of card No. 17 (Figure 8-13) in the active network panel. Adjust BAL 1 of the same card for a reading of 212°F on the temperature monitor.

b. Replace the jumper wire between the orange and red test terminals with a 17.9 mv voltage source. Adjust GAIN 1 until the temperature monitor reads 1000°F.

c. Select channel 005 on the temperature monitor. Replace the shorting wire between the orange and red test terminals. Adjust BAL 2 for an output of 212°F.

d. Replace the jumper wire between the orange and red terminals with a -6.16 mv voltage source. Adjust GAIN 2 for an output of 0°F.

e. Repeat the adjustments of BAL 1, GAIN 1 and BAL 2, GAIN 2 as necessary until both voltage settings produce the proper output without further adjustments.

9.4 Control Position Indicator. The following procedure shall be used to calibrate the digital control position indicator (Figure 1-12).

a. Adjust each stick position transducer (linear or rotary potentiometers) so that its center of travel corresponds approximately with the center of travel of its respective control stick or pedal.

b. Connect external hydraulic power to the ship and determine the full throw positions of each control.

c. Place the lateral cyclic stick in the full left position.

d. Locate the adjustment potentiometers visible on the front of ANP card No. 11. Gain and balance controls are provided for each control position function (see Figure 8-5).

e. Adjust the LAT BAL control to the point where the lateral position indicator switches from "1" to "0."

f. Place the lateral cyclic stick in the full right position.

g. Adjust the LAT GAIN control to the point where the lateral position indicator switches from "96" to "99."

h. Go back and forth between 0 and 99 percent, adjusting both balance and gain controls until both zero and 99 percent positions are correctly indicated.

i. Repeat steps 4 through 8 for the other position indicators.

9.5 Scannivalve Setup. Schematic and flow diagrams for the pressure scanning system are shown in Section 4. Checkout of scannivalve data channels is accomplished with the flight line tester using the following procedures.

a. The flight line tester shall be dialed to the item code and channel number that the scannivalve setup sheet (Table 9-VII) calls out for the scannivalve port under test.

b. Set the control switch on the scannivalve control box to the "home disable" position.

c. Using the scannivalve setup sheet (Table 9-VII), check port No. 1 for positive identification and sign convention to ensure that the system is working. This can be done by applying test pressure to port No. 1 using a piece of tubing and a low pressure source (mouth, pressure bulb, etc.).

d. When assured that the data channel for port No. 1 is functional, step through each of the remaining ports and check them for positive identification and sign convention by applying pressure to each port.

e. When the manual sequence has been checked, put the control switch on the scannivalve control box to "AUTO" and push the prime data trigger switch on the pilot's power lever. This should step the scannivalve at a 4/sec rate [driven by the scannivalve control card (SVD) in RMDU A].

f. When assured that both "MANUAL" and "AUTO" modes of the scannivalve circuitry work correctly, and checkout of the scannivalve system is complete.

9.6 Shaft Encoder Setup and Checkout. The rotor azimuth shaft encoder will be set up with the aircraft in helicopter mode.

9.6.1 Right Rotor. The shaft encoder for the right rotor azimuth shall be set up for correct positioning using the following procedure.

a. Rotate the right-hand rotor so that the tip of the red blade is pointing directly aft.

b. Loosen the hold-down screws that fasten the shaft encoder to the right-hand rotor.

c. With an oscilloscope connected to the output of the encoder, rotate the case of the encoder until the index pulse occurs.

d. Tighten the hold-down screws and rotate the rotor to ensure that the index pulse occurs when the red blade is directly aft.

9.6.2 Left Rotor. The shaft encoder for the left rotor azimuth shall be set up using the procedure of 9.6.1 for the left rotor.

9.7 Preflight Checks. Preflight checkout procedures for the XV-15 research instrumentation system are given in Table 9-VIII.

TABLE 9-I. XV-15 SYSTEM PASS/FAIL CHECKOUT SHEET

XV-15 (MODEL 301) SYSTEM PASS/FAIL CHECKOUT SHEET (Example)

SHIP # ______

	PROCEDURE REFERENCE	PASS	FAIL	REASON FOR FAILURE	INITIALS
1. DC Power to Data System	9.1.1(a)				
2. DC Power to Inverter	9.1.1(b)				
3. AC Power to Data System	9.1.1(c)				
4. Equipment Circuit Breakers	9.1.1(d)				
5. Tape Start-Stop	9.1.2(a)				
6. Tape Motion Light	9.1.2(b)				
7. Prime Data Light	9.1.2(c)				
8. Fault Light	9.1.2(d)				
9. Fault Clear Switch	9.1.2(e)				
10. Tape Remaining Light	9.1.2(f)				
11. Record Number Updates	9.1.2(g)				
12. Pilot's Time Code Display	9.1.2(h)				
13. Sensor Setup Sheet*	9.2				
a. Positive Identification	9.2.1				
b. Sign Convention	9.2.2				
c. Noise	9.2.3				
14. Thermocouple Setup Sheet*	9.3				
a. Control Signal Checkout	9.3.1				
b. Reference Junction Monitors	9.3.2				
c. Temperature Monitors	9.3.3				
15. Control Position Indicator	9.4				
16. Scannivalve Setup	9.5				
17. Shaft Encoder Setup	9.6				
a. Right Rotor Shaft Encoder	9.6.1				
b. Left Rotor Shaft Encoder	9.6.2				

*These items checked after completion of setup sheet checkout.

TABLE 9-II. XV-15 PCM TAPE DATA SYSTEM SETUP

XV-15 (MODEL 301) PCM TAPE DATA SYSTEM SETUP

Prog. No. (1) Model (2) S/N (3) Date (4) 1st Flt/Gr (5) 1st Rec. No. (6)

Track (7) RMDU (8) Data Cord. (9) Engr. (10) Tech. (11)

Prog. (12) EWA (13) DLN (14) W/O (15)

Frame Location (17) MF	Frame Location (18) SF	Frame Location (16) POS	(19) Item Code	(20) (21) Item (22) Location	Sta	BR. No. Lab. No.	PAF CS/Chan	RMDU CS/Chan	Cable No.	PSP Gain	GPA Gain	Cal Req C.E.	Ref. Value Units	REMARKS
1	1	1	—	FRAME SYNC	(23)	(24) (25)	(26)	(27)	(28)	(29)	(30)	(31) (32)	(33) (34)	(35)
2	1	1	—	FRAME SYNC										
3	1	1	—	SUB FRAME I.D.										
4	1	1	—	INFO / CONTROL										
5	1	1					1/1	10/1						
6	1	1					1/2	10/2						
7	1	1					1/3	10/3						
8	1	1					1/4	10/4						
9	1	1					2/1	10/5						
10	1	1					2/2	10/6						
11	1	1					2/3	10/7						
12	1	1	....				2/4	10/8						

TABLE 9-II. XV-15 PCM TAPE DATA SYSTEM SETUP (CONTINUED)

1. Prog. No. - Program number assigned to the program that is currently being run on the ship. This number is assigned by G. Carter and can remain the same or can be changed for different phases of the program [i.e., one (1) for ground run and one (1) for flight].

2. Model - Model number of the aircraft, in this case Model 301 (XV-15 could be used).

3. S/N - Serial number of aircraft (either Ship #1 or Ship #2).

4. Date - Date of the last change made to this setup sheet.

5. 1st Flt/Gr - The number of the 1st flight/ground run after the last change made to this setup sheet.

6. 1st Rec. No. - 1st record number taken after the last change made to this setup sheet.

7. Track - The number of the track on the tape deck which this setup sheet is being recorded.

8. RMDU - The RMDU bit stream which this setup sheet covers ("A" or "B").

9. Data Cord. - The name of the data coordinator (responsible person from Data Reduction Group) assigned to this program.

10. Engr. - The name of the Instrumentation engineer assigned to this program.

11. Tech. - The name of the Instrumentation technician assigned to this program.

12. Prog. - The title assigned to the phase of the program being conducted at the present time (ground run, hover performance, flight test, etc.).

13. EWA - The Engineering Work Authorization number assigned to this program (A427, A439, etc.).

14. DLN - The Daily Labor Number assigned to this phase of the program (67646_ - Ship #2 flight test).

15. W/O - The Work Order number assigned to this phase of the program (A4[illegible]7, etc.).

TABLE 9-II. XV-15 PCM TAPE DATA SYSTEM SETUP (CONTINUED)

16. Frame Location - The frame location (word location) of a given parameter in the bit stream.

17. MF - The mainframe word location in the bit stream (1 - Word #1, 28 - Word #28, etc.).

18. SF - The depth of the subframe (1 - 1 deep, 2 - 2 deep, and 8 - 8 deep).

19. Pos. - The position in the subframe of a given parameter
[7-1-1 Mainframe word (100 Hz)]
[52-2-2 Mainframe word 52, second subframe word (50 Hz)]
[80-8-5 Mainframe word 80, fifth subframe word (12 Hz)]

20. Item Code - A number assigned to a given measurement parameter for identification purposes.

21. Item - The name of the measurement parameter (beam bending).

22. Loc. - The location of the transducer (right rotor blade).

23. Sta. - The station on the part where the strain gage is located (blade Sta. 52.5).

24. Br. No. - The bridge number specified in the Laboratory Work Sheet. Bridge numbers are assigned to each bridge on the part at the time the part is gaged.

25. Lab. No. - The number assigned to a part by the Instrumentation Laboratory at the time of gaging.

26. PAF Cs/Chan - These are channels which go into a pre-amplifier filter box. The upper number is card slot location in the box, the lower number is the channel number on that card: 1/1 Card Slot #1/Channel #1.

    Note: In cases where there is no number in this column, the channel does not go through a PSF card, but directly into the RMDU and into a AMX or DMX card.

27. RMDU CS/Chan - The RMDU AMX designations for each parameter. The upper number is the card slot location in the box and the lower number is the channel number on that card: 10/20 Card Slot #10/Channel #20.

28. Cable No. - The J-box channel number that this parameter is brought into the data system on (RR-1B, LW-1M, etc.).

TABLE 9-II. XV-15 PCM TAPE DATA SYSTEM SETUP (CONCLUDED)

29. PSF Gain - The gain set up for each channel in the PAF boxes (all channels are factory set at a gain of 256).

30. GPA Gain - The gain of the gain programmable amplifier for each parameter.

31. Cal. Res. - The value of the calibration resistor for each parameter (115KΩ or 500KΩ).

    Note: In cases where no value appears in this location, indicate that the channel is a AMX or DMX channel and does not use a calibration resistor.

32. The calibration equivalent taken from the calibration sheets [factored to fit 115KΩ calibration resistor (calibration sheet shows 100KΩ = XXX in engineering units, etc.), and to allow for voltage drop from R-Cal point to actual bridge excitation voltage, and individual channel sensitivity].

    C.E. = 115 K Ω Cal = Slope x Δ counts

    Δ counts = R-Cal Counts - Reference Counts

$$\text{Slope} = \frac{\text{U.C.}}{\text{B.V.}} \times \frac{5120}{1024} \times \frac{1}{256} \times \frac{1}{\text{GPA GAIN}}$$

    where:

    U.C. = Unity Cal from Calibration Sheet

    B.V. = Bridge Voltage at Bridge

$$\frac{5120}{1024} = \frac{\text{Input MV}}{\text{Output Counts}}$$

$$\frac{1}{256} = \frac{1}{\text{PSF Card Gain}}$$

33. Ref. Value - The reference value designated by preflight (reference) conditions (F/A cyclic stick → 50%, F/A pilot's seat accel → 0 g's, pylon pos → 95°, etc.).

34. Units - The engineering units that the parts were calibrated in (in-lbs, lbs, g's, psi, etc.).

35. Remarks - A column for any special comments that will clarify each parameter.

TABLE 9-III. SAMPLE FORMAT RMDU A

LOCATION	ITEM CODE	GPA GAIN	LOCATION	ITEM CODE	GPA GAIN
1_1-1	SYNC 1	--	24_1-1	B193	1
2_1-1	SYNC 2	--	25_1-1		1
3_1-1	ID 1	--	26_1-1	B127	4
4_1-1	INFO	--	27_1-1	B613	1
5_1-1	F638	2	28_1-1	M612	1
6_1-1	S145	16	29_1-1		4
7_1-1	S146	16	30_1-1	F163	4
8_1-1	M128	2	31_1-1	P153	1
9_1-1	S147	16	32_1-1	P178	1
10_1-1	S148	16	33_1-1	P149	1
11_1-1	M138	2	34_1-1	P504	1
12_1-1	B120	4	35_1-1	P512	1
13_1-1	M129	1	36_1-1	B194	1
14_1-1	M277	1	37_1-1	M619	1
15_1-1	B615	1	38_1-1	B613	1
16_1-1	B126	2	39_1-1	B622	1
17_1-1	F614	4	40_1-1	B282	1
18_1-1	B195	1	41_1-1	B280	1
19_1-1	F621	4	42_1-1	F286	4
20_1-1	M279	1	43_1-1	B264	1
21_1-1	B109	4	44_1-1	P505	1
22_1-1	M129	1	45_1-1	B171	1
23_1-1	B192	1	46_1-1	B172	1

NOTE: All PSF gain is 256.

TABLE 9-III. (CONTINUED)

LOCATION	ITEM CODE	GPA GAIN	LOCATION	ITEM CODE	GPA GAIN
47_{1}-1	B173	1	61_{2}-1	P323	1
48_{1}-1	B174	1	61_{2}-2	P325	1
49_{1}-1	E154	1	62_{2}-1	S630	128
50_{1}-1	E155	256	62_{2}-2	S631	128
51_{1}-1	T506	512	63_{2}-1	S632	128
52_{2}-1	F330	4	63_{2}-2	S633	128
52_{2}-2	F331	4	64_{2}-1	S634	128
53_{2}-1	F332	4	64_{2}-2	S635	128
53_{2}-	F334	4	65_{2}-1	S636	128
54_{2}-1	B259	4	65_{2}-2	S637	128
54_{2}-2	B268	4	66_{2}-1	D317	1
55_{2}-1	M275	4	66_{2}-2	D305	1
55_{2}-2		4	67_{2}-1	E374	1
56_{2}-1		1	67_{2}-2		1
56_{2}-2	B274	1	68_{2}-1		1
57_{2}-1	M276	1	68_{2}-2		1
57_{2}-2	B278	1	69_{2}-1		1
58_{2}-1	A304	1	69_{2}-2		16
58_{2}-2	A020	4	70_{2}-1	R338	1
59_{2}-1	S609	4	70_{2}-2	D617	1
59_{2}-2	S610	2	71_{2}-1		1
60_{2}-1	S628	4	71_{2}-2	M336	1
60_{2}-2	S629	2	72_{2}-1	D110	16

NOTE: All PSF gain is 256.

TABLE 9-III. (CONTINUED)

LOCATION	ITEM CODE	GPA GAIN	LOCATION	ITEM CODE	GPA GAIN
72_2-2	D160	1	79_8-5	E197	1
73_2-1	R503	1	79_8-6	E298	1
73_2-2	R515	1	79_8-7	D360	64
74_2-1	D348	1	79_8-8	E708	512
74_2-2	D349	1	80_8-1	E299	1
75_2-1		1	80_8-2	T351	512
75_2-2	R328	1	80_8-3	E372	1
76_2-1	R329	1	80_8-4	E647	1
76_2-2	R339	1	80_8-5	E648	1
77_2-1	M335	1	80_8-6	T322	1
77_2-2	D111	2	80_8-7	E703	128
78_8-1	D645	1	80_8-8	E709	512
78_8-2	D281	1	81_8-1	D510	1
78_8-3	D284	1	81_8-2	D309	1
78_8-4	T524	128	81_8-3	E074	1
78_8-5	T531	128	81_8-4	E075	1
78_8-6	D509	1	81_8-5	E198	1
78_8-7	E701	16	81_8-6	E199	1
78_8-8	E707	512	81_8-7	E704	256
79_8-1	R326	1	81_8-8	E710	512
79_8-2	E072	1	82_8-1	D511	--
79_8-3	E073	1	82_8-2	E375	1
79_8-4	E196	1	82_8-3	E369	1

NOTE: All PSF gain is 256.

TABLE 9-III. (CONCLUDED)

LOCATION	ITEM CODE	GPA GAIN	LOCATION	ITEM CODE	GPA GAIN
82_8-4	E370	1			
82_8-5	E371	1			
82_8-6	E373	1			
82_8-7	E705	512			
82_8-8	E711	--			
83_8-1	X365	--			
83_8-2	R516	--			
83_8-3	P002	1			
83_8-4	T513	512			
83_8-5	P342	1			
83_8-6	E700	4			
83_8-7	E706	512			
83_8-8	E712	--			

NOTE: All PSF gain is 256.

TABLE 9-IV. SAMPLE FORMAT RMDJ B

LOCATION	ITEM CODE	GPA GAIN	LOCATION	ITEM CODE	GPA GAIN
1_1-1	SYNC 1	--	24_1-1	F142	4
2_1-1	SYNC 2	--	25_1-1	F523	2
3_1-1	ID 1	--	26_1-1	F522	2
4_1-1	INFO	--	27_1-1	F187	4
5_1-1	M143	2	28_1-1	F188	4
6_1-1	M107	2	29_1-1	F189	16
7_1-1	F611	2	30_1-1	A175	4
8_1-1	B132	1	31_1-1	A176	4
9_1-1	B133	2	32_1-1	A177	4
10_1-1	B122	1	33_1-1	B108	2
11_1-1	B134	1	34_1-1	B112	1
12_1-1	B135	2	35_1-1	B124	2
13_1-1	B136	2	36_1-1	B125	2
14_1-1	B137	4	37_1-1	A150	4
15_1-1	B114	1	38_1-1	A151	4
16_1-1	B115	1	39_1-1	A152	4
17_1-1	B140	2	40_1-1	F162	4
18_1-1	B141	4	41_1-1	F521	2
19_1-1	F164	16	42_1-1	F520	2
20_1-1	B123	2	43_1-1	B130	4
21_1-1	F060	4	44_1-1	F032	4
22_1-1	F061	4	45_1-1	F103	4
23_1-1	F062	4	46_1-1	F104	4

NOTE: All PSF gain is 256.

TABLE 9-IV. (CONTINUED)

LOCATION	ITEM CODE	GPA GAIN	LOCATION	ITEM CODE	GPA GAIN
47_1-1	F055	4	61_2-1	P324	1
48_1-1	B112	1	61_2-2	P326	1
49_1-1	E179	1	62_2-1	M337	1
50_1-1	E180	256	62_2-2		1
51_1-1		1	63_2-1	B316	128
52_2-1	A301	4	63_2-2		1
52_2-2	A300	4	64_2-1	F353	128
53_2-1	A003	4	64_2-2		512
53_2-2		4	65_2-1	B312	128
54_2-1	A019	4	65_2-2	F318	128
54_2-2	B190	4	66_2-1	B357	128
55_2-1	B191	4	66_2-2		512
55_2-2	B603	2	67_2-1		16
56_2-1	B606	1	67_2-2	B346	128
56_2-2	M606	4	68_2-1	F347	128
57_2-1	B165	4	68_2-2		1
57_2-2	B166	4	69_2-1		1
58_2-1	B262	4	69_2-2		1
58_2-2	B263	4	70_2-1	V012	1
59_2-1	M266	4	70_2-2	V013	1
59_2-2	B258	1	71_2-1	V014	1
60_2-1	B270	1	71_2-2	D011	
60_2-2	B259	4	72_2-1	D010	

NOTE: All PSF gain is 256.

TABLE 9-IV. (CONTINUED)

LOCATION	ITEM CODE	GPA GAIN	LOCATION	ITEM CODE	GPA GAIN
72_2-2	D009	4	79_8-5	D185	1
73_2-1	D066	2	79_8-6	D131	1
73_2-2	A507	2	79_8-7	E727	64
74_2-1	A514	2	79_8-8	E733	512
74_2-2	A508		80_8-1		1
75_2-1	A500	2	80_8-2	D646	1
75_2-2	A502	2	80_8-3	D314	1
76_2-1	A501	2	80_8-4	D315	1
76_2-2	D308	1	80_8-5	D186	1
77_2-1	D306	1	80_8-6		1
77_2-2	D307	1	80_8-7	E728	128
78_8-1	D021	1	80_8-8	E734	512
78_8-2	D022	1	81_8-1	D327	1
78_8-3	D023	1	81_8-2		1
78_8-4	D024	1	81_8-3	D007	1
78_8-5	B318	1	81_8-4	D008	1
78_8-6	D144	16	81_8-5	A352	1
78_8-7	E726	16	81_8-6	R321	1
78_8-8	E732	512	81_8-7	E729	256
79_8-1		1	81_8-8	E735	512
79_8-2	D182	1	82_8-1		1
79_8-3	D183	1	82_8-2	D156	1
79_8-4	D184	1	82_8-3	D157	1

NOTE: All PSF gain is 256.

TABLE 9-IV. (CONCLUDED)

LOCATION	ITEM CODE	GPA GAIN	LOCATION	ITEM CODE	GPA GAIN
82_8-4	D158	1			
82_8-5	D159	1			
82_8-6	D161	1			
82_8-7	E730	512			
82_8-8	E736	--			
83_8-1	X366	DMX			
83_8-2	R517	DMX			
83_8-3	E649	1			
83_8-4		1			
83_8-5		1			
83_8-6	E725	4			
83_8-7	E731	512			
83_8-8	E737	--			

NOTE: All PSF gain is 256.

TABLE 9-V. SIGN CONVENTIONS FOR RECORDERS.

PARAMETER	PARAMETER ABBREVIATION	TRACE MOVES UPSCALE IF:
1. Airspeed	A/S	Speed increases
2. Voltage	Volt	Voltage increases
3. Current	Amps	Amperage increases
4. Altitude	Alt	Altitude increases
5. Power Lever		
a. Boost Tube Axial Force	Power Lever, Boost Axial	Tube in t[illegible]ion
b. Pilot Effort (torque on jack-shaft or something in the system calibrated in terms of force at grip)	Pilot Effort, Power Lever	Pull up on power lever [illegible]
c. Stick Position	Power Lever Stick Position	Power lever stick up
6. Cyclic		
a. Boost Tube Axial Force	F/A or Lateral Cyclic Boost Axial	Tube in tension
b. Fore and Aft Stick Position	F/A Cyclic Position	Cyclic stick moved forward
c. Pilot Effort, Fore and Aft	Pilot Effort, F/A Cyclic	Forward force on cyclic stick
d. Lateral Stick Position	Lateral Cyclic Position	Cyclic stick moved to the right
e. Pilot Effort, Lateral	Pilot Effort Lateral	Pull right on cyclic stick
7. R/H, L/H Directional Control Tube Axial Force	Directional Control Tube	Control tube in tension
8. Elevator		
a. Beam Bending	Lt or Rt Elevator Beam Bending	Lower surface in tension

TABLE 9-V. (CONTINUED)

PARAMETER	PARAMETER ABBREVIATION	TRACE MOVES UPSCALE IF:
b. Drive Tube Torque	Lt or Rt Elevator Drive Tube Torque (Control Arm Force)	Trailing edge up
9. Rudder		
a. Beam Bending	Lt or Rt Rudder Beam Bending	Left surface in tension
b. Drive Tube Torque	Lt or Rt Rudder Drive Tube Torque	Trailing edge to the left
c. Position	Rudder Position	Trailing edge to the right
10. Flaps		
a. Beam Bending	Lt or Rt Flap Beam Bend	Lower survace in tension
b. Drive Tube Torque	Lt or Rt Flap Drive Tube Torque	Trailing edge up
c. Position	Lt or Rt Flap Position	Trailing edge down
11. Flaperons		
a. Beam Bending	Lt or Rt Flaperon Beam Bend	Lower surface in tension
b. Control Arm Force	Lt or Rt Flaperon Con Arm Force	Tube in tension
c. Position	Flaperon Position	Trailing edge down
12. Aileron		
a. Position	Lt or Rt Aileron Pos	Right aileron trailing edge up
13. Engine		
a. RPM	Eng RPM	RPM increases
b. Torque	Eng Torque	Torque increases - engine power output increases
14. Fuel Flow	Fuel Flow	Fuel flow increases

C-4

TABLE 9-V. (CONTINUED)

PARAMETER	PARAMETER ABBREVIATION	TRACE MOVES UPSCALE IF:
15. Main Rotor		
a. Azimuth	M/R Azimuth	Red blade aft = 0° Az
b. Blade Pitch Angle	M/R Pitch Ang	Pitch increases
c. Blade Flapping Angle	M/R Flap	Red blade up
d. Blade Beam Bending	M/R Bl Bm	Lower side in tension
e. Blade Cnord Bending	M/R Bl Ch	Leading edge in tension
f. Trunnion Fork Bending	Trunnion Fork Bend	Leading edge in tension
g. Yoke Extension (Grip/Spindle) Beam Bending	M/R Yoke Ext Bm	Lower side in tension
h. Yoke Extension (Grip/Spindle) Chord Bending	M/R Yoke Ext Ch	Leading edge in tension
i. Swashplate Driver Bending	Swashplate Drive Bend	Leading edge in tension
j. Mast Perpendiculer Bending	M/R Mast Perp	Red blade forward, top of mast to right
k. Mast Parallel Bending	M/R Mast Para	Red blade forward, top of mast aft
l. Mast Torque	M/R Mast Torque	Input torque to main rotor increases (leading edge of main rotor in tension)
m. Pitch Link Axial Force	M/R Pitch Link	Pitch link in tension
n. Spinner - Lower Support Arm		
a) Red Beam Bending	Spinner Support Arm Red Beam Bend	Lower surface in tension

TABLE 9-V. (CONTINUED)

PARAMETER	PARAMETER ABBREVIATION	TRACE MOVES UPSCALE IF:
b) Chord Bending	Spinner Support Arm - Chord Bend	Leading edge in tension
o. Swashplate Motion		
a) Fore and Aft	Swashplate Motion-F/A	Red blade forward Red blade up
b) Lateral	Swashplate Motion-Lat	Red blade outboard Red blade down
16. Hub Spring Motion		
a. Fore and Aft	Hub Spring Motion F/A	Red blade forward Red blade up
b. Lateral	Hub Spring Motion Lat	Red blade outboard Red blade down
17. Actuator Position		
a. Fore and Aft Cyclic	Act Pos - F/A Cyclic	Forward on cyclic stick
b. Lateral Cyclic	Act Pos - Lat Cyclic	Outboard diameter of blade disc down
c. Collective	Act Pos - Coll	Increase pitch - power lever up
18. Control Boost Actuator Axial Force		
a. Fore and Aft Cyclic	Control Boost Act Axial - F/A Cyc	Tube in tension
b. Lateral Cyclic	Control Boost Act Axial - Lat Cyc	Tube in tension
c. Collective	Control Boost Act Axial - Coll	Tube in tension
19. Pylon Conversion Spindle		
a. Beam Bending	Pylon Conv Spindle Beam Bend	Helicopter mode Lower surface in tension
b. Chord Bending	Pylon Conv Spindle Chord Bend	Helicopter mode forward surface in tension

TABLE 9-V. (CONTINUED)

PARAMETER	PARAMETER ABBREVIATION	TRACE MOVES UPSCALE IF:
c. Position	Pylon Conv Spindle Position	Airplane to Helicopter Conv
20. Pitch		
a. Acceleration	Pitch Ang Acc	Ship's nose has upward angular acceleration about pitch axis
b. Attitude	Pitch Att	Nose of helicopter moves upward about pitch axis
c. Rate	Pitch Rate	Nose of ship has upward angular velocity about pitch axis
21. Roll		
a. Acceleration	Roll Accel	Ship has clockwise angular acceleration about roll axis as viewed from behind
b. Attitude	Roll Att	Ship has clockwise motion about roll axis as viewed from behind
c. Rate	Roll Rate	Ship has clockwise angular velocity about roll axis as viewed from behind
22. Yaw		
a. Acceleration	Yaw Ang Accel	Ship's nose has angular acceleration to the right about the yaw axis as viewed from above
b. Attitude	Yaw Att	Ship's nose moves to the right about yaw axis as viewed from above

TABLE 9-V. (CONTINUED)

PARAMETER	PARAMETER ABBREVIATION	TRACE MOVES UPSCALE IF:
c. Rate	Yaw Rate	Ship's nose has angular velocity to the right about the yaw axis as viewed from above
23. Pressures	Pres	Pressure increases
24. Rudder Pedal Position	Rudder Pedal Pos	Motion of right pedal forward
25. Rudder Pedal Force	Rudder Pedal Force	Right pedal up scale
26. Horizontal Stabilizers		
a. Beam Bending	Horiz Stab Beam Bending	Lower surface in tension
b. Torque	Horiz Stab Beam Bending	Leading edge up, trailing edge down
c. Chord Bending	Horiz Stab Chord Bending	Leading edge in tension
27. Vertical Fin		
a. Beam Bending	Fin Lat Bending	Tail fin bends to the right as viewed from rear
b. Chord Bending	Fin F/A Bending	Leading edge of fin in tension
c. Torque	Fin Torq	Leading edge to the right
28. Temperature	Temp	Increasing temperatures
29. Vibration		
a. Fore and Aft	F/A Accel	Ship accelerates forward
b. Lateral	Lat Accel	Ship accelerates to the right
c. Vertical	Vert Accel	Ship accelerates upward

TABLE 9-V. (CONTINUED)

PARAMETER	PARAMETER ABBREVIATION	TRACE MOVES UPSCALE IF:
30. Nose Boom Vanes		
a. Angle of Attack	Angle of Attack	Nose of horizontal vane moves down
b. Angle of Sideslip	Angle of Sideslip	Nose of vertical vane moves to right
31. SCAS Actuator Position		
a. Fore and Aft	F/A SCAS Pos	1" forward step input applied to cyclic stick from a static position
b. Lateral	Lat SCAS Pos	1" right step input applied to cyclic stick from a static position
c. Directional	Dir SCAS Pos	1" forward step input applied to right pedal from a static position NOTE: SCAS traces will return to zero following completion of step input.
32. Swashplate Drive Links	Swplate Drive Link	Leading edge in tension
33. Swashplate Anti-Drive Links	Swplate A/D Link	Right side in tension as viewed from rear
34. Main Landing Gear		
a. Trunnion Arm Vertical Bending	Main Land Gear - Trunnion Arm Vert Bend	Lower surface in tension
b. Oleo Strut Fore and Aft Bending	Main Land Gear - Oleo Strut F/A	Aircraft forward - upscale (aft on wheels - upscale)
c. Oleo Strut Lateral Bending	Main Land Gear - Oleo Strut Lat Bend	Aircraft right - Upscale (left on wheels - upscale)

TABLE 9-V. (CONTINUED)

PARAMETER	PARAMETER ABBREVIATION	TRACE MOVES UPSCALE IF:
d. Drag Strut Axial Force	Main Land Gear - Drag Strut Axial	Link in tension
e. Actuator Position	Main Land Gear - Act Pos	Landing gear down - full upscale (extend goes upscale)
f. Oleo Extension Position	Main Land Gear - Oleo Ext Pos	Extend goes upscale
35. Nose Landing Gear		
a. Trunnion Vertical Bending	Nose Land Gear - Trunnion Vert Bend	Lower surface in tension
b. Oleo Strut Fore and Aft Bending	Nose Land Gear - Oleo Strut F/A Bend	Aircraft forward - upscale (aft on wheels - upscale)
c. Oleo Strut Lateral Bending	Nose Land Gear - Oleo Strut Lateral Bend	Aircraft right - upscale (left on wheels - upscale)
d. Drag Strut Axial Force	Nose Land Gear - Drag Strut Axial	Link in tension
e. Actuator Position	Nose Land Gear - Act Pos	Landing gear down - full upscale (extend goes upscale)
f. Oleo Extension Position	Nose Land Gear - Oleo Ext Pos	Extend goes upscale
g. Steering Position	Nose Land Gear - Steer Pos	Nose of ship moves to right
36. Wing		
a. Panel Bending	Wing - Panel Bend	Panel in tension
b. Beam Bending	Wing - Beam Bend	Lower surface in tension
c. Chord Bending	Wing - Chord Bend	Leading edge in tension
d. Torque	Wing - Torque	Leading edge up

TABLE 9-V. (CONTINUED)

PARAMETER	PARAMETER ABBREVIATION	TRACE MOVES UPSCALE IF:
e. Shear - Right Wing	Item S630 - Front Spar Upper Shear WS 66.0	Airplane to helicopter conversion
	Item S631 - Front Spar Lower Shear WS 66.0	Helicopter to airplane conversion
	Item S632 - Rear Spar Upper Shear WS 66.0	Helicopter to airplane conversion
	Item S633 - Rear Spar Lower Shear WS 66.0	Airplane to helicopter conversion
	Item S634 - Front Spar Upper Shear WS 142.0	Helicopter to airplane conversion
	Item S635 - Front Spar Lower Shear WS 142.0	Airplane to helicopter conversion
	Item S636 - Rear Spar Upper Shear WS 142.0	Airplane to helicopter conversion
	Item S637 - Rear Spar Lower Shear WS 142.0	Helicopter to airplane conversion
37. Fuel Control Lever Position	Fuel Cont Lever Pos	Forward on lever (throttle)
38. Flap Control Lever Position	Flap Cont Lever Pos	(Trailing edge down)
39. Differential Cyclic Washout Actuator Position	Diff Cyc Washout Act Pos	Increase airspeed
40. Control Tube Bending		
a. Lateral Bending	Lat Cont Tube Bend	Left side in tension
b. Vertical Bending	Vert Cont Tube Bend	Bottom side in tension

TABLE 9-V. (CONCLUDED)

PARAMETER	PARAMETER ABBREVIATION	TRACE MOVES UPSCALE IF:
c. Fore and Aft Bending	F/A Cont Tube Bend	Aft side in tension

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TABLE 9-VI.

XV-15 (MODEL 301) THERMOCOUPLE SETUP SHEET

ENGR. ______________ SHIP NO. ______ DATE ________

TECH. ______________ FLT NO. ______ G/R NO. ________

TEST PURPOSE ______________ EWA ________ DLN ________

TEMPERATURE SCANNER NO. 1 - LEFT PYLON			
CHAN	T/C TYPE	LOCATION	ITEM CODE
100	CR-AL	Left Engine, T-7 Harness	T524
101	CR-AL		
102	CR-AL		
103	CR-AL		
104	1-CN	Left Transmission Case - Inlet	T513
105	1-CN		
106	1-CN		
107	1-CN		
108	1-CN		
109	1-CN	Left Engine, IAT at 0°	T513
110	1-CN	Left Engine, IAT at 120°	T513
111	1-CN	Left Engine, IAT at 210°	T513
112	1-CN	Left Transmission Case - Conversion Axis	T513
113	1-CN	Left Transmission Case - Swivel	T513
114	1-CN	Left Engine, Oil Cooler Inlet	T513
115	1-CN	Left Transmission Case - Inlet	T513
116	1-CN	Left Rotor Hub Spring Bearing	T513
117	1-CN	Left Engine, No. 2 Oil Bearing Scavenge	T513
118	1-CN		
119	1-CN		
120	1-CN		
121	1-CN		
122	1-CN		
123	1-CN		
124	1-CN	Left Transmission - Oil Inlet	T513
125	1-CN	Left Transmission - Oil Outlet	T513
126	1-CN		
127	1-CN		
128	1-CN		
129	1-CN		

TABLE 9-VI (CONTINUED).

XV-15 (MODEL 301) THERMOCOUPLE SETUP SHEET

ENGR. ______ SHIP NO. ______ DATE ______

TECH. ______ FLT NO. ______ G/R NC ______

TEST PURPOSE ______ EWA ______ DLN ______

TEMPERATURE SCANNER NO. 2 - FUSELAGE			
CHAN	T/C TYPE	LOCATION	ITEM CODE
200	CR-AL		
201	CR-AL		
202	CR-AL		
203	CR-AL		
204	1-CN	Drive Shaft Hanger Bearing - Cvrsn Spdl, RH	T351
205	1-CN	Drive Shaft Hanger Bearing - Outboard, RH	T351
206	1-CN	Drive Shaft Hanger Bearing - Inboard, RH	T351
207	1-CN	Drive Shaft Hanger Bearing - Cvrsn Spdl, LH	T351
208	1-CN	Drive Shaft Hanger Bearing - Outboard, LH	T351
209	1-CN	Drive Shaft Hanger Bearing - Inboard, LH	T351
210	1-CN	Outside Air	
211	1-CN		
212	1-CN		
213	1-CN		
214	1-CN	Center Gearbox	
215	1-CN		
216	1-CN		
217	1-CN		
218	1-CN		
219	1-CN		
220	1-CN		
221	1-CN		
222	1-CN		
223	1-CN		
224	1-CN		
225	1-CN		
226	1-CN		
227	1-CN		
228	1-CN		
229	1-CN		

TABLE 9-VI (CONCLUDED).

XV-15 (MODEL 301) THERMOCOUPLE SETUP SHEET

ENGR. ____________ SHIP NO. ______ DATE ______

TECH. ____________ FLT NO. ______ G/R NO. ______

TEST PURPOSE ____________ EWA ______ DLN ______

TEMPERATURE SCANNER NO. 3 - RIGHT PYLON			
CHAN	T/C TYPE	LOCATION	ITEM CODE
300	CR-AL	Right Engine, T-7 Harness	T531
301	CR-AL	Right Engine, Exhaust Diffuser	T531
302	CR-AL	Right Engine, Axial Compressor	T531
303	CR-AL	Right Engine, Centrifugal Compressor	T531
304	1-CN	Right Engine, Compressor Diffuser	T506
305	1-CN	Right Engine, Ignition Unit	T506
306	1-CN	Right Engine, Igniter Solenoid Valve	T506
307	1-CN		
308	1-CN		
309	1-CN	Right Engine Inlet Housing	T506
310	1-CN	Right Engine Accessory Housing	T5[illegible]6
311	1-CN	Right Engine Oil Cooler Inlet	[illegible]6
312	1-CN	Right Engine Fuel Control	[illegible]06
313	1-CN	Right Engine No. 2 Bearing Oil Scavenge	T506
314	1-CN	Right Engine Airbleed Control	T506
315	1-CN	Right Engine Thermocouple Harness	T506
316	1-CN	Hub Spring Bearing	T506
317	1-CN	Right Engine N_1 Tach Generator	T506
318	1-CN	Right Engine Ambient	T506
319	1-CN		
320	1-CN		
321	1-CN	Right Transmission Case - Inlet	T506
322	1-CN		
323	1-CN	Right Transmission Case - Ambient	T506
324	1-CN		
325	1-CN	Right Transmission Case - Oil Inlet	T506
326	1-CN	Right Transmission Case - Oil Outlet	T506
327	1-CN	Right Transmission Case - Conversion Axis	T506
328	1-CN	Right Transmission Case - Swivel	T506
329	1-CN		

TABLE 9-VII.

XV- 5 (MODEL 301) SCANNIVALVE SETUP SHEET

LEFT ENGINE INLET

PORT NO.	LOCATION	ITEM CODE
1	Left Engine Bellmouth, 0-Deg, Pos 1	P512
2	Left Engine Bellmouth, 0-Deg, Pos 2	P512
3	Left Engine Bellmouth, 0-Deg, Pos 3	P512
4	Left Engine Bellmouth, 0-Deg, Pos 4	P512
5	Left Engine Bellmouth, 40-Deg, Pos 5	P512
6	Left Engine Bellmouth, 40-Deg, Pos 6	P512
7	Left Engine Bellmouth, 40-Deg, Pos 7	P512
8	Left Engine Bellmouth, 40-Deg, Pos 8	P512
9	Left Engine Bellmouth, 80-Deg, Pos 9	P512
10	Left Engine Bellmouth, 80-Deg, Pos 10	P512
11	Left Engine Bellmouth, 80-Deg, Pos 11	P512
12	Left Engine Bellmouth, 80-Deg, Pos 12	P512
13	Left Engine Bellmouth, 120-Deg, Pos 13	P512
14	Left Engine Bellmouth, 120-Deg, Pos 14	P512
15	Left Engine Bellmouth, 120-Deg, Pos 15	P512
16	Left Engine Bellmouth, 120-Deg, Pos 16	P512
17	Left Engine Bellmouth, 160-Deg, Pos 17	P512
18	Left Engine Bellmouth, 160-Deg, Pos 18	P512
19	Left Engine Bellmouth, 160-Deg, Pos 19	P512
20	Left Engine Bellmouth, 160-Deg, Pos 20	P512
21	Left Engine Bellmouth, 200-Deg, Pos 21	P512
22	Left Engine Bellmouth, 200-Deg, Pos 22	P512
23	Left Engine Bellmouth, 200-Deg, Pos 23	P512
24	Left Engine Bellmouth, 200-Deg, Pos 24	P512

TABLE 9-VII (CONCLUDED)

XV-15 (MODEL 301) SCANNIVALVE SETUP SHEET

LEFT ENGINE INLET

PORT NO.	LOCATION	ITEM CODE
25	Left Engine Bellmouth, 240-Deg, Pos 25	P512
26	Left Engine Bellmouth, 240-Deg, Pos 26	P512
27	Left Engine Bellmouth, 240-Deg, Pos 27	P512
28	Left Engine Bellmouth, 240-Deg, Pos 28	P512
29	Left Engine Bellmouth, 280-Deg, Pos 29	P512
30	Left Engine Bellmouth, 280-Deg, Pos 30	P512
31	Left Engine Bellmouth, 280-Deg, Pos 31	P512
32	Left Engine Bellmouth, 280-Deg, Pos 32	P512
33	Left Engine Bellmouth, 320-Deg, Pos 33	P512
34	Left Engine Bellmouth, 320-Deg, Pos 34	P512
35	Left Engine Bellmouth, 320-Deg, Pos 35	P512
36	Left Engine Bellmouth, 320-Deg, Pos 36	P512
37	Left Engine Bellmouth, Static	P512
38	Tailpipe, 45-Deg	P512
39	Tailpipe, 135-Deg	P512
40	Tailpipe, 225-Deg	P512
41	Tailpipe, 315-Deg	P512
42	Engine Compartment, Rt Outboard	P512
43	Engine Compartment, Rt Inboard	P512
44	Engine Compartment, Lt Outboard	P512
45	Engine Compartment, Lt Inboard	P512
46	Engine Compartment, Static	P512
47		
48		

TABLE 9-VIII. XV-15 PREFLIGHT CHECKLIST.

STEP NO.	PROCEDURE	CHECK
1.	Turn on system power. Master power switch on pilot's info panel. (Allow 15 minutes warmup before beginning preflight.)	( )
2.	Hook up flight line tester to RMDU-1.	( )
3.	Have shop connect hydraulic boost cart and turn on.	( )
4.	Install null fixtures:	
	a. 50% rudder pedal	( )
	b. 50% F/A and lateral stick	( )
	c. 0% - full down power lever	( )
	d. 0% on throttle (not flight idle)	( )
	e. 0° on flap control	( )
	f. 95° pylon conversion (helicopter mode).	( )
	g. Governor wheel as low as it can be turned without moving the power lever.	( )
5.	Turn off hydraulic boost (DO NOT REMOVE).	( )
6.	Put following in reference position:	
	a. Oleo extension and actuator potentiometers fully retracted (nose, LHLG and RMLG).	( )
	b. 0° clamps on YAPS head (angle of attack and angle of sideslip).	( )
	c. Turn OAT and altitude reference switch (on program board) to reference.	( )
	d. Pull torque system circuit breaker (eng. torque sig. cond.) located on panel to left of cockpit doorway. LEAVE CROSS SHAFT SIGNAL CONDITIONER ON.	( )
	e. Pull fuel quantity circuit breaker (fuel qty.) on overhead panel for Rt and Lt fuel quantity (tank) zeros.	( )

TABLE 9-VIII. (CONTINUED)

STEP NO.	PROCEDURE	CHECK
6.	f. Check to insure that both of the ships inverters are on. *NOTE: Ship's inverters must be on for Rt and Lt pylon conversions position zeros.	( )
7.	Check scannivalve to insure it steps in the auto mode. Start prime data and listen to the unit as it steps through one complete cycle. Open active network panel and turn temperature and scannivalve reference switch to reference (switch located between cards 16 and 17). Dial in Channel 329 on temperature readout in copilot's panel.	( )
8.	By using scanner switch on copilot panel, step through all thermocouples to insure all are operating. Good channels should read room temperature (assuming ship has not been running), bad or open channels should read randomly changing number.	( )
*9.	Using the flight line tester, dial through all channels and check all zeros against preset zeros. Fix or flag any problems	( )
*10.	Turn on R-Cals and check values against pre R-Cal values. Fix or flag any problems.	( )
	*A program to let the computer do these functions by use of the telemetry link is being completed.	
11.	Hook up RMDU-2 to the flight line tester and repeat steps 9 and 10.	( )
12.	Set correct record number at pilot's info panel.	( )
13.	Turn on time code generator and check to see if it is functioning properly.	( )
14.	Set correct time in time code generator.	( )
15.	Load tape on tape deck.	( )
16.	Run 30 second leader and turn off tape deck.	( )
17.	Call Ground Data Center for telemetry preflight.	( )
18.	Turn on telemetry transmitter.	( )

TABLE 9-VIII. (CONTINUED)

STEP NO.	PROCEDURE	CHECK
*19.	When requested press R-Cal switch, wait two seconds, release R-Cal switch, wait two seconds, press R-Cal switch, wait two seconds, then release R-Cal switch.	( )
*20.	Ground Data Center checks zeros.	( )
*21.	Ground Data Center checks R-Cals.	( )
	*When the before-mentioned computer program is used, Step 19 is performed, but while the system is in Prime Data, Steps 19, 20 and 21 are repeated (while in Prime Data) with RMDU-A connected to the telemetry transmitter. Switch to put RMDU-A on TM is located on auxiliary instrumentation pallet.	
22.	Turn on tape deck (at the same time Ground Data Center turns on the telemetry tape deck).	( )
23.	Press prime data switch and run 10 second reference record; press prime data switch second time to get system out of prime data.	( )
24.	Press prime data switch and run R-Cal record (repeat Step 19)(2-2 second R-Cals). Press prime data switch second time to get out of prime data.	( )
25.	Turn off tape deck.	( )
26.	Remove null fixtures.	( )
27.	Turn on hydraulic boost.	( )
28.	Turn on tape deck.	( )
29.	Run full throw record (for onboard tape and telemetry tape).	( )
30.	Turn off tape deck.	( )
31.	Turn off telemetry transmitter.	( )
32.	Check visual indication (full throws).	( )
33.	Disconnect flight line tester.	( )

TABLE 9-VIII. (CONCLUDED)

STEP NO.	PROCEDURE	CHECK
34.	Turn off system power.	( )
35.	Put the following in data position:	
	a. 90° pylon conversion	( )
	b. Connect oleo extension string position cables (nose, LMLG and RMLG).	( )
	c. Remove 0° clamps from YAPS head.	( )
	d. Turn OAT and altitude reference switch to data.	( )
	e. Open active network panel and turn temperature and scannivalve reference switch to data.	( )
	f. Push in engine torque signal conditioner circuit breaker.	( )
	g. Push in fuel quantity (tank) circuit breaker.	( )
	h. Turn off both ships inverters.	( )
36.	Disconnect hydraulic boost cart.	( )
37.	Sign off preflight item in ship's workbook and instrumentation preflight sheet.	( )

SECTION 10. MAINTENANCE

This section covers special tools and test equipment, alignment and calibration instruction, scheduled inspections, testing and troubleshooting, and recommended spare parts required to maintain the XV-15 research instrumentation system.

10.1 Ground Support Equipment. Common and peculiar test equipment and special tools required to perform flight line maintenance, testing and troubleshooting, inspections and preflight checks are listed in Table 10-I.

10.2 Flight Line Testing. The Model AIFTDS-4000 flight line tester (Figure 10-1) is a piece of special ground support equipment used to check out and troubleshoot the research instrumentation system. It is a portable test set, designed to operate in conjunction with a remote multiplexer/demultiplexer unit (RMDU) configured with a stand-alone timing card (SAT-M). The flight line tester will operate at any frame rate, word length and bit rate provided from the RMDU. It acts as a combined bit and frame synchronizer capable of receiving and decoding the IRIG Serial PCM data stream from the RMDU and displaying any single channel of data manually selected from the PCM format. As a plug-in option to the basic unit, the flight line tester can verify operation of the Sperry 1819A computer (or any other computer) interface card installed in the RMDU.

The flight line tester contains a power supply assembly which can be operated from 115 Vac, 400 Hz power.

10.2.1 Input Signals. Signal inputs to the flight line tester from the RMDU PCM output connector are transmitter output, tape recorder output, PCM-frame sync pulse and PCM clock. The signal input lines are differential and conform electrically to the output characteristics of the SAT-M line drivers, which are capable of driving a 250-foot twisted pair shielded cable.

10.2.2 Controls and Displays. Controls are defined as below:

a. Data point selection control: Locates
   (1) Subframe number, and
   (2) Word number

b. Display rate sample control: Controls
   (1) Continuous display, or
   (2) One of 8 detented sample rates

c. Port selector: Selects signal from
   (1) Transmitter port, or
   (2) Tape recorder port

d. Decoder selector: Selects from one of
   (1) NRZ-L
   (2) NRZ-M
   (3) Bi-phase-L
   (4) Bi-phase-M
   (5) Miller

e. Display control
   (1) Hold
   (2) Reset
   (3) Lamp test

f. Test/monitor mode control: Selects
   (1) Test, or
   (2) Simultaneous monitoring

g. Gain display

h. Data value display

i. Discrete data display

j. Buffered output (BNC)
   (1) Transmitted input
   (2) Tape recorder input
   (3) Bit clock
   (4) Frame sync pulse
   (5) Analog output

10.2.3 Operation. The selection of one data word from the PCM format display on the test is achieved by setting two groups of quick action lever type thumbwheel switches requiring only 90 degrees rotation to cover all ten (10) numbers. The two groups of switches control selection of the data cycle subframe and the individual data word of that subframe. The data word from the PCM format is trapped, decoded and displayed on the numberical indicators along with the gain tag bit. The data word is also displayed in binary form on the 12-bit indicator lamps. One switch controls data selection between the RF transmitter line and the tape recorder line from the SAT-M so that both outputs may be verified. A display sample rate control switch controls the display update rate. The test set can provide continuous updates of the displayed data or controlled samples per second updates so that bit jitter or noise can be measured. There are 8 different sample rates available. Since PCM word rate is a variable, the user may also select a suitable display sample rate for the program.

10.2.3.1 Verifier Option. The mode selector toggle switch selects whether the data being displayed is standard analog/ discrete data or computer I/O verification. In the SC I/O position the verify/fail indicators tell whether the sampled computer words are valid or invalid. If a data transmission failure occurs, the fail light illuminates and stays illuminated until manually reset, and the actual data value is displayed on the numerical data indicators and the 12-bit indicator lamps.

10.2.3.2 Personal Card. The following program variable must be understood by the flight line tester. The task is achieved by inserting of a hard-wire personal card into the system.

- Word size
- Subframe ID word location
- Customized word re-structure
- 2's complement or offset binary code

10.2.3.3 Power Controls. The flight line tester operates from 115 Vac, 400 Hz, 1Ø power. The power control switches are push button switches with integral power on indicator lamps. Power for the test set is less than 50 watts.

10.2.3.4 Mechanical Configuration. The flight line tester is assembled in a lightweight case. The tester case dimensions are: width, 5.75 inches; depth, 6.5 inches; and height, 9 inches.

Parallel signal connectors are provided on the rear side so that the L-band transmitter and digital recorder can be connected to the test set and operated simultaneously to achieve real time dynamic test of the complete RMDU as well as an individual channel data readout. Four buffered test points are available for scope display of each of the four signal lines from the RMDU output.

10.3 Scheduled Maintenance Inspections. This section contains the requirements for preflight, 25-hour, 50-hour, special inspections, and confitional inspections. The inspection intervals designated herein are the maximum allowable and should not be exceeded. Where unusual environmental exposure, utilization rates, or operational modes dictate a higher level of maintenance, it is the responsibility of the operator to increase the scope and frequency of inspections as necessary to ensure efficient operation of the instrumentation and data acquisition system.

10.3.1 Preflight Checks. Preflight checkout procedures for the XV-15 research instrumentation system are given in Table 9-VIII.

10.3.2 25-Hour Inspection. Prior to inspection, remove or open as necessary cowling, fairing inspection doors, and plates.

Instrumentation - right pylon

a. Visually inspect slip ring mounting bracket for condition and security.

b. Visually inspect engine oil cooler outlet thermocouple for security and leakage.

c. Visually inspect engine oil pressure transducer for condition, security and leakage.

d. Visually inspect engine fuel line thermocouple for condition, security and leakage.

Instrumentation - left pylon

a. Visually inspect slip ring mounting bracket for condition and security.

b. Visually inspect engine oil cooler outlet thermocouple for security and leakage.

c. Visually inspect engine oil pressure transducer for condition, security and leakage.

d. Inspect bellmouth temperature thermocouples (induction system) for security and condition.

e. Inspect bellmouth pressure probes (induction system) for security and condition.

10.3.3 50-Hour Inspection. Prior to inspection, remove or open as necessary cowling, fairing, inspection doors and plates.

Instrumentation slip ring

a. Inspect and clean left proprotor instrumentation slip ring as follows:

(1) Remove slip ring package from top of collective head. Refer to Wendon drawings W84-101 and W84-103.

(2) Inspect slip rng for obvious damage or excessive wear. Clean slip ring and inspect brushes for wear. Replace brushes if required.

(3) Check slip ring brushes for proper contact and uniform spring tension.

(4) Reassemble slip ring and install above rotor on top of collective head.

b. Inspect and clean right proprotor instrumentation slip ring as follows:

(1) Remove slip ring package from top of collective head. Refer to Wendon drawings W84-101 and W84-103 (Volume IV).

(2) Inspect slip ring for obvious damage or excessive wear. Clean slip ring and inspect brushes for wear. Replace brushes if required.

(3) Check slip ring brushes for proper contact and uniform spring tension.

(4) Reassemble slip ring and install above rotor on top of collective head.

c. Cable potentiometers

(1) Remove covers of cable potentiometers and clean the cable and interior of the unit.

(2) Apply one drop of instrument oil (for wide temperature range) to the negator spring bearings. (Note: If used in a dusty atmosphere, frequency of cleaning should be increased.)

10.4 Calibration Procedures. Calibration and adjustment of transducers and signal conditioners are in accordance with Section 7. Calibration instructions are specified in the manufacturer's technical data (see Volume IV).

10.5 Testing and Troubleshooting. Testing of the research instrumentation to validate individual measurement channels shall be in accordance with the procedures of Section 9. Troubleshooting, repair, and overhaul of instrumentation equipment shall be in accordance with the manufacturer's recommendation (see Volume IV for contractor furnished equipment).

10.6 Recommended Spare Parts. Recommended spare parts required to support the research instrumentation system through 200 hours of flight research testing are given in Table 10-II.

TABLE 10-I. GROUND SUPPORT EQUIPMENT

GFAE Item No.	Description	Model No./ Part No.	Manufacturer	Usage
1034	Flight Line Tester	P/N 838963	Teledyne	Positive Channel ID
1034AB	Tape Recorder Service Kit	P/N 75001181	Astroscience	Tape Transport Serv and Troubleshoot
1038	ANP Extender Boards	-	-	ANP Card Troubleshoot
1036	Prom Puller	9013	Hexacon	To Remove Intel 1072A Proms in SATM
1035	Head Degausser	200-3C	Amplifier Corp	Tape Transport Maintenance
1033	Remote Monitor Test Unit (RMTU)	94001161	Astroscience	Tape Transport Maintenance
1032	Card Test Fixture	838957	Teledyne	RMDU Maintenance
1031	Card Extractor	838952-1	Teledyne	RMDU Maintenance
1030	Card Extender	838955-1	Teledyne	RMDU Maintenance
1536	Cyclic Stick Rigging Fixture	T-9019921-SPT	Rockwell-Tulsa	Instr

TABLE 10-II. RECOMMENDED SPARES
(CFE PARTS ONLY)

ISPL Item No.	Nomenclature	Part Number	Manufacturer	Recommended Qty
2445	Accelerometer, Engine Vibration	2271A	Endevco	2
2444	Accelerometer, Servo	303T16	Sundstrand	1
2441	Accelerometer, Strain Gage, 10 g	A69TC-25-350	Gould	2
2440	Accelerometer, Strain Gage, 05 g	A69TC-10-350	Gould	2
2439	Accelerometer, Strain Gage, 25 g	A69TC-05-350	Gould	2
2438	Amplifier, Charge, Engine Vibration	2647M77	Endevco	2
2531	Antenna, Telemetry	741L003	BHT	1
2524	Brush Assy, Slip Ring	W120-104-2	Wendon	8
2514	Bulbs, Digital Display	905-503-002	Master Speciality Corp	100
2513	Cables, Program Board (27-inch)	5000909	Mac Panel	100
0268	Circuit Assy, Data Control Word, C/S 17	SKHD3-20-78-1-17	BHT	2
2437	Circuit Assy, Digital Stick Position, C/S 11	SKHD3-20-78-3-11	BHT	2
2436	Circuit Assy, Mean/P-P Detector	301ASW220-1	BHT	2
2454	Circuit Assy, Temperature Scanner, C/S 12	SKHD3-20-78-2-12	BHT	2
2176	Circuit Assy, Temperature Scanner, C/S 13	SKHD3-20-78-2-13	BHT	2
2190	Circuit Assy, Temperature Scanner, C/S 16	SKHD3-20-78-2-16	BHT	2
2506	Connector, Slipring Assy	M1KM6-5-85PH	ITT Cannon Electric	4
2507	Connector, Slipring Cable	M1KM0-5-85SH	ITT Cannon Electric	4
2529	Control Unit, Scanivalve	SKTASW166-2	BHT	2
2453	Converter, Frequency	PI-355-100 Hz	Anadex	4
2020	Converter, Synchro to Linear DC	SLD 214-L-1	Computer Conversions	2
2509	Encoder, Shaft	815-512-IBLP-TTL	Disc	2
2530	Filter Unit, Engine Vibration	301ASW6780-1	BHT	4
2519	Fittings, Thermocouple	SSL-116	Omega	20
2340	Gyro, Attitude	VM02-0110-1	Humphrey	2
2139	Gyro, Rate, 3-Axis	402405	Timex	2
2450	Indicator, Control Position	301075-20	BHT	2
2452	Indicator, Data System Control Monitor	301075-25	BHT	2
2515	Indicator, Critical Function	301075-23	BHT	2
2451	Indicator, Temperature Monitor	301075-22	BHT	2

TABLE 10-II. (Concluded)

ISPL Item No.	Nomenclature	Part Number	Manufacturer	Recom-mended Qty
2160	Inverter, Static, 750 VA	PC-17A	Flite-Tronics	2
2033	Junction, Temperature Reference	TR34-24PP	Validyne	4
2137	Potentiometer, Cable (16 in)	7101-16	Research Inc	4
2511	Potentiometer, Cable (3.5 in)	4046-3 1/2	Research Inc	4
2136	Potentiometer, Linear (6 in)	Series 950	Spectrol	4
2502	Potentiometer, Linear, 12-Inch	80294-2001941502	Bourns	4
2503	Potentiometer, Linear, 6-Inch	3,378,805	Bourns	10
2516	Potentiometer, Rotary, Control	158-116	Spectrol	4
2517	Potentiometer, Rotary, Control	66345-15-102/102	Bourns	8
2510	Potentiometer, Rotary, Single Section (1K)	Series 708	Spectrol	4
2525	Power Supply, Excitation	CC3D3.5	Abbott	1
2528	Power Supply, TDU, 5 Vdc	C28D3.5	Abbott	1
2527	Power Supply, 05 Vdc	C5D5.0	Abbott	1
2526	Power Supply, 16 Vdc	CC15D1.0	Abbott	1
2518	Probe, Thermocouple	1CSS-116G-3 inch	Omega	20
2138	Relay, Temperature Logic Box	MRR2ADLXV	Dunco	100
2532	Sensor, Current Limiter	7235-1-70	Tex Instr	10
2448	Signal Conditioner, OAT	510BF65	Rosemont	1
2159	Slip Ring Assembly	W84-100	Wendon	2
2446	Switch, Pressure Sampling	48J4-1	Scannivalve	1
2520	Transducer, Air Pressure	PM6TC ±2.5-350	[illegible]d	2
2512	Transducer, Airspeed-Altitude	542K2	[illegible]mont	1
2442	Transducer, Oil Pressure (150 psi)	PL822-200	[illegible]	2
2443	Transducer, Oil Pressure (5000 psi)	PA822-5M	Gould	2
2447	Transducer, Outside Air Temp	101AN	Rosemont	2
2508	Transducer, Pressure Sampling Switch	PM131TC-2.5-350	Gould	2

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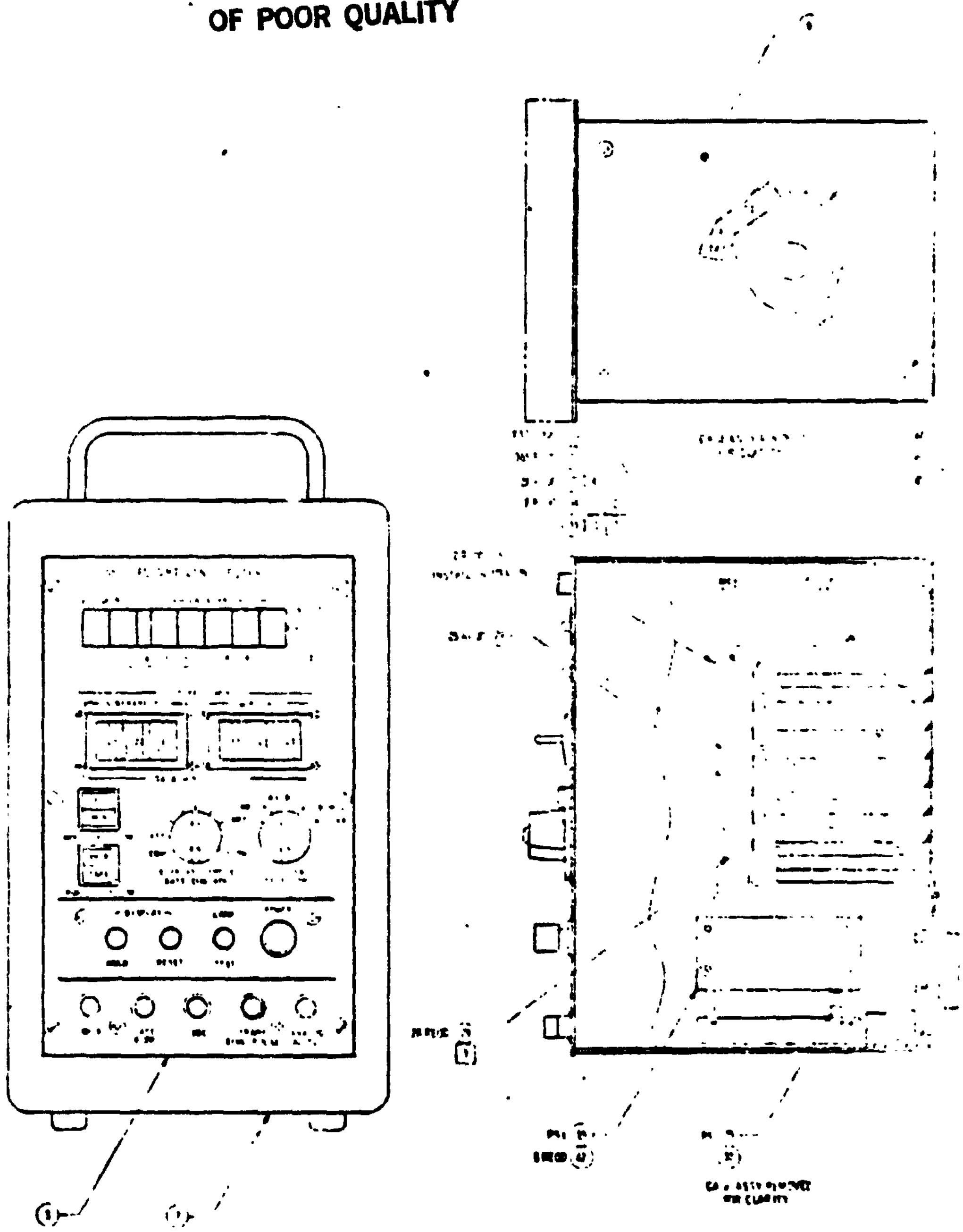


Figure 10-1. Flight line tester.

LIST OF REFERENCES

1. BHT Instrumentation Laboratory Operating Procedure No. 13-OP-0401, "Strain Gaging of Structural Parts Worksheets and Documentation," dated 2-16-77.

2. BHT Engineering Laboratory Group Function No. 80-13-004, "Instrumentation Laboratory - Strain Gaging of Structural Parts," dated 2-16-77.

3. BHT Engineering Laboratory Group Function No. 13-OP-0402, "Instrumentation Lab - Strain Gaging of Structural Parts - Strain Gage Application," dated 4-25-77.

4. BHT Engineering Laboratory Group Functions No. 80-15-005, "Instrumentation Laboratory - Calibration of Strain Gaged Parts," dated 2-16-77.

5. BHT Instrumentation Laboratory Operating Procedure No. 13-OP-0501, "Calibration of Strain Gaged Parts - Acquisition of Calibration Data," dated 12-20-77, Revision A.

6. BHT Instrumentation Laboratory Operating Procedure No. 13-OP-503, "Calibration of Strain Gaged Parts, Documentation and Records," Revision A, dated 3-14-77.

7. BHT IOM 86:ASW:mc-3710, "XV-15 Periodic Calibration of Flight Test Instrumentation," dated 18 August 1978.

Bell Helicopter TEXTRON	INSTRUMENTATION LABORATORY OPERATING PROCEDURES	No. 13-OP-0401 Rev. Date 4-25-77
TITLE STRAIN GAGING OF STRUCTURAL PARTS - WORKSHEETS AND DOCUMENTATION		Prepared by: [illegible] Date 5-2-77 Checked by: [illegible] Date 5-[illegible]-77 Approved by: [illegible] Date 5-11-77

GENERAL: The Instrumentation Laboratory has responsibility for all strain gage laboratory worksheets. These sheets include most of the information necessary for gaging test parts, and become a permanent record for future reference.

REFERENCE: Engineering Laboratories Group Function 80-13-004, Instrumentation Laboratories Strain Gaging of Structural Parts.

PROCEDURE:

1.0 DESCRIPTION - The strain gage lab work sheet is designed to contain most of the information necessary to determine where gages should be applied to a structural part. A sketch of the structural part shows gage locations and needed reference points for measuring these locations. Spaces are also provided to record strain gage information such as type, resistance, factor and lot number. Other spaces are provided for date, bridge balance, resistance to ground, technicians name, and current work order, EWA and DLN

2.0 COORDINATION WITH REQUESTOR - Before a lab worksheet can be started, various information must be acquired. This includes (a) correct EWA, (b) priority, schedule, (c) special requirements and any other information necessary to perform the task.

3.0 GAGE SELECTION AND PLACEMENT - Specific information is needed from the Structures Group on what type of gage installation is necessary and at what places they should be applied. The normal installation at BHT is usually one of the following (a) bending, (b) torsion, (c) axial, (d) rosette, or (e) a single active arm uniaxial gage, most often referred to as a stress gage. Four active arm bridges, measuring either bending, torsion or axial loads are the ones most commonly selected. These bridges are more stable during changes of temperature and with an accurate calibration provide very reliable data. When the necessary information has been received, a work sheet can then be started.

4.0 DRAWING OF WORKSHEET - Form No. 7872 55420 is used for the actual drawing. These drawings are not as critical as blueprints and are intended to be a guide for the strain gage technician. An original is made with pencil and Xerox copies are distributed as follows. One copy goes to the technician doing the work. After the gage work is complete, this copy is returned to the technician supervisor. Information is transferred from this copy and will be retained as the file copy. Two copies go the the Instrumentation Test Operations Group, one to the Mechanical Lab Calibration Engineer and one to the Instrumentation Calibration Technician. This is done if the part is for flight test. If the part is for fatigue test, the two normally going to Flight Test are not used. This distribution is the normal route and is sufficient for most parts.

5.0 ASSIGNMENT OF PROJECT - The assignment of parts to be gaged is usually done by the Technician Supervisor. Assignments are made after considering the workload, Technician abilities, time element and any other factors that may affect the job. Strain gaging, particularly the smaller parts, requires very special handling. In this respect, assignments are made accordingly.

6.0 CHECK AND FILE WORK SHEET - Upon completion of gaging, the worksheet must be finished. The technician completes all information as shown in paragraph 1.0, then gives it to the Technician Supervisor who files the original and distributes the rest as noted in paragraph 4.0. Filing is done by lab numbers for future reference.

No. 13-OP-0401

INSTRUMENTATION LABORATORY WORK SHEET

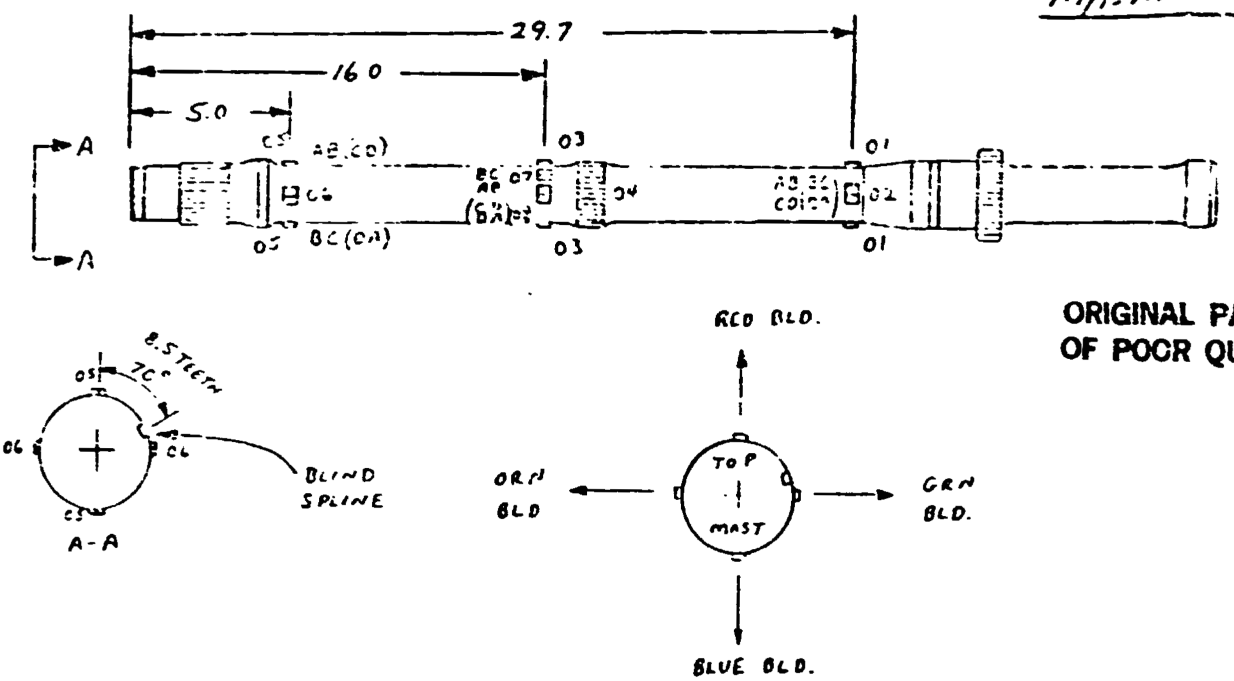
MODEL NO 206 LM	GAGE TYPE EA-06-250MQ-350	EA-06-125TK-350	SHEET NO 691254
EWA NO 292AZJ1.31	RESISTANCE 350Ω	350Ω	LAB NO 11437A
WORK ORDER 4645	GAGE FACTOR Q-A35AL14	2.07 ± 0.5%	PART NO 206-040-365-1
REQUESTED BY W. CRESAP	LOT NO 2.09 ± 0.5%	Q-A21AD164	SERIAL NO NJF-1

TITLE OF TEST

MODEL 206 LM FLIGHT TEST

SKETCH:

M/R MAST



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REMARKS

INSTALL BENDING AND TORSION BRIDGES AS SHOWN. USE BR-600 CEMENT. APPLY FLAT TERMINALS AT APPROX STA. 150 AND 21.0 COVER WITH 9309. APPLY PAINT STRIPES TO MAST OF COLORS INDICATED AT STA 13.0 1" x 0.5"

	PARA RED/BLUE	PERP ORN/GRN	PARA. RED/BLUE	PERP ORN/GRN	PARA RED/BLUE	PERP ORN/GRN		
BRIDGE	BND 29.7-01	BND 29.7-02	BND 16.0-03	BND 16.0-04	BND 5.0-05	BND 5.0-06		TORS 16.0
BALANCE (mv/v)	1.26	-0.94	-0.02	10.56	-0.26	±0.20		+0.11
RES TO GROUND	10KM	10KM	10KM	10KM	10KM	10KM		10KM

DATE ASSIGNED 1-2?-77	TECHNICIAN [illegible]	EST HRS	APPROVED BY
DATE COMPLETED 1-2?-77	ENGINEER	ACT HRS	

RF-4

No.13-OP-0401

INSTRUMENTATION LABORATORY WORK SHEET

MODEL NO	GAGE TYPE	SHEET NO
ENG NO	RESISTANCE	LAB NO
WORK ORDER	GAGE FACTOR	PART NO
REQUESTED BY	LOT NO	SERIAL NO

TITLE OF TEST

SKETCH

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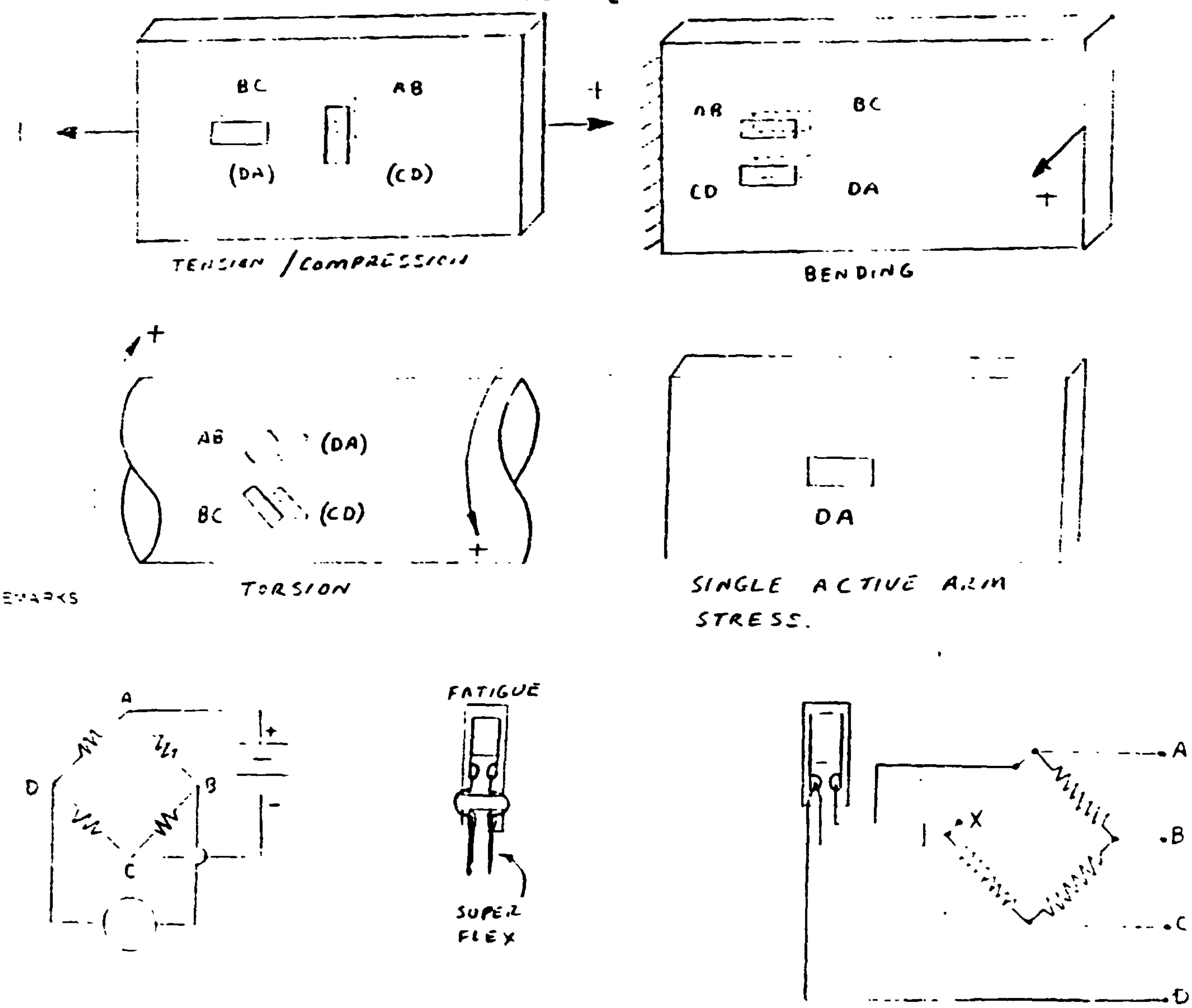

REMARKS

BRIDGE								
BALANCE								
RES. TO GROUND								

DATE ASSIGNED	TECHNICIAN	EST HRS	APPROVED BY
DATE COMPLETED	ENGINEER	ACT HRS	RF-5

Bell Helicopter TEXTRON	ENGINEERING LABORATORIES GROUP FUNCTIONS	No. 80-13-001 Rev. Date 2-16-77
TITLE	INSTRUMENTATION LABORATORY - STRAIN GAGING OF STRUCTURAL PARTS	Prepared by: [illegible] Date [illegible] Checked by: [illegible] Date [illegible] Approved by: [illegible] Date [illegible]

GENERAL: The Instrumentation Laboratory applies strain gages to structural parts for flight tests, fatigue tests, R&D Lab and other tests.

REFERENCES: None

FUNCTIONS:

1. Worksheets and Documentation - Group 13 coordinates with Project, Design, and Laboratory personnel to determine the location and quantity of strain gages to be applied. A laboratory worksheet is then prepared to describe and document all pertinent facts regarding the installation procedure to be used by the strain gage technician.

2. Strain Gage Application - With the worksheet as a guide, the strain gage technician follows established laboratory procedures and practices to accomplish the strain gage application.

3. Quality Control - Each strain gaged part is thoroughly inspected by Group 13 supervisory personnel prior to and after calibration. Each part must meet established performance standards for bridge balance, resistance to ground, linearity, cross talk, etc.

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Bell Helicopter TEXTRON	ENGINEERING LABORATORIES GROUP FUNCTIONS	No. 13-OP-0402 Rev. Date 4-25-77

TITLE INSTRUMENTATION LAB - STRAIN GAGING OF STRUCTURAL PARTS - STRAIN GAGE APPLICATION	Prepared by: [signature] Date 5-11-77 Checked by: [signature] Date 5-11-77 Approved by: [signature] Date 5-11-77

GENERAL: Application of all strain gages at BHT is the responsibility of the Instrumentation Lab, Group 13.

REFERENCES: Engineering Lab Group Function 80-13-004, Instrumentation Lab Strain Gaging of Structural Parts.

FUNCTION:

1. ASSIGNMENT AND DISCUSSION OF PROJECT - The Instrumentation Lab Technician Supervisor has responsibility for assigning strain gage jobs to individual technicians. Some of the things considered are scope of job, technician capabilities, location and time necessary for completion. At the time of assignment, some questions about the project that may come up are discussed. These questions may be concerned with special instructions not covered on the work sheet or something not considered as general practice. Most items gaged are general in application and very little discussion is necessary.

2. DIMENSIONAL LAYOUT OF PART FOR GAGING - Most dimensions for strain gaged parts are shown on the lab work sheet. If not, verbal instructions are necessary. Dimensional tolerances are usually given in hundredths so as to place the gage very close to the desired area as wanted by the requesting group. A close tolerance installation is a very necessary part of the final outcome of a test.

3. CLEANING OF PART - Cleaning of parts for strain gaging has one main function - to get down to the basic material that is to be gaged. Paint, plating, or other covering must be removed in order to expose the basic material. If a part is painted, either sanding or paint stripper is used. Diluted ammonium hitrate is used for stripping cad plate. In addition to removing paint, etc., from parts, a good bonding surface is necessary. This can be achieved by vapor blasting, sand blasting, sanding, grinding, or some surfaces, just cleaning. Vapor blasting is the preferred method to prepare the surface. Steel parts must also have metal conditioner applied to prevent rust from forming. When the surface is properly prepared the next step is cleaning. On steel, aluminum and fiberglass, ammonia cleaning detergent is used to remove oil. This is followed by several applications of acetone. A cotton swab will show no trace of dirt when completely clean. All titanium parts must be heated to approximately 50°F above the M-bond adhesive curing temperature, wiping with acetone and repeated three times. This drives the oil out of the pores of the metal. After this treatment, titanium can be cleaned in the normal manner. A clean area is absolutely necessary for bonding of gages.

4. APPLICATION OF GAGES - Gages can be applied in several ways, however two preferred methods are used at BHT. The first and best method is using M-Bond 600. This is a heat and pressure curing method which

gives excellent stability and long life. Complete instructions are given in the lab notebook IL-B-001A (copy attached). The second, less desirable method, is with Eastman 910. This is a cyanoacrylate contact bonding agent. The time involved for installation is less but so is the expected life of the adhesive. This type of installation is used mostly on items that cannot be readily heated, off-site installations, tail booms, fuselages and short term tests. About one year is the expected life of a 910 installation. Some special techniques have been developed by several technicians for using 910 but in general, following instructions given in micro-measurement instruction bulletin B-127 (copy attached) is sufficient. The main difference between this instruction and actual use in the Instrumentation Lab is substituting 3M 5490 teflon tape in place of cellophane tape.

5. CURING OF ADHESIVES - As 910 is a contact adhesive only M-Bond 600 will be discussed. For proper curing, M-Bond 600 requires a clamping pressure of 10 to 70 psi with 30 to 40 psi as the optimum. Several curing cycles, dependent on temperature, can be used. They are five hours at 150°F, two hours at 180°F, and one hour at 225°F with eight hours at 125°F used on occasion. Either one of these cycles can be used for a good long lasting cure.

6. WIRING OF BRIDGES - Wiring of bridges for flight test is done in a conventional manner using single strand, color coded, teflon insulated wire. The four gages of a bridge are labeled: AB - BC - CD - DA. An accompanying drawing shows the various methods of bridge layout for bending, torsion, axial, and single active arm stress. Fatigue test requires a different approach due to the higher loads encountered. Gages are wired to a flat terminal using a small loop of wire to relieve high strains. This is referred to as a "Kitty Whisker". Using this method in conjunction with multistranded superflex wire has resulted in very good fatigue life.

7. CHECKOUT OF BRIDGES - Checkout of bridges is covered in Procedure 13-OP-0403, Strain Gaging of Structural Parts, Quality Control.

8. COVERING OF INSTALLATION - As protection is needed to keep the strain gages in good operating condition, a covering is used over all gages for most tests except fatigue tests. The covering used is Hysol 9309 Epoxy. This covering also provides a small degree of mechanical protection, and is clear enough so that visual observation of the gages can be maintained.

9. COMPLETION OF WORK SHEET - All work sheets are completely filled out with necessary information and kept in a file in the Instrumentation Lab. This is covered in Procedure 13-GP-931, Strain Gaging of Structural Parts, Worksheets and Documentation.

REVISION A (3-24-72)

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STRAIN GAGE APPLICATIONS WITH M-BOND 600 ADHESIVES

I. INTRODUCTION

Micro-Measurement M-Bond 600 Adhesive is a high performance epoxy resin formulated specifically for bonding strain gages, temperature sensor gages, and S/N' Fatigue Life Gages. When properly cured, it is useful from -452°F to over 700°F for short-term tests. In common with most other materials, life is limited by oxidation and sublimation effects at elevated temperatures.

II. MIXING INSTRUCTIONS

1. Resin and curing agent bottles must be at room temperature before opening.

2. Using the disposable plastic funnel, pour the curing agent Part B into the resin bottle containing Part A. Drain curing agent until it takes two (2) seconds for a drop to form on lip of Part B bottle.

3. After replacing the brush-cap, shake the bottle vigorously for 10 seconds to mix.

4. The freshly-mixed adhesive should be allowed to stand for at least 10 minutes before use.

5. Write the mixing date in the space provided after the bottles have been mixed. The mixed shelf life is approximately two weeks. However, when adhesive begins to thicken, it should be discarded.

III. SURFACE PREPARATION

1. Using ink pen or pencil, mark off gage location areas per instructions on lab work sheet.

2. Remove all foreign matter (paint, oxide, scale, etc.) from surface in gage area, using either one or a combination of the following: paint stripper (D lchem 2236-A), abrasive wheels turned by air motors, fiberglass brushes or 180 grit sandpaper. On blades, etc., lead-in wires can be routed on top of primer. Cadmium

plating must be removed from steel parts, in gage and wire routing areas, by use of cad stripper (Ammonium Nitrate 50% - Water 50%). Use acetone to neutralize cad stripper or water to neutralize paint stripper.

3. Have specimen degreased or degrease in lab with solvents. To degrease titanium parts, heat to a temperature of 50°F above the curing temperature that will be used and clean with acetone. Repeat this step three (3) times before applying gages to titanium parts.

4. Sand or vapor blast gage areas when possible or abrade the surface with metal conditioner (Budd No. 1) and clean with ammonia followed by acetone.

5. Using ink pen, mark gage location points per lab work sheet.

IV. GAGE PREPARATION

1. All currently available micro-measurements gages, except the H-backed series, do not require a pre-cleaning before application unless contaminated during handling, which we assume always happens. The gages may be cleaned on the bonding side by using a cotton applicator moistened with acetone.

2. Remove gage from acetate envelope with tweezers and place on a chemically clean glass or metal plate or the gage box with the bonding side of the gage down.

3. Press a strip, approx. 2 or 3 inches long, of Scotch Brand Teflon Film Plastic Tape No. 549 across gage, either lengthwise or widthwise, depending on available space for placing gage on specimen. Using a metal straight edge and X-Acto knife, trim tape width to approx. width or length of gage matrix.

V. GAGE INSTALLATION

1. Position gage on specimen so that gage alignment marks match gage location ink lines on specimen surface.

BY G. Linnstaedt	BELL HELICOPTER COMPANY	MODEL ____ PAGE ____ 1L-B-001C
CHECKED J. Estes		RPT ____

REVISION A (3-24-72)

2. Using Scotch Brand No. 549 tape, mask off each side of gage and across one end of gage holding tape. (approx. 0.1 inch from gage)

3. Using a pair of tweezers, peel gage/tape assembly back from surface and finish masking gage area. Remove ink lines with ammoniated cotton tipped applicator.

4. Reclean specimen and gage with cotton applicators moistened in acetone.

5. Coat specimen and back of gages with adhesive, and allow surfaces to air dry at least ? minutes at 75°F and 50% relative humidity to allow solvents to evaporate. Longer drying times required at lower temperatures and higher relative humidity. DO NOT ALLOW ADHESIVE APPLICATOR TO TOUCH TAPE MASTIC.

6. Re-position gage on surface of specimen.

7. Place a piece of Teflon film tape crosswise over installation.

8. Place silicone rubber pad and back-up plate over installation.

9. Spring-clamp or C-clamp installation. Once clamps are applied, DO NOT RELEASE CLAMPING PRESSURE UNTIL ADHESIVE CURE IS COMPLETE. Clamping pressure: 10 to 70 psi, 30 to 40 psi optimum. Steps 5 through 9 should be completed within 20-30 minutes.

VI. CURE PROCEDURE

1. Place specimen in oven, and raise temperature, per instructions on lab work sheet, to curing level. Time and cure temperature recommendations are as follows: 5 hours at 150°F, 2 hours at 180°F, 1 hour at 225°F.

2. Upon completion of cure cycle, cool specimen to a temperature of approx. 100°F before removing clamping hardware. Tag to identify hot part to prevent accidental burns to persons in the area.

REVISION A (3-24-72)

VII. FINAL INSTALLATION PROCEDURE

1. Very carefully remove the tape from and around gages.

2. Reclean gage and surrounding area with cotton applicators moistened in acetone.

3. Using ink pen, identify all gages per work sheet.

4. Select appropriate solder and attach lead-in wires to gages, being sure to use soldering flux. Remove flux with acetone.

5. Route wires neatly to terminal strip, completing a bridge circuit or as instructed by lab work sheet.

6. Check and record on lab work sheet the following: bridge balance, 100K bridge balance and resistance to ground. Be sure bridge has proper output and good "zero" return stability. (Check for mixed wiring at this time.)

7. Using ink pen, mark lab number on specimen.

8. Very carefully clean area to be covered with acetone and apply protective coating per instructions on lab work sheet.

9. Total completed installation must be checked for quality and workmanship, as specified by the lab work sheet, by another qualified person or lab technician, acknowledging approval by signing the work sheet.

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No.13-OP-0402
M-LINE ACCESSORIES
Instruction Bulletin B-127
November, 1988

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Strain Gage Installations With M-M Certified Eastman 910

I. Introduction:

Micro-Measurements Certified Eastman 910 cement is an excellent general-purpose laboratory adhesive because of its fast room-temperature cure and ease of application. When properly handled it can be used for high elongation tests, for fatigue studies, for one-cycle proof tests to over 200°F or to below −300°F. It is compatible with all M-M strain gages and all common structural materials. For best reliability it should be applied to surfaces between the temperatures of 70°F and 85°F and a relative humidity environment of 20 to 65%. M-M 910 Catalyst has been specially formulated to control the reactivity rate of this adhesive. The catalyst should be used sparingly for best results. Excessive catalyst can contribute many problems, e.g. poor bond strength, age embrittlement of the adhesive, poor glue-line thickness control, extended solvent evaporation time requirements, etc. Since Eastman 910, a cyano-acrylate, is very hygroscopic it should be carefully protected against moisture absorption.

II. Surface Preparation:

There are many surface preparation techniques available to suit the requirements of various structural materials, such as those indicated in M-M TECH NOTE TN-135. Basic metallic cleaning procedures are to degrease with solvents such as Chlorothene NU or Freon TF; abrade surface, and clean with M-Prep Conditioner A and Neutralizer 5, in that sequence. Eastman 910 will not produce satisfactory bond strengths to acidic surfaces nor to highly alkaline surfaces. Best surface conditions can be obtained with a final cleaning solution such as M-M Neutralizer 5. Since this solution is weakly alkaline, it should not be allowed to dry at its own evaporation rate on the surface but should be removed with one stroke using gauze sponges. 910 Cement should not be used on porous or heavily pitted surfaces since proper bond formation occurs only in a thin film.

III. Gage Preparation:

1. All present-day M-M gages used for experimental stress analysis have been treated for optimum bonding conditions and require no pre-cleaning before use unless contaminated during handling. The back of any gage may be cleaned with a cotton applicator slightly moistened with Neutralizer 5.
2. Place the bonding side of the gage on a chemically clean work surface such as a glass plate or the gage box.
3. Pick up the gage with a strip of 3-M #157 cellophane tape and apply terminal strip in desired location.

IV. Gage Installation:

1. Position gage cellophane tape over lay-out lines on specimen.
2. Lift one end of tape at a shallow angle to surface (about 45°) until gage and terminal are free from surface.
3. Tuck loose end of tape under and press to surface so that the exposed gage lays flat.
4. Remove 910 catalyst brush from bottle and wipe several times on neck of bottle to remove excess fluid.
5. Apply catalyst to gage by swabbing surface without lifting brush. Move down to terminal strip, swab, and then lift brush.
6. Allow catalyst to dry for at least one minute.
7. Apply a drop of M-M Certified 910 to surface just below edge of tape.
8. Lift end of tape and bridge over adhesive at approximately a 45° angle.
9. With a piece of gauze or teflon film make a single firm stroke over tape and within one second place thumb over installation and hold for at least 60 seconds.
10. When ready to attach leads, remove tape by peeling back over gage installation so that tape remains parallel to surface.

NOTE: To prevent excessive flow of 910 cement over surface of specimen, mask desired area with the 3-M #157 cellophane tape prior to gage installation.

Bell Helicopter TEXTRON	INSTRUMENTATION LABORATORY OPERATING PROCEDURES	No. 13-OP-0403 Rev. A D 1-20-78

TITLE STRAIN GAGING OF STRUCTURAL PARTS - QUALITY CONTROL	Prepared by: [signature] Date 5-2-77 Checked by: [signature] Date 5-2-77 Approved by: [signature] Date 5-11-77

GENERAL: The Instrumentation Laboratory has responsibility for quality control of strain gage installations.

REFERENCE: Engineering Laboratories Group Function 80-13-004, Instrumentation Laboratories Strain Gaging of Structural Parts

PROCEDURE:

1.0 VISUAL INSPECTION OF INSTALLATION - A visual inspection of all installations is conducted by the gaging technician to determine if gage is bonded in the correct place, wiring is correct, and no obvious defects exist, that can be seen with the naked eye.

2.0 ELECTRICAL BALANCE OF BRIDGES - An electrical balance of each bridge is made to determine if all gage resistances are approximately equal. A bridge balance box with a millivoltmeter is used for this purpose. For all tests, a reading between plus and minus ten millivolts, with ten volts excitation (±1 mv/volt) is acceptable. This condition is satisfactory with 350 ohm gages on metal and 1000 ohm gages on fiberglass. When 350 ohm gages are used on fiberglass specimens, the voltage must be reduced to approximately three volts. When the strain gage bridge or "stress gage" has met this requirement, in an unstrained condition, it is deemed satisfactory as far as balance is concerned.

3.0 RESISTANCE TO GROUND CHECKS - The next step in checking a bridge for quality is made using an insulation tester. A very high resistance to ground of at least 10,000 meg ohms per bridge is required with a minimum resistance of 1000 megs for multiple (in excess of ten) bridges that are common wired. Many bridges may be tied together through the common voltage, and low resistance to ground would degrade the whole system. Some degradation occurs with time and the elements so it is mandatory to have a very high resistance to ground to start with. Anything less than this requires rework of the gages or associated wiring.

4.0 POSITIVE ID OF GAGES - Positive identification of gages is an absolute necessity to prevent the possibility of mistaking one bridge for another. Several methods can be used but the most acceptable and accurate is to verify continuity from each bridge terminal through all associated wiring to the connector or terminal block. Bridge interwiring can usually be detected using this method too. A very bad assumption is "thinking" that a bridge is one parameter when it is another. All bridges must be verified before data can be accepted, as many decisions are based on good usable information obtained from strain gage bridges.

5.0 CALIBRATION, EVALUATION AND FINAL ACCEPTANCE - The final determination of a good bridge is made during calibration. A known load is mechanically applied to the strain gaged part and the electrical output is measured to establish a unity cal. Acceptable quality of calibrations involving linearity and cross talk limits are given in Operating Procedure 13-OP-0502.

Bell Helicopter TEXTRON	ENGINEERING LABORATORIES GROUP FUNCTIONS	No. 80-13-005 Rev. Date 2-16-77

TITLE	INSTRUMENTATION LABORATORY - CALIBRATION OF STRAIN GAGED PARTS	Prepared by: Date
		Checked by: Date
		Approved by: Date

GENERAL: The Instrumentation Laboratory provides equipment and personnel to support the acquisition, reduction, and documentation of calibration data from strain gaged parts.

REFERENCES: None

FUNCTIONS:

1. Acquisition of Calibration Data - Group 13 provides equipment, wiring, and personnel to indicate and record the output voltages from strain gaged parts during calibration. Close coordination with the Mechanical Lab, Group 18, is involved in this effort.

2. Data Reduction and Checking - Calibration data is reduced and checked by Group 13 personnel. This effort is generally accomplished using a calculator based data system although other methods may be used. Data is also checked and approved by Group 18.

3. Documentation and Records - All reduced calibration data is entered into a file maintained by Group 13 personnel.

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Reference 5

Bell Helicopter TEXTRON	INSTRUMENTATION LABORATORY OPERATING PROCEDURES	No. 13-OP-050[illegible] Rev. A Date 12-20-77

TITLE CALIBRATION OF STRAIN GAGED PARTS - ACQUISITION OF CALIBRATION DATA	Prepared by: [illegible] Date 1-20-78
	Checked by: [illegible] Date [illegible]
	Approved by: [illegible] Date [illegible]

GENERAL: Group 13 provides equipment, wiring, and personnel to acquire and record the output voltages from strain gaged parts during calibration. Close coordination with the Mechanical Lab, Group 18, is involved in this effort.

REFERENCES:
(1) Engineering Laboratories Group Function 80-13-005, Calibration of Strain Gaged Parts
(2) Instrumentation Laboratory Group Procedure 13-OP-0502
(3) HP 9830 Operation and Software Manual

PROCEDURE:

1.0 GENERAL CALIBRATION PROCEDURES

1.1 Group Responsibilities - The responsibility for calibration of structural parts is shared by Group 13 and Group 18 (Mechanical Lab). Group 18 is primarily responsible for providing the equipment, personnel, and procedure used to load the part. Similarly, Group 13 acquires the output data from the strain gages, reduces the data, and files and catalogs the results. The data is checked by both groups, however, final responsibility for approval of the calibration lies with Group 18.

1.2 Load Standards - Depending on the method chosen, the load standard may consist of calibrated load cells or calibrated hydraulic cylinders and pressure gages.

1.3 Data Acquisition Equipment - The equipment used to acquire strain gage output voltage readings may be any of the following:

a. HP 9830A Calculator Based Data Acquisition System
b. HP2013J Calibrator System
c. Fatigue DAS

1.4 Accuracy Classification - Calibration accuracy is dependent on the nature of the part and the equipment and method used for calibration. After a part is calibrated, an analysis of the data will be made to determine the accuracy classification for that particular part. Specific criteria to be used for this classification are agreed upon by Groups 13, 18, 46 and other data users. See 13-OP-0502, Data Reduction and Checking, Section 2.0.

1.5 Recalibration Intervals - The use and required accuracy determines the necessary recalibration interval. All parts shall be downgraded to the next accuracy classification after 1 year has elapsed since the date of calibration. At the discretion of the test engineer, a part may be recalibrated or else continue in use at the downgraded accuracy classification.

2.0 CALIBRATIONS DONE WITH HP9830A CALCULATOR - The preferred calibration method is to use the HP9830A calculator system with load cells as the force standard. This method not only provides best accuracy but saves considerable time and effort.

2.1 Calibration Setup - Preliminary steps involve coordination with Group 18 to determine the type of pull, number of calibration points, load cells to be used, gage and load stations, etc.

2.1.1 Calculator System Preparation - The calculator system is prepared by connecting it to a 115V AC power source and allowing a 15 minute warmup. During this time each of the input channels should be connected and the calibration data sheet prepared. After warmup, the pr[illegible] r bridge voltage should be set on the power supp[illegible] (6.000 volts for flight test parts, 10.000 vo[illegible]s for parts to be used on the fatigue DAS). The calibrate program is next entered into the calculator using detailed operating instruction provided by the "HP9830 Operation and Software Manual".

2.1.2 Setup Data Entry - The calibration data sheet is filled out using information provided by Group 18 and the worksheet for the part being calibrated. This information is entered into the oalculator using the "start" and "input" subroutines (Ref. "HP9830 Operation and Software Manual").

2.2 Data Acquisition - The first step prior to beginning data acquisition is to perform a positive identification check for each of the bridges being calibrated. This is done using the "monitor" subroutine.

2.2.1 Zero Point - With the test specimen at the zero load condition, execution of the "load" subroutine is begun. After several cycles to the max. load point and back to zero and when indicated by the calculator, the zero load readings are taken and stored.

2.2.2 Load Points - Each succeeding load is applied and a set of readings are taken. At least five load points are taken (plus the pre and post zero points). Only increasing load point are recorded. This procedure is continued until all pulls (beam, chord, torsion, etc.) are complete.

2.3 Data Output and Handling - After each pull the "1st order" subroutine is executed. This subroutine performs a 1st order least squares curve fit forcing the curve through zero. The calculator then checks gage output and deviation from the fitted line to determine which calibration class the gage meets. The unity cal and 100K CE are then printed out along with the load and MV output for the data pull on each gage.

2.3.1 After all pulls are complete, the "crosstalk" subroutine is used to calculate the percent crosstalk for each gage for each pull. The calculator then checks the crosstalk to determine which calibration class each gage falls in.

2.3.2 After execution of the "crosstalk" subroutine, the "data summary" routine may be used to obtain a data summary tabulation. At this point, the calculator has checked the data for crosstalk, linearity, etc., and provided final unity cal values. This data is further checked for proper values by the instrumentation technician and the Mechanical Lab Test Engineer. If the data does not meet acceptable standards, it may be necessary to regage the part or make other changes prior to recalibration. All acceptable calibrations are signed by the Group 18 Test Engineer and the part is returned to the Instrumentation Lab for final covering and shipping. Approved data is delivered to the Group 13 data analyst for filing.

3.0 CALIBRATIONS DONE WITH HP2013J - This method is less accurate and requires more data reduction time and should, therefore, be used only as a backup to the HP9830A.

3.1 Calibration Setup - Preliminary steps include coordination with Group 18 to determine the type of pull, number of calibration points, jack factors, lever arm lengths, etc. Calibrator system preparation includes a 15 minute warmup time, connection of input cables and check and setting of the excitation voltage level. The calibration data sheet is completed with information from Group 18 and the worksheet.

3.2 Data Acquisition - The first step prior to beginning data acquisition is to perform a positive identification check for each of the bridges being calibrated. This is done in the manual scan mode.

3.2.1 Zero Point - With the test specimen at the zero load condition, each bridge balance potentiometer is adjusted for zero volts offset. After several cycles to max load and back to zero, a set of zero readings is taken.

3.2.2 Load Points - Each succeeding load is applied and a set of readings is taken. At least four load points are taken (plus the pre and post zero points). Only increasing load points are recorded. This procedure is continued until all pulls (beam, chord, torsion, etc.) are complete.

3.3 Data Handling - After all pulls are complete, the output data is given a preliminary check by the Group 18 Test Engineer for linearity, crosstalk, and proper output. Depending on whether the calibration data meets accepted standards, the part is either returned for regaging and recalibration or else the calibration is approved and signed by the Group 18 Test Engineer and the part returned to the Instrumentation Lab for final covering and shipping. Approved data is delivered to the Group 13 data analyst for filing.

4.0 CALIBRATIONS DONE ON FATIGUE DAS - In machine calibrations done on the Fatigue DAS are handled similarly to those done on the HP9830A. DAS software operation details are maintained by Group 92 and Scientific and Technical Computing.

Bell Helicopter TEXTRON	INSTRUMENTATION LABORATORY OPERATING PROCEDURES	No.13-OP-059 Rev. A Date 3-14-77

TITLE CALIBRATION OF STRAIN GAGED PARTS, DOCUMENTATION AND RECORDS	Prepared by: MLW Date 3-16-77
	Checked by: FEO. Date 3 11 77
	Approved by: FEO. Date 5 11 77

GENERAL: The Instrumentation Lab is responsible for the documentation and recording of all calibrations of strain gaged parts done for both flight and fatigue testing. Also, the calibrations for gyros, pressure transducers and flow meters calibrated in the Standards Lab are documented and recorded by the Instrumentation Group.

REFERENCE: Engineering Laboratories Group Function #80-13-005, Documentation and Records

PROCEDURE:

1.0 CALIBRATIONS DONE ON HP9830A CALCULATOR:

1.1 Upon receipt of the calibration, the actual date of calibration is logged in the Calibration Equivalent Book and in the cross-reference file.

1.2 The calibration is then separated into data and crosstalk sections.

1.3 At this point any crosstalk which has been questioned is hand plotted.

1.4 After questioned crosstalk has been plotted, copies of all data and plotted crosstalk are made for flight test, fatigue and stress groups.

1.5 Calibrate equivalents and unit cals are then recorded in the appropriate files.

1.6 The original data is then filed in notebooks.

2.0 CALIBRATIONS DONE ON HP2013J CALIBRATOR:

2.1 When the calibration is received from the lab, the actual date of calibration is recorded in the Calibrate Equivalent Book and in the cross-reference file.

2.2 Following the instructions for computing program FCCR33, the calibrations are keypunched for batch data loading into the computer. A copy of the description and operation procedures for the FCCR33 program is available in the Instrumentation office.

2.3 The FCCR33 program generates four (4) copies of the final computated data which is distributed as follows:

(1) Group 13 retains the original for recording and filing.
(2) Group 46 or Group 18, depending on intended use of the part, receives the second copy.

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OF POOR QUALITY

(3) Stress Group receives the third copy.
(4) Group 92 receives the fourth copy.

2.4 The original copy from computing is combined with the raw millivolt data for storage.

2.5 The calibrations from this point are handled the same as the data from the HP9830A calculator.

3.0 CALIBRATIONS DONE ON OSCILLOGRAPH

3.1 After calibration data is logged into the Calibrate Equivalent Book and in the cross-reference file, the actual data is read in inches from the oscillograph. This data includes zeros, cal steps, and actual load readings.

3.2 The zero is subtracted from each data point read to arrive at a delta inch value for each loading increment.

3.3 These delta readings are then hand plotted against their corresponding load points.

3.4 The resulting slope is used to arrive at the desired calibrate equivalent. For symmetrical 350Ω bridges the unit cal is determined by multiplying the 100K calibrate equivalent by the factor of 0.874.

3.5 From this point, copies, recording, and filing are done the same as for the previous calibrations.

4.0 INSTRUMENT CALIBRATIONS FROM THE STANDARDS LAB:

4.1 The calibrations of pressure transducers, except for logging of the calibration date in the Calibrate Equivalent Book, are handled the same as the ones from the HP2013J using the FCCR3 computer program.

4.2 The gyros, rate and attitude, are hand plotted to determine the calibrate equivalent and the unit cal or the calibrate constant.

4.3 The flow meter calibrations are also hand plotted to determine the calibrate constant only.

4.4 Each of these three types of instrument calibrations is recorded in the instrument card file then filed in the separate instrument file notebooks. Only one copy of the original computed data is sent to the Standards Lab for distribution. The original is retained by Instrumentation.

TITLE CALIBRATION OF STRAIN GAGED PARTS - DATA REDUCTION AND CHECKING

Prepared by: F.L.D. Date 4/27/
Checked by: [illegible] Date 5/3/77
Approved by: F.S.D. Date 5/11/77

GENERAL: Calibration data is reduced and checked by Group 13 personnel. This effort is generally accomplished using a calculator based data system although other methods may be used. Data is also checked and approved by Group 18.

REFERENCES:
(1) Engineering Laboratories Group Function 80-13-005, Calibration of Strain Gaged Parts
(2) HP9830 Operation and Software Manual

PROCEDURE:

1.0 TERMINOLOGY - Specialized terminology relative to data reduction and checking include the following:

a. Unity Cal (UC) - A calibration constant for bridge type transducers. In the general case, this is determined by plotting individual calibration data points of bridge voltage output in terms of millivolts per volt of excitation versus physical input to the transducer in appropriate engineering units. Unity cal is defined as the slope in engineering units per millivolt per volt of a straight line fitted to these data points.

b. 100K Calibration Equivalent (100K C.E.) - An alternate calibration constant for bridge type transducers. This is determined by dividing unity cal by the amount of bridge output in millivolts per volt of excitation produced when a 100K ohm resistor is shunted directly across the CD leg of the bridge.

c. Accuracy Class - A classification system applied to calibration data. The numerical value of the class is indicative of the approximate three-sigma error percentage to be expected in the unity cal value. The method and equipment used during calibration as well as the characteristics of the part will determine which of three accuracy classes is assigned.

d. Least-Squares Error Band - The allowable range of deviations of bridge output values from a least-squares line (i.e. - the straight line for which the sum of the squares of the deviations is minimized).

e. Crosstalk - Undesirable output from a strain gage bridge when a part is loaded in any direction other than the sensitive axis of the bridge. As an example, a beam gage on a rotor blade may exhibit undesirable output when the blade is loaded in torsion, or in the chord direction.
Percent crosstalk is the amount of output with maximum cross axis loading relative to the amount of output with maximum sensitive axis loading.

2.0 ACCURACY CLASSIFICATION CRITERIA - As previously stated, the method and equipment used during calibration as well as the characteristics of the part will determine which of four accuracy classes is assigned to an individual bridge. Table 1 lists the minimum performance standards, equipment requirements, and recalibration interval for each class.

TABLE 1

ACCURACY CLASSIFICATION CRITERIA

Minimum Performance Standards	Class 3	Class 5	Class 10
1. Minimum Output Voltage	8 mv	4 mv	2 mv
2. Least-Squares Error Band	±0.5% FSO	±1% FSO	±2% FSO
3. Crosstalk	2.5%	4%	9%
Equipment Requirements			
1. Load Standard	Load Cells or Dead Wts.	Pressure/Cyl., Load Cells, Dead Wts.	Pressure/Cyl Load Cells, or Dead Wts.
2. Readout Equipment	HP9830A, HP2013J, or DAS	HP9830A, HP2013J, or DAS	HP9830A, HP2013J, or DAS
Recalibration Interval	1 year	2 years	3 years
Approximate Error (3-Sigma) in Unity Cal	±3%	±5%	±10%

Class 99 indicates no calibration on gage.

3.0 HP9830A CALIBRATIONS

3.1 Calculator Checks - Each bridge calibrated using the HP9830A is automatically compared to the criteria listed in Table 1. The calculator determines and prints out the best accuracy class met by the bridge. Also listed is maximum output voltage, actual error band and percent crosstalk.

3.2 Calibration Approval - Should the accuracy class determined be deemed acceptable by the Group 18 calibration engineer, he will sign the output listing and the calibration will be complete. Should it not be acceptable, regaging or changes in equipment may be required.

4.0 HP2013J CALIBRATIONS

4.1 Preliminary Data Check - The Group 18 calibration engineer will make a preliminary check of printer output data to verify linearity and crosstalk amounts. If these are found acceptable, the data is keypunched by the Group 13 data analyst and reduced by computer program FCCR33.

4.2 Calibration Approval - Final output data is checked by the Group 13 data analyst to determine whether the data meets Class 5 or Class 10 requirements. After a final review by the Group 18 calibration engineer, the data sheet is signed or else the part is returned for regaging or recalibration.

5.0 FATIGUE DAS CALIBRATIONS - Calibrations done on the fatigue DAS have final output data available which is similar to that produced by FCCR33. Calibration approval is similar to that listed in paragraph 4.2 above.

Bell Helicopter TEXTRON
Division of Textron Inc

Reference 7

INTER-OFFICE MEMO

18 August 1978
86:ASW:mc-3710

Memo to: Mr. K. G. Wernicke

Copies to: Messrs. S. Blackman, P. Darden, J. Dillard, W. Jennings, J. Kidwell, H. Lawton, P. Mahaney, R. Marr, L. Roach, G. Rodriguez, T. Thomason, Files

Subject: XV-15 PERIODIC CALIBRATION OF FLIGHT TEST INSTRUMENTATION

The BHT recalibration policy is that shelf life on sensors is one year. Shelf life is defined as the time between the date a part is calibrated and the date the part is actually used.

Sensors such as accelerometers, pressure transducers (calibrated by the Standards and Calibration Laboratory) are good for six months after the date the sensor is tagged (end of shelf life).

Strain gage sensors are calibrated by the Mechanical Laboratory. With the existing technology in strain gage materials, bonding materials and bonding procedures, it is felt the shelf life for strain gage parts can be extended almost indefinitely. This assumes that the part is not subjected to adverse conditions such as moisture, temperature or loading. Once installed, strain gage structural parts are used without recalibration for the duration of a particular flight test program. Experience has shown that malfunction of a strain gage sensor on a structural part will manifest itself in such a manner as to be detectable during normal preflight checks.

It is recommended that this policy be continued during the XV-15 flight test program.

Aaron Whitener
XV-15 Research Instrumentation Coordinator
Instrumentation Test Operations
Ext. 4882

APPENDIX I

XV-15 PCM CALIBRATION FORMULAS AS USED IN GDC PROCESSING

PSF cards with Rcal resistors ("P" module code)

$$M = \frac{RCAL(EU)}{VRCAL(cts) - VREF(cts)} \qquad B = REF(EU) - M\ VREF\ (cts)$$

AMX cards no cal resistor ("A" module code)

$$M = \frac{RCAL(EU)\quad 512}{LLCAL(cts) - GPAO(cts)\quad GAIN(GPA)} \qquad B = REF(EU) - M\ VREF\ (cts)$$

Definitions: All readings based on an average of 40 data cycles

RCAL(EU) "P": Engineering units represented by Rcal resistor used on aircraft

RCAL(EU) "A": Engineering units represented by difference between LLCAL and GPAO

Cts RCAL(VRCAL): Digital counts with Rcals switched in

Cts REF(VREF): Digital counts with aircraft in reference condition

REF(EU): Engineering units associated with sensors when in reference condition

LLCAL: An inserted cal value of precise voltage on each AMX card; available at gain of 512

GPAO: Shorted input to gain programmable amplifier; available at certain gains

Transformation of calibration sheet 100k calibration equivalent to calibration equivalent used on ship.

SHIP CAL (SET UP SHEET) =

$C.E. = 115\ K\ \Omega\ Cal = Slope \times \Delta\ counts$

$\Delta\ counts = R\text{-}Cal\ Counts - Reference\ Counts$

$$Slope = \frac{U.C.}{B.V.} \times \frac{5120}{1024} \times \frac{1}{256} \times \frac{1}{GPA\ GAIN}$$

where:

U.C. = Unity Cal from Calibration Sheet

B.V. = Bridge Voltage at Bridge

$$\frac{5120}{1024} = \frac{\text{Input MV}}{\text{Output Counts}}$$

$$\frac{1}{256} = \frac{1}{\text{PSF Card Gain}}$$

APPENDIX II

XV-15 PCM CALIBRATION FORMULAS AS USED IN GDC PROCESSING (PRIOR METHOD)

PSF cards with Rcal resistors ("P" module code)

$$M = \frac{RCAL(EU)}{VRCAL(cts) - VREF(cts)} \qquad B = REF(EU) - M\ VREF\ (cts)$$

AMX cards no cal resistor ("A" module code)

$$M = \frac{RCAL(EU)}{LLCAL(cts) - GPAO(cts)} \frac{512}{GAIN(GPA)} \qquad B = REF(EU) - M\ VREF(cts)$$

Definitions: All readings based on an average of 40 data cycles

RCAL(EU) "P": Engineering units represented by Rcal resistor used on aircraft

RCAL(EU) "A": Engineering units represented by difference between LLCAL and GPAO

Cts RCAL(VRCAL): Digital counts with Rcals switched in

Cts REF(VREF): Digital counts with aircraft in reference condition

REF(EU): Engineering units associated with sensors when in reference condition

LLCAL: An inserted cal value of precise voltage on each AMX card; available at gain of 512

GPAO: Shorted input to gain programmable amplifier; available at certain gains

Transformation of calibration sheet 100k calibration equivalent to calibration equivalent used on ship.

SHIP CAL (SET UP SHEET) =

$$\frac{100k\Omega}{RCAL\ RESISTOR\Omega} \times \frac{\text{BRIDGE VOLTAGE AT PROGRAM BOARD}}{\text{BRIDGE VOLTAGE MEASURED AT TRANSDUCER}} \times \text{100k CE FROM SET UP SHEET}$$