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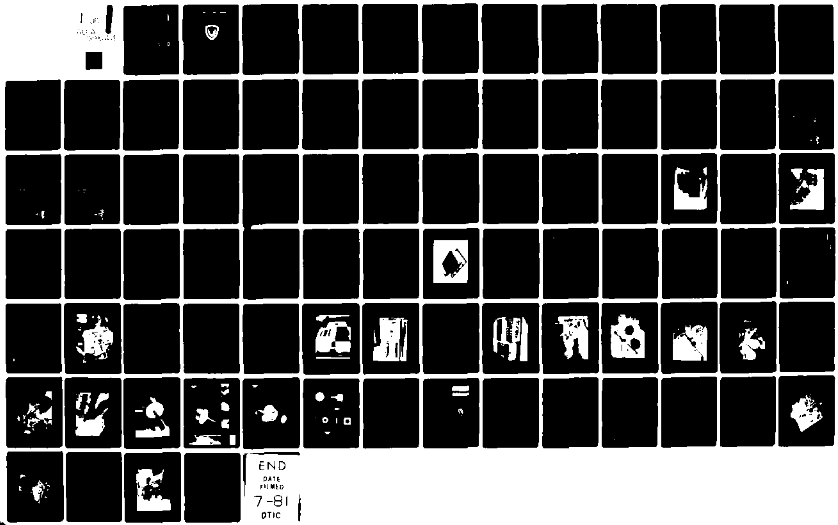

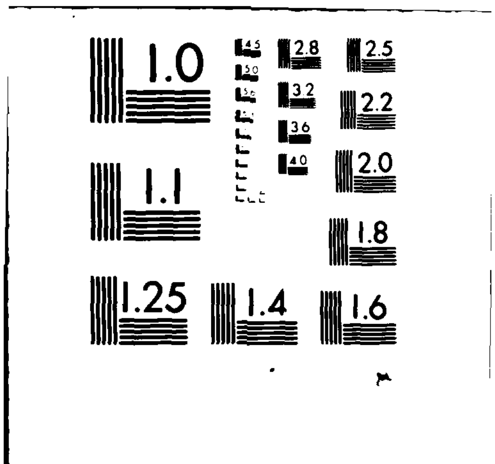

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AD A099643

DTIC ACCESSION NUMBER

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LEVEL

INVENTORY

2.75 INCH ROCKET/AH-1G HELICOPTER WEAPONS SYSTEMS
BASELINE INSTRUMENTATION TEST REPORT. VOLUME I APRIL 1972

DOCUMENT IDENTIFICATION

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U. S. ARMY ELECTRONICS COMMAND

Fort Monmouth, New Jersey

2.75 INCH ROCKET/AH-1G HELICOPTER WEAPONS SYSTEM BASELINE INSTRUMENTATION TEST REPORT

VOLUME I

AIRCRAFT INSTALLATION and TEST TECHNICAL AREA
AVIONICS LABORATORY

By
Benjamin Tirabassi and Edmund Tognola

April 1972

TABLE OF CONTENTS

VOLUME 1

PAGE

REPORT OUTLINE

This report is presented in two volumes and deals with the acquisition and retrieval of data pertinent to the analysis of the 2.75 Inch Rocket/AH-1G Weapons System Baseline Accuracy Tests. A brief description of each volume is given below:

Volume I details the various phases of the 2.75" Rocket Baseline Accuracy Test as they pertain to ECOM supported functions and its airborne data retireval system. A complete description is included of the instrumentation system, aircraft flight configurations, alignment and preflight procedures and a comprehensive description of the major subsystems both procured and fabricated for the test program.

Volume II is a presentation of retrieved data samples, recorded during Phase A and Phase B testing at the Yuma Proving Grounds, to verify airborne instrumentation performance. Analysis of the data is presented including plots of retrieved data, correlations between data samples taken with various transducers and a frequency analysis of the sampled data.

1.0 Purpose and Background

The Aircraft Installation and Test Technical Area, Avionics Laboratory, US Army Electronics Command was tasked by the MUCOM Project Manager Office, 2.75 Inch Rocket System to provide technical assistance and support in the instrumentation of the 2.75 Inch Rocket Baseline Accuracy Test, Project TPR-RK-1141.

ECOM furnished a recently developed high accuracy digital data acquisition unit and integrated this unit in an AH-1G aircraft with various transducers and sensors to provide a highly sophisticated airborne recording system. The recorded data is used for the assessment and subsequent analysis of the crucial independent functions that were pertinent to a comprehensive study of the total rocket weapons system. The functions, whose parameters were monitored and recorded in their natural system environment, that comprise the major subsystems of the 2.75 Inch Rocket System/AH-1G weapons system are as follows:

- Helicopter Performance as a Stable Platform
- Rocket Performance
- Pilot/Gunner Performance
- Gunsight and Launcher Subsystems Alignment
- Aiming Accuracy of the Helicopter

ECOM personnel specified and controlled the configuration of the airborne data retrieval package and coordinated all associated contractor efforts and procurements. American Electronics Laboratory (AEL) performed the aircraft installation and integration of the various electronics, transducers and sensors and fabricated a major portion of the specialty hardware designed for the test. The initial instrumentation test procedure and check out flights were conducted by American Electronics Laboratory at their Monmouth County Airport facility.

Airborne data system maintenance, operation, renovation and support at the Yuma Proving Grounds Test Site was jointly provided by USAECOM, American Electronics Laboratory and Minneapolis Honeywell personnel.

The following is a listing of major program milestones in chronological sequence:

June 1970	Preliminary Discussions Between MUCOM and ECOM
August 1970	Program Work Request from MUCOM
September 1970	Design of Instrumentation System Procurement of Major Subsystems Commenced Systems Installation Started (A/C #67-15691)

November 1970	Hardware Fabrication Completed
December 1970	Sensor and Transducer Validation
February 1971	Systems Installation Started (A/C #66-15250) Installations Completed Preliminary Flight Test at AEL, Monmouth County Facility
March 1971	Aircraft Arrived Yuma Proving Ground Preliminary Phase A Testing Commenced
May 1971	Phase A Testing Commenced
August 1971	Phase B Testing Commenced
February 1972	Phase B "Add-On" Testing Commenced

2.0 Summary

US Army airborne system testing capability has been advanced significantly as a result of innovative techniques established and utilized during the comprehensive testing of the FFAR Weapon System The introduction and application of these techniques permitted the first quantified assessment of the AH-1G aerial platform subsystems as they function in the total system environment. The accurate simultaneous monitoring and recording of the critical subsystem parameters when analysed in conjunction with the normal system evaluation methods provides both cause and effect information.

Guiding concepts and goals established for the instrumented test are outlined below:

- Establish Parameters Critical to Gunship Performance
- Quantify Subsystem/System Referenced Data
- Monitor and Control Spurious System Disturbances
- Record Aerial Weapons System Baseline Data
- Correlate Rocket Accuracy and Aerial Vehicle Stability
- Develop a High Accuracy Digital Airborne Instrumentation System
- Format Compatible Data Tapes for Universal Application

The data relevant to the analysis of the AH-1G mounted 2.75 Inch Rocket System was obtained using a specially developed ECOM airborne instrumentation system in conjunction with Yuma Proving Ground (YPG) ground based tracking and recording network. The instrumentation system was designed to function on a noninterfering basis to maintain the integrity of the weapons platform operating in its natural mission environment.

Cinetheodolite stations position fixed the aircraft in space and an inertial reference system established the orientation of the aircraft coordinate system with respect to local gravity. The inertial reference system also sensed the angular rotation of the aircraft coordinate system as well as measured the linear acceleration along its axes. These parameters fixed the rocket launching point and gunsight aim point with respect to the target.

The relative wind profile was monitored in front of the rocket launchers and at the nose of the aircraft to determine and measure the perturbing effects of the airflow which may cause a deviation in the rocket flight path when launched from the aerial vehicle. The initial launch conditions of the rocket launcher were monitored with respect to the aim point to determine its error contribution to the flight of the rocket and the overall accuracy of the system.

An onboard gunsight camera system was used to determine the orientation and sighting of the AH-1G weapon system during target acquisition and recorded the flight of the rocket to the target. The trigger time and time of egress of the rocket from the launcher were sensed to determine the delay characteristics of the aircraft launching system and its impact on sighting versus launch time aircraft orientation. The average velocity of the rocket was calculated from the recorded data in order to assess its contribution to the total accuracy of the rocket system.

3.0 Test Program Phases

3.1 System Design

The system design phase was initiated at ECOM based on a presentation of the program requirements and objectives by MUCOM. A complete analysis of the program definition followed with emphasis on the responsibilities assigned this facility. A systems approach was developed with the understanding that the airborne instrumentation package would eventually be a subsystem of a greater data retrieval system. This requirement dictated the fact that the airborne system must interface and be compatible with existing and proposed facilities at the Yuma Proving Grounds.

Transducers and sensors were selected that were capable of withstanding a helicopter environment. Environmental specifications, including high temperature, sand and dust dictated that the equipments be ruggedized but retain the accuracy requirements of laboratory type instruments. The transducers also were required to be compatible with the existing Data Acquisition Unit (DAU).

The mechanical assemblies for mounting the linear variable differential transformers (LVDT), had to be easily installed, aligned and calibrated and yet remain truly independent of any movement in the wing structures. The angle of attack pods which house the transmitters must be easily transferable between aircraft and cause a minimal amount of disturbance to the airflow.

The inertial reference system (IRS) was required to be mounted as close to the center of gravity as possible yet be in a position that allowed easy access for mechanical alignment.

A technique was developed whereby the data acquisition system could be easily removed from the test aircraft and reinstalled in the back-up aircraft within one day. Identical instrumentation harnesses were fabricated for each of the two aircraft. In order to transfer the instrumentation package, the entire instrumentation pallet was designed to be easily removed from the ammunition compartment of the test aircraft and remounted in the back-up aircraft.

The data requirements dictated that the instrumentation system be capable of accepting and recording both analog and digital information with a high degree of accuracy. Twenty-five analog inputs, with various ranges up to 25 volts had to be monitored to provide system data. Multiplexing rates of 100 and 1000 samples/second were required to provide the data resolution necessary for the accurate analysis of the system.

The overall airborne instrumentation system was under the direct control of the co-pilot. Via the instrument control panel and DAU control unit, the co-pilot controlled the data acquisition unit, all transducers, two on-board cameras and the digital recorder.

The airborne system was capable of interface with the YPG ground facilities. The telemetry serial data transmission, when properly "locked", provided real time data analysis via a six channel strip chart recorder. YPG was responsible for data retrieval and analog presentation. Compatibility was required between the airborne recorded magnetic tape and the ground computer used to decommutate the data and format a 1/2 inch IBM compatible tape for final analysis. An analog channel was provided on the recorder to allow a Pulse Amplitude Modulated (PAM) range time signal to be recorded. The range time transmission linked all portions of the data retrieval system together. A run number generated by the co-pilot via the control panel for each flight test, tied each data frame to a particular test for ease of handling and data recognizance during analysis.

3.2 Preliminary Flight Tests

ECOM testing of the airborne sensors was performed in several stages. The transducers and other subsystems were acceptance tested to verify that they were fabricated in accordance with specifications. Frequency response, dynamic range, accuracy, resolution and scale factors were of prime importance. The units were then interfaced with the data acquisition unit to assure compatibility and to verify that the linear tracking and analog to digital (A to D) conversion of the sensed inputs was being performed and recorded accurately. Finally the senors and test subsystems were installed in the aircraft and a complete systems check performed. These tests were designed to determine if the installation of individual equipments affected the system and data was taken to verify performance.

The aircraft was then flight checked as an airborne instrumented testbed. The test vehicle was flown through a series of simulated rocket launch flight patterns and the sensed data was recorded onboard while being simultaneously transmitted to a ground station for real time display.

An ECOM ground receiving and recording station was established at Monmouth County Airport, Monmouth County New Jersey for the preliminary flight tests. An American Electronics Laboratory (AEL) six foot parabolic antenna Type APN-111B, tracked the aircraft's S-Band PCM/FM transmitted data to distances of 25 miles. The data was received at the ground station using a Defense Electronics PCM/FM Telemetry Receiver, Type TMR-74, fed into an EMR Signal Conditioner, Type 2721, and then to an EMR Frame Synchronizer, Type 2731, prior to being converted back to analog information for display on six EMR, Type 2755, Analog Displays. The information was simultaneously recorded on a Brush 6 channel strip chart recorded, Type Mark 260, for analysis and verification of system performance.

Flight test results verified that data could be transmitted from the helicopter over line of sight distances without data loss or degradation. It was determined that data dropout occurred only at the times the aircraft banked towards the receiver antenna at angles greater than 20 degrees and in low level head on approaches, both of which cause airframe shading of the antenna from the ground station receiver. It was recommended that the ground based receiving antenna should be in line with and to the rear of the flight path so that the transmitting antenna would be unobstructed when the aircraft flew in the normal pitch down position.

A digital program was written at ECOM to verify the accuracy of the airborne recorded data. A technique was devised to transfer the onboard recorded digital data from the Leach Corporation digital magnetic recorder, Model 3200, to a 1/2 inch magnetic tape that was compatible with the Electronic Associates Inc. Digital Computer, Model 8400. This transfer was performed by an EAI DDP-24 Digital Computer in conjunction with a DOS 350 Patch Panel.

Several data channels had shown sensitivity to system and aircraft ambient noise levels which masked some low level analog data. In order to reduce the noise susceptibility and preserve the desired accuracy, several DAU filter modifications were required to narrow the analog data bandwidth to a level commensurate with the individual sensor cut-off frequency.

3.3 Preliminary Phase A

Preliminary Phase A commenced several months prior to the delivery of the instrumented aircraft to the test station at Yuma Proving Ground (YPG). Information was forwarded to YPG concerning the data acquisition unit data frame, sampling rates, synchronization words and other pertinent information relevant to the decommutation process and data lock received condition. Several test tapes were made available to the data reduction personnel, following the flight tests executed in the preliminary test phase. These test tapes were furnished for checkout of YPG's data decommutation and reduction procedure.

During the preliminary testing of Phase A, compatibility between the ECOM provided instrumented aircraft and the YPG provided ground based data retrieval system was of prime concern.

The first test was to confirm that the serial transmission of data from the aircraft via the PCM/FM telemetry transmitter could be received properly. With a "data lock" condition, it could be assured that the transmitter output level was adequate, the receiving antenna was properly monitoring the flight path, and the serial-bit synchronization words were being recognized. This link provided the real time analysis of the flight. Several flight parameters were monitored including aircraft attitude and the nose angle of attacks in order to verify that the airborne data could be received at the telemetry van, relayed to the data reduction center and retransmitted to the communications van for display.

Several tests were performed to verify that the infrared detectors were working properly. Rockets were fired and the data recorded on-board by the data acquisition system. The test tapes were taken to the decommutation center for analysis. A special program was written by YPG to provide a listing of the trigger and IR detector pulse. The pulses were then checked to assure that they were recognizable in the ambient noise and were being identified correctly by the computer.

3.4 Phase A Tests

Phase A testing was programmed to verify that all data systems were properly coordinated and to evaluate the flight conditions to be flown in Phase B. Comprehensive data was recorded in the aircraft and telemetered to the ground station for all sensed parameters in several instrumented configurations. Phase A flight tests were indicative of the Phase B flights with all systems active including actual triggering of dummy rocket rounds. Each organization was responsible for the operational capability and accuracy of their instrumentation or equipment. Data systems compatibility became a joint effort in an attempt to isolate and correct problem areas which developed in the initial flight runs.

During the Phase A test program, the primary source data was recorded on the ECOM airborne digital magnetic tape recorder. The tapes were transferred to the data reduction center for formatting and processing. A resultant engineering unit tape was made available to Picatinny Arsenal and Fort Monmouth personnel for detailed study. Resultant engineering unit printout was distributed by YPG to personnel of various commands for analysis and verification.

The determination of the aerodynamic flow profile about the aircraft and rocket launcher pods under various flight conditions was of prime interest. Straight and level, 12° and 15° dive flight data at various power settings were recorded and studied. Ten angle of attack transmitters were mounted on the aircraft in order to determine the aerodynamic profile. Angle of attack sensor data was taken in eleven different instrumented configurations. The recorded information was processed and correlated with respect to the other sensors in the same plane and all pitch sensors were also correlated to the pitch angle of the aircraft. The data was reviewed for repeatability and accuracy in order to determine if the instrument configurations biased the normal airflow patterns.

Information was gathered to determine the pitch down angle of the aircraft as it flew in a straight and level flight path at various airspeeds between 90 and 145 knots. The pitch angle has a direct bearing on the gunsight setting for the 2.75" rocket and therefore was significant in the study of the accuracy dependent parameters of the weapon system.

3.5 Phase B Tests

All of the instrumentation used in the Phase A tests and the optimal sensor configurations determined from those tests were utilized for the live rocket firing runs comprising the Phase B tests. The additional instrumentation required during this phase to obtain data for complete specification of the system performance included the infrared (IR) detectors and linear variable differential transformers (LVDT).

Two IR detectors on each side of the aircraft were used to detect the IR in the plume of the rocket. The first detector responded to the IR immediately upon the rocket's egress from the launcher tube. Using this information and the precise time of trigger, the delay characteristics of the system could be determined. A second detector mounted to the aircraft five feet ahead of the first was used to detect the passage of the rocket and made available information for determining the average velocity of the rockets with respect to the aircraft. Each rocket firing was monitored and an indication of the passage was recorded by the onboard instrumentation package.

The LVDTs were used to detect the motion of the 2.75" rocket launcher with respect to the airframe during the entire test run, with the time period beginning just prior to and ending immediately following the firing being most important. Four position sensors were mounted on the outside circumference of each pod, two on the front and two on the rear. Two of the sensors were mounted in the pitch plane and two in the yaw plane. Linear motion of the rocket pods in the pitch and yaw plane and rotational motion about the pitch and yaw axis were determined by monitoring the outputs of the LVDTs.

Using the range time or elapsed time code data, velocity and acceleration of the rocket pod in the pitch and yaw planes and about the pitch and yaw axes can be determined as the first and second derivatives of the displacement data with respect to time.

4.0 Instrumentation System

4.1 System Description

4.1.1 Total Data System

The general block diagram for the data flow technique as used in the retrieval of data for the test program is shown in Figure 1.

The Yuma range provided the capability for determining the position of the aircraft with respect to the ground target by continuous monitoring of its position using cinetheodolite stations. The theodolite stations triangulate the position of the aircraft in a 3 axis coordinate system. The theodolite data was corrected by viewing the films on a scoring board, determining the tracking error and then correcting the data accordingly.

Aircraft range data was obtained using a radar provided by White Sands Missile Range and operated by RCA Corporation personnel. The AH-1G was tracked throughout the flight test by the radar and position information was transmitted to all ground stations by the flight coordinator monitoring the radar plotting board. The pilot was continuously updated on his lateral and vertical position with respect to the predesignated flight path.

Meteorological information including air density, wind speed and air temperature was monitored on a 100 foot tower in the vicinity of the test range. The air density and temperature information was used to correct aircraft flight data. A maximum air speed of 10 knots was allowed before testing was terminated.

The position of the aircraft and the rocket impact points were photographed by an overhead reconnaissance aircraft.

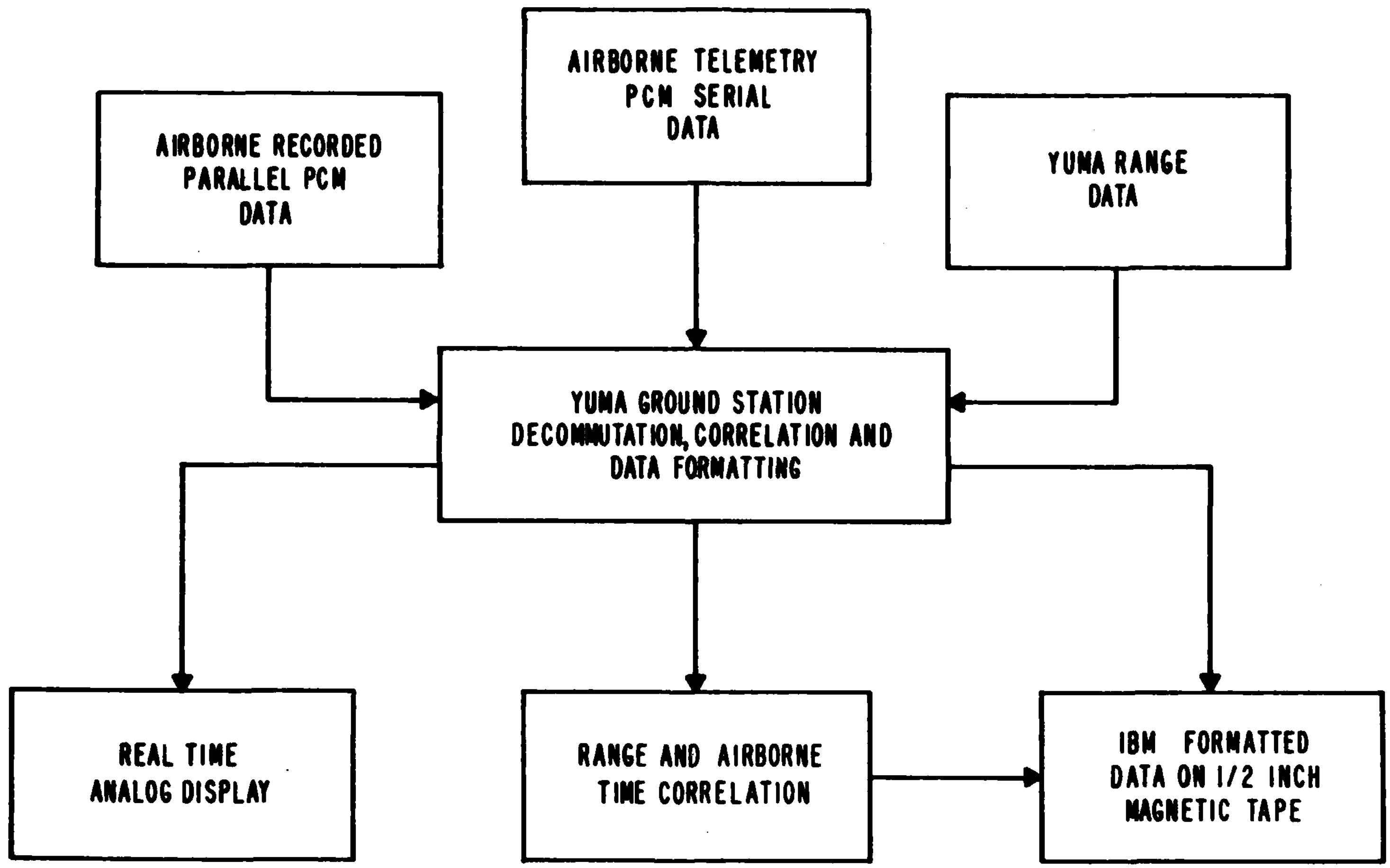


FIG. 1 DATA FLOW BLOCK DIAGRAM

Flight data was also available from film exposed onboard the aircraft. A camera was used in conjunction with the rocket gunsight. The camera recorded the position of the gunsight pipper with respect to the target and monitored the flight of the rocket to the impact area. A second camera was used to record fuel quantity, engine torque and the aircraft bank and turn indicator available on the co-pilot's instrument panel.

The airborne instrumentation system sensed, digitized and recorded on magnetic tape all of the appropriate flight parameters which are described in detail in section 4.1.2. The entire information package was made available to the data reduction center for decommutation, correlation and formatting.

The PCM serial telemetry data was processed in real time and transmitted back to the communications station for display. The ground unit was capable of displaying up to six channels of information in real time. Three channels were used to monitor the aircraft attitude in the yaw, pitch and roll planes. Two channels were assigned to monitor the two nose angle of attack indicators on the aircraft and one channel was available for the trigger pulse indication. Monitoring of the real time display was done so that any abnormalities in the flight characteristics including severe attitude changes or large wind gusts could be detected and noted as a transient initial condition during data analysis.

The data reduction center processed the information from the parallel tape, films, radar, theodolite, and meteorological data and time correlated it to standard range time. A range time clock signal was available for transmission to all units for recording with the data. The correlation then became a simple matter of aligning the time periods so that the data could be accurately compared and analyzed.

The final output from the data reduction center consisted of printout of all data except the parallel recorded PCM data. The airborne tape was decommutated at the data reduction center and a 9-track IBM formatted tape was written. This tape was made available to MUCOM for detailed analysis.

4.1.2 Airborne Instrumentation System

The total airborne instrumentation system as configured and delivered for the baseline test is shown in Figure 2 with data signal flow depicted between major subsystems.

4.1.2.1 Sensors and Transducers

The instrumentation sensors and transducers were designed to monitor the various test parameters and convert the information into a voltage representation compatible with the ECOM supplied data acquisition unit. The performance characteristics of each transducer selected were evaluated individually and functionally in the overall installation to assure that the sensitivity and accuracy requirements of the system were as specified.

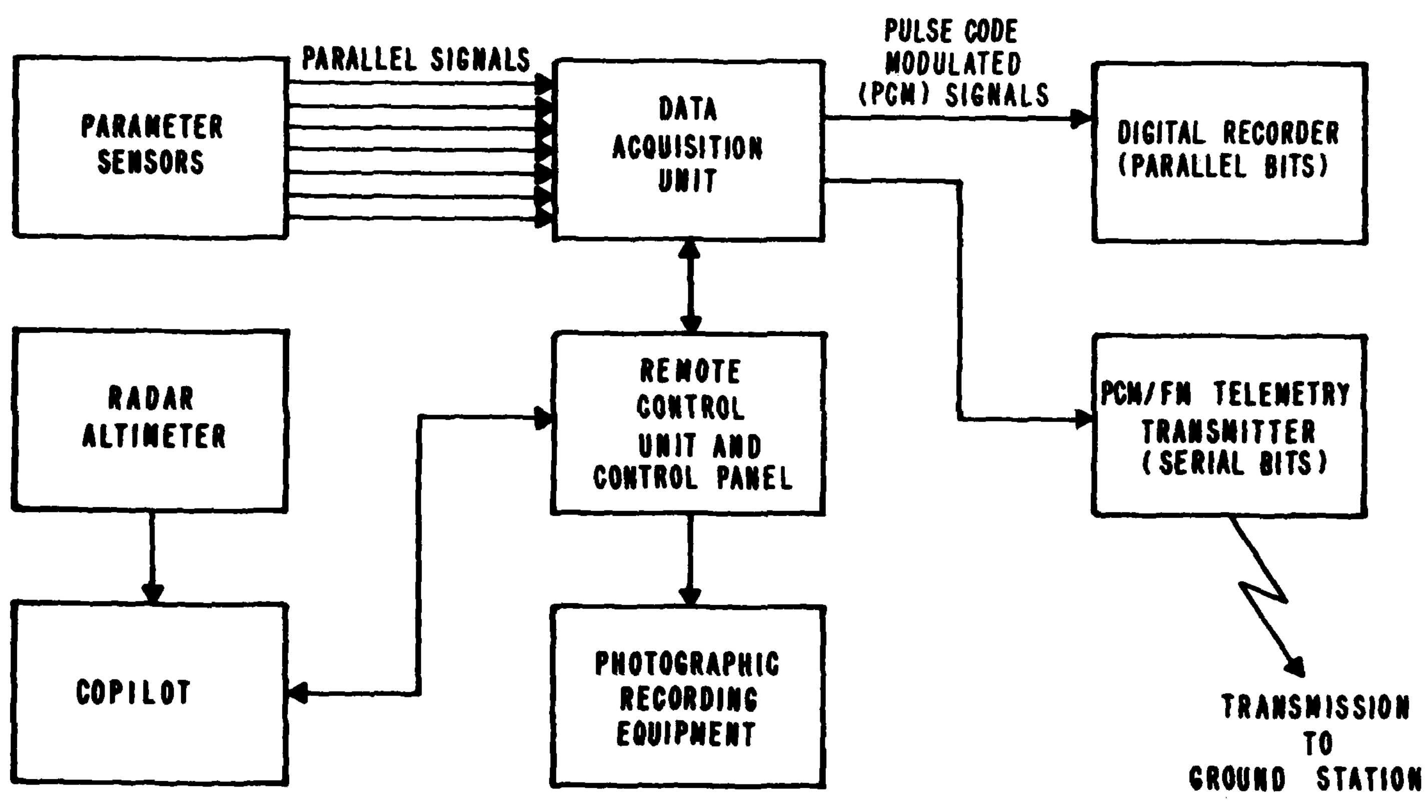


FIG. 2 2.75" ROCKET BASELINE ACCURACY INSTRUMENTATION AIRBORNE PACKAGE

SENSOR TYPE	SENSOR STATISTICS			DATA STATISTICS		
	SCALE FACTOR	SENSOR SENSITIVITY		DATA RESOLUTION	DATA PRECISION	DATA FREQUENCY CUTOFF
		ACCURACY	FREQUENCY RESPONSE			
ANGLE OF ATTACK TRANSMITTERS	12.5 DEG / VOLT *	±.1 DEG	12 Hz	.0625 DEG	.125 % OF FULL SCALE (F.S.)	200 Hz
LINEAR VARIABLE DIFFERENTIAL TRANSFORMER (LVDT)	0.32 IN / VOLT	±.005 IN.	100 Hz	.0016 IN.	.08 % OF F.S.	200 Hz
ACCELEROMETER	1.0 G / VOLT	±.001 G	> 100 Hz	.005 G	.05 % OF F.S.	100 Hz
RATE GYRO	10 DEG / SEC / VOLT	±.15 DEG/SEC	> 22 Hz	.04 DEG/SEC	.066 % OF F.S.	100 Hz
POSITION GYRO	18 DEG / VOLT	±.1 DEG	> 22 Hz	.09 DEG	.05 % OF F.S.	100 Hz

* AVERAGE VALUE FOR ALL ANGLE OF ATTACK TRANSMITTERS

FIG. 3 SENSOR & DATA STATISTICS

The parameter sensor statistics including scale factor, accuracy and frequency response are shown in Figure 3 and are self-explanatory. Total data statistics, including data resolution precision and frequency cutoff, for each sensor type are also shown in Figure 3. Definitions of the data statistics are as follows:

Data Resolution	The smallest engineering unit value or change in value that can be detected by the data acquisition system.
Data Precision	The percentage of full scale that the smallest detectable incremental value represents.
Data Frequency Cutoff	The frequency at which the magnitude of the output data has fallen 3 db below the input.

The parameters sensed and monitored during Phase A testing and the enumerated data word assigned to each sensor are listed in Figure 4.

DATA WORD	PARAMETER TRANSDUCER
A1	Left IR Detector
A2	Lateral Accelerometer
A3	Vertical Accelerometer
A4	Fore/Aft Accelerometer
A5	Right IR Detector
A6	Roll Rate
A7	Yaw Rate
B1	Aircraft Pitch
B2	Aircraft Roll
B3	Aircraft Yaw
B4	Pitch Rate
B5	Angle of Attack 2 Left Pitch
B6	Angle of Attack 2 Left Yaw
B7	Angle of Attack 4 Right Pitch
B8	Angle of Attack 4 Right Yaw
B13	Angle of Attack Nose Yaw
B14	Angle of Attack Nose Pitch
B15	Angle of Attack 1 Left Yaw
B16	Angle of Attack 1 Left Pitch
B17	Angle of Attack 5 Right Yaw
B18	Angle of Attack 5 Right Pitch

NOTE: The angle of attack sense planes listed here correspond to configuration number 4.

FIG. 4 PHASE A TRANSDUCER DATA WORD ASSIGNMENT

The transducer used during Phase B testing and the data words assigned to the sensors are shown in Figure 5.

DATA WORD	PARAMETER TRANSDUCER
A1	Left IR Detector
A2	Lateral Accelerometer
A3	Vertical Accelerometer
A4	Fore/Aft Accelerometer
A5	Right IR Detector
A6	Roll Rate
A7	Yaw Rate
B1	Aircraft Pitch
B2	Aircraft Roll
B3	Aircraft Yaw
B4	Pitch Rate
B5	LVDT Left Horizontal Forward
B6	LVDT Left Vertical Forward
B7	LVDT Left Horizontal Aft
B8	LVDT Left Vertical Aft
B9	LVDT Right Horizontal Forward
B10	LVDT Right Vertical Forward
B11	LVDT Right Horizontal Aft
B12	LVDT Right Vertical Aft
B13	Angle of Attack Nose Yaw
B14	Angle of Attack Nose Pitch
B15	Angle of Attack Left Yaw
B16	Angle of Attack Left Pitch
B17	Angle of Attack Right Yaw
B18	Angle of Attack Right Pitch

NOTE: The angle of attack sense planes listed above correspond to configuration number 5.

FIG. 5 PHASE B TRANSDUCER DATA WORD ASSIGNMENT

4.1.2.2 Control Panel

An instrumentation control panel was provided for the co-pilot to control the following functions: inertial reference system power, azimuth gyro cage, transducer excitation, camera control, and run number selection. The control panel is more completely described in paragraph 5.1.2.

4.1.2.3 Radar Altimeter

An ECOM provided radar altimeter was installed on each AH-1G helicopter with displays in both the pilot and co-pilot compartments. The radar altimeter provided altitude information to the pilot during the test flights. The information supplemented the ground radar data, provided via the flight director, particularly at low altitudes.

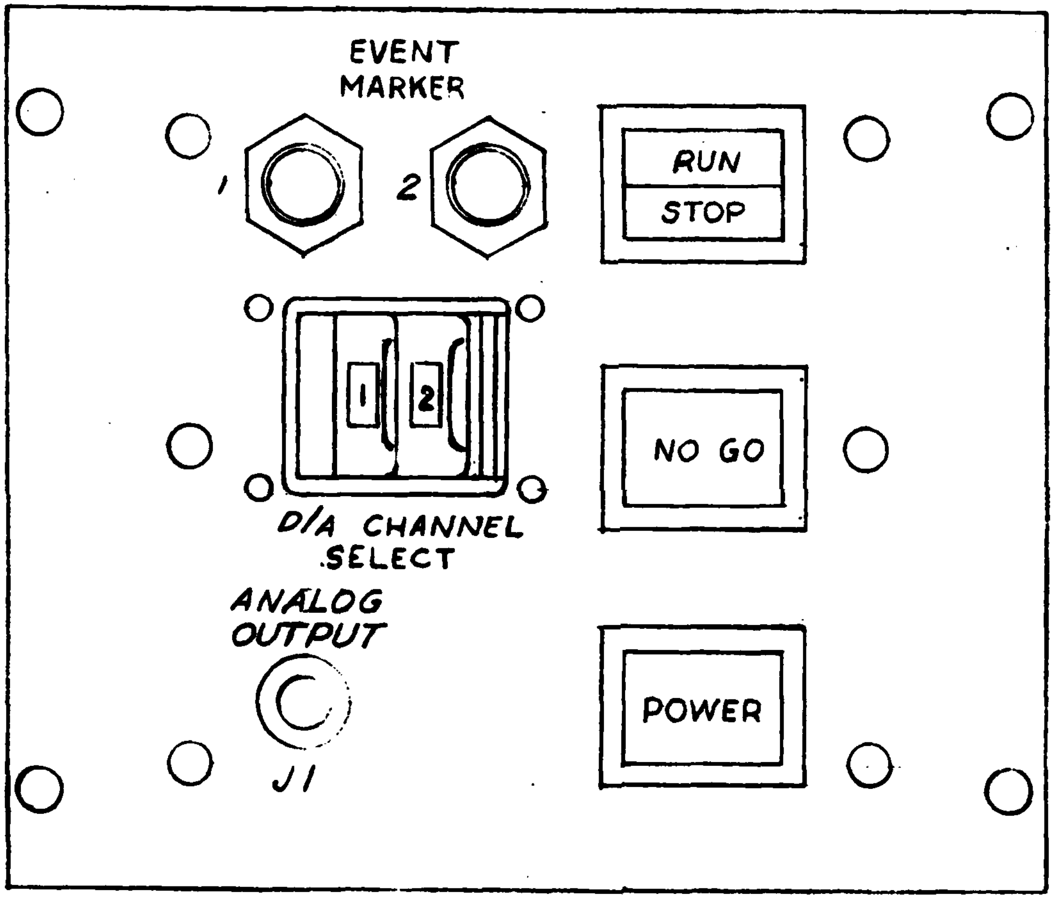


FIG. 6 CONTROL UNIT

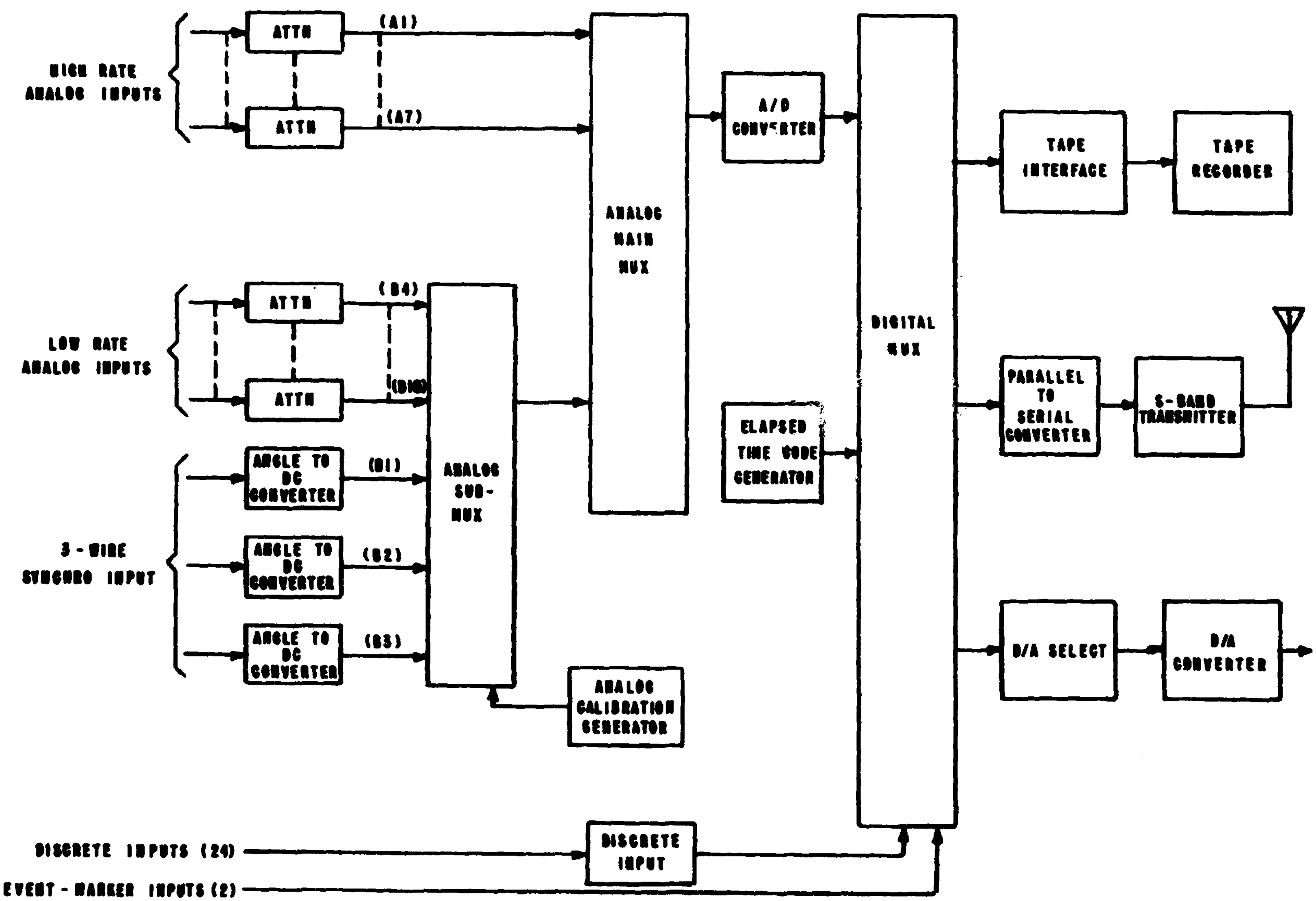


FIG. 7 DATA ACQUISITION SYSTEM BLOCK DIAGRAM

4.1.2.4 Control Unit

The data acquisition system is activated by a control unit (CU), Figure 6, located in the co-pilot's compartment of the AH-1G helicopter. The control unit "NO GO" light indicates the condition of all internal power supply voltages required for operation of the sampling system. Two event marker pushbuttons are available on the CU for marking special events during the flight test. An output is provided on the control unit where the digital output from the multiplexer is converted back to an analog voltage. Any of the analog channels can be viewed with a digital voltmeter connected to J1 on the CU. The channel is selected by the "D/A CHANNEL SELECT" thumbwheel switches on the CU face panel.

4.1.2.5 Data Acquisition Unit

The output of the parameter transducers is input to the Data Acquisition Unit (DAU) which provides the central control for the operation of the instrumentation system. The DAU functional block diagram is shown in Figure 7.

Data is transmitted by the DAU to the digital magnetic tape recorder in a bit parallel pulse code modulated format as shown in Figure 8. The data is stored on the one inch tape for data analysis which was performed later at the data reduction center. The digital words are also converted into a serial bit stream by the DAU parallel to serial converter and transmitted by the PCM/FM telemetry transmitter to the ground station real time data display.

RECORDER TAPE TRACK	FUNCTION
1	Not Used
2	Parity
3	Sign
4	Bit 10 (MSB)
5	Bit 9
6	Bit 8
7	Bit 7
8	Word Mark
9	Bit 5
10	Bit 4
11	Bit 3
12	Bit 2
13	Bit 1 (LSB)
14	Bit 6
15	Not Used
16	Range Time (Pulse Amplitude Modulated)

FIG. 8 RECORDER DATA FORMAT

The multiplexing system begins sampling the transducer outputs immediately upon activation of the "power" switch in accordance with the preselected format. Power is simultaneously applied to the telemetry transmitter and transmission of the serial data commences via the S-band telemetry antenna. The sampled data is applied to the digital recorder following activation of the "power" switch but the data is not recorded until the "run" switch is depressed. Recorder transport power, tape speed selection, and tape recording direction is accomplished on the tape transport located in the ammunition compartment of the aircraft.

The parameter sensor outputs are input to either the high rate or low rate channels depending upon the sampling rate requirements. The inputs to the DAU are in the ±5 volt or ±25 volt range. The attenuation card converts the higher voltage analog inputs into a common range of ±5 volts and provides selected filtering of the higher frequency noise components. The high rate channels, channels A1 thru A7, are applied directly to the analog main multiplexer. The low rate channels, which include the three synchro channels, are inputs to an analog submultiplexer. The synchro information is converted to a DC voltage prior to application to the submultiplexer. As can be seen from the block diagram the DAU analog calibration voltage is also input to the submultiplexer. The calibration generator provides five calibration voltages to the system which aids in determining if the system is operational.

An analog to digital (A to D) converter converts the data samples output from the main multiplexer into a digital binary code consisting of 10 magnitude bits plus a sign bit. System sensitivity is set at 5 volts = 1000 counts, the least significant bit is representative of a 5 millivolt analog step. The digital words are applied to the digital multiplexer along with information from the discrete inputs, the time code generator and the event markers. These digital inputs are then arranged into the desired parallel and serial output formats. The data format frame selected for the Baseline Test is shown in Figure 9. The DAU processes 100 frames of sampled data per second. Therefore the analog inputs to the "A" channels are sampled 1000 times per second and the "B" channels are sampled 100 times per second.

4.2 Aircraft Configuration Control

4.2.1 Instrumentation Configuration

Phase A flight tests were performed in order to determine the aerodynamic flow patterns around the two instrumented aircraft. Each rocket launcher was equipped with an angle of attack transmitter pod that was designed to cause minimal disturbances in the airflow. Each pod housed two transmitters sensitive to the airflow in the yaw and pitch planes.

The IR detector trigger shaping networks were used during the simulated rocket firing flights to indicate the occurrence of a trigger pulse.

A1	A2	A3	A4	A5	A6	A7	B1	CA	CD	B11	D1
A1	A2	A3	A4	A5	A6	A7	B2	CA	CD	B12	D2
A1	A2	A3	A4	A5	A6	A7	B3	CA	CD	B13	D3
A1	A2	A3	A4	A5	A6	A7	B4	CA	CD	B14	D4
A1	A2	A3	A4	A5	A6	A7	B5	CA	CD	B15	D5
A1	A2	A3	A4	A5	A6	A7	B6	CA	CD	B16	C1
A1	A2	A3	A4	A5	A6	A7	B7	CA	CD	B17	C2
A1	A2	A3	A4	A5	A6	A7	B8	CA	CD	B18	CAL
A1	A2	A3	A4	A5	A6	A7	B9	CA	CD	ET1	ET2
A1	A2	A3	A4	A5	A6	A7	B10	CA	CD	S1	S2

DATA INPUT CHANNELS

WORD	INPUT
A1 – A7	HIGH RATE ANALOG
B1 – B3	SYNCHRO
B4 – B18	LOW RATE ANALOG
D1	FLIGHT TEST RUN CODE
D4	EVENT MARKERS

DAU GENERATED INFORMATION

WORD	FUNCTION
ET1 – ET2	ELAPSED TIME CODE
CAL	CALIBRATION WORD
S1 – S2	SYNCHRONIZATION WORD

NOTE: ALL OTHER WORDS ARE UNUSED.

FIG. 9 DATA FRAME FORMAT

Two aircraft, tail numbers 66-15250 and 67-15691 were identically configured for Phase A as shown in Figure 10 entitled "Phase A Aircraft Configuration". The starred (*) items are common to both aircraft in Phases A and B.

In addition to the common items, aircraft 66-15250 was instrumented to allow rockets to be fired from the inboard pods during Phase B. The accommodating mounts for the LVDTs were provided in the appropriate position for monitoring the rocket pod motion. Angle of attack pods remained in the nose and outboard pod positions to monitor the airflow during these flights. The LVDT and the angle of attack pod configuration for aircraft 66-15250 is indicated in Figure 11 The common items shown in Figure 10 were not repeated in Phase B configuration drawings.

Aircraft 67-15691 was configured to allow the 2.75 inch rockets to be fired from the outboard pods while monitoring of the airflow patterns was accomplished by the angle of attack transmitters installed in the inboard position as indicated in Figure 12.

A composite Phase A and B configuration checklist for the two aircraft is provided as a reference in Figure 13.

Six different angle of attack configurations were used in Phase A to obtain the desired aerodynamic flow patterns. These configurations are shown in Figure 14 with the angle of attack transmitters drawn as seen by the pilot. The various angle of attack arrangements provided information to determine: the flow pattern about the aircraft, the optimal instrumentation configuration and aircraft angle of attack as a function of dive angle and power setting.

Three Phase B configurations for aircraft 66-15250 and two Phase B configurations for aircraft 67-15691 were flown during the live firing passes of the 2.75 Inch Rocket Program. The configurations can be seen in Figure 15. The angle of attack transmitter positions are shown as viewed by the pilot.

4.2.2 Electrical Configuration

The electrical cabling block diagram of the data acquisition system as installed in two AH-1G helicopters for the baseline test program is depicted in Figure 16. Except for the 28 VDC aircraft power input, only the outputs from the junction box are shown in this figure.

The junction box is a central distribution point for all power and signal information. Each signal line is easily accessible for monitoring during calibration, preflight, and troubleshooting operations. The junction box also contains power supplies to provide instrumentation energizing voltages and the filtering networks required to minimize the conducted, coupled and radiated electrical interference on the data lines.

Aircraft 28 VDC power to the junction box is controlled by a circuit breaker in the pilot's compartment. The power is distributed to the tape recorder and telemetry transmitter from the DAU connectors J8 and J7,

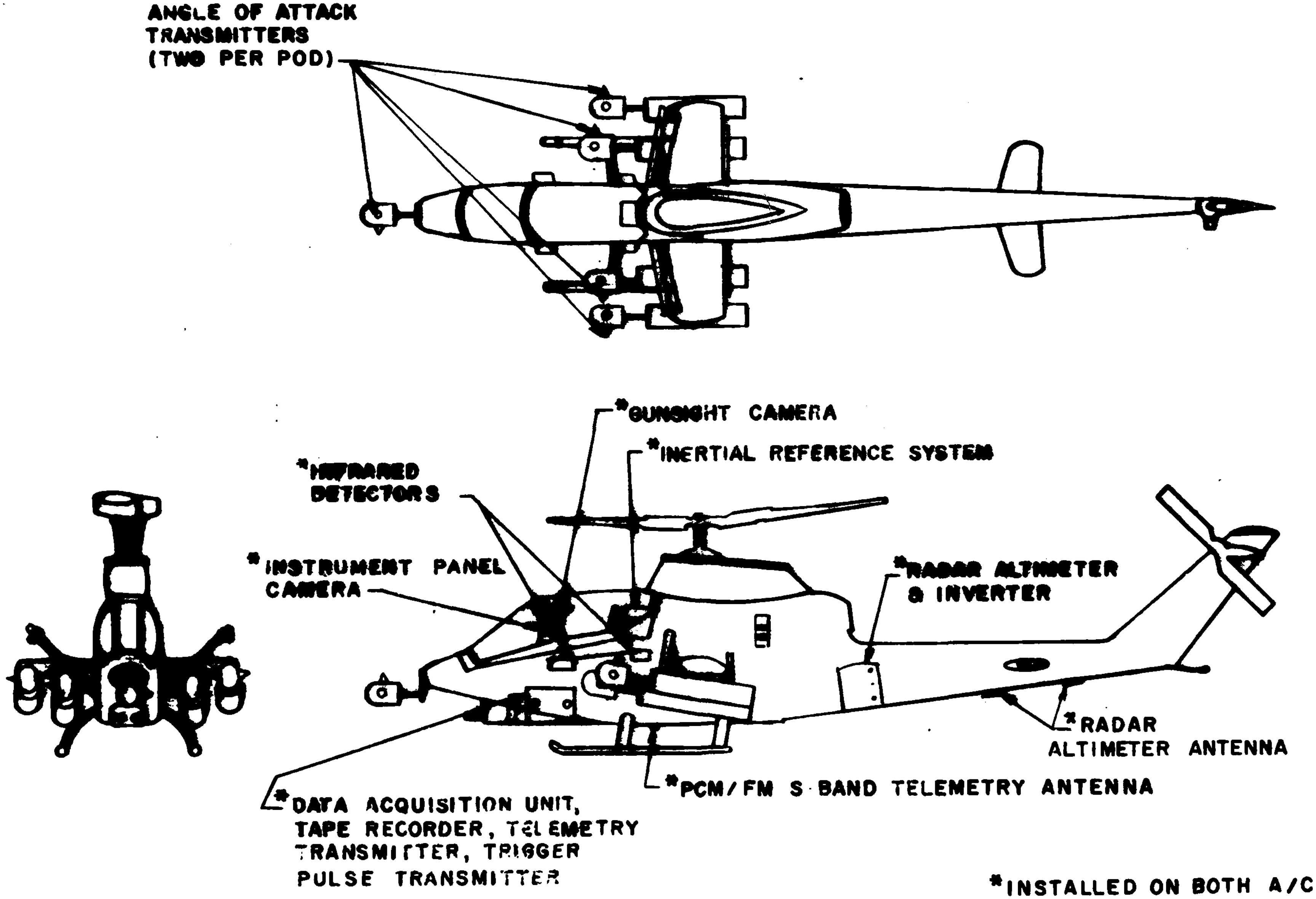


FIG. 10 PHASE A AIRCRAFT CONFIGURATION

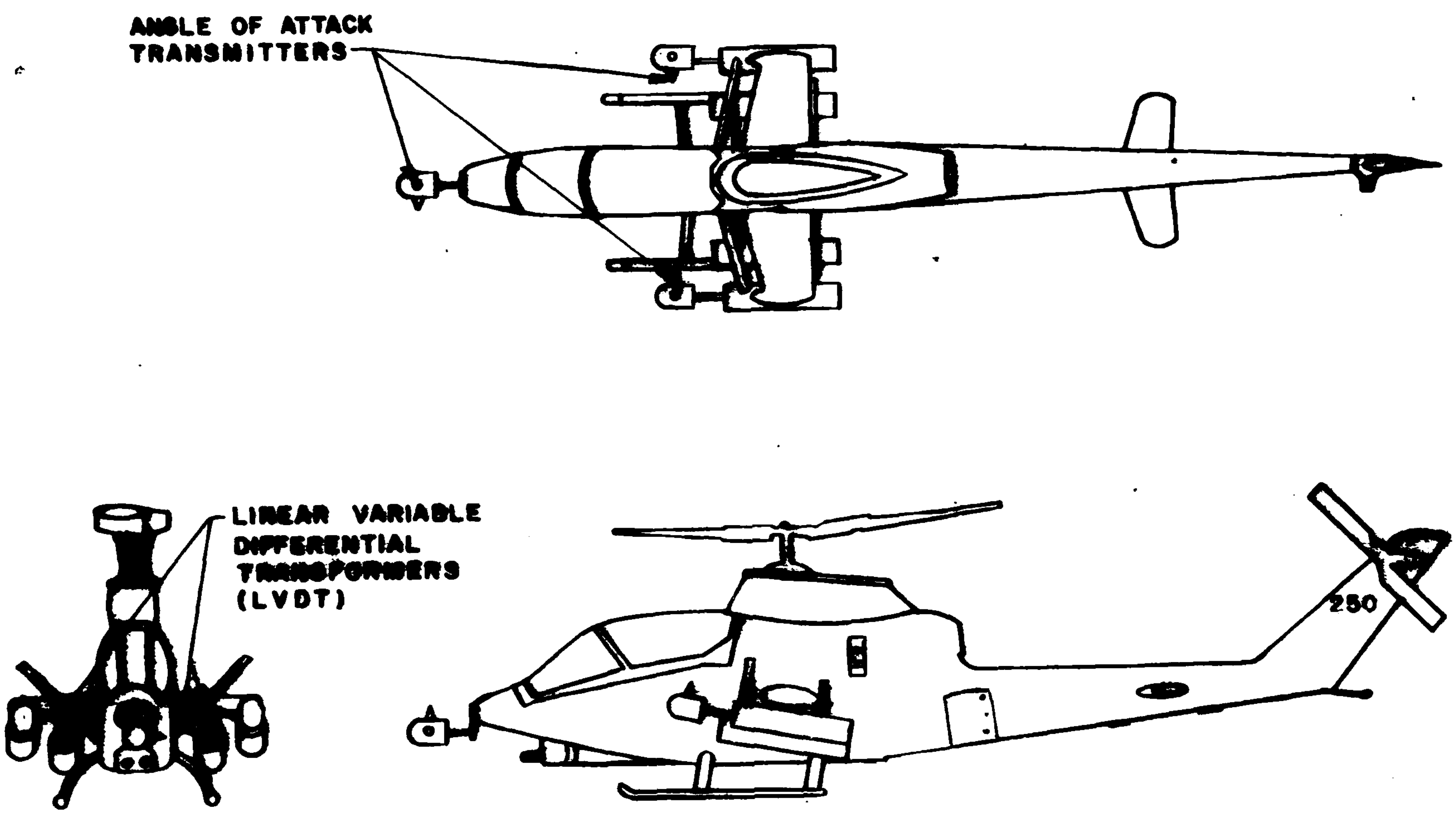


FIG. 11 PHASE B AIRCRAFT CONFIGURATION
(AC #250)

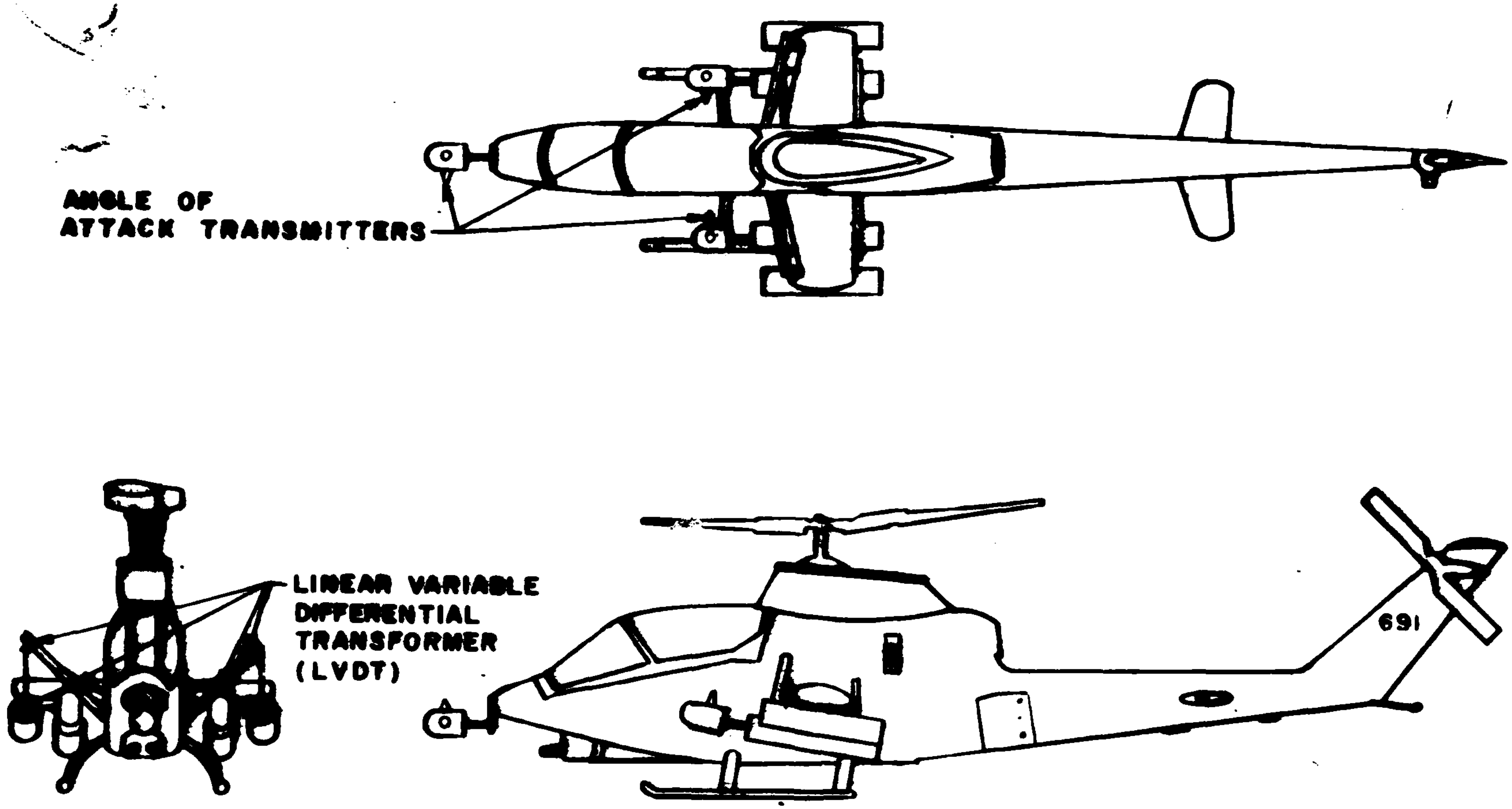


FIG. 12 PHASE B AIRCRAFT CONFIGURATION
(AC #691)

CONFIGURATION CHECKLIST

Angle of Attack Sensors	Phase A	Phase B(A/C 250)	Phase B(A/C 691)
Left Outboard	X	X	
Left Inboard	X		X
Nose	X	X	X
Right Inboard	X		X
Right Outboard	X	X	
LVDT			
Left Outboard			X
Left Inboard		X	
Right Inboard		X	
Right Outboard			X
Inertial Reference System			
Altitude	X	X	X
Rate	X	X	X
Acceleration	X	X	X
Radar Altimeter	X	X	X
Infrared Detectors	X(Trigger pulse only)	X	X
Gunsight Camera	X	X	X
Instrument Panel Camera	X	X	X

FIG. 13

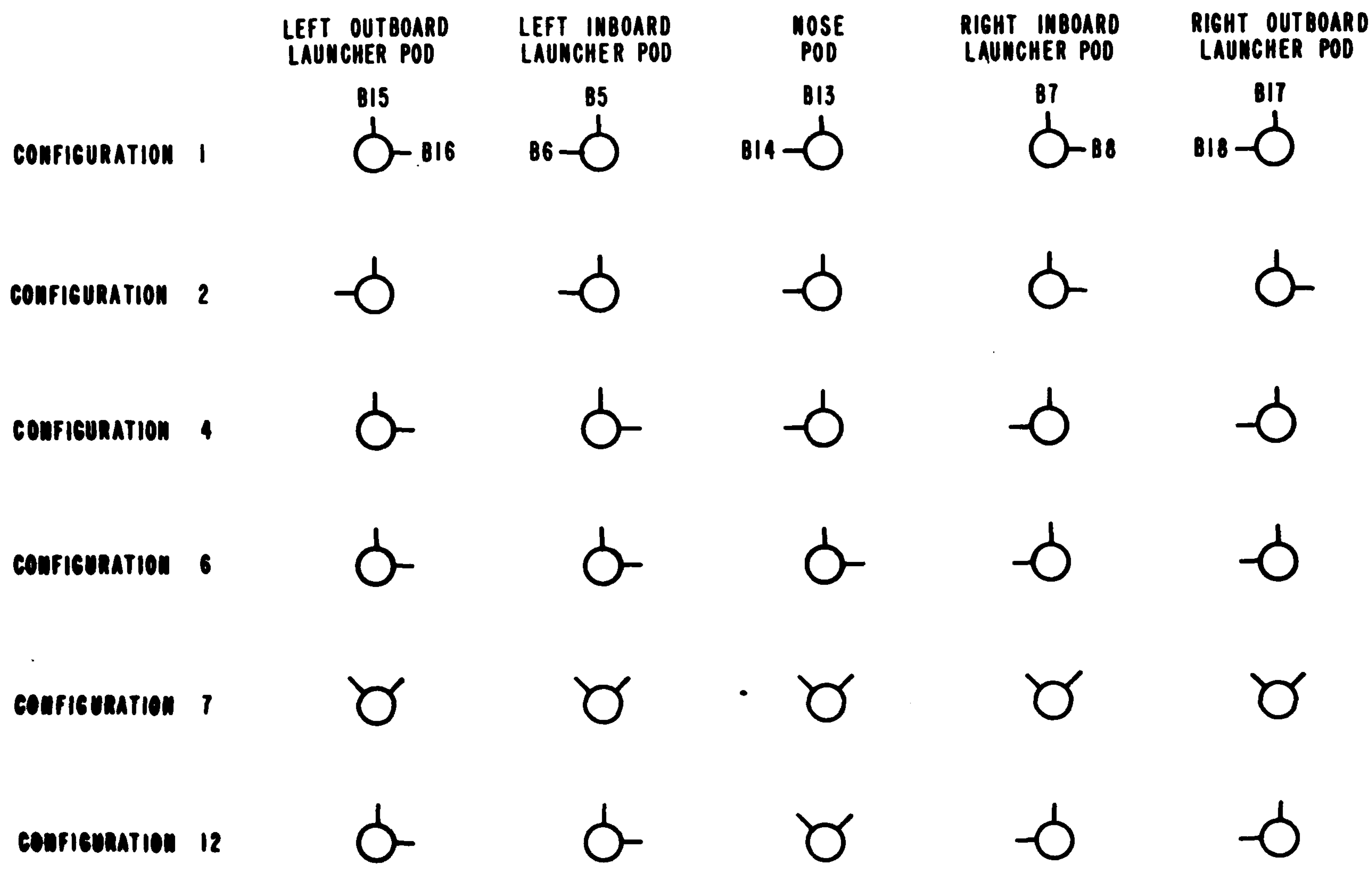


FIG. 14 PHASE "A" SENSOR CONFIGURATION

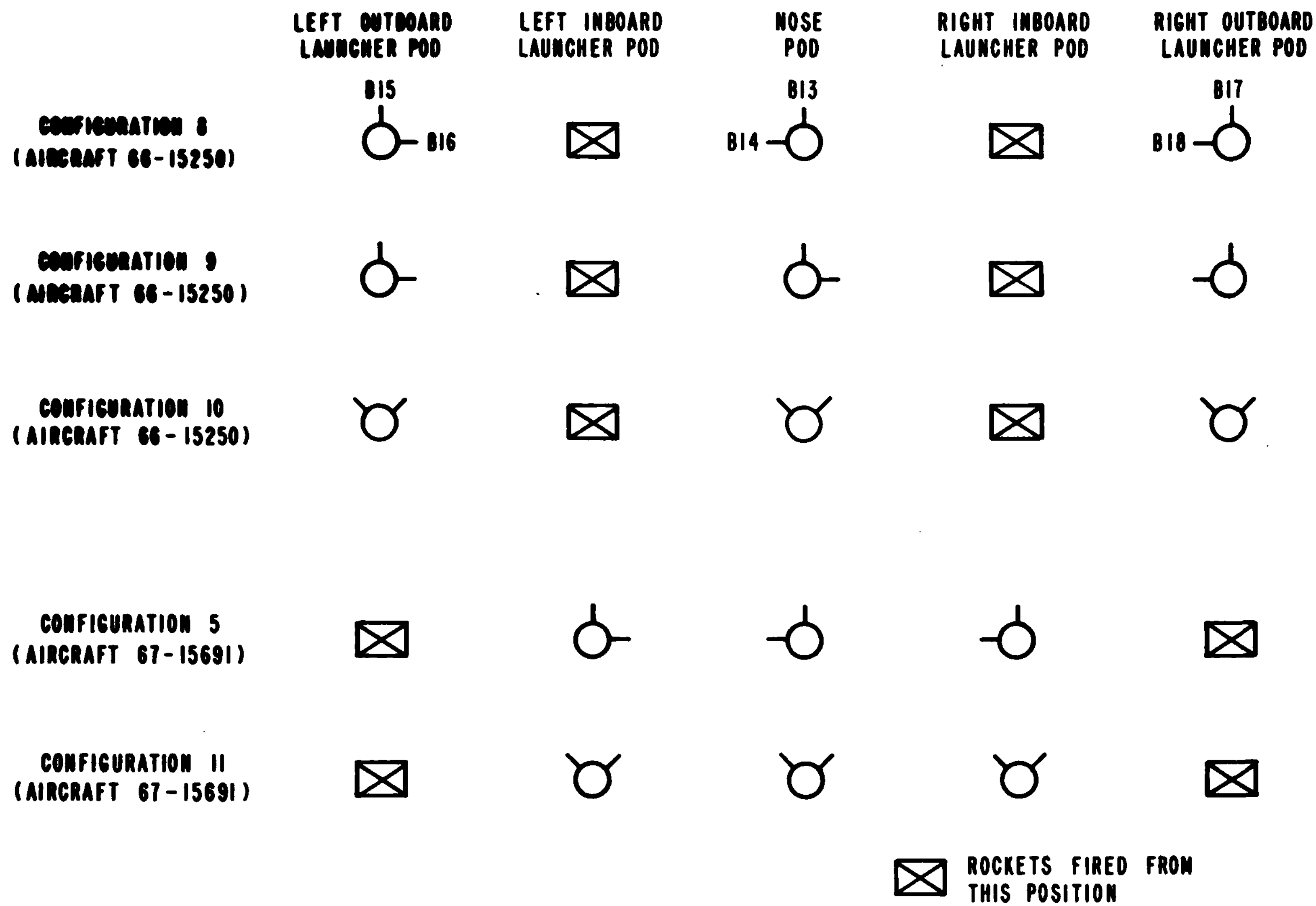


FIG. 15 PHASE "B" SENSOR CONFIGURATIONS

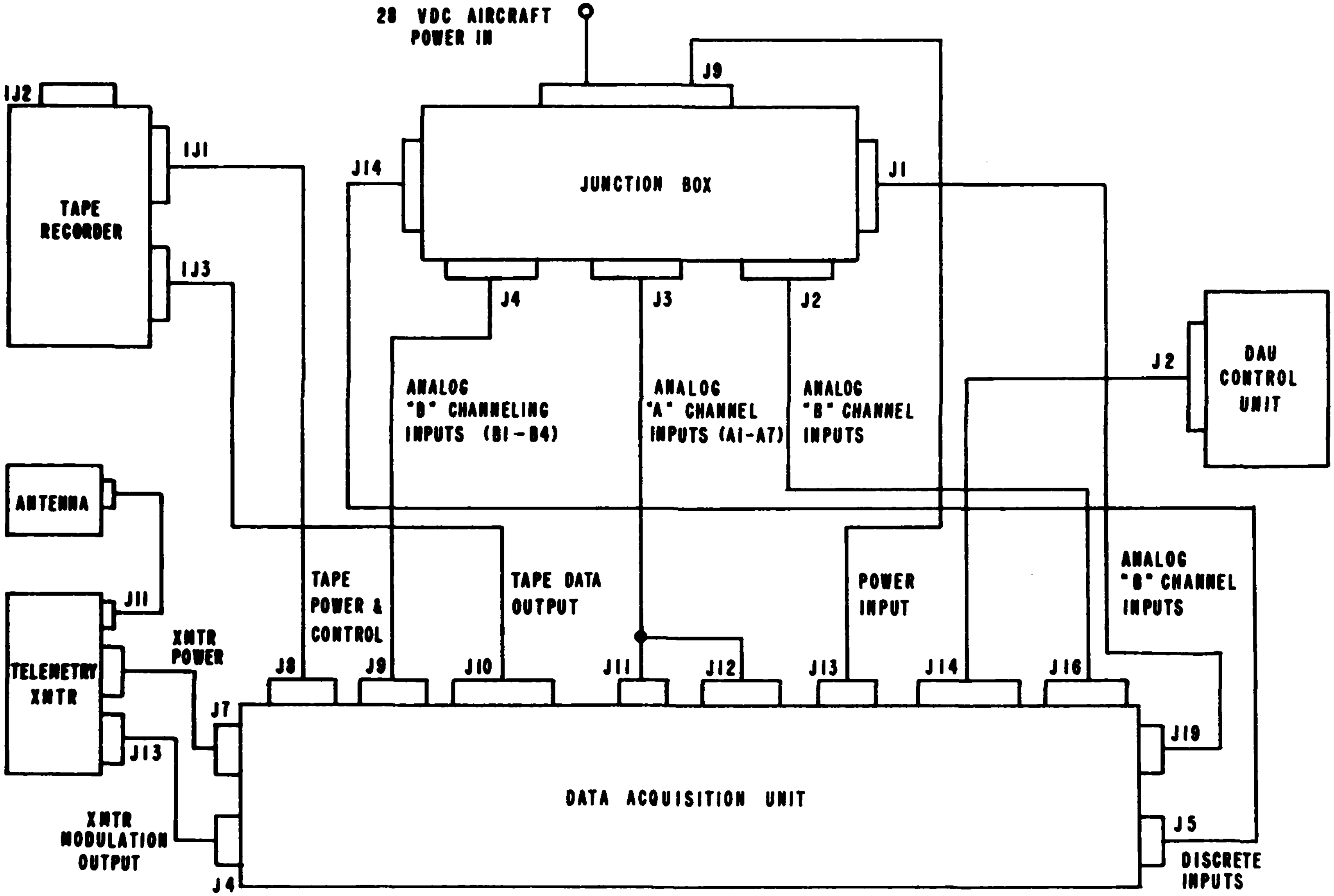


FIG. 16 DATA ACQUISITION SYSTEM CABLING DIAGRAM

respectively, when the DAU "power" switch is depressed on the control unit. The DAU processes the analog information available at connectors J9, J11, J10, and J19 and generates the multiplexing format, test code, event markers, and time code, all of which is available at the output of the DAU connector J10. The PCM data is distributed to the telemetry transmitter from DAU connector J4 and is transmitted to the ground station via the S-Band telemetry antenna. Separate control of the tape recorder is provided at the control unit.

The cabling diagram included as Figure 17 shows the analog interface with the junction box which includes sixteen LVDT channels into connectors J5 - J8, ten angle of attack transmitters channels into J11, four IR detectors channels through J12 and J13 and outputs from the inertial reference system into J10. The analog information is output to the DAU via connectors J1 - J4 of the junction box.

The cabling diagram for the control panel and aircraft camera system interface is depicted in Figure 18. The panel provides control of the following four functions: (1) transducer excitation; (2) camera ON/OFF control; (3) inertial reference system excitation; and (4) yaw gyro caging. The test code associated with each test run is programmable by selecting a binary combination of switches on the control panel. This information is recorded as digital data on the discrete channel D1 in the main data frame.

4.3 Instrumentation Alignment Procedures

4.3.1 Initial Hardware Mounting and Alignment

Initial instrumentation hardware alignment was accomplished in accordance with the American Electronics Laboratory (AEL) prepared document entitled "Test Plan for the 2.75 Inch FFAR Baseline Accuracy Test". This procedure was accomplished at AEL's Monmouth County Facility prior to the preliminary flight tests described in paragraph 3.2. Upon completion of the alignment procedure scribe marks were made on the LVDT supports, the angle of attack pod extension tubes, the infrared detector mounts, and the adjacent structures to simplify the remounting of the sensors in the correct position during instrumentation changes.

Following the transfer of the aircraft to YPG the instrumentation hardware was remounted and aligned using the scribe marks as a reference. The alignment was checked to prove that it was accomplished accurately.

The alignment of the gunsight and rocket launchers was accomplished in accordance with the following procedure:

a. Two plum bobs were hung from hard points located on the longitudinal axis of the aircraft.

b. A line coincident with longitudinal axis of the aircraft was determined using a transit and sighting the two plum bobs.

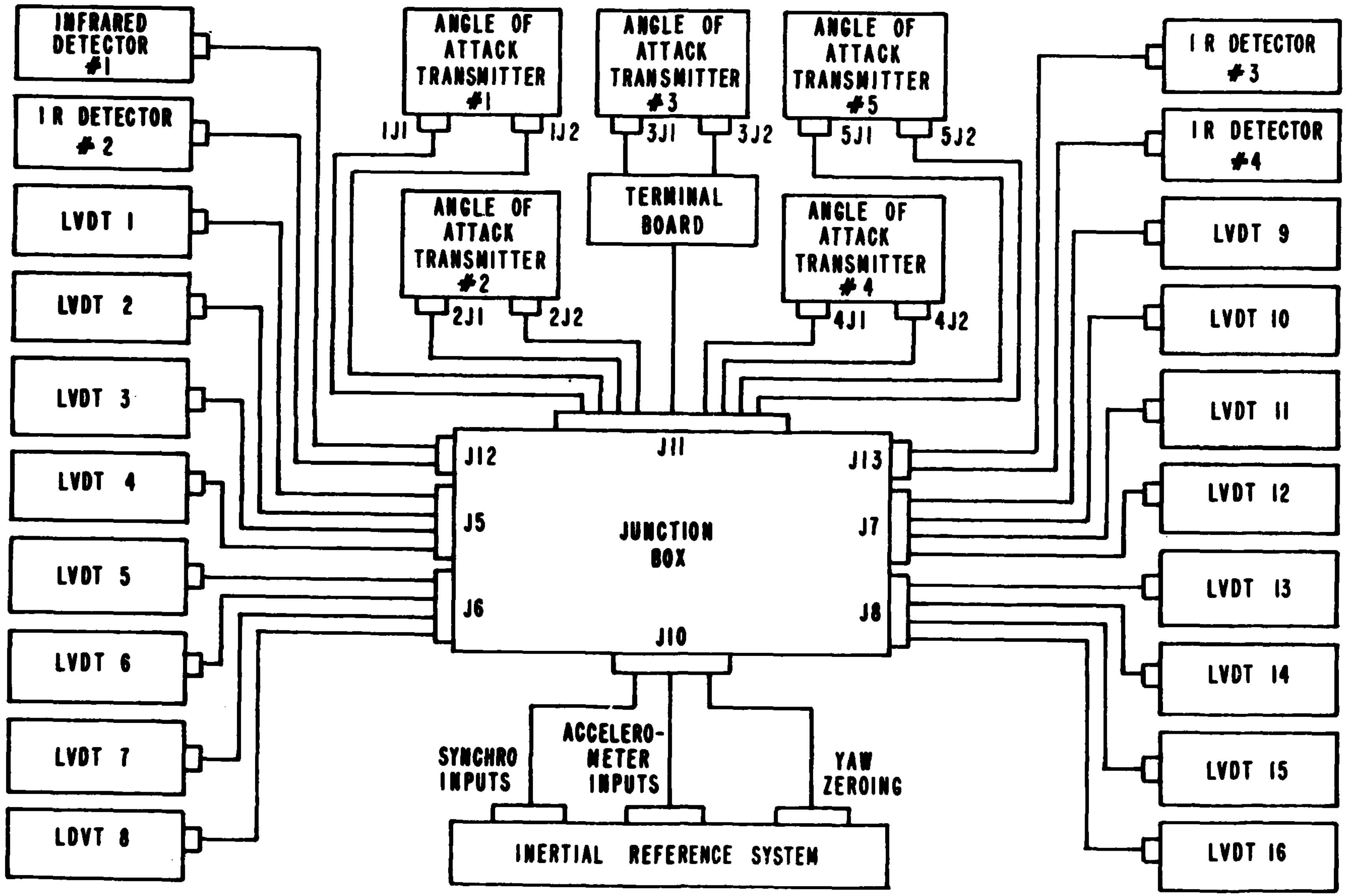


FIG. 17 TRANSDUCER SYSTEM CABLING DIAGRAM

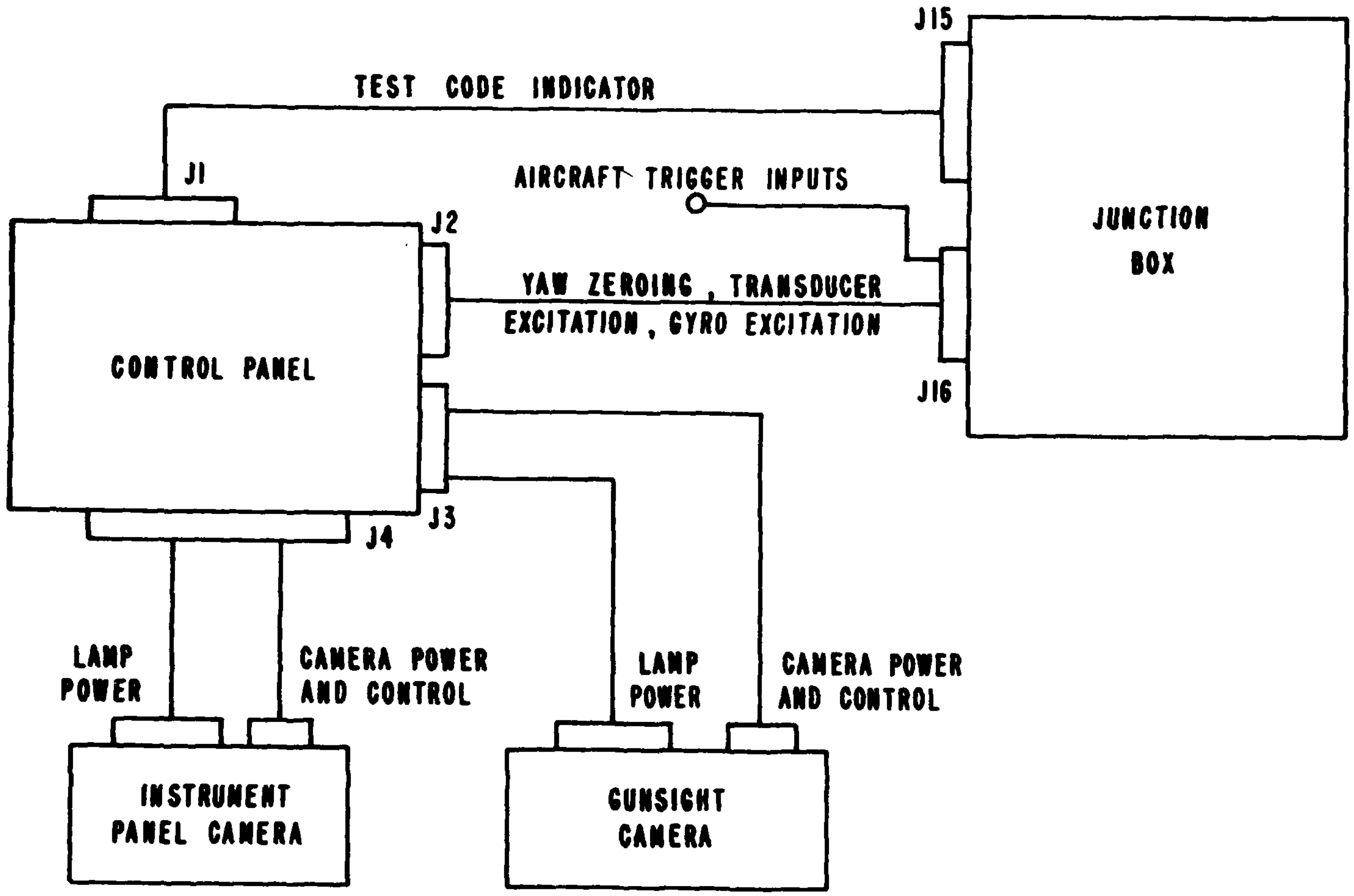


FIG. 18 CONTROL PANEL AND CAMERA CABLING DIAGRAM

c. The gunsight was adjusted until the pipper was accurately sighted on the "target" located on the extended axis at a distance of approximately 1000 inches.

d. Crosshairs were formed at the front and rear opening of the center tube of each launcher.

e. The launchers were then adjusted until the center tube was accurately aimed at the distant "target".

4.3.2 Equipment Alignment Procedure

The following is a description of the procedures used during the test to align and adjust the various sensors and equipments used in the aircraft instrumentation package.

4.3.2.1 Inertial Reference System (IRS)

The method used to properly install and calibrate the IRS required that the aircraft be leveled. This was done using standard aircraft jacks and determining the proper orientation using a sensitive bubble level placed on special leveling blocks located in the ammunition compartment. Once it was determined that the aircraft was level, power was applied to the IRS system. Monitoring the output synchro channels with a digital voltmeter connected to the analog output connector on the DAU control unit indicated how far the system was out of trim. Shims were then used to level the IRS in pitch and roll. A reading of approximately 0 VDC indicated the gyro package was level. The alignment of the system in yaw was not critical. Centering the IRS platform in the mounting holes allowed an error of only ±3°. This offset was of no significance because of minimal cross coupling onto the pitch and roll erected axes. The yaw gyro was caged to zero degrees when the azimuth of the aircraft was recorded on the gunsight camera film and any subsequent yaw motion was accurately indicated to within ±.1 degree.

An alternate method of aligning the IRS would be to determine the pitch and roll attitude of the aircraft and align the platform to duplicate the relative aircraft attitude. As an example the aircraft may be in a +3° pitch position. Each digital bit in the synchro channel represents 0.09 degrees and each bit represents 5 millivolts. Therefore the required digital voltmeter reading can be determined using the conversion factors:

$$(3 \text{ degrees}) \times (11.11 \text{ bits/degree}) \times (5 \text{ mv/bit}) = 166.6 \text{ mv}$$

The package can then be shimmed until the digital voltmeter indicates 166.6 mv output. The IRS will then be properly oriented in the pitch plane. A similar procedure would be followed to adjust the system in the roll plane. The outputs must be checked in each plane when shims are inserted and again when the unit is secured to its mounting frame.

4.3.2.2 Angle of Attack Transmitters (AAT)

Upon completion of the initial alignment as described in the AELSC prepared test plan, the yaw and pitch angle of attack indicators lie in a plane perpendicular to the extension tube and are mutually perpendicular. (See Figure 44, paragraph 5.1.5)

The only adjustment necessary to align the pair of AAT transmitters after insertion in the appropriate rocket tube is to align the horizontal AAT so that it is coincident with the aircraft pitch axis. This adjustment will automatically align the yaw AAT. The alignment is made using a sensitive bubble level on the specially machined surface located in the rear of the pod shell. Following the alignment of the pod a cap is placed over the extension tube at the rear of the launcher and a locking bolt draws the pod and tube assembly together in the launcher and secures it in position.

4.3.2.3 Infrared Detector

The rear infrared detector mount must be adjusted so the IR field of view is the area immediately ahead of the rocket launcher. Realignment is required whenever the elevation angle of the launcher changed significantly. The adjustment is made by loosening the bolt on the mount (See Figure 19) until the IR detector and its adjacent mounting surface move freely. With the launcher adjusted for the proper elevation angle, a flashlight positioned directly opposite the IR detector and moved forward from behind the launcher simulates the plume of an egressing rocket. It can be determined if the detector is monitoring the area properly by connecting an oscilloscope at the output of the detector. The output can be monitored in the junction box on terminal board #3. Pins 6A and B are the output of the IR detectors on the left side of the aircraft and pins 10A and B are the output for the right side detectors. A negative pulse (-1.5 volts) should be noted with a duration of 1.5 milliseconds when the light impinges on the sensor. The mount can be locked into position by tightening the bolt when the correct position has been determined.

The forward IR detectors located five feet ahead of the rear detectors can be checked using the light and monitoring the output for a -0.5 volt pulse.

There are no electrical adjustments to be made on the IR detectors when they are moved between aircraft.

4.3.2.4 Linear Variable Differential Transformer (LVDT)

The LVDTs must be aligned in the following manner. The metal band around the launcher is loosened until the rod coupling can move freely. The coupling is moved until the LVDT sensing rod (vertical and horizontal) is perpendicular to the launcher axis. The band is then tightened. For the outboard launcher horizontal LVDTs only, the sensing rod is adjusted at a 12° angle in order to clear the inboard pod.

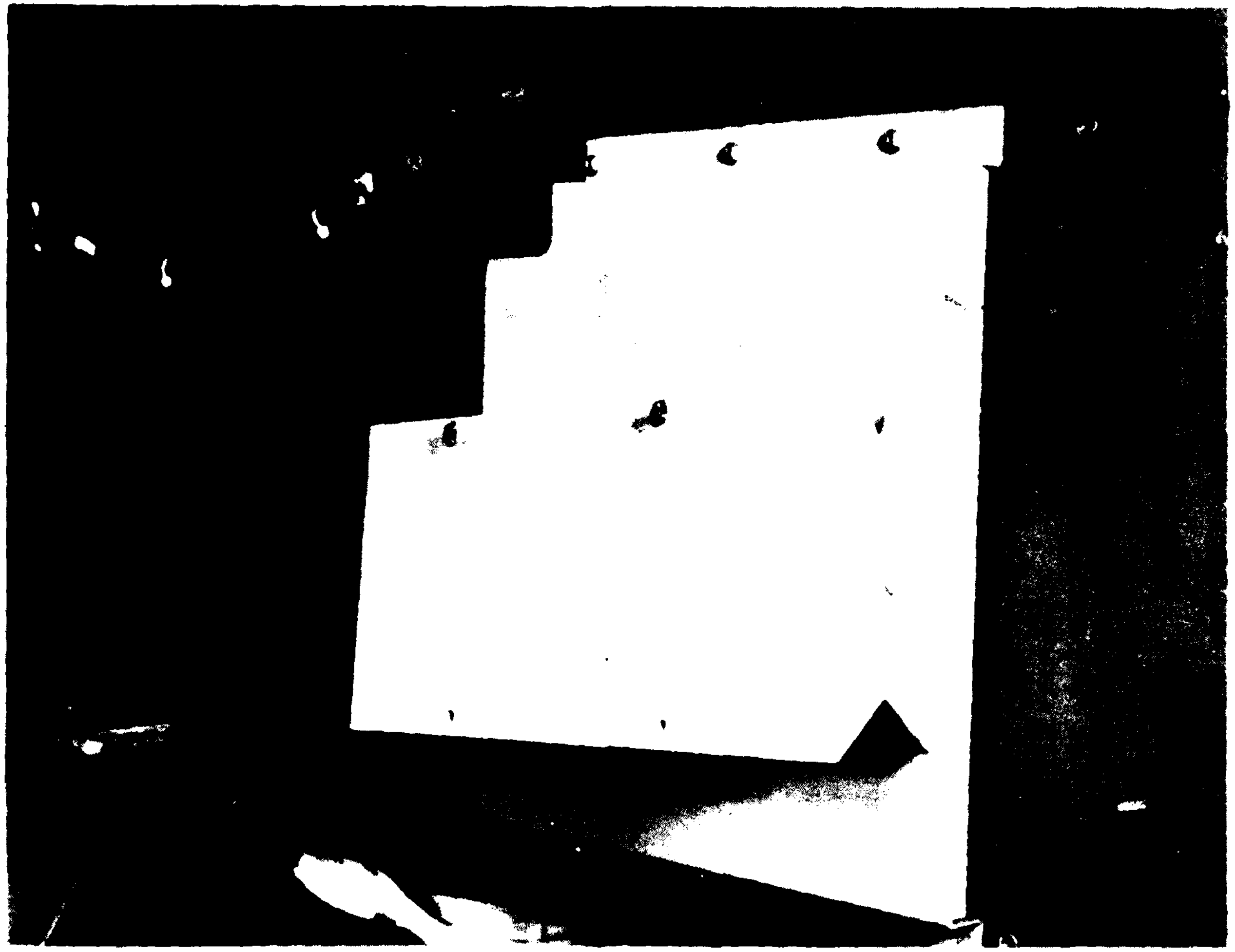


FIG. 19 INFRARED DETECTOR MOUNTING BRACKET

The LVDTs are adjusted for a null output by loosening the housing from its mounting bracket (See Figure 20) and then adjusting the position of the housing until the output is zero as indicated on the digital voltmeter connected to the control unit analog output jack. The housing is then locked tightly in this nulled position.

4.4 Preflight Procedures and Instrumentation Calibration

Prior to each flight test, a complete preflight check is performed on the instrumentation system in accordance with the preflight checksheet shown in Figure 21. The data is recorded on the checksheet and compared with the known standard values for each output. If an error is found during the checkout procedure, a systematic troubleshooting procedure is followed in order to determine the cause of the error. Troubleshooting usually commences at the junction box which contains all test points necessary for monitoring the sensor excitation voltages, the sensor outputs and the inputs to the Data Acquisition Unit.

A digital voltmeter and the supplied DAU testset is all that is required to checkout, calibrate and troubleshoot a major portion of the instrumentation package.

The Data Acquisition Unit contains several internal checks that readily determine its operational readiness. The calibration signal is internally generated and applied to the analog-to-digital converter through the analog multiplexer in the same manner as all other analog signals thus checking total system operation. The digital multiplexer formats the calibration data in the CAL word and is submultiplexed to include five calibration levels. The calibration voltage can be checked using either the testset or the control unit. If the testset is used, WORD 12 and FRAME 8 are selected to monitor the calibration voltage. The calibration switch can be switched to any of the five calibration voltage positions. The alternate method of checking the calibration voltages is to connect a digital voltmeter to J1 on the DAU control unit. Selecting switch positions 31, 32, 33, 34, or 35 monitors the calibration words 1, 2, 3, 4 and 5 respectively.

Selecting WORD 11, FRAME 10 or WORD 12, FRAME 10 on the testset will monitor one half of the two part binary synchronization word. The first word when properly displayed is 110101101010 and the second word is 010010110100. The test verifies that the data words are being formatted properly into the data frame.

To complete the check-out of the DAU, WORD 12 FRAME 4 should be selected on the DAU testset. Pushing EVENT MARKER #1 will light the least significant bit of the digital word and EVENT MARKER #2 will light the second least significant bit.

Completing the checkout of the DAU and finding that it is operational, the remainder of the instrumentation preflight can be performed.

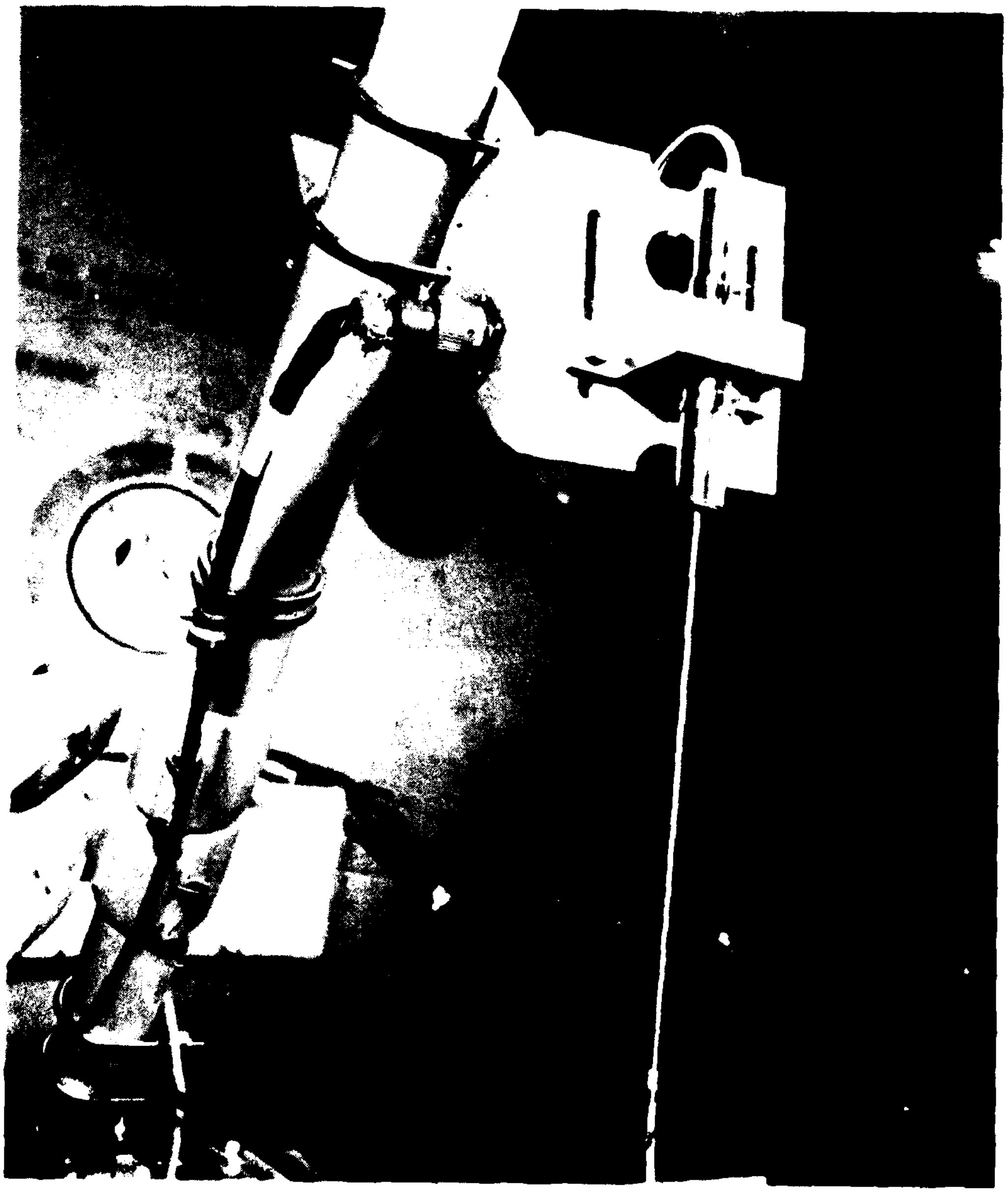


FIG. 20   LVDT INSTALLATION

INSTRUMENTATION PREFLIGHT CHECKLIST

Aircraft No.________ Phase________ Date: __________

Angle of Attack	*Channel	Location	Output (Min/Max)
Yaw #1	15/16	Pod 1	/
Pitch #1	15/16	Pod 1	/
Yaw #2	5/6	Pod 2	/
Pitch #2	5/6	Pod 2	/
Yaw #3	13/14	Nose Pod	/
Pitch #3	13/14	Nose Pod	/
Yaw #4	7/8	Pod 3	/
Pitch #4	7/8	Pod 3	/
Yaw #5	17/18	Pod 4	/
Pitch #5	17/18	Pod 4	/

Linear Differential Variable Transformer	Channel	Location	Minimum Output (volts)	Maximum Output (volts)
1/5	5	Pod 2/1	/	/
2/6	6	Pod 2/1	/	/
3/7	7	Pod 2/1	/	/
4/8	8	Pod 2/1	/	/
9/13	9	Pod 3/4	/	/
10/12	10	Pod 3/4	/	/
11/13	11	Pod 3/4	/	/
12/14	12	Pod 3/4	/	/

Unit	Reading/Value	Checked
Power Supply #1	+15, -15 VDC	
Power Supply #2	+15, -14 VDC	
Power Supply #3	+22 VDC	
Power Supply #4	+22 VDC	
Aircraft Power	24 - 28 VDC	
Telemetry Transmitter	60 ua	
Sync Word 119	110101101010	
Sync Word 120	010010110100	
Calibration Word #1	-5 VDC	
Calibration Word #2	-2.5 VDC	
Calibration Word #3	0 VDC	
Calibration Word #4	+2.5 VDC	
Calibration Word #5	+5.0 VDC	
Aircraft Pitch	0.150 VDC	
Aircraft Roll	0 VDC	
Aircraft Yaw	0 VDC	
Infrared Detector #1	-0.5 volts	
Infrared Detector #2	-1.5 volts	
Infrared Detector #3	-0.5 volts	
Infrared Detector #4	-1.5 volts	
Trigger Pulse	+1.5 volts	

*Varies with configurations, see Phase A or B word assignment sheet.

FIG. 21

The angle of attack transmitters are rotated to the extremes and the voltages read on a digital voltmeter. Using the minimum and maximum values the scale factor can be computed and compared with the known scale factors used by the computer to decommutate and convert the data to engineering units.

The LVDTs are checked by moving the LVDT rod one inch either side of the null position and calculating the scale factor. These readings can also be compared with known scale factors.

Aircraft power is checked to determine if the power is available to operate the DAU and recorder. Internally generated power supply voltages PS1 - PS4 are checked for the indicated outputs. These power supplies provide the proper excitation voltage to various transducers.

The S-band telemetry antenna is checked only to determine if there is radiation from it.

The IRS gyro pitch, roll and yaw can be evaluated using the control unit and digital voltmeter. With the aircraft on the ground the roll channel will indicate approximately 0 VDC. Dialing the appropriate data word for the yaw synchron will show a random voltage. Switching "on" the cage switch on the control panel will bring the reading to 0 VDC. On the ground the helicopter will not be level in the pitch position. The position varies from aircraft to aircraft and is dependent on landing surface and skid slip. An output in the range of 0 to 150 mv could be expected indicating a pitch position between 0 and +2.4 degrees.

The infrared detector and trigger pulse transmitter can be best monitored at the junction box using an oscilloscope. Pulling the trigger will give +1.5v pulse on both IR channels. With a flashlight the IR channels can be stimulated. Flashing the light across the narrow opening will produce a -1.5 volt pulse from the rear detector and a -.5 volt pulse from the forward detector. As a final check several minutes of tape can be recorded. A check with the oscilloscope will determine if data is being recorded on the tape.

The sensor word assignments for all configurations of Phase A and B are shown in Figures 22 and 23. The sensor outputs assigned to the A words are sampled 1000 times per second while the B words are sampled 100 times per second. Description of the data frame and the arrangement of the words in the sampling sequence are described in paragraph 4.1.2.

Figure 24 provides a reference to be used during preflight and troubleshooting checks during Phase A testing. The sensor and DAU assigned word is shown in the Phase A reference list for configuration 4. The DAU channel select column indicates the position of the thumbwheel switch on the DAU Control Unit to monitor the assigned word. The switch selects the channel that is converted back into an analog voltage available at J1 on the control unit. The sensor output has then been converted into the digital representation by the DAU and then reconverted back to the analog voltage for display.

PHASE A DAU WORD ASSIGNMENT

SENSOR	PHASE A CONFIGURATION					
	1	2	4	6	7	12
IR Detector (Left)	A1	A1	A1	A1	A1	A1
Lateral Accelerometer	A2	A2	A2	A2	A2	A2
Vertical Accelerometer	A3	A3	A3	A3	A3	A3
Fore/Aft Accelerometer	A4	A4	A4	A4	A4	A4
IR Detector (Right)	A5	A5	A5	A5	A5	A5
Roll Rate	A6	A6	A6	A6	A6	A6
Angle of Attack (#2LP)	B6	B6	B5	B5	B6-H/B5-H	B5
Angle of Attack (#2LY)	B5	B5	B6	B6	B6-V/B5-V	B6
Angle of Attack (#4RP)	B8	B8	B7	B7	B7-H/B8-H	B7
Angle of Attack (#4RY)	B7	B7	B8	B8	B7-V/B8-V	B8
Angle of Attack (#3MP)	B14	B14	B14	B13	B14-H/B13-H	B14-H/B14-H
Angle of Attack (#3MY)	B13	B13	B13	B14	B14-V/B13-V	B14-V/B13-V
Angle of Attack (#1LP)	B16	B15	B16	B16	B15-H/B16-H	B16
Angle of Attack (#1LY)	B15	B16	B15	B15	B15-V/B16-V	B15
Angle of Attack (#5RP)	B18	B17	B18	B18	B18-H/B17-H	B18
Angle of Attack (#5RY)	B17	B18	B17	B17	B18-V/B17-V	B17
Aircraft Pitch	B1	B1	B1	B1	B1	B1
Aircraft Roll	B2	B2	B2	B2	B2	B2
Aircraft Yaw	B3	B3	B3	B3	B3	B3
Yaw Rate	A7	A7	A7	A7	A7	A7
Pitch Rate	B4	B4	B4	B4	B4	B4

FIG. 22

PHASE B DAU WORD ASSIGNMENT

SENSOR	CONFIGURATION				
	5	8	9	10	11
IR Detector (Left)	A1	A1	A1	A1	A1
Lateral Accelerometer	A2	A2	A2	A2	A2
Vertical Accelerometer	A3	A3	A3	A3	A3
Fore/Aft Accelerometer	A4	A4	A4	A4	A4
IR Detector (Right)	A5	A5	A5	A5	A5
Roll Rate	A6	A6	A6	A6	A6
LVDT - LHF	B5	B5	B5	B5	B5
LVDT - LVF	B6	B6	B6	B6	BC
LVDT - LHA	B7	B7	B7	B7	B7
LVDT - LVA	B8	B8	B8	B8	B8
LVDT - RHF	B9	B9	B9	B9	B9
LVDT - RVF	B10	B10	B10	B10	B10
LVDT - RHA	B11	B11	B11	B11	B11
LVDT - RVA	B12	B12	B12	B12	B12
Angle of Attack Nose Pitch	B14	B14	B13	B14-H/B13-H	B14-H/B13-H
Angle of Attack Nose Yaw	B13	B13	B14	B14-V/B14-V	B14-V/B14-V
Angle of Attack Left Yaw	B15	B15	B15	B16-V/B15-V	B16-V/B15-V
Angle of Attack Left Pitch	B16	B16	B16	B15-H/B16-H	B15-H/B16-H
Angle of Attack Right Pitch	B18	B18	B18	B18-H/B17-H	B18-H/B17-H
Angle of Attack Right Yaw	B17	B17	B17	B18-V/B17-V	B18-V/B17-V
Aircraft Pitch	B1	B1	B1	B1	B1
Aircraft Roll	B2	B2	B2	B2	B2
Aircraft Yaw	B3	B3	B3	B3	B3
Yaw Rate	A7	A7	A7	A7	A7
Pitch Rate	B4	B4	B4	B4	B4

FIG. 23

PHASE "A" PREFLIGHT TEST REFERENCE

DAU Channel	D/A Channel Select	DAU Test Set Word-Frame	Junction Box	Aircraft #691 & #25J Configuration 4
A1	21	W1-F1	TB3-6A&B	Infrared Detector (Left)
A2	22	W2-F1	TB3-7A&B	Lateral Accelerometer
A3	23	W3-F1	TB3-8A&B	Vertical Accelerometer
A4	24	W4-F1	TB3-9A&B	Horizontal Accelerometer
A5	25	W5-F1	TB3-10A&B	Infrared Detector (Right)
A6	26	W6-F1	TB4-3A&B	Roll Rate
A7	27	W7-F1	TB4-4A&B	Yaw Rate
B1	01	W8-F1	TB5-4&6	Synchro 1 - Pitch Position
B2	02	W8-F2	TB5-1&3	Synchro 2 - Roll Position
B3	03	W8-F3	TB5-7&[illegible]	Synchro 3 - Yaw Position
B4	04	W8-F4	TB3-5A&B	Pitch Rate
B5	05	W8-F5	TB2-8A&B	AAT #2 Left Pitch
B6	06	W8-F6	TB2-9A&B	AAT #2 Left Yaw
B7	07	W8-F7	TB2-10A&B	AAT #4 Right Pitch
B8	08	W8-F8	TB3-1A&B	AAT #4 Right Yaw
B13	13	W11-F3	TB2-2A&B	AAT Nose Yaw
B14	14	W11-F4	TB2-3A&B	AAT Nose Pitch
B15	15	W11-F5	TB2-4A&B	AAT #1 Left Yaw
B16	16	W11-F6	TB2-5A&B	AAT #1 Left Pitch
B17	17	W11-F7	TB2-6A&B	AAT #5 Left Yaw
B18	18	W11-F8	TB2-7A&B	AAT #5 Left Pitch
Cal Word #1	31	W12-F8-S1		
Cal Word #2	32	W12-F8-S2		
Cal Word #3	33	W12-F8-S3		
Cal Word #4	34	W12-F8-S4		
Cal Word #5	35	W12-F8-S5		

FIG. 24

The DAU Test Set Word-Frame is the word sequence in the row and column respectively that is selected to monitor the sensor input on the test set. The test set display consists of 12 lights each representing a binary bit in the 12 bit data word. Each data word consists of ten data bits plus sign and parity. The digital output can be compared with the analog input by determining the number of counts represented and then multiplying by 5 millivolt/count. The least significant bit (LSB) represents one count and each succeeding bit represents 2, 4, 8, 16, 32, 64, 128, 256 and the most significant bit (MSB) represents 512 counts.

The column entitled "Junction Box" indicates the terminal board pins in the junction box where the indicated sensor inputs can be monitored during the preflight checks.

A similar reference list for Phase B is shown in Figure 25. Configuration 5 is indicated for aircraft 67-15691 and configuration 8 is indicated for aircraft 66-15250. The other Phase B configurations have slight variation in the angle of attack transmitter channels which can be readily determined when the chart is used in conjunction with the Phase "B" Sensor Configurations, Figure 15.

5.0 Instrumentation Equipments

5.1 Developed Instrumentation

5.1.1 Infrared Detectors

To perform a complete and accurate data analysis of the 2.75 inch rocket system, it is necessary that the time of trigger, the precise time of rocket egress from the rocket launcher, and the average velocity of the rocket with respect to the aircraft be known.

An infrared (IR) detector system of sensors was developed and fabricated by American Electronics Laboratory (AEL) that accomplished all of the above mentioned requirements. The infrared detectors were designed to sense the rocket exhaust plume as the 2.75" rocket passed through the narrow window aperture. An IR detector is shown in Figure 26.

Four IR sensors were installed per aircraft (See Phase A Aircraft Configuration, Figure 10). Two of the detectors, the "rear IRs", were mounted in such a manner that the rocket would be detected immediately upon egress from the launcher tube. The "forward IRs" were positioned five feet forward of the rear sensors. The time required for the rocket to traverse the distance between adjacent IR sensors gives an estimate of the average velocity of the missile at the time of launch.

Two data channels were allocated, one each for the left and right sides of the aircraft, and each channel recorded the trigger pulse plus two IR passage pulses for each rocket fired. The trigger and IR detector pulses were differentiated by the ECOM installed hardware and produced a narrow (1.5 millisecond) pulse for each event to reduce time of occurrence ambiguity. A uniform width pulse compatible with the 1000 Hz multiplexer

PHASE "B" PREFLIGHT TEST REFERENCE

DAU Channel	D/A Channel Select	DAU Word-Frame	Junction Box	Aircraft #601 Configuration 5	Aircraft #250 Configuration 8
A1	21	W1-F1	TB3-6A&B	Infrared Detector (Left)	Infrared Detector (Left)
A2	22	W2-F1	TB3-7A&B	Lateral Accelerometer	Lateral Accelerometer
A3	23	W3-F1	TB3-8A&B	Vertical Accelerometer	Vertical Accelerometer
A4	24	W4-F1	TB3-9A&B	Horizontal Accelerometer	Horizontal Accelerometer
A5	25	W5-F1	TB3-10A&B	Infrared Detector (Right)	Infrared Detector (Right)
A6	26	W6-F1	TB4-3A&B	Roll Rate	Roll Rate
A7	27	W7-F1	TB4-4A&B	Yaw Rate	Yaw Rate
B1	01	W8-F1	TB5-4&6	Synchro 1-Pitch Position	Synchro 1-Pitch Position
B2	02	W8-F2	TB5-1&3	Synchro 2-Roll Position	Synchro 2-Roll Position
B3	03	W8-F3	TB5-7&9	Synchro 3-Yaw Position	Synchro 3-Yaw Position
B4	04	W8-F4	TB3-5A&B	Pitch Rate	Pitch Rate
B5	05	W8-F5	TB2-8A&B	LVDT #5LHF	LVDT #1LHF
B6	06	W8-F6	TB2-9A&B	LVDT #6LVF	LVDT #2LVF
B7	07	W8-F7	TB2-10A&B	LVDT #7LHR	LVDT #3LHR
B8	08	W8-F8	TB3-1A&B	LVDT #8LVR	LVDT #4LVR
B9	09	W8-F9	TB3-2A&B	LVDT #13RHF	LVDT #9RHF
B10	10	W8-F10	TB3-3A&B	LVDT #14RVF	LVDT #10RVF
B11	11	W11-F1	TB3-4A&B	LVDT #15RHR	LVDT #11RHR
B12	12	W11-F2	TB2-1A&B	LVDT #16RVR	LVDT #12RVR
B13	13	W11-F3	TB2-2A&B	AAT - Nose Yaw	AAT - Nose Yaw
B14	14	W11-F4	TB2-3A&B	AAT - Nose Pitch	AAT - Nose Pitch
B15	15	W11-F5	TB2-4A&B	AAT - Left Inboard Yaw	AAT - Left Outboard Yaw
B16	16	W11-F6	TB2-5A&B	AAT - Left Inboard Pitch	AAT - Left Outboard Pitch
B17	17	W11-F7	TB2-6A&B	AAT - Right Inboard Yaw	AAT - Right Outboard Yaw
B18	18	W11-F8	TB2-7A&B	AAT - Right Inboard Pitch	AAT - Right Outboard Pitch
Cal Word #1	31	W12-F8-S1			
Cal Word #2	32	W12-F8-S2			
Cal Word #3	33	W12-F8-S3			
Cal Word #4	34	W12-F8-S4			
Cal Word #5	35	W12-F8-S5			

NOTE: Key for LVDT Position

L - Left   R - Rear
R - Right   H - Horizontal
F - Forward   V - Vertical

FIG. 25

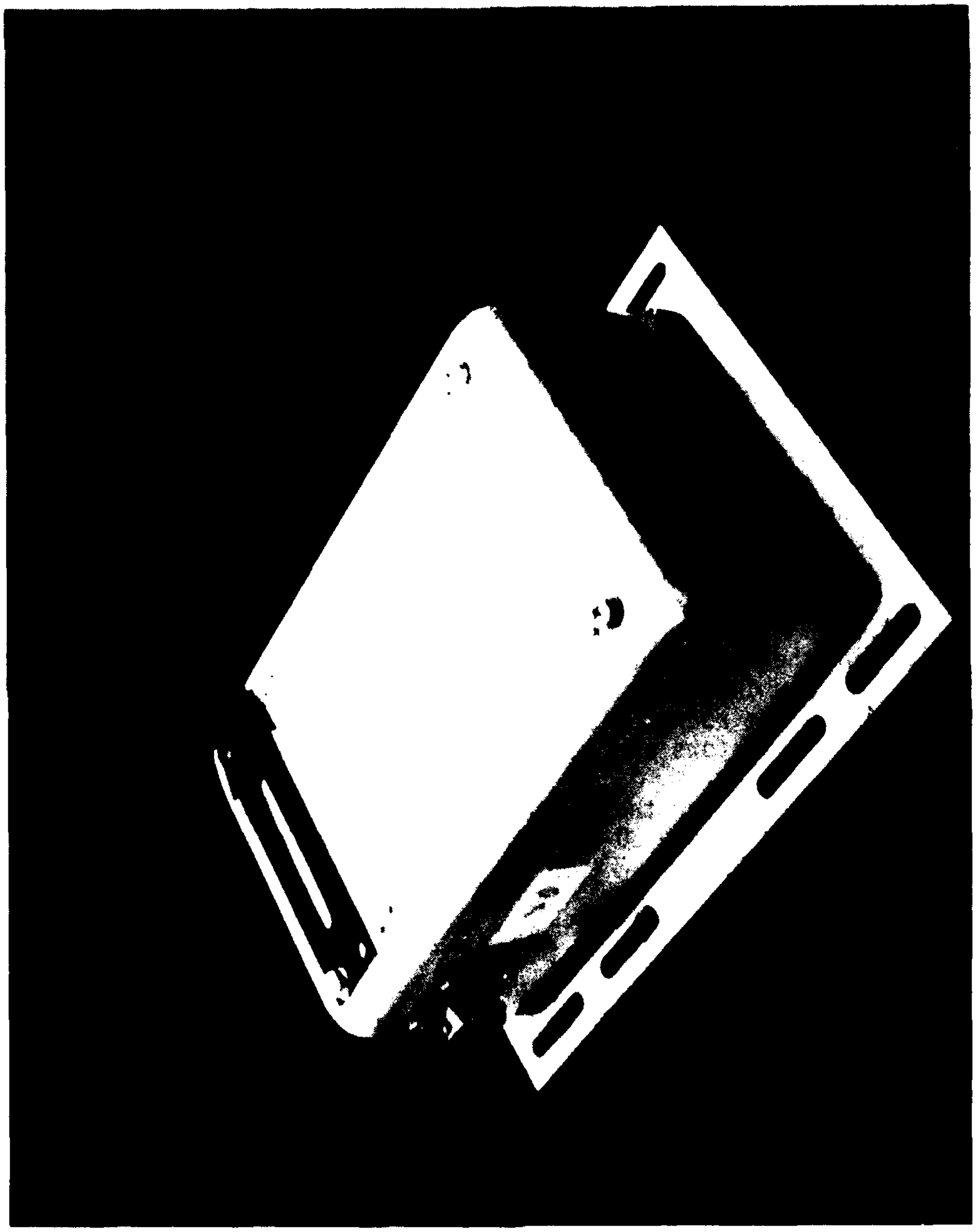


FIG. 26 INFRARED DETECTOR

sampling rate was generated with the amplitude dependent on the data source. Since two IR detector strobes plus the trigger pulse were all recorded on a single channel for each side of the aircraft the varied amplitude served as a positive means of pulse source identification other than the sequence of events. The trigger pulse was +1.5v in amplitude.

Following the successful bench test of the IR detectors by AEL, two tests were performed at Picatinny Arsenal on 16 and 24 November 1970. Several 2.75" rockets were fired to check the operation of the sensors. An analysis of the results from the 16 November test indicated that the sensitivity of the units was too high and the low temperature compensation was inadequate. Results from the test of 24 November proved that the sensitivity problem was corrected but the low temperature compensation deficiency remained. On 3 December 1970 additional tests verified that the temperature of the rocket plume was not 2500°K as anticipated. The sensed wavelength was determined to be in the 2 - 3 micron range. A redesign of the units was accomplished using lead sulfide photocells type number B3-SA21 to detect the presence of the IR at this wavelength. Bench tests again proved the system operational and further static fire testing was arranged. During the scheduled test on 29 December 1970, the gain of the IR detectors was set and an integrating capacitor was included in the circuitry of the first amplifier to reduce the susceptibility of the system to small changes in the temperature. This modification eliminated the numerous pulses that occurred as the rocket passed the sensor and resulted in a single easily recognizable pulse. Six sets of rockets were successfully fired and data recorded to conclude the IR static testing phase.

The specification sheet for the IR Industries Inc. Plate Type Lead Sulfide Detectors is shown in Figure 27. Type B3-SA21 Detectors were used to detect the IR in the rocket plume. Environmental and operational characteristics for the detectors are shown in Figures 28 and 29.

The electrical schematic for the fabricated IR detector and trigger shaping circuit is shown in Figure 30 with the parts identified in the AEL Parts List pages 49 and 50.

5.1.2 Control Panel

Control of the instrumentation equipments, except the DAU, is accomplished through a specially designed control panel. This panel and the DAU control unit (CU), both accessible to the co-pilot, provide control of all instrumentation except for main power to the digital recorded. The DAU control unit was described in section 4.1.

The control panel as installed in upper left portion of the co-pilot's instrumentation panel is shown in Figure 31.

The control panel as shown in Figure 32 provides the following functions:

a. GYRO PWR — Applies 28 VDC to the inertial reference system (IRS) accelerometers and inverters. The inverters provide the 26 VAC

Infratron Detector Data Sheet
Infratron Plate-Type Lead Sulfide Detectors
4.1

These Infratron Lead Sulfide Photoconductors are available for immediate shipment from stock. They offer equivalent performance to custom-designed detectors, but at production quantity prices. Just select the detector to fit your requirements and order by Type (Table I) and Size No. (Table 2). Delivery is within one week.

SPECIFICATIONS

TABLE 1	TYPE B1	TYPE B2	TYPE B3	TYPE T1	TYPE T2
λc (μ)	2.90	2.90	2.90	2.55	2.55
TIME CONSTANT	< 60	60 - 150	150 - 250	> 300	> 300
RESISTANCE	.5 - 1.5	.5 - 1.5	.5 - 1.5	5.0 - 10.0	.5 - 2.0
D* (500, 750, 1)	$2.0 - 3.0 \times 10^{8}$	$3.2 - 4.5 \times 10^{8}$	$5.0 - 8.0 \times 10^{8}$	$2.0 - 2.8 \times 10^{8}$	$2.0 - 2.8 \times 10^{8}$
D* (PEAK, 750, 1)	$2.0 - 3.0 \times 10^{10}$	$3.2 - 4.5 \times 10^{10}$	$5.0 - 8.0 \times 10^{10}$	$7.2 - 10.0 \times 10^{10}$	$7.0 - 10.0 \times 10^{10}$
D* (500, 1500, 1)	$2.7 - 4.2 \times 10^{8}$	$3.6 - 5.5 \times 10^{8}$	$3.9 - 6.5 \times 10^{8}$	$1.4 - 2.0 \times 10^{8}$	$1.4 - 2.0 \times 10^{8}$
D* (PEAK, 1500, 1)	$2.7 - 4.2 \times 10^{10}$	$3.6 - 5.5 \times 10^{10}$	$3.9 - 6.5 \times 10^{10}$	$5.1 - 7.0 \times 10^{10}$	$5.1 - 7.0 \times 10^{10}$
D* (500, 3000, 1)	$3.2 - 5.0 \times 10^{8}$	$3.0 - 4.6 \times 10^{8}$	$2.9 - 4.5 \times 10^{8}$	$1.0 - 1.4 \times 10^{8}$	$1.0 - 1.4 \times 10^{8}$
D* (PEAK, 3000, 1)	$3.2 - 5.0 \times 10^{10}$	$3.0 - 4.6 \times 10^{10}$	$2.9 - 4.5 \times 10^{10}$	$3.6 - 5.0 \times 10^{10}$	$3.6 - 5.0 \times 10^{10}$

λc (microns) — Spectral point at which the response is down to 30% of maximum.

Time Constant (μ sec) — Time required for the signal to build up to 63% of maximum when exposed to square-wave-modulated radiation.

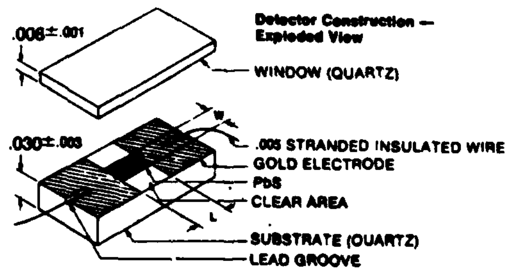
Resistance (megohms) — Electrical impedance per unit area.

D* [cm (Hz)½/watt] — Detectivity as measured under following conditions:
Source — Monochromatic peak (2.3) or 500°K black body
Modulation frequency — 750, 1500, or 3000 Hz
Bandwidth — 1 Hz

TABLE 2
AVAILABLE SIZES FOR TYPES B1, B2, B3

SIZE NUMBER	SENSITIVE AREA L x W (INCHES)	SUBSTRATE SIZE (INCHES)
SA1	.010 x .010	.250 x .250
SA2	.020 x .020	.250 x .250
SA3	.040 x .040	.250 x .250
SA4	.060 x .060	.250 x .250
SA5	.080 x .080	.250 x .250
SA6	.120 x .120	.250 x .250
SA7	.160 x .160	.250 x .250
SA8	.200 x .200	.375 x .375
SA9	.240 x .240	.375 x .375
SA10	.320 x .320	.500 x .500
SA11	.400 x .400	.500 x .500
SA12	.010 x .040	.250 x .250
SA13	.040 x .080	.250 x .250
SA14	.040 x .120	.250 x .250
SA15	.040 x .160	.250 x .250
SA21	.010 x .100	.250 x .250
AVAILABLE SIZES FOR TYPES T1, T2		
SA16*	.060 x .060	.250 x .250
SA17	.160 x .160	.250 x .250
SA18**	.010 x .040	.250 x .250

**T1 ONLY **T2 ONLY*



Detector Construction — Exploded View

HOW TO ORDER:

To order Infratron lead sulfide detectors, select a type code from Table 1, and a size code from Table 2.

For example, from Table 1 you might select type B3 because of its greatest sensitivity with long wavelength response; then from Table 2 you would select size SA1 because of the need to obtain the smallest possible sensitive area for compatibility with system optics.

You would then order in the following manner:

Quantity	Description
(specify)	Infratron Detector B3 - SA1

PHOTOCONDUCTOR DIV., INFRARED INDUSTRIES, INC., 62 FOURTH AVE., WALTHAM, MASS. 02154 • PHONE 617-893-5400 • TWX 710-324-1190

FIG 27

Characteristics, Environment and Operation of Infratron Detectors
2.3

Typical Characteristics of Infratron Lead Sulfide Detectors For 2π Steradians Field of View, 298°K Background Temperature

RESISTIVITY VS. DETECTOR TEMPERATURE

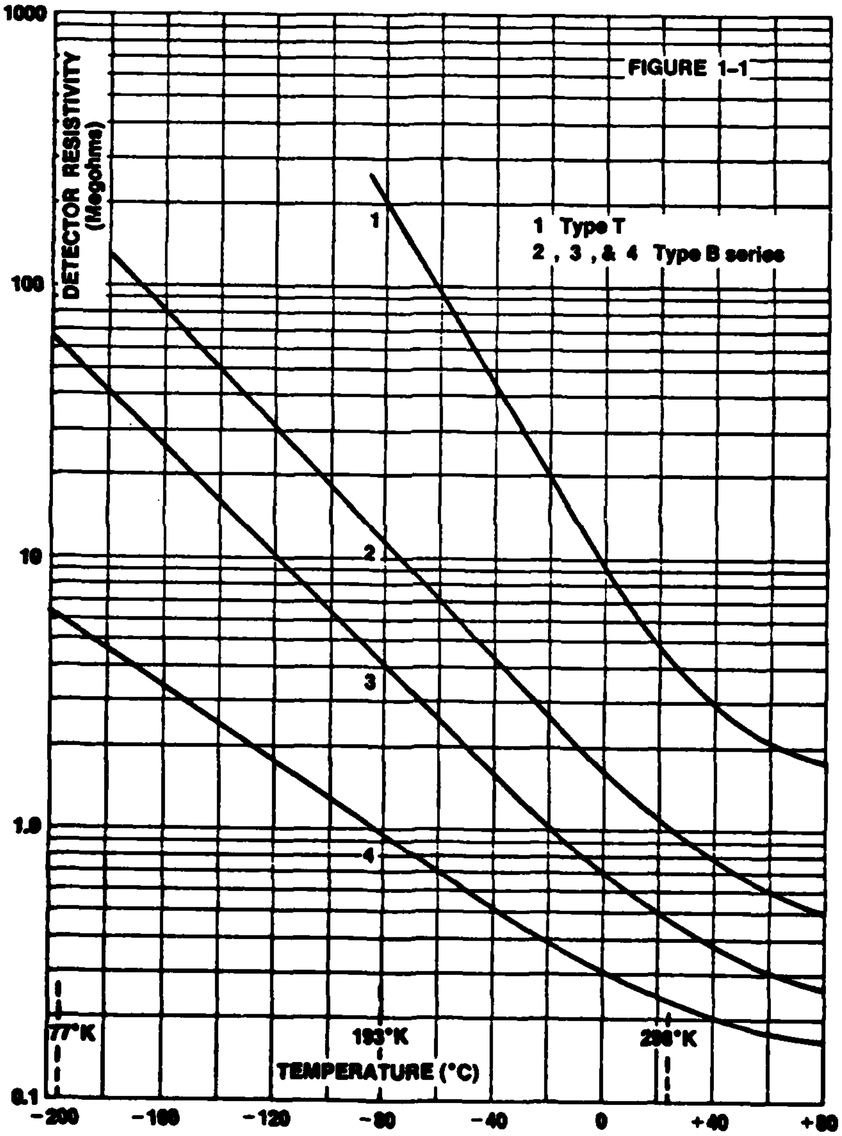


FIG 28

Typical Characteristics of Infratron Lead Sulfide Detectors For 2π Steradians Field of View, 298°K Backgroud Temperature

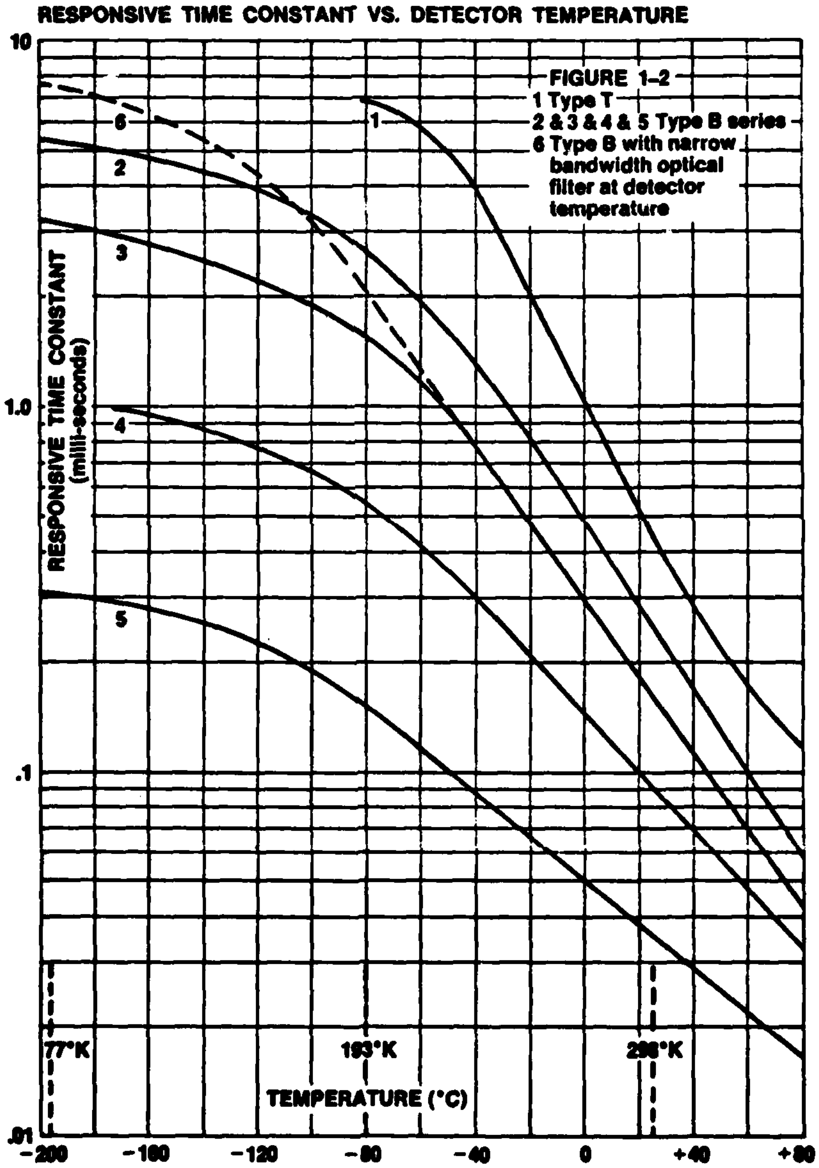


FIG 29

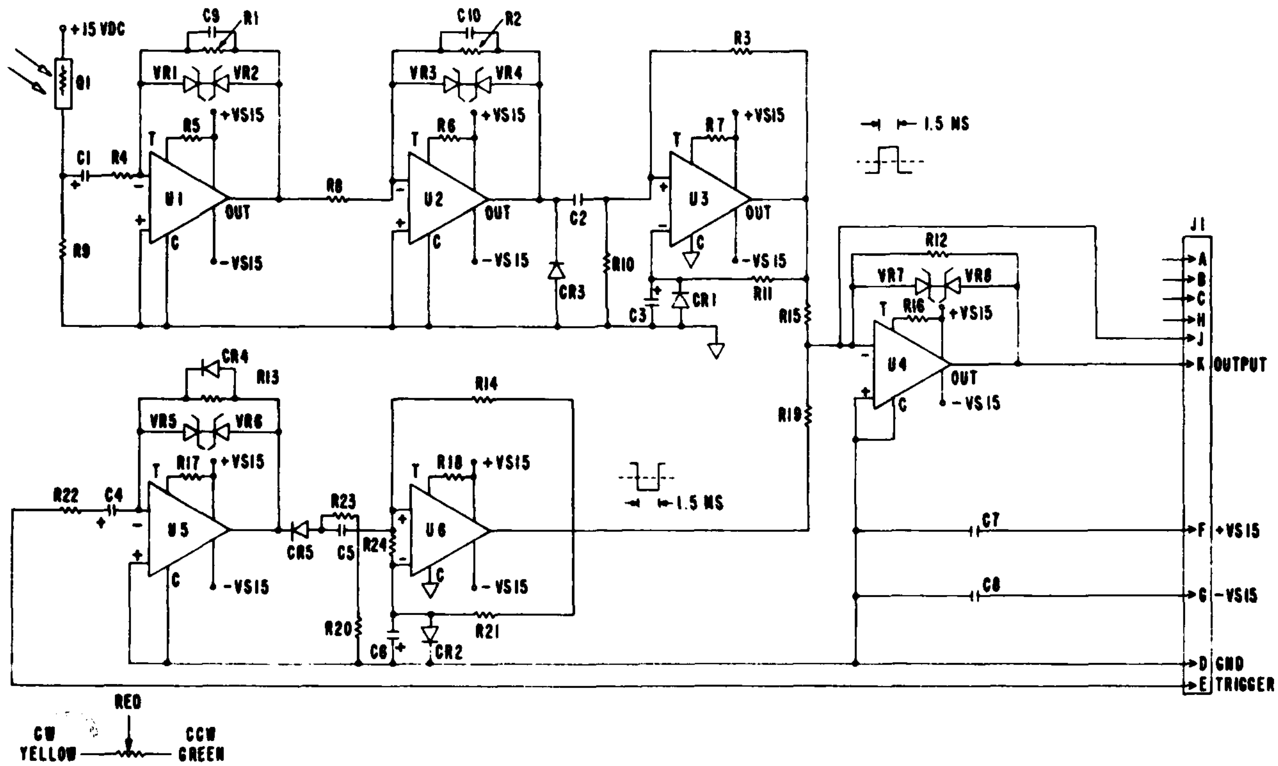


FIG. 30 IR DETECTOR & TRIGGER SHAPING CIRCUIT

PARTS LIST	AMERICAN ELECTRONIC LABORATORIES, INC. COLMAR, PA.	CONTRACT OR ORDER NO.	CODE IDENT 93346	PL	REV LTR	DATE 25 Jan 71
LIST TITLE I.R. DETECTOR - Trigger, Shaping Circuit		AUTHENTICATION		REV AUTH NO. ECN	SHEET 1 OF 2 SHEETS	

QTY REQD. 504	503	502	501	ITEM	CODE IDENT	PART NUMBER	DESCRIPTION	MAT'L/FINISH	SPECIFICATION
			1	Q1	IRI	B3-SA21	Lead Sulphide Photoconductor		
			1	U1	Analog	118 A	Operational Amplifier		
			1	U2					
			1	U3					
			1	U4					
				U5					
			1	U6					
			1	R1		RN60 402 K 1%	Resistor, Carbon		
			1	R2		RC07 1.0 megohm 5%	Resistor, Carbon		
			1	R3		10K 5%			
			1	R4		1.0K 5%			
			1	R5		RN60 24.9K 1%			
			1	R6		24.9K 1%			
			1	R7		24.9K 1%			
			1	R8		RC07 1.0K 5%			
			1	R9		RC07 27.0K 5%	Resistor, Carbon		
			1	R10		RC07 680 ohm 5%	Resistor, Carbon		
			1	R11		2.2K 5%			
			1	R12		1.2K 5%			
			1	R13		75 K 5%			
			1	R14		10 K 5%			
			1	R15		RN60 9.76K 1%			
			1	R16		24.9K 1%			
			1	R17		24.9K 1%			
			1	R18		24.9K 1%			
			1	R19		RC07 10K 5%	Resistor, Carbon		
			1	R20		680 ohm 5%			
			1	R21		2.2K 5%			
			1	R22		RC07 5.6K 5%			
			1	R24		RC07 1 K 5%			
			1	C1		0.56 mfd	Capacitor, CS13BF564K		
			1	C2		0.1	Capacitor		
			1	C3		31 DTL 1127	5.0 mfd 12VDC		
			1	C4		31 DTL 1127	5.0 mfd 12VDC		
			1	C5		31 DTL 1127	Capacitor, 5.0 mfd 12VDC		[redacted]
			1	C6		31DTL1127	5.0 mfd 12VDC		
			1	C7		CK63AW103M	Capacitor, Ceramic Disk		0.01 mfd 500V 20%

FORM 530 (5-68)

PARTS LIST	AMERICAN ELECTRONIC LABORATORIES, INC. COLMAR, PA.	CONTRACT OR ORDER NO	CODE IDENT 93346	PL	REV LTR / DATE 25 Jan 71
LIST TITLE	I.R. DETECTOR - Trigger, Shaping Circuit	AUTHENTICATION		REV AUTH NO. ECN	SHEET 2 OF 2 SHEETS

QTY REQD. 504	503	502	501	ITEM	CODE IDENT	PART NUMBER	DESCRIPTION	MAT'L/FINISH	SPECIFICATION
			1	C8		CK63AW103M	Capacitor, Ceramic Disk		0.01 mfd 500V 20%
			1	C9		150D124X9050A2	Capacitor, 0.12 mfd 50VDC		
			1	C10		CK06CW103K	" 0.01 mfd		
			1	CR1		1N645(Jan)	Diode		
			1	CR2		1N645(Jan)	Diode		
			1	CR3		1N645(Jan)	Diode		
			1	VR1		1N751(Jan)	Diode, Zener 5.1V 400 mw		
			1	VR2		1N751(Jan)			
			1	VR3		1N758(Jan)	10.V 400 mw		
			1	VR4		1N758(Jan)	10.V 400 mw		
			1	VR5		1N751(Jan)	5.1V 400 mw		
			1	VR6		1N751(Jan)	5.1V 400 mw		
			1	VR7		1N750(Jan)	Diode, Zener 4.7V 400 mw		
			1	VR8		1N750 (Jan)	" " 4.7V 400 mw		
			1	J1		MS3112E-12-10P	Connector		
			1	CR4		1N645(Jan)	Diode		
			1	CR5		1N645(Jan)	Diode		
			1	R23		RC07 1 meg. 5%	Resistor, Carbon		

FORM 350 (8-68)

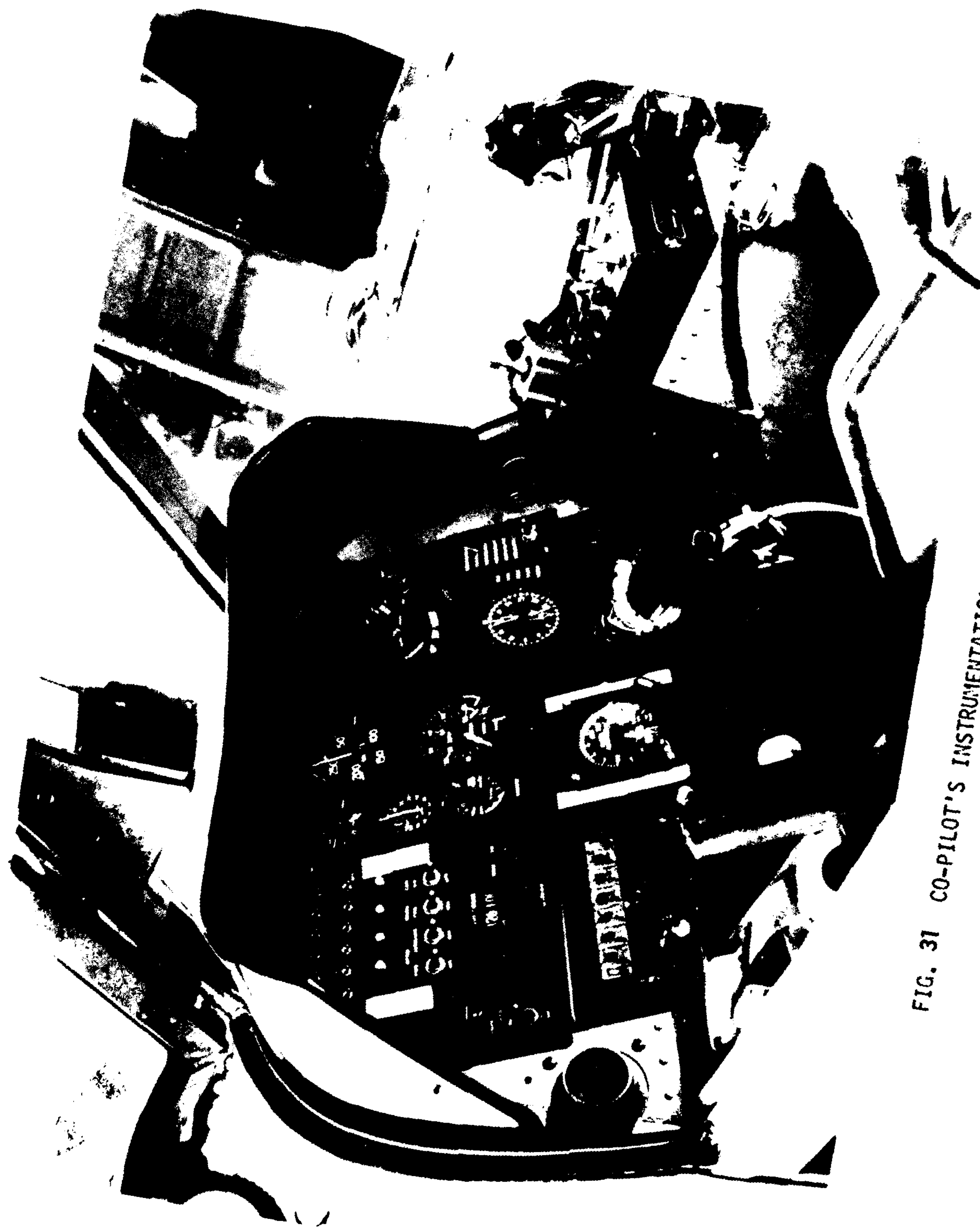


FIG. 31 CO-PILOT'S INSTRUMENTATION PANEL

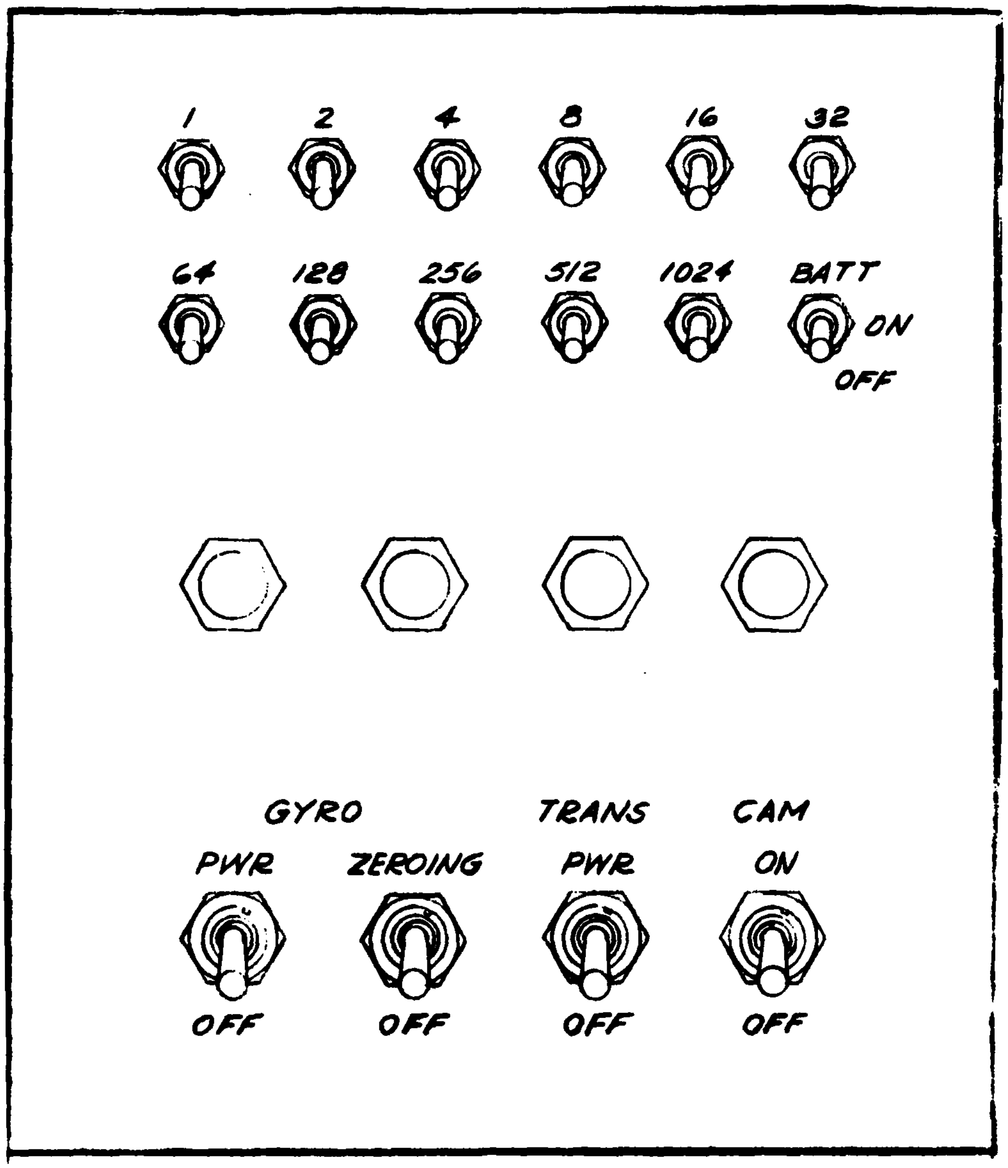


FIG. 32 CONTROL PANEL

	and 115 VAC 400 cycle for synchro reference and excitation for the position and rate gyros.
b. GYRO ZEROING	"Cages" the yaw gyro when placed in the "zeroing" position. In the "off" position the gyro operates normally and is free to drift at a very slow rate.
c. TRANS PWR	Provides excitation voltage to the Angle of Attack Indicators and Linear Variable Differential Transformers.
d. CAM	Provides control of the gunsight and instrument panel cameras.
e. BINARY CODED SWITCHES	Provides a method of coding each test run for easy identification during data analysis. The battery switch provides a 9 volt level to each of the eleven code identification switches on the panel. When a code switch is "on" 9 volts are applied to a particular bit in the discrete word D1 in the data frame. During the data analysis, the computer converts the binary coded switch closures into the run number.

Panel lights are provided over the gyro, transducer and camera switches to indicate an "on" condition.

The electrical schematic of the control panel is shown in Figure 33.

5.1.3 Instrumentation Pallet and Junction Box

Two AH-1G aircraft were instrumented and wired by ECOM to be used for the 2.75" Rocket Program. Since data would be taken and test flights scheduled for only one aircraft with the other serving as a back-up, a system design was devised that would permit a complete instrumentation exchange within a day. The exchanged items included the data acquisition system and the angle of attack pods. The wiring harness and instrumentation transducers were duplicated and interchangeable between aircraft.

In order to minimize the time for exchanging the single data acquisition system, an instrumentation pallet was fabricated that would mount in two slides provided in the ammunition compartment of the aircraft. The data acquisition unit (DAU), digital recorder, junction box and telemetry transmitter were mounted on the removable pallet, as shown in Figure 34. The cabling between the units remained intact during the change-over procedure. Figure 35 shows the installation of the pallet and equipment mounted in the ammunition compartment, prior to final lacing of the cabling. Removing four locking pins allows the data acquisition pallet to move

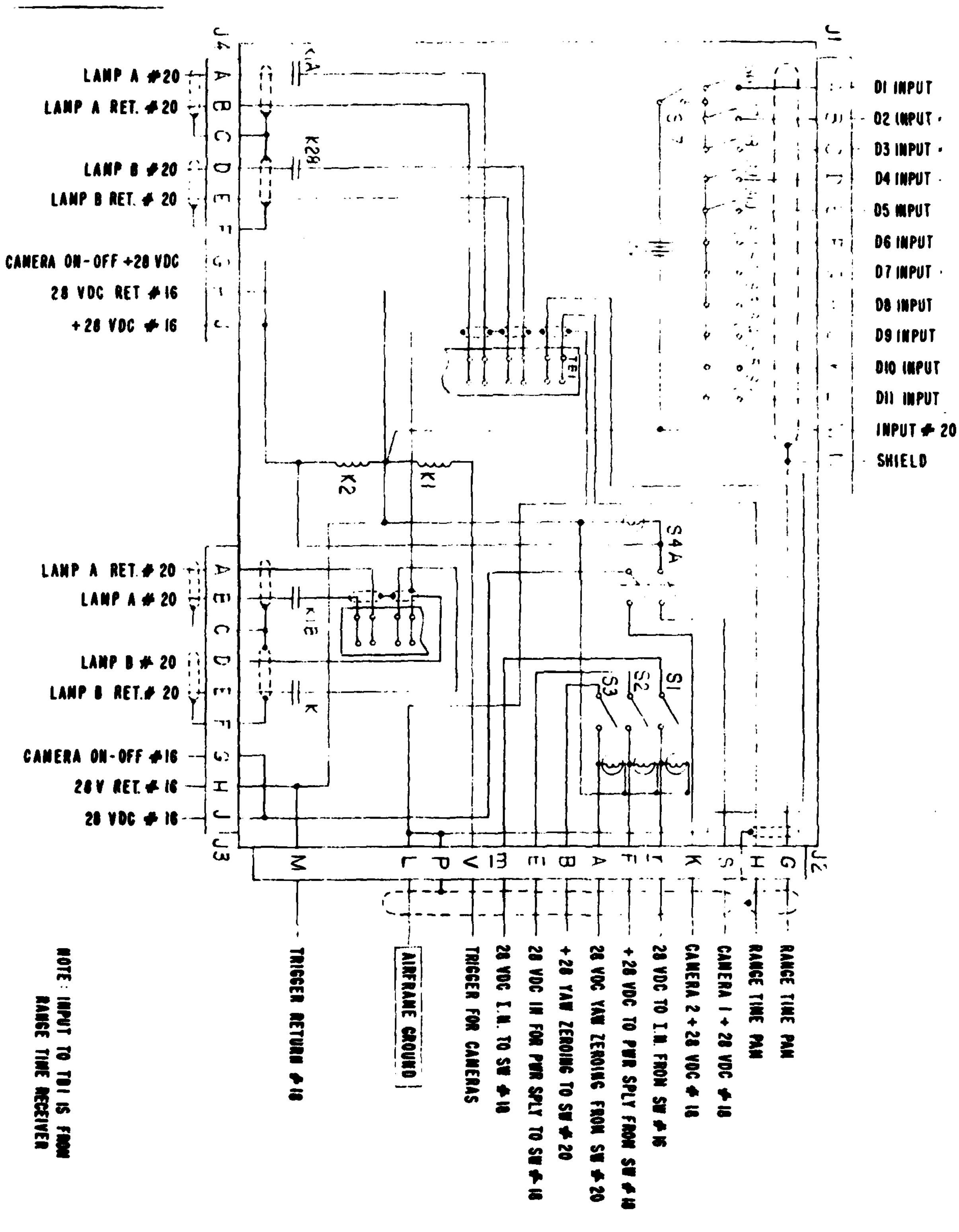


FIG. 33 CONTROL PANEL SCHEMATIC

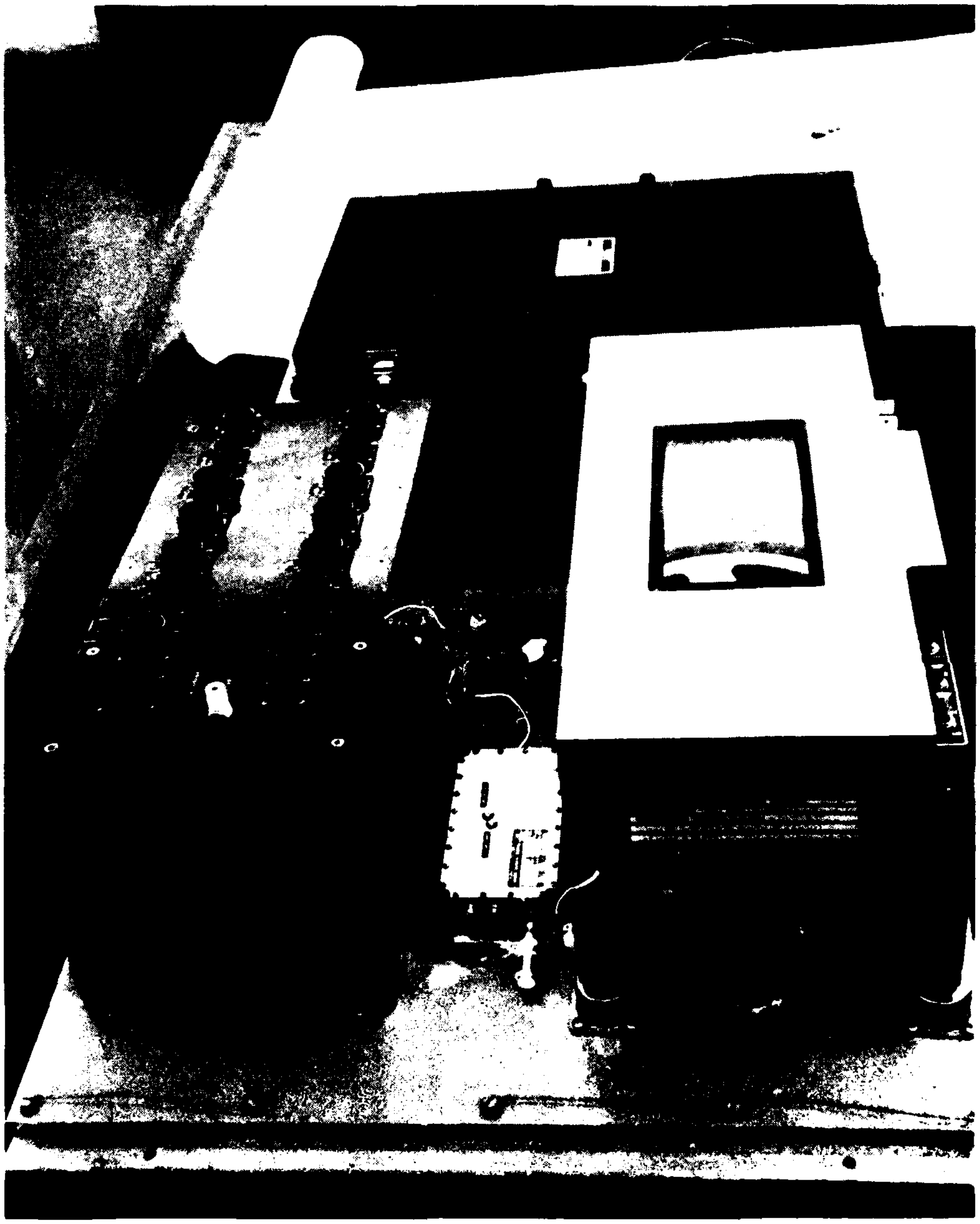


FIG. 34 INSTRUMENTATION PALLET

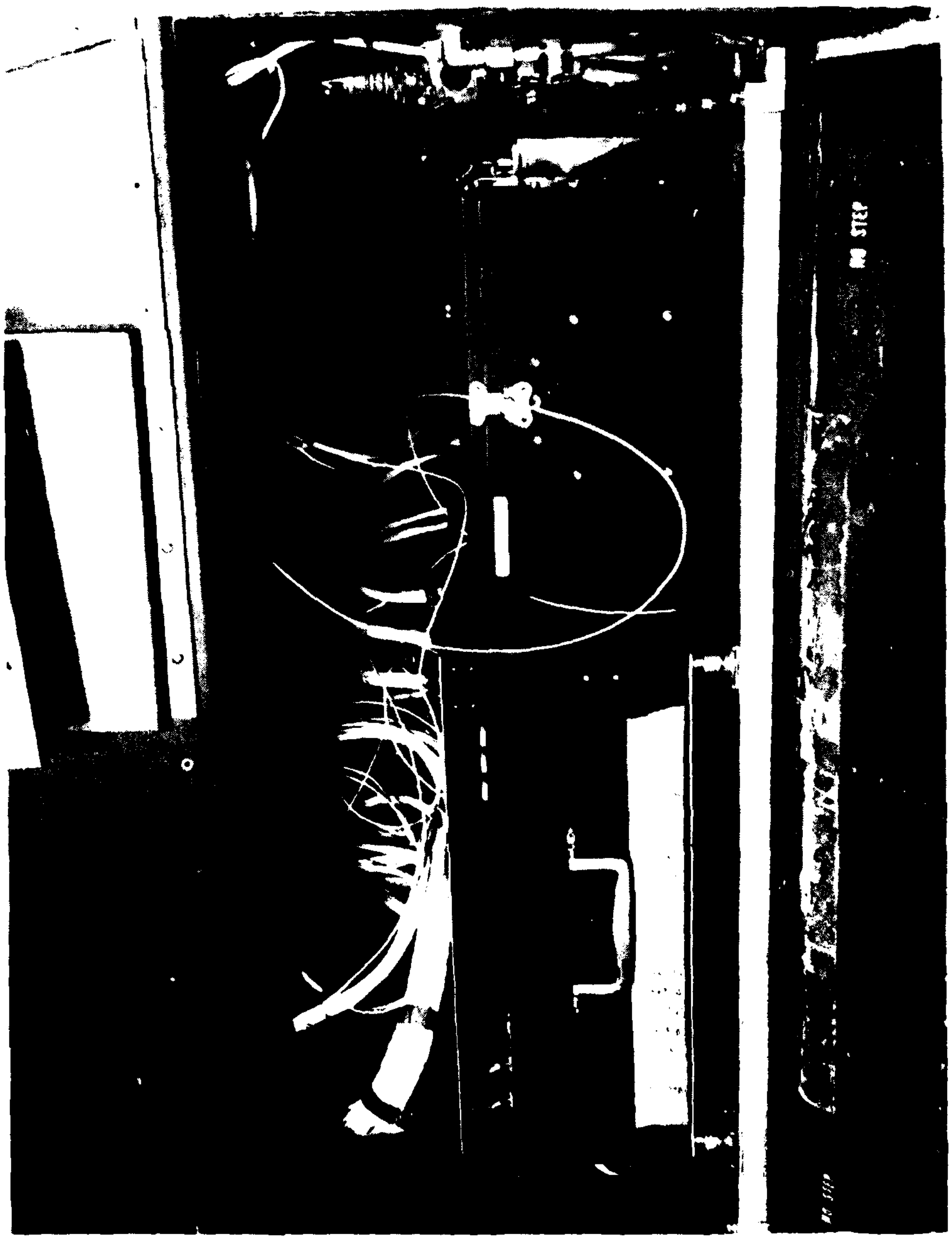


FIG. 35 PALLET INSTALLATION IN AIRCRAFT

freely in the slides. Whenever a reel of magnetic tape was changed or calibration was to be performed the pins could be removed and the pallet pulled out from either side of the compartment into a good working position without removing any cabling.

The junction box, shown in Figure 36 brought all subsystems of the instrumentation system together. The box contained all power supplied for transducer excitation, filter networks to reduce ambient noise levels and test points for monitoring the complete system. All transducer outputs were brought into the box prior to being routed to the proper DAU channel. By removing the side panel as shown in Figure 36 all test points became accessible for ease of calibration and troubleshooting checks.

The Phase B configurations are different from those of Phase A as has been previously described. In order to eliminate several of the angle of attack inputs and replace them with LVDT inputs, some angle of attack inputs to the terminal board were removed, taped and tied back. Jumper wires were routed from the LVDT terminals to the vacated (input side) AAT terminals. Following this procedure LVDT data information was available on previously designated AAT channels as required.

5.1.4 LVDT Support Brackets

The LVDT sensors, were provided to accurately measure the relative movement of the rocket launcher during Phase B testing of the 2.75" Rocket Program. The supports, Figures 37 - 40, were designed to minimize the movement of the LVDTs with respect to the airframe. The supports were bolted to the airframe via several hard points and through compression rods joined the left and right hand support structure into a unified rigid box assembly. The structure was completely independent of the aircraft wing and the rocket pod assembly. Due to the rigidity of the system all movement indicated by the LVDTs was attributed to the motion of the launchers relative to the aircraft inertial axes. Vibration testing of the various points of interest support this assumption.

5.1.5 Angle of Attack Pods

The angle of attack pods were specially designed and fabricated by American Electronics Laboratory (AEL) to meet the following requirements:

a. Each pod was to house two mutually perpendicular angle of attack transmitters.

b. The pod should cause minimal airflow disturbance about the aircraft during the flight tests.

c. The pods must be readily interchangeable between aircraft.

d. Five pods were required during Phase A flight tests. One pod mounted from each of four rocket launchers and the fifth extended into the airstream in front of the nose of the aircraft.

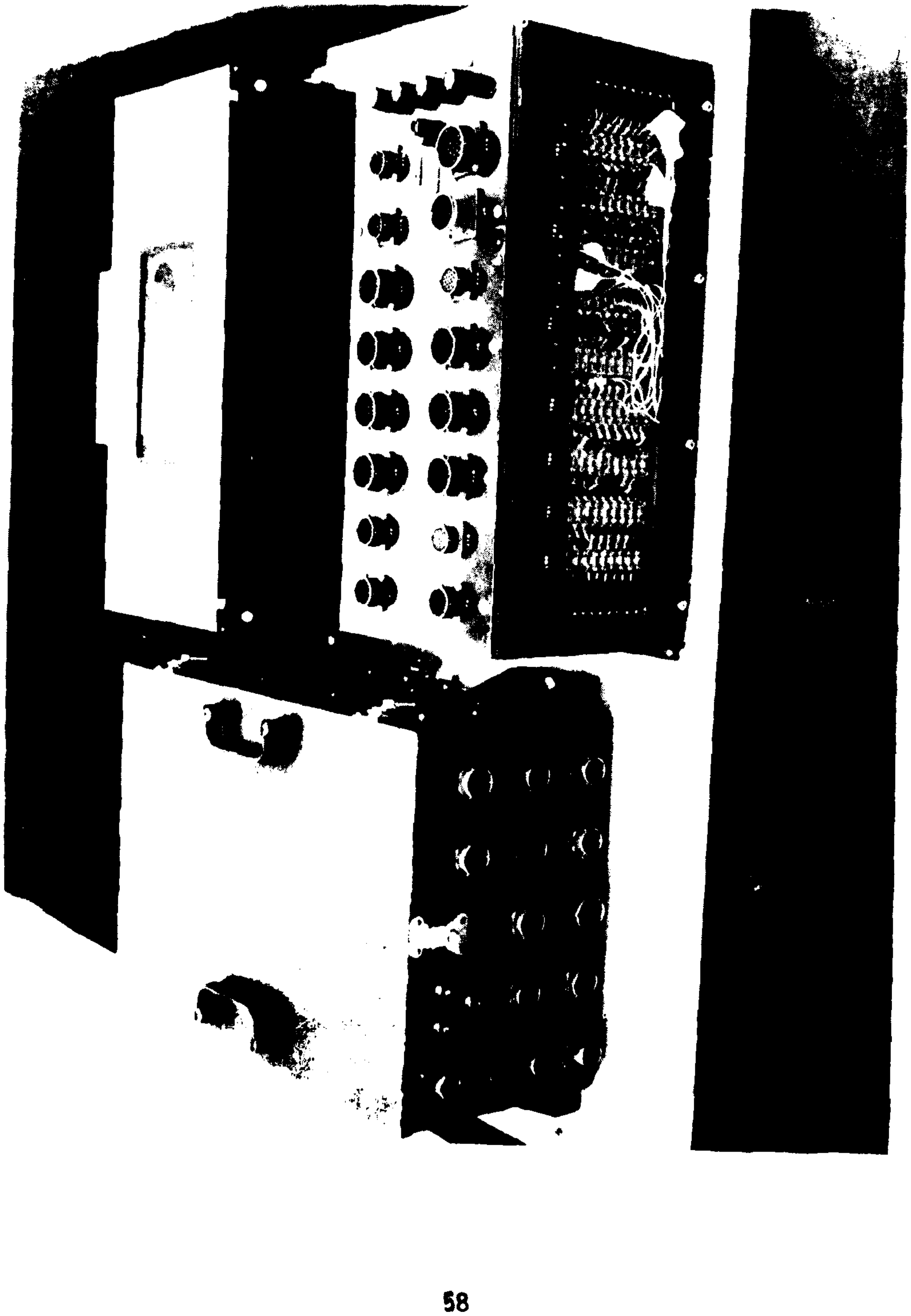


FIG. 36 JUNCTION BOX INSTALLATION

FIG. 37 RIGHT/FORWARD LVDT SUPPORT ASSEMBLY

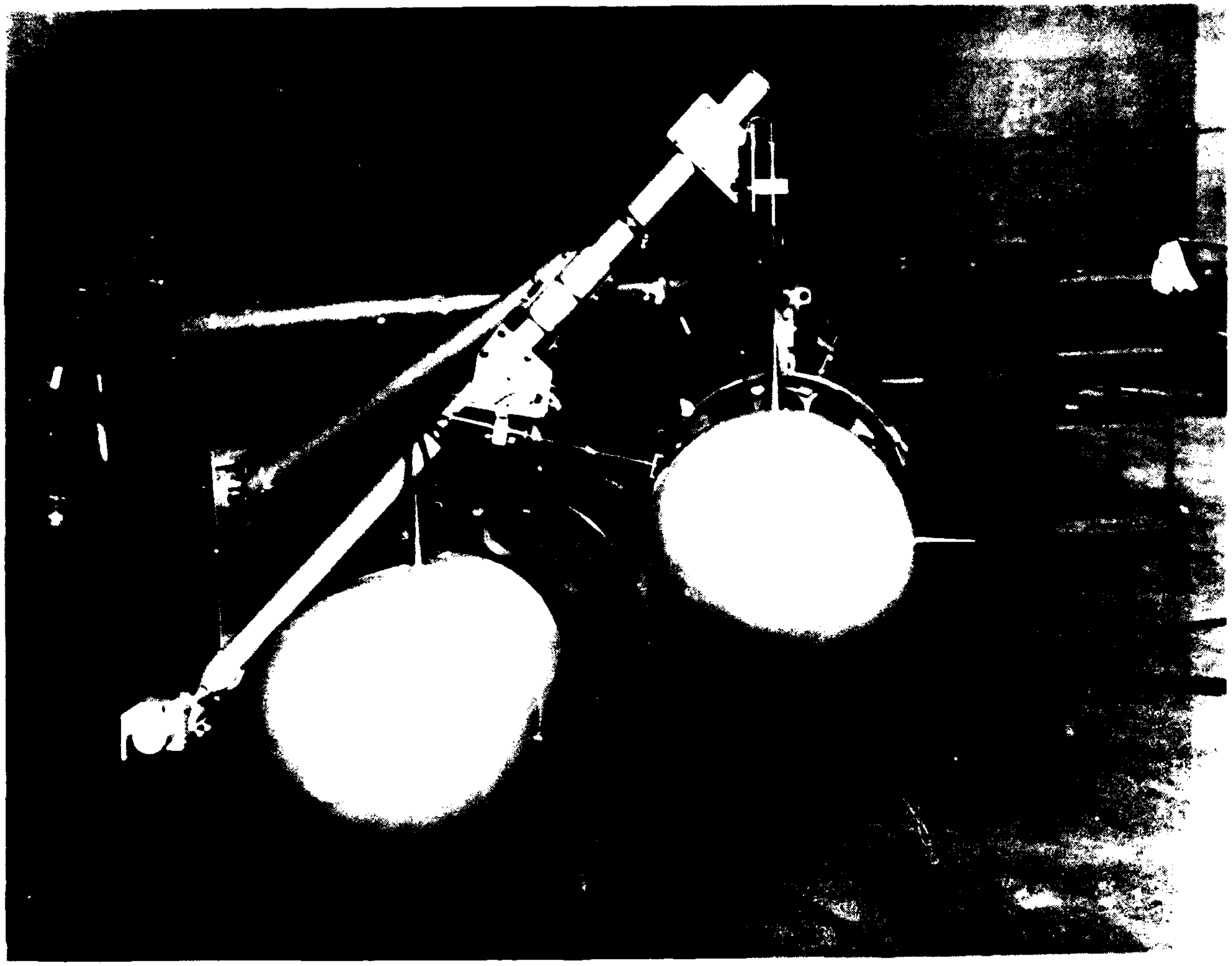


FIG. 38 LEFT/FORWARD LVDT SUPPORT ASSEMBLY

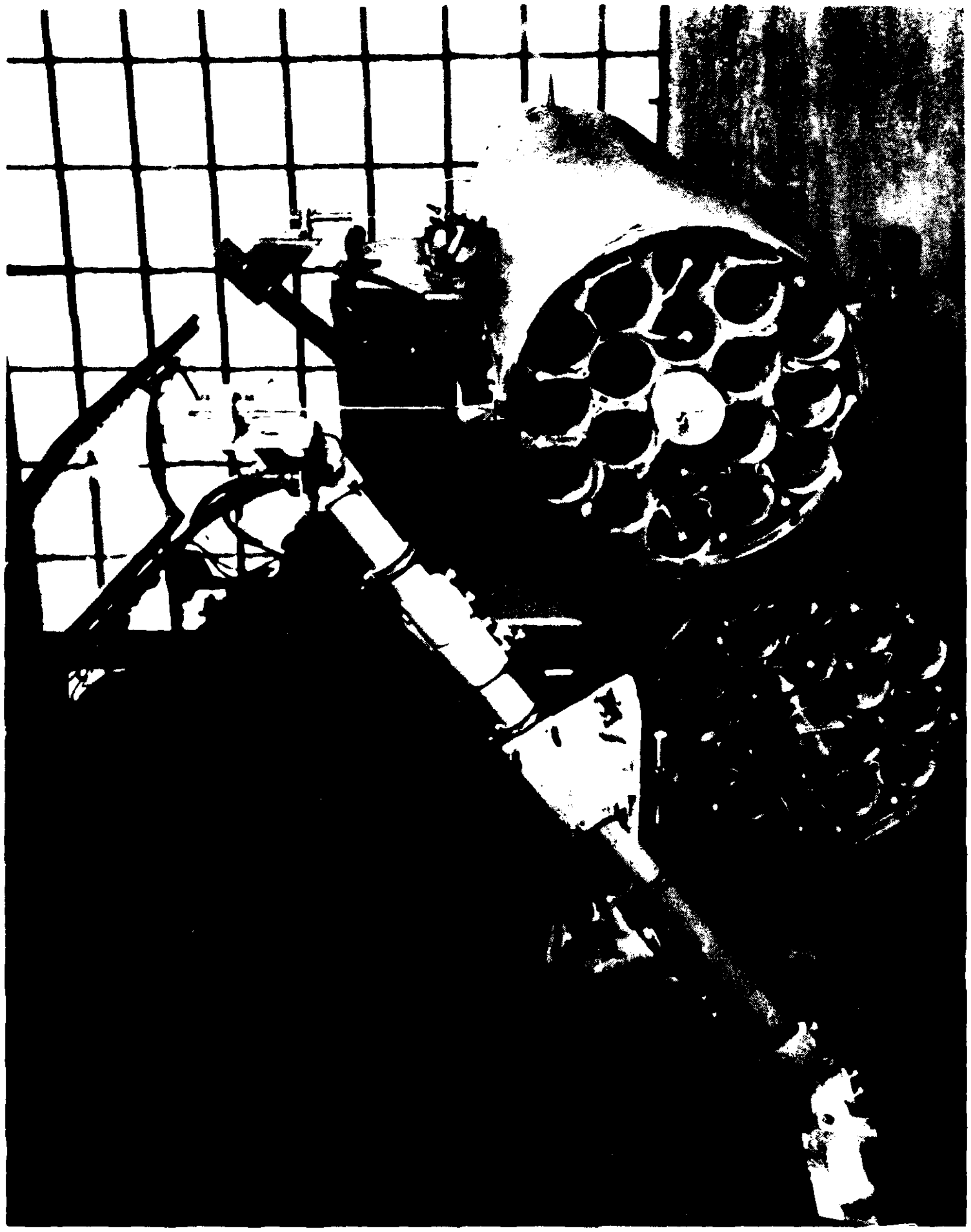


FIG. 39 RIGHT/REAR LVDT SUPPORT ASSEMBLY

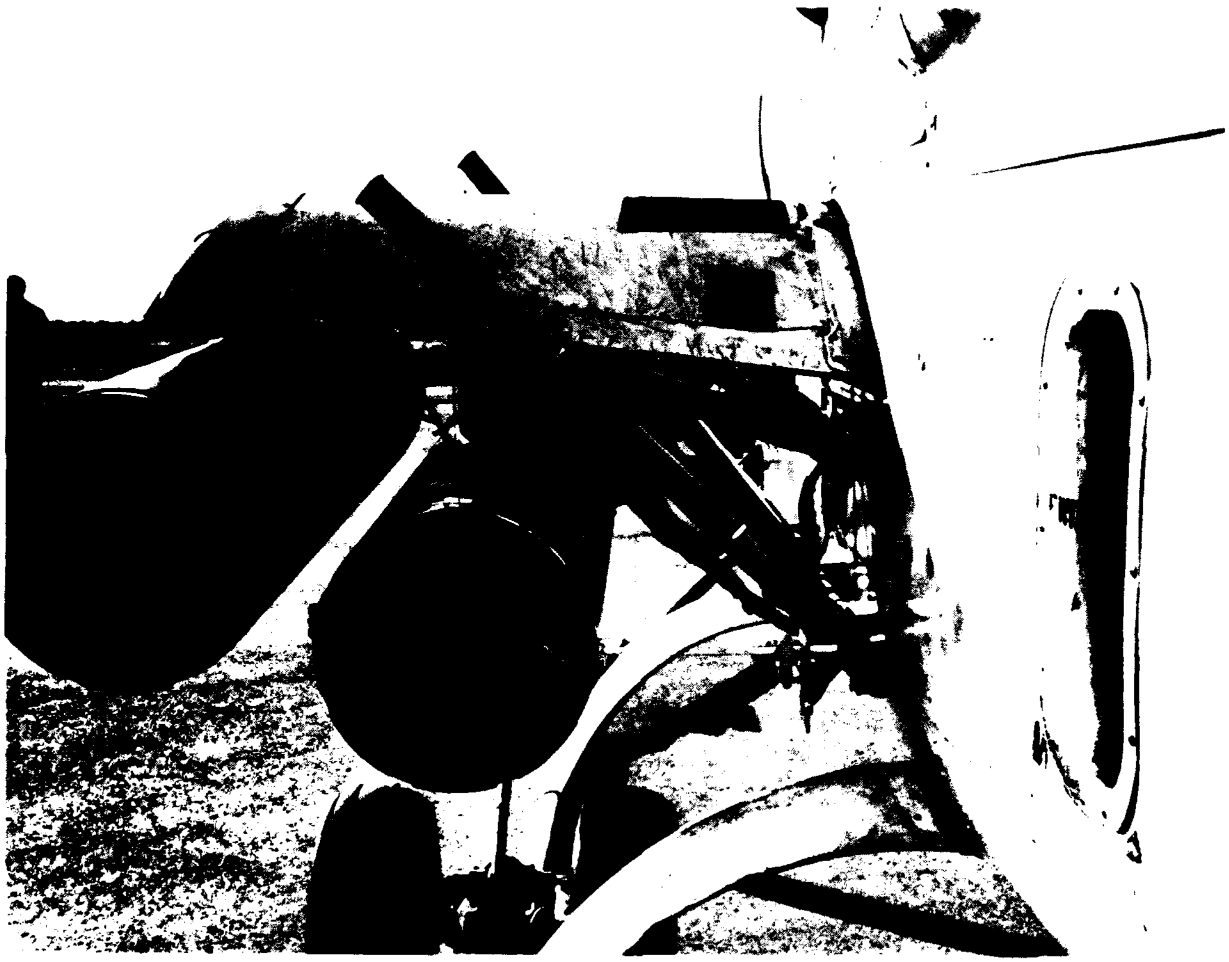


FIG. 40 LEFT/REAR LVDT SUPPORT ASSEMBLY

e. The pods should be easily and accurately aligned in the pitch and roll axes.

Two angle of attack pods are shown in Figure 41, as they were installed in aircraft 67-15691 for Phase A testing. In paragraph 5.1.4 several other views of the pod installation are shown.

The nose pod is shown in Figure 42. The pod was located in a position approximately 18" below the aircraft nose so that the Pitot reading would not be effected.

5.2 Procured Instrumentation

5.2.1 Angle of Attack Transmitters

The angle of attack transmitters are specifically designed to measure the angle between the aircraft coordinate system and the relative airflow in a plane perpendicular to the sensor probe.

For the 2.75" Rocket Program, ten angle of attack sensors are mounted on the aircraft as shown in Figure 10 Four sensors measure the angles between the longitudinal axes of the rocket pods and the relative airflow in front of the pod. A fifth sensor mounted in the nose of the aircraft measures a similar angle at that point. These angles are in the yaw plane of the aircraft. Five additional sensors are mounted horizontally to detect relative airflow information in the pitch plane of the aircraft.

The theory of operation and the mounting dimensions of the angle of attack transmitters are indicated in the Teledyne, Inc brochure, pages 67 through 69..

The Teledyne angle of attack transmitters were selected for use in the program because of their high accuracy, good frequency response and reliability. The units weigh only 2 pounds each and can be mounted in such a manner that only the probe extends into the airstream. For installation on the AH-1G helicopter each angle of attack was housed in an aerodynamic pod designed to minimize disruption and turbulence in the airflow. The angle of attack as mounted in the pod can be seen in Figure 43. The angle of attack transmitter specifications are listed below:

ANGLE OF ATTACK TRANSMITTER SPECIFICATION

ACCURACY	± 0.1 degrees
SENSING RANGE	70 knots to Mach 4.5
WEIGHT	2 Pounds
ANGULAR RANGE	50 Degrees
OUTPUTS	2 Potentiometers
HEATER (If Required)	AC or DC

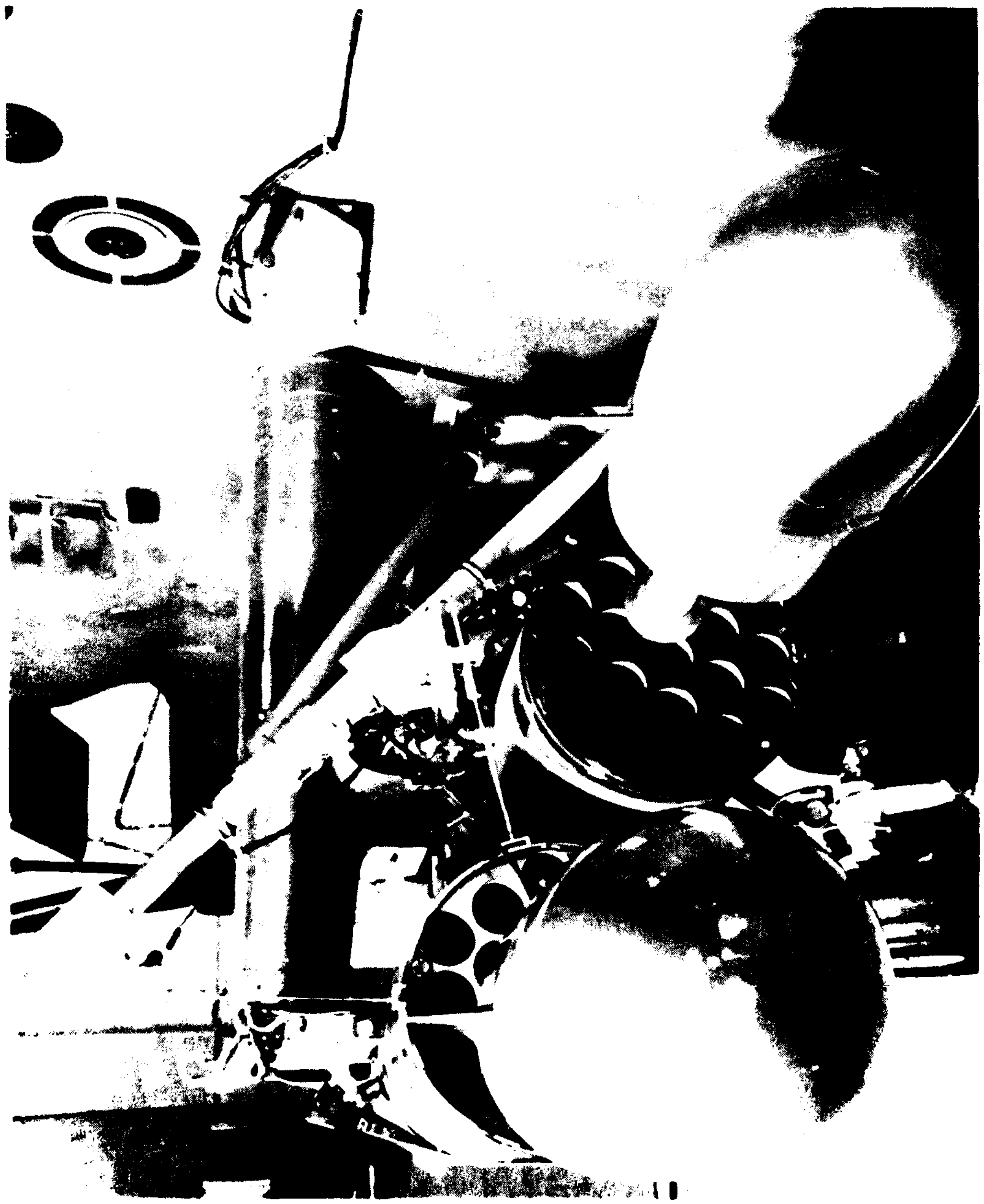


FIG. 41 ANGLE OF ATTACK PODS

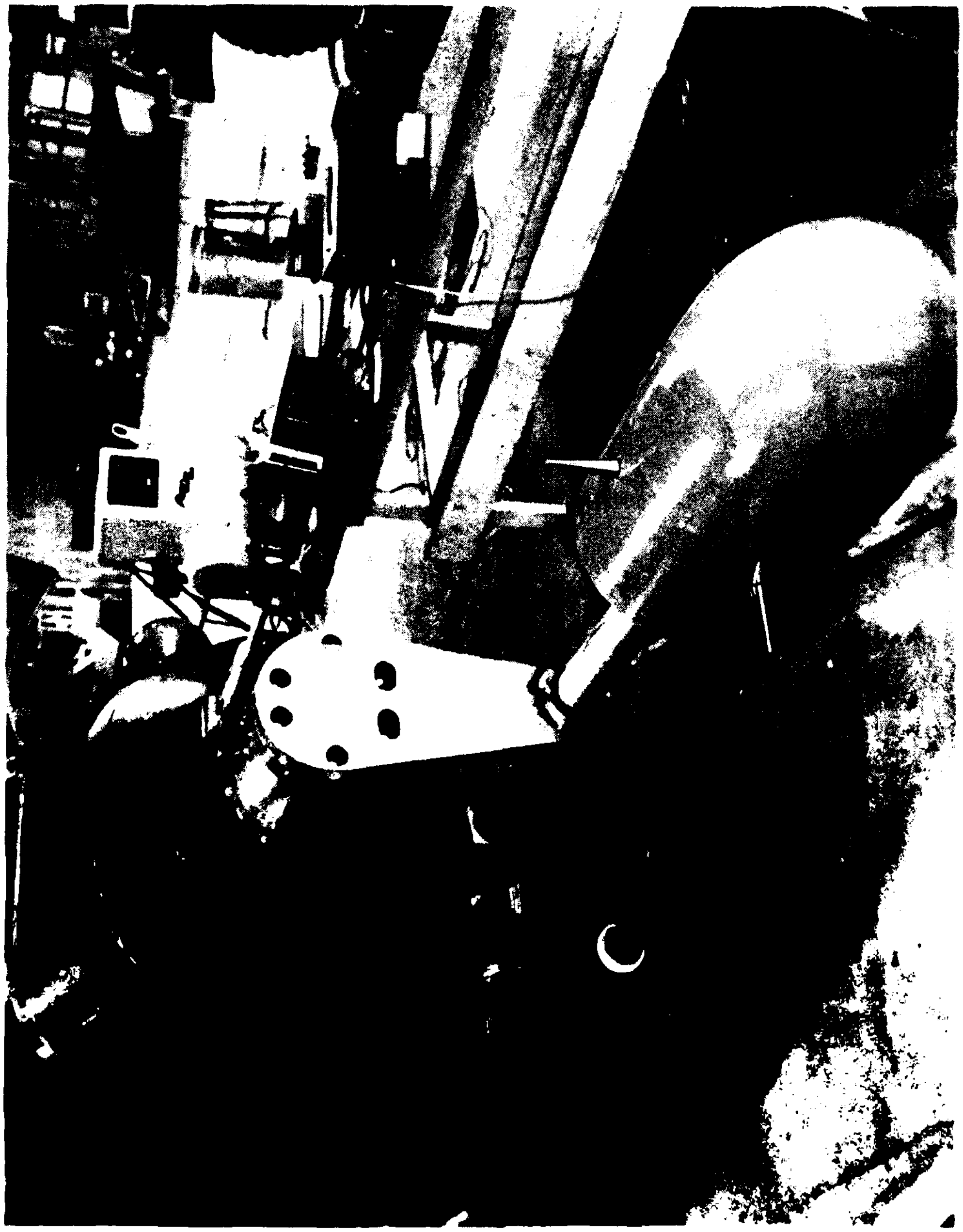


FIG. 42 NOSE ANGLE OF ATTACK INSTALLATION

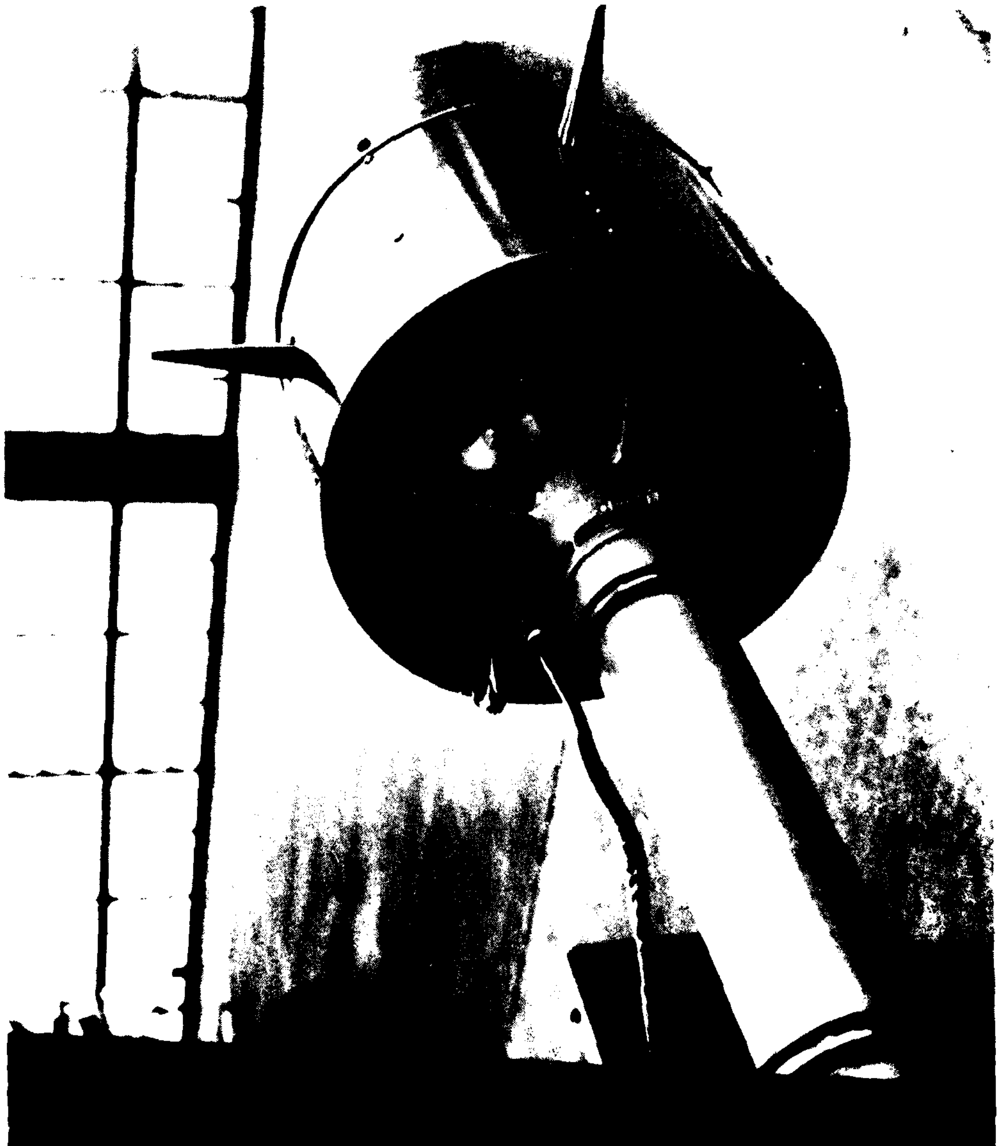
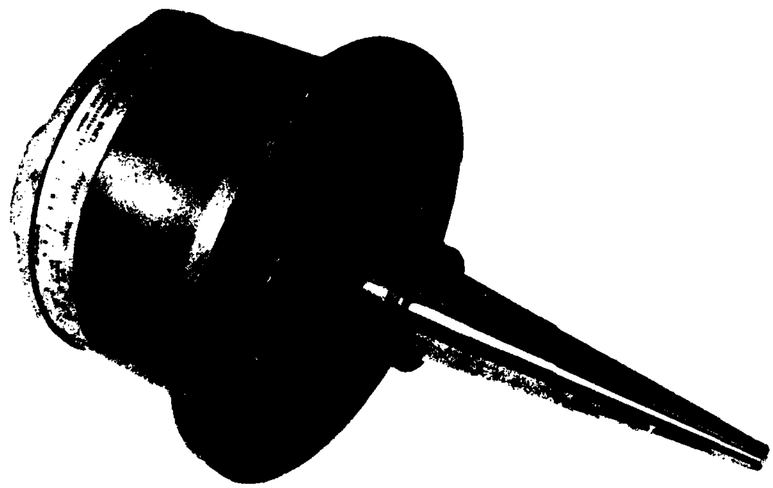


FIG. 43 ANGLE OF ATTACK TRANSMITTER INSTALLATION

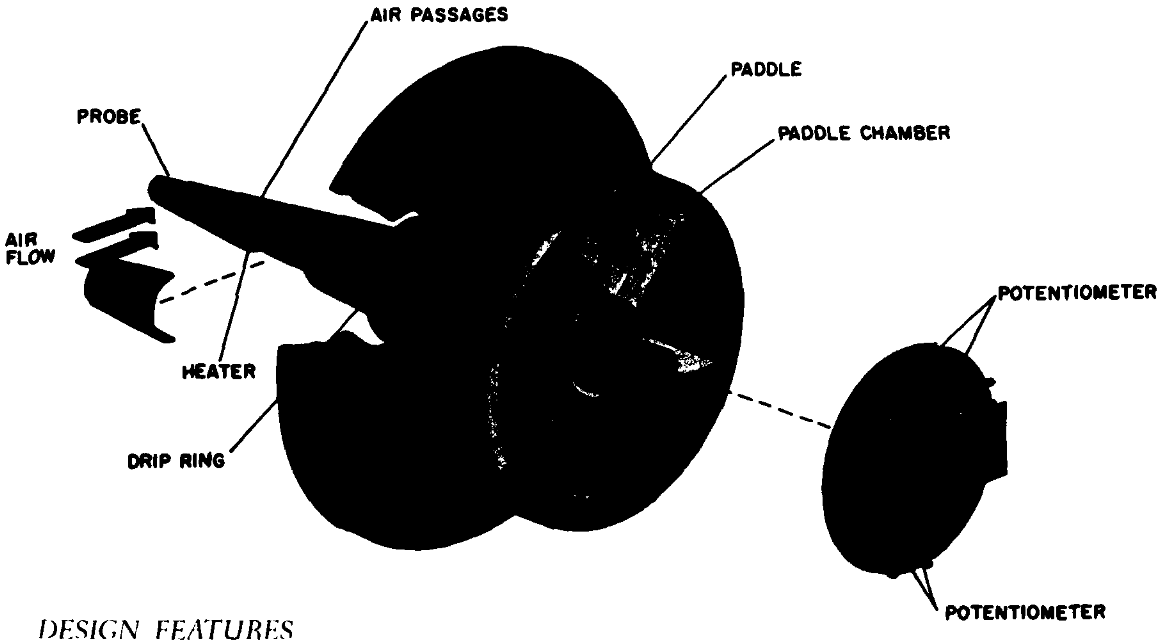
TELEDYNE, INC.
AUTOMATED SPECIALTIES DIVISION
P. O. BOX 888, CHARLOTTESVILLE, VA.

ANGLE OF ATTACK TRANSMITTER



PRINCIPLE OF OPERATION

A conical probe extends through the aircraft skin perpendicular to the flow of air. The probe is attached to a paddle inside the transmitter housing. The probe and paddle are free to rotate. Two sets of slots in the probe allow pressure variations, caused by changes in airstream direction, to be transmitted through separate air passages to opposite sides of a paddle chamber. When the pressure acting on one side of a paddle is greater than the pressure on the other side, the paddle and probe rotate until the pressures are equal. The probe thus positions itself to determine the angle of attack of the aircraft. The probe also drives the electrical pick offs such as potentiometers or synchros.



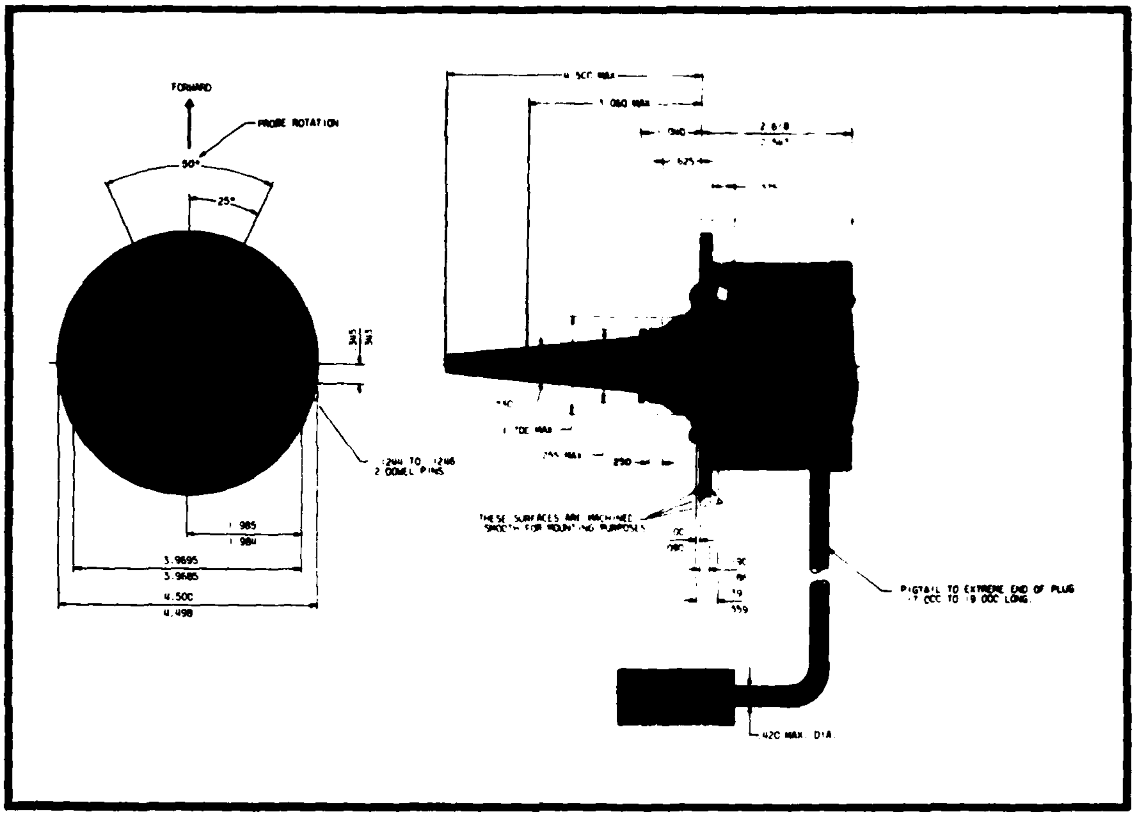
DESIGN FEATURES

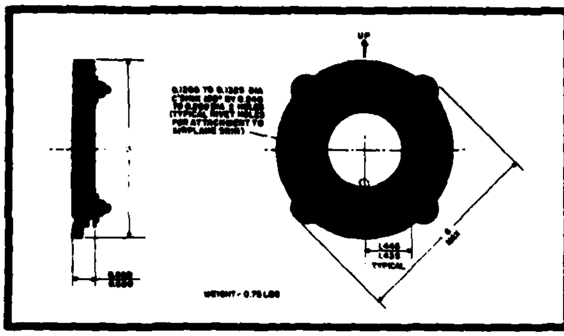
RESPONSE — Low moment of inertia and viscous damping derived from the resistance of the internal passages to air flow produce a fast, non-oscillatory response at all operating speeds. As a result displays are enhanced and completely flyable under all flight conditions.

MOISTURE PROOF — Heat and ventilation prevent condensation. Ingested moisture is trapped inside the probe and rapidly drained overboard through drain holes aided by a drip ring.

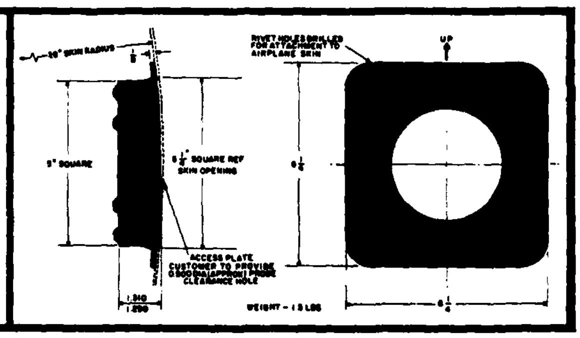
ICE PROOF — Ice removal and prevention is achieved by an electrical heater imbedded in the leading edge of the probe.

MECHANICAL STRENGTH — Excellent mechanical strength results from the conical shape of the probe and the generous size of ball bearings and shaft. Structural portions of the probe are stainless steel. Endures all normal service use and handling.





INTERNAL MOUNTING PLATE



EXTERNAL MOUNTING PLATE

TELEDYNE, INC.

AUTOMATED SPECIALTIES DIVISION
P. O. BOX 888, CHARLOTTESVILLE, VA.
Phone: Area Code 703-973-3311
TWX 296-5400

5.2.2 Linear Variable Differential Transformer (LVDT)

The LVDTs, as used in the program to measure relative motion of the rocket pods, were described in paragraph 4.3.2.4.

The Sanborn units were selected for the program because of their small size, rugged construction, high accuracy, sensitivity and data stability.

A complete description of the units, the theory of operation, outline drawing and specifications are described in the brochure provided by Sanborn Division of Hewlett Packard (See Pages 71 through 75).

Figure 20 shows a typical installation of the LVDT Model 24DCDT-1000 on the LVDT supports used to measure relative motion of the rocket launcher in the vertical direction.

5.2.3 Inertial Reference System (IRS)

The inertial reference system (IRS), Humphrey Inc. Model CF 32-0201-1, was selected for the 2.75" Rocket Program because of its ready availability, small space requirement, low weight and its ability to meet the rigid accuracy specifications. The IRS specification sheet is included as Figure 44.

The IRS is a self contained package including position gyros, accelerometers, rate gyros and power supplies which operate in the specified temperature and vibration environment. Figures 45 and 46 show the internal construction of the IRS with the case opened. Outline dimensions are presented in Figure 47.

A unit had to be selected that could be physically located close to the aircraft's center of gravity. The installation in the aircraft closest to this point is behind the pilot's seat as shown in Figure 48. The package was mechanically and electrically leveled in order to align the three IRS axes (roll, pitch and yaw) with the three axes of the aircraft.

The unit is normally pressure tight at all times, as indicated on the specification sheet. However, during flight tests at YPG the temperature exceeded the specification limits and several internal power supply failures resulted. It was determined that a circulation fan was required in the IRS and the installation of the fan solved the high temperature problem.

Bench testing of the system could be performed by monitoring the desired output with a digital voltmeter and manually altering either position, rate or acceleration fields with the appropriate calibrated equipment. The electrical schematic is shown in Figure 49.

DISPLACEMENT TRANSDUCERS

Series 7DCDT and 24DCDT

SANBORN TRANSDUCER DIVISION

F 25M-7-64

DESIGN FEATURES

- *High Resolution*
- *Zero Hysteresis*
- *Linearity Error Less than 0.5%*
- *Built-in Carrier Oscillator*
- *Built-in Phase Sensitive Demodulator*
- *DC Input — DC Output*
- *No Phasing Problems*
- *No Harmonic and Quadrature Null Problems*
- *Easy to Use*

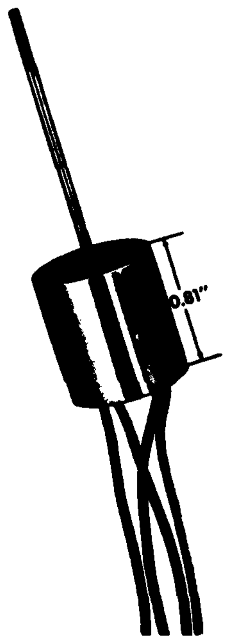


Figure 1. Model 7DCDT-050

CONDENSED SPECIFICATIONS

TRANSDUCER TYPE: DC-input, DC-output differential transformer with built-in carrier oscillator and phase sensitive demodulator providing DC output proportional to linear displacement.

INPUT: Displacements of ±0.050" to ±3.0" full scale.

OUTPUT: DC voltage amplitude proportional to core (armature) displacement and polarity related to the direction of displacement. Deviation from the best straight line through zero not more than 0.5% of total stroke range.

SENSITIVITY: Series 7DCDT: Full scale outputs from ±1.5 VDC (for ±0.050" stroke range model) to ±5 VDC (for ±3.0" stroke range model). Requires 6 VDC nominal excitation.

Series 24DCDT: Full scale outputs from ±5 VDC (for ±0.050" stroke range model) to ±13.5 VDC for (±3.0" stroke range model). Requires 24 VDC nominal excitation.

SIZE AND WEIGHT: Series 7DCDT: 0.75" diameter x 0.81" long to 0.75" diameter x 10.50" long; 22.6 to 208 grams.

Series 24DCDT: 0.75" diameter x 0.88" long to 0.75" diameter x 10.52" long; 23 to 208 grams.

TYPICAL USES: To measure, monitor, and/or control mechanical displacements where high accuracy and resolution are desired.

Examples: Measurement of strain in structural members; position indication and/or position-feedback in control systems; automatic dimensioning in tape-controlled machine tools; as the sensor in a pressure transducer i.e., Bourdon tube or bellows displacement.

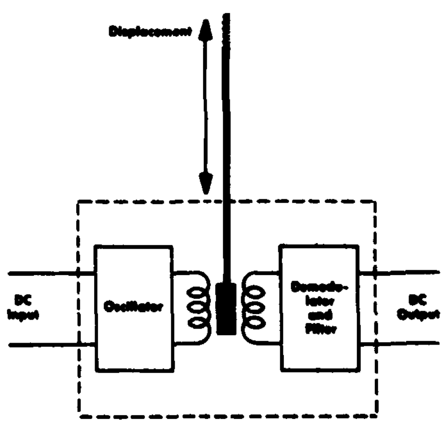


Figure 2. Functional Diagram

DESCRIPTION

The Sanborn 7DCDT and 24DCDT Series of displacement transducers are linear variable differential transformers with built-in 6 or 24-volt DC excited carrier oscillator and phase sensitive demodulator systems. Though small in size, they are ruggedly constructed. They provide the unlimited resolution, high accuracy and sensitivity of Sanborn displacement transducers while eliminating the extra space and cost of complex carrier systems. Input and output circuits are electrically isolated from each other and the coil assembly case, making them usable directly in floating or ground return systems. The DC output is sufficient to drive most standard DC indicators, recorders or control systems. The design of these transducers eliminates the usual phase shift correction and harmonic-and-quadrature null problems associated with differential transformers.

A DCDT consists of a coil assembly and a core which, when displaced linearly along the axis and within the bore of the coil assembly, produces a voltage change in the output proportional to the displacement. Both series of transducers are available in seven stroke ranges. Cores are available with either a 0.001" or 0.013" radial clearance between the coil bore and core OD; and with (1) an integral core extension rod, (2) a tapped hole at each end, or (3) a blind hole at each end.

THEORY OF OPERATION

A DCDT coil assembly consists of a differential transformer coil, a DC-excited solid-state oscillator and a phase-sensitive demodulator all in one small package. The oscillator converts the DC input power to AC which is used to excite the primary winding. The axial core position determines the amount of voltage induced in the secondary windings. Each of the two secondary circuits contains a secondary winding, a full-wave bridge, and an RC filter. These secondary circuits are connected in series opposition so that the resultant output is a DC voltage proportional to the core displacement from electrical center. The polarity of the voltage is a function of the location of the core with respect to electrical center.*

A simplified functional diagram of the transducer is shown in Figure 2.

PERFORMANCE CHARACTERISTICS

The frequencies at which transducer outputs are down 3 db are listed in the specifications on page 4 and are based on test data. Output amplitudes and phase relationships at other frequencies can be approximated from the following equations:

$$\theta = \arctan \frac{f_o}{f_{-3db}}$$

$$A_r = \frac{1}{\sqrt{1 + \left(\frac{f_o}{f_{-3db}}\right)^2}}$$

Where:

θ = phase angle between displacement and electrical output.

A_r = amplitude ratio

f_o = displacement frequency

f_{-3db} = displacement frequency where the DCDT output is down 3 db

**Electrical center is the position of the core relative to the coil when the output is zero and is located approximately ½ way along the coil length.*

If less ripple is desired, additional external filtering may be added, but a consequent loss of frequency response should be expected. If, on the other hand, better frequency response is desired, DCDTs with networks having shorter time constants can be supplied on special order. Then, if the ripple is excessive, the user can add an external network with sharper cut-off characteristics than those ordinarily supplied as an integral part of the transducer. The sensitivity specifications listed on page 4 are derived from tests taken with the transducers operating into an infinite impedance. For other values of load impedances, the output impedance of the DCDT should be taken into consideration. Typical output characteristics are shown in Figure 3.

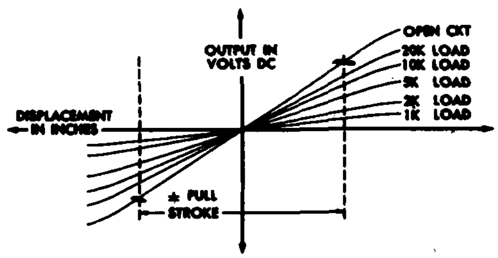


Figure 3. Typical Output Characteristics

To realize the guaranteed linearity of 0.5% of full scale, the load impedance should not be less than 10,000 ohms. Load impedances less than 10,000 ohms may be used, but the linearity range of the transducer will be reduced. The resolution capability of DCDTs is theoretically infinite, being limited only by the read-out device. If a Model 7DCDT-050 is used with a Sanborn recording system having a Model 350-1000 DC coupling preamplifier, the sensitivity of the system will be a 30 division stylus deflection for a 0.001 inch displacement of the transducer core . If connected to a portable Sanborn single channel Model 299 recorder, the maximum sensitivity would be a three division stylus deflection for a 0.001 inch displacement of the transducer core.

Nominal excitation is 6 VDC, 20 milliamps for the 7DCDT Series and 24 VDC, 38 milliamps for the 24DCDT Series. These values are the basis for the listed specifications. The excitation voltage range for 7DCDTs is 5 to 7 VDC and 20 to 28 VDC for 24DCDTs. The scale factor is a function of the amplitude of the excitation voltage. The percentage change in scale factor as a function of the excitation voltage will not exceed the percentage change of the excitation voltage.

APPLICATION CONSIDERATIONS

The 7DCDT and 24DCDT Series have identical stroke ranges. 24DCDTs have sensitivities that are approximately three times those of comparable 7DCDT models. The power consumption of a 7DCDT is approximately 120 milliwatts; 24DCDT, approximately 900 milliwatts. 24DCDT models can be used in temperature environments up to 250°F, whereas 7DCDT models must not be subjected to temperatures greater than 140°F. When selecting a DCDT, the maximum peak-to-peak displacement to be measured, the operating temperature range, and the full scale sensitivity of the associated electronic equipment should be considered.

INSTALLATION AND OPERATION

DCDTs are easily installed. The core should be connected to the moving member and the coil mounted to a mechanical reference point in a device such as a Sanborn T52-6 Mounting Block, tubular clamp or similar fixture. The mounting setup should have provisions for adjusting both the radial and axial alignment between the coil and the core. Connection to the moving member is accomplished by coupling the moving member to the threaded connecting rod (standard models) or to the core by means of an extension rod T18-19P1 or -19P2, see back page. The extension rod can either be threaded or cemented to the core, (using LOCTITE Sealant, Grade A), depending on the core type. The mounting hardware should be made of non-magnetic materials such as brass or 303 stainless steel.

Two different diameter cores are available; the 0.120-inch diameter core makes a sliding fit when inserted into the coil so that the coil may be used as a supporting bearing. In some applications, particularly where a line has already been established by two or more points, the lack of clearance when using the 0.120-inch diameter core may make it difficult to align the core with the coil bore. In this case, the 0.098-inch diameter core is recommended as it will provide 0.026-inch diametrical clearance between the coil ID and the core OD. After the transducer has been installed, the core and coil should be adjusted for radial alignment and then zeroed.

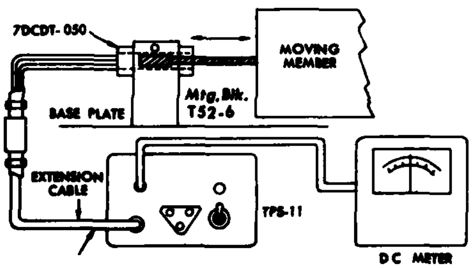


Figure 4. Typical Application

TYPICAL APPLICATIONS

Figure 4 shows an application which includes a Sanborn TPS-11 power supply connected to the transducer excitation terminals (red lead to +, black lead to −)* and a zero-centered meter connected to the output terminals.

The moving member (and consequently the transducer core) is first placed at mid-travel which is mechanical zero. The coil or the core is then adjusted axially until the meter reads zero. The core will then be axially positioned approximately in the center of the coil. No additional balancing, phasing, quadrature rejection or other usual adjustments for differential transformers are required.

The combination of a Sanborn DCDT and LVsyn (linear velocity transducer) is often used in servo linear positioning systems. An example is a hydraulic servo control system shown in Figure 5. The DCDT provides spool position feedback and the LVsyn, spool velocity feedback for servo stability. Another example is the use of a DCDT and LVsyn combination in a counter-measure system to provide linear position and velocity feedback in the magnetron magnet servo positioning system. (A separate data sheet describing Sanborn LVsyns is available on request.)

Proper excitation polarity must be observed. Reversal of excitation leads will burn out the primary circuits.

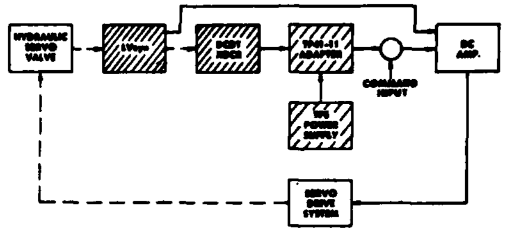


Figure 5. Sanborn transducers as sensing devices in a closed-loop servo system

CONNECTORS AND ACCESSORIES

All DCDTs are supplied with 18" long #22 AWG teflon insulated leads. 7DCDTs are also available with 5-pin Amphenol Blue Ribbon #126-217 Connectors viz., 7DCDT-050-C1, etc.; and 24DCDTs with 7-pin Amphenol #126-195 connectors viz., 24DCDT-050-C1.

DCDTs should be energized by a low impedance power source. Sanborn regulated 115 volt, 60-cycle 6- and 24-VDC Power Supply Models TPS-11 (6 VDC) and TPS-12 (24 VDC), with convenient *Transducer* and *Signal* output connectors on the front panel, are designed to provide excitation for DCDTs. Standard banana jacks with ¾" core spacing are also mounted on the front panel (Figure 6) so that these units may be also used as auxiliary power supplies. Both power supplies have the capacity to power up to five DCDTs. The T41-11 Multiple DCDT Power Supply Adapter (Figure 7) permits utilization of this capability by providing five excitation and transducer output channels with individual sensitivity adjustments.

Sanborn Portable Power Supply TPS-10 is a handy source of 6.5 VDC for use when 115 VAC is not readily available, see Figure 8. A data sheet describing both power supplies and the adapter is available on request.

Sanborn mounting block, core extension rods and extension rod coupler accessories for DCDTs are described and illustrated on page 4.

ASSOCIATED READOUT INSTRUMENTS

For maximum simplicity and economy, the output of DCDTs can be fed directly to a DC voltmeter which will give a voltage indication proportional to displacement. The signal may also be fed to signal conditioning equipment, for recording and/or control, such as: Sanborn single, dual, 4, 6, or 8-channel recording systems; HP Model 405 Automatic Digital Voltmeter; Dymec Model 2401B Integrating Digital Voltmeter; Moseley Autograf high input impedance X-Y Plotters; etc.

For a comprehensive review of the many combinations of Sanborn, Hewlett-Packard and other instrumentation available for use with Sanborn transducers, consult your nearest Hewlett-Packard field office.

SPECIFICATIONS FOR MODELS 7/24DCDT

MODEL	7DCDT-050	7DCDT-100	7DCDT-250	7DCDT-500	7DCDT-1000	7DCDT-2000	7DCDT-3000	24DCDT-050	24DCDT-100	24DCDT-250	24DCDT-500	24DCDT-1000	24DCDT-2000	24DCDT-3000
Full Scale Output (VDC)	1.5	2.8	1.5	3.3	4.8	4.6	5.0	5.0	9.0	7.0	12.5	18.0	14.0	13.0
Displacement Range Full Scale (inches)	±.050	±.100	±.250	±.500	±1.000	±2.000	±3.000	±.050	±.100	±.250	±.500	±1.000	±2.000	±3.000
Scale Factor v/in	30	28	6.0	6.6	4.8	2.3	1.4	100	90	28	25	18.0	7.0	4.3
Maximum Non-Linearity (% of full scale)	±0.5	±0.5	±0.5	±0.5	±0.5	±0.5	±0.5	±0.5	±0.5	±0.5	±0.5	±0.5	±0.5	±0.5
*Excitation Voltage (Volts DC), Nominal	6	6	6	6	6	6	6	24	24	24	24	24	24	24
Internal Carrier Freq. (KC), Nominal	9.0	9.0	1.2	2.4	1.5	1.0	1.0	14	15	4.0	3.8	3.6	1.8	1.6
% Ripple (RMS), Nominal	0.7	0.7	2.2	1.2	1.5	1.8	3.0	0.6	0.7	0.85	0.75	0.8	1.5	1.5
Output Impedance (K ohms)	2.2	3.0	5.0	5.3	5.5	5.2	5.0	2.5	3.5	5.2	5.5	5.6	5.5	5.6
Freq. Response 3 db Down at CPS	350	170	120	135	114	128	100	300	140	115	110	100	110	75
Temperature Range	—65°F to 140°F							—65°F to 250°F						
Weight (Grams) Typical (Coil and Core)	23	28	68	78	100	167	208	29	35	70	79	97	177	218

*Series 7DCDT: max excitation voltage 7 VDC, min 5 VDC. Series 24DCDT: max excitation voltage 28 VDC, min 20 VDC.

ORDERING INFORMATION

DCDT DISPLACEMENT TRANSDUCER: Specify the basic model number, e.g., Model 7DCDT-050 for 6-volt excitation and a ±0.050 inch displacement range. If you want this transducer with other than a standard core assembly, select the core configuration desired (see outline drawings) and add the proper suffix to the basic model number, e.g., Model. 7DCDT-050-B12. If you want the leads terminated with Connector 126-217, add -C1 to the existing number, and $6.00 to price, e.g., Model 7DCDT-050-C1 or 7DCDT-050-B12-C1. Twenty-four volt operation transducers can be ordered by substituting the prefix (24) for (7) in the above numbers.

ACCESSORIES: Spare cores can be ordered with transducers. These cores are carefully manufactured from selected, heat-treated materials to obtain the desired magnetic properties. When cores are ordered with coil assemblies they are carefully matched to insure transducer operation within rated specifications. Specify the model or part number given in the price list. When ordering cores separately, refer to the outline drawing and select the model number of the desired core style. Then, refer to the price list for the actual part number, e.g., if you want a model T19-4 core for use in a 7DCDT-500 Transducer, order core part number T19-4P5.

PRICES

TRANSDUCERS

7DCDT-050	$ 99.00	24DCDT-050	$146.00
-100	104.00	-100	151.00
-250	119.00	-250	164.00
-500	132.00	-500	177.00
-1000	141.00	-1000	186.00
-2000	155.00	-2000	200.00
-3000	162.00	-3000	207.00

*Prices for 7/24DCDT-X-B11, -B12, -B13, etc. same as for equivalent stroke standard models listed above (where X equals stroke in thousandths).

Power Supplies		Accessories	
TPS-10 for 7DCDT Series (w/battery)	$42.00	T52-3 Coupler	$5.00
TPS-11 for 7DCDT Series	150.00	T52-6 Mtg. Block	12.00
TPS-12 for 24DCDT Series	175.00	T18-19P1 7" Extension Rod	3.50
T41-11 Multiple DCDT Power Supply Adapter for 7/24DCDT Series	175.00	T18-19P2 15" Extension Rod	3.75

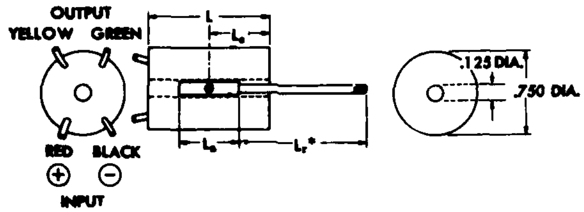
Replacement Cores/Core Assemblies

TRANSDUCER	STD.	-B11	-B12	-B13	-B14	-B15	PRICE
7/24DCDT-050	T29-1P1	T29-2P1	823-2P11	T19-4P1	T19-2P1	T19-3P1	$5.20
7DCDT-100	T29-1P2	T29-2P2	823-2P21	T19-4P2	T19-2P2	T19-3P2	5.20
24DCDT-100	T29-1P8	T29-2P8	823-2P17	T19-4P14	T19-2P14	T19-3P14	5.20
7/24DCDT-250	T29-1P3	T29-2P3	823-2P22	T19-4P3	T19-2P3	T19-3P3	5.20
7/24DCDT-500	T29-1P4	T29-2P4	823-2P23	T19-4P4	T19-2P4	T19-3P4	5.75
7/24DCDT-1000	T29-1P5	T29-2P5	823-2P24	T19-4P5	T19-2P5	T19-3P5	5.75
7/24DCDT-2000	T29-1P6	T29-2P6	823-2P25	T19-4P6	T19-2P6	T19-3P6	5.75
7/24DCDT-3000	T29-1P7	T29-2P7	823-2P25	T19-4P6	T19-2P6	T19-3P6	5.75

Prices subject to change without notice. All prices F.O.B. Waltham, Mass. In areas where sales and use taxes apply, these taxes are added to the invoice.

OUTLINE DRAWINGS

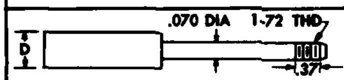
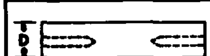
TRANSDUCERS



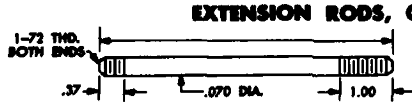
7 DCDT MODELS	L	L_s^*	L_r^*	L_o
—050	0.81	0.56	1.90	0.33
—100	1.06	0.87	1.90	0.45
—250	3.00	1.75	1.90	1.40
—500	3.50	1.87	2.4	1.65
—1000	4.50	2.00	3.2	2.20
—2000	8.00	3.50	5.2	3.95
—3000	10.50	3.50	8.4	5.06
* STANDARD CORES				

24 DCDT MODELS	L	L_s^*	L_r^*	L_o
—050	0.87	0.56	1.90	0.33
—100	1.12	0.75	1.90	0.48
—250	3.21	1.75	1.90	1.40
—500	3.71	1.87	2.4	1.65
—1000	4.71	2.00	3.2	2.20
—2000	8.21	3.50	5.2	3.95
—3000	10.52	3.50	8.4	5.06
* STANDARD CORES				

CORES

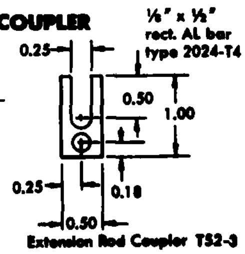
Core Style	Core Style No.	Core Model No.	D
 .070 DIA 1-72 THD .37	STD	T29-1	0.120
	B11	T29-2	0.098
 1-72 THD .187 DP BOTH ENDS	B12	823-2	0.098
	B13	T19-4	0.120
 .073 DIA .093 DP BOTH ENDS	B14	T19-2	0.120
	B15	T19-3	0.098

EXTENSION RODS, COUPLER



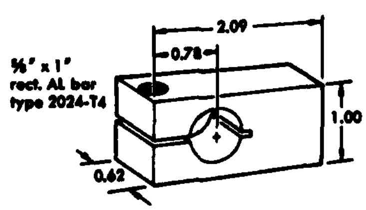
NOTE: (2) 1-72 NUTS AND (2) WASHERS SUPPLIED WITH EACH ROD

EXTENSION ROD MODEL NO.	L
T18-19P1	7.0
T18-19P2	15.0



Extension Rod Coupler T52-3

MOUNTING BLOCK



Mounting Block T52-6

SPECIFICATIONS

1.0	POWER INPUT	28 VDC ±1% APPROX. 4.5 AMP RUNNING, 5.0 STARTING
1.1	POWER TO CAGE DIRECTIONAL GYRO	28 VDC [illegible].5 AMP [illegible] SEC. MAX.
2.0	VERTICAL REFERENCE (PITCH AND ROLL)	
2.1	PITCH	±30 DEGREES
2.2	ROLL	±60 DEGREES
3.0	ELECTRICAL OUTPUTS FROM SIZE 11 SYNCHRO	3-WIRE OUTPUT 11.8V
3.1	ACCURACY	0.1 DEGREE REFERENCE TO TRUE VERTICAL
4.0	AZIMUTH REFERENCE (YAW)	
4.1	YAW	360 DEGREES
4.2	ELECTRICAL OUTPUTS FROM SIZE 11 SYNCHRO	3-WIRE OUTPUT 11.8V
4.3	ACCURACY	0.1 DEGREE
4.4	YAW DRIFT	LESS THAN 0.1 DEGREE/MIN.
4.5	YAW CAGING SYSTEM LOCKS GYRO IN ZERO POSITION SPIN AXIS FORE AND AFT.	
4.6	SPIN AXIS OF YAW GYRO ERECTS TO HORIZONTAL FOR CONTINUOUS OPERATION. NON TUMBLING.	
5.0	PITCH, ROLL AND YAW RATE OUTPUTS	
5.1	RATE RANGE	±80 DEGREES/SECOND
5.2	OUTPUT	0.2 TO 4.8 VOLTS DC
5.3	ACCURACY	0.5% AT NULL, 1.0% AT FULL RATE
5.4	DAMPING	0.7 NOMINAL
5.5	NATURAL FREQUENCY	MORE THAN 22 HZ
6.0	VERTICAL, FORE-AFT AND LATERAL ACCELERATION OUTPUTS	
6.1	ACCELERATION RANGE	±[illegible]
6.2	OUTPUT	[illegible] VDC
6.3	ACCURACY	[illegible] OF FULL RANGE TO 0.2% AT FULL SCALE
6.4	NATURAL FREQUENCY	MORE THAN [illegible] HZ
6.5	DAMPING	[illegible]
7.0	ENVIRONMENTAL CONDITIONS	
7.1	NOTE: RATE AND ACCELERATION OUTPUTS FOR NOMINAL 5K LOAD.	
7.2	TEMPERATURE	-40°F TO +165°F
7.3	VIBRATION	HARD MOUNTING - 0.036 INCHES D.A. OF 5 5 TO 500 HZ
7.4	SHOCK	50G, 11 ±1 MILLISECOND
8.0	CASE SEAL	PRESSURE TIGHT, ALTITUDE ZERO TO 50,000 FT.
8.1	WEIGHT	35 LBS.

ELECTRONICS AND INSTRUMENTS

C

FIG 44

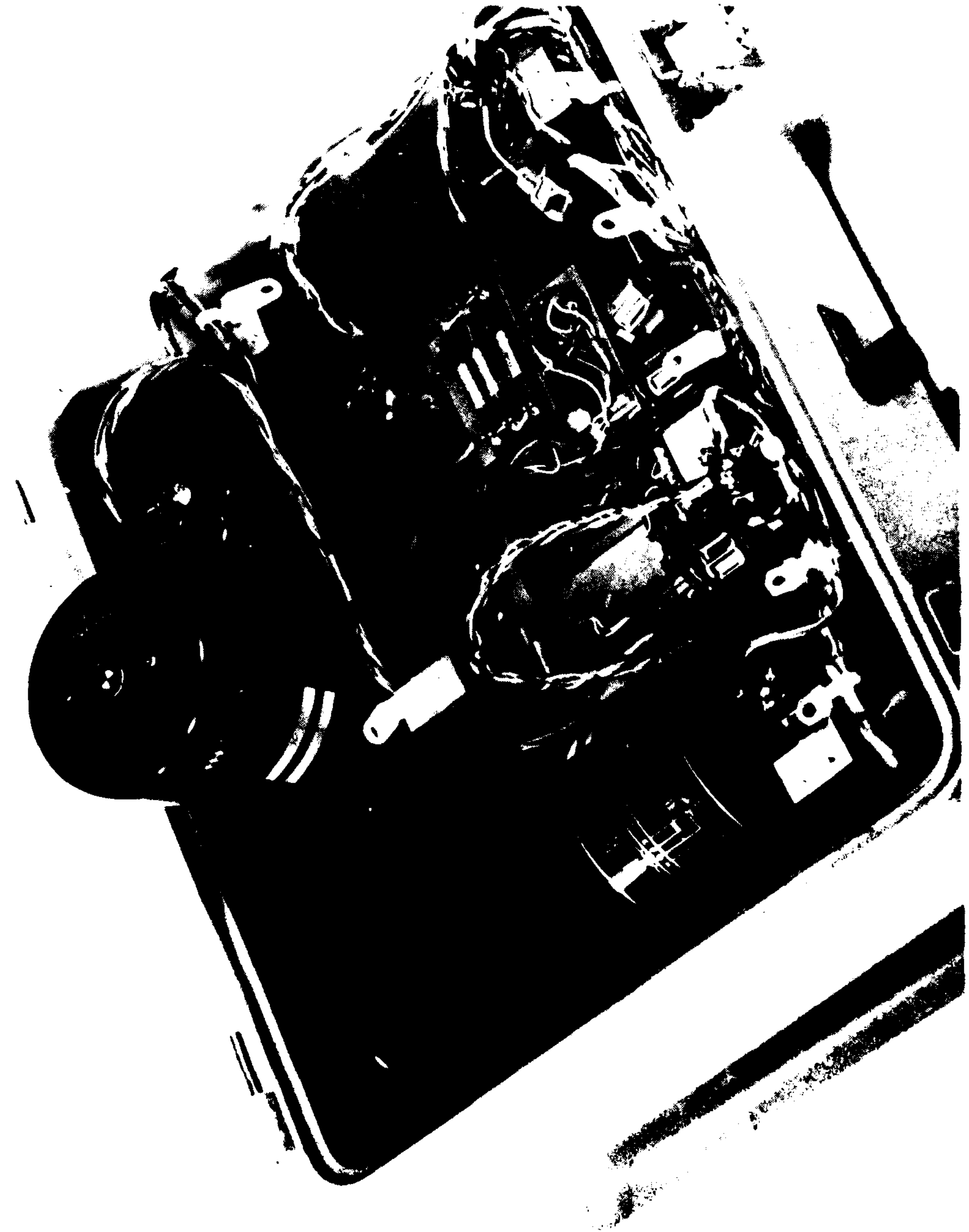


FIG. 45 INERTIAL REFERENCE SYSTEM

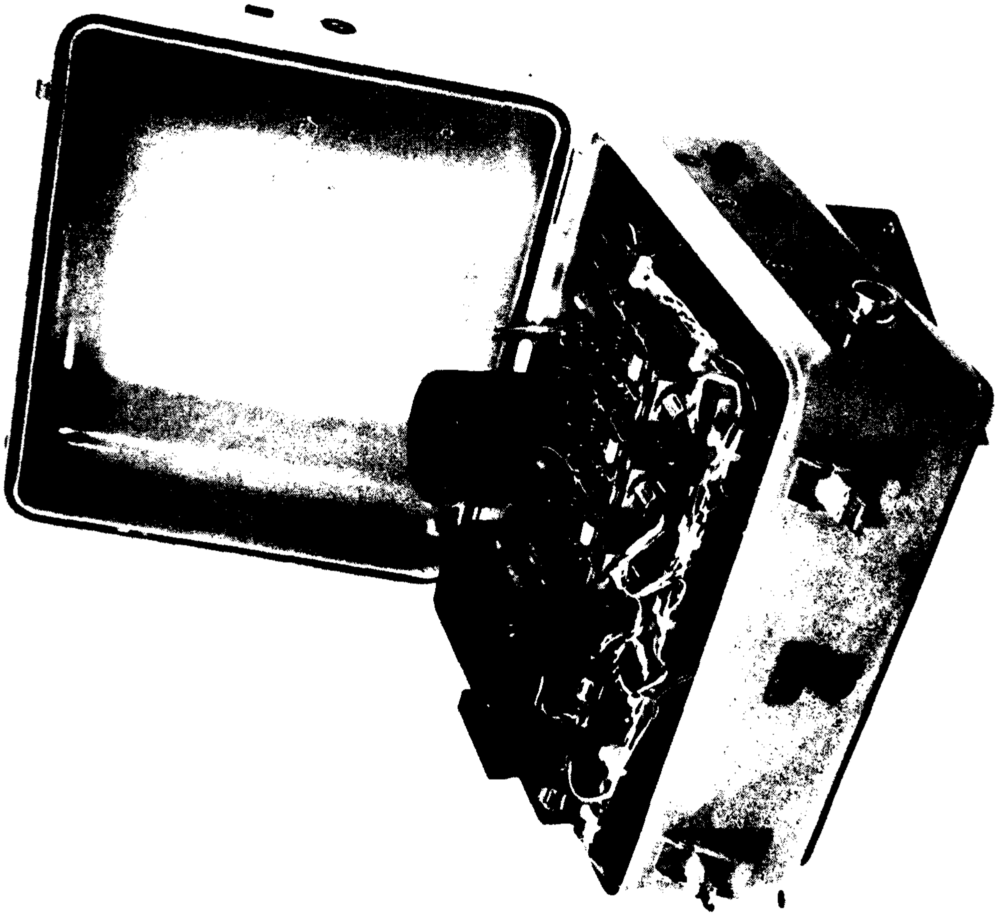


FIG. 46 INERTIAL REFERENCE SYSTEM

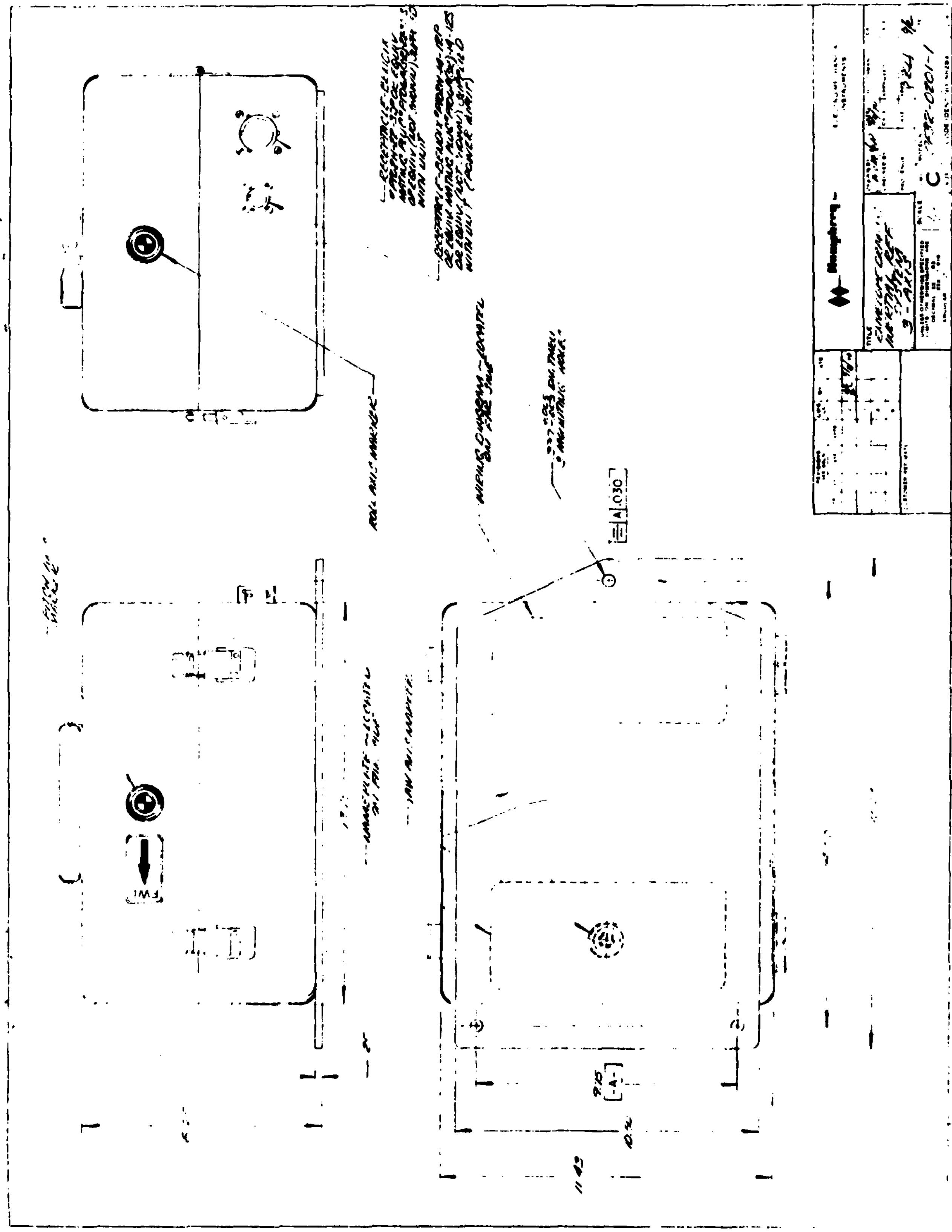


FIG 47

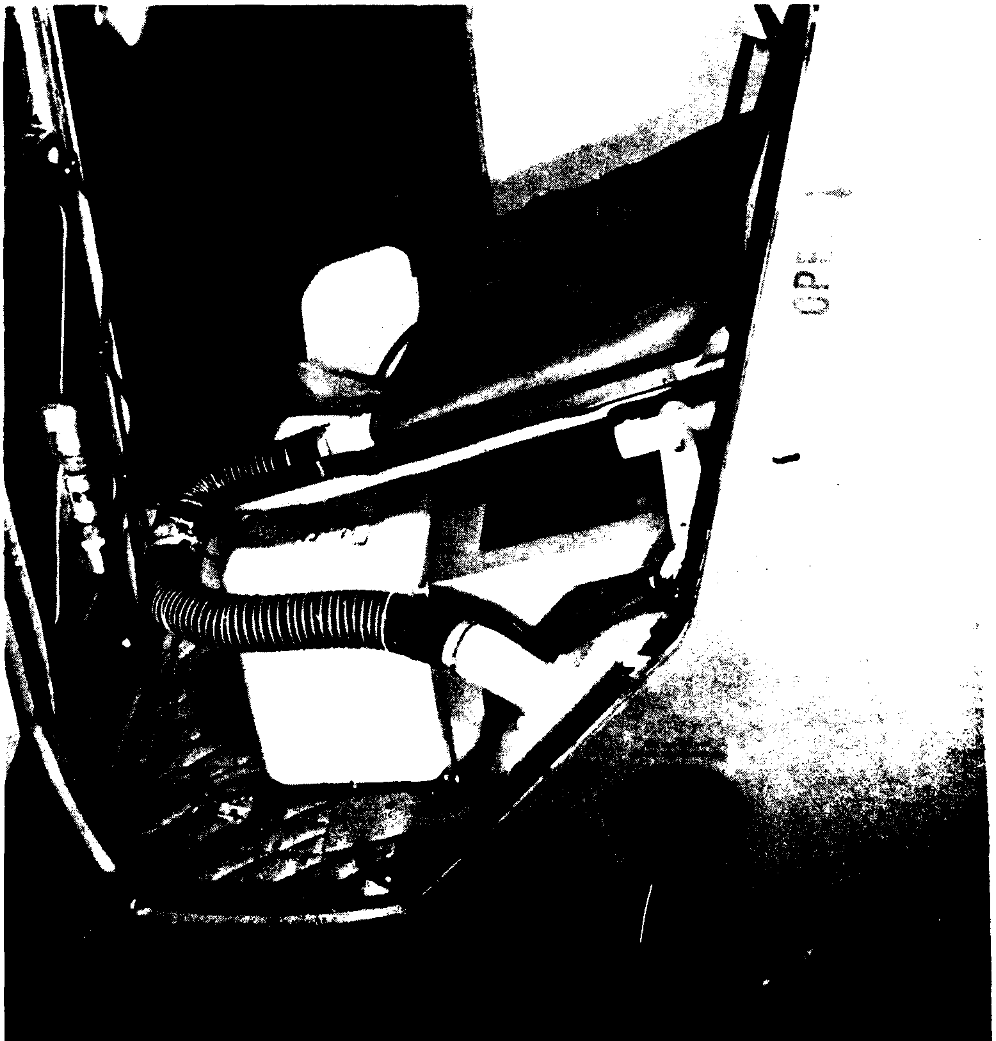


FIG. 48 INSTALLATION OF INERTIAL REFERENCE SYSTEM

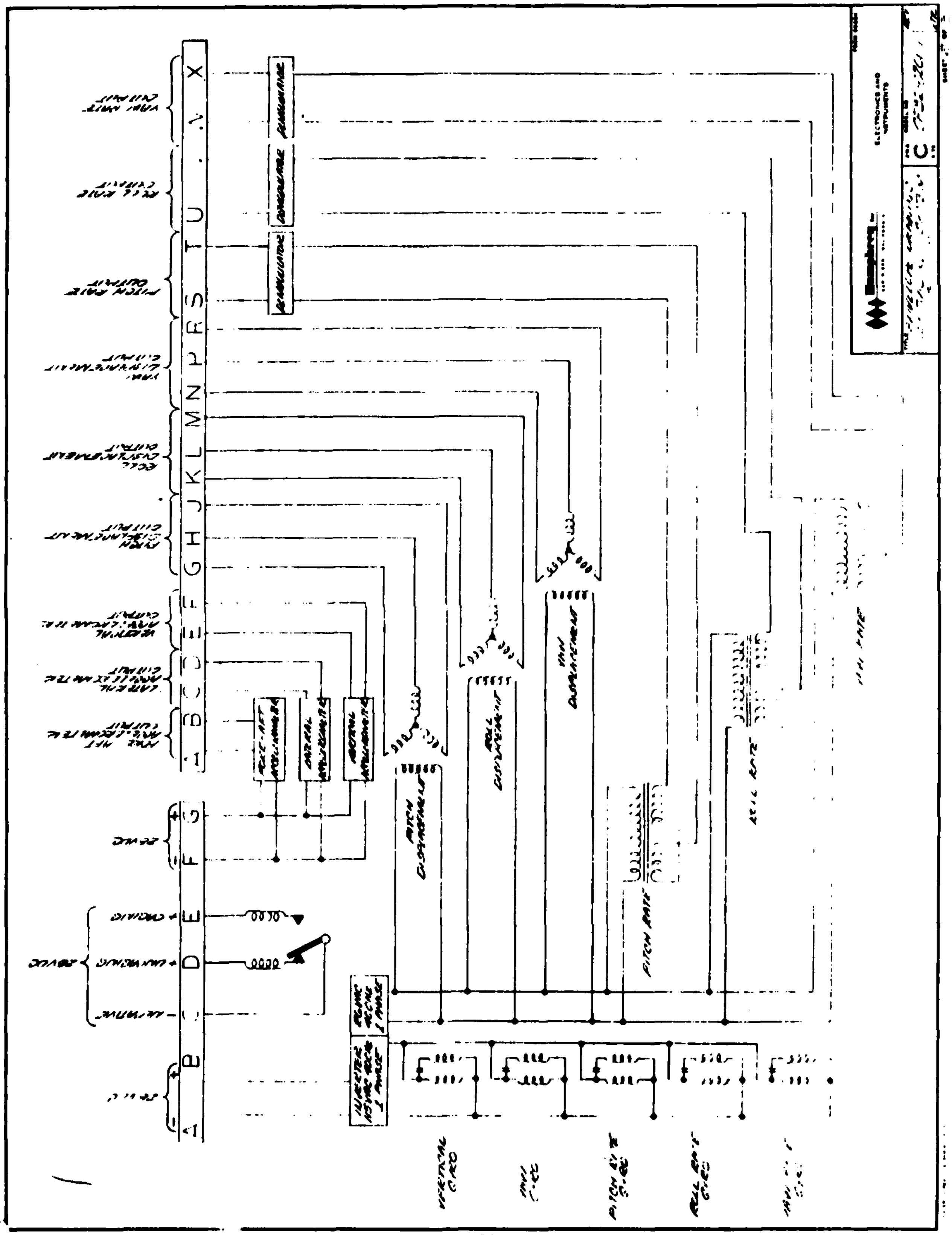


FIG 49