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M-1 ENGINE TEST COMPLEX DATA ACQUISITION SYSTEMS

By

J. D. Anderson

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TECHNOLOGY REPORT

M-1 ENGINE TEST COMPLEX DATA ACQUISITION SYSTEMS

Prepared for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

25 April 1966

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Prepared by:

AEROJET-GENERAL CORPORATION
LIQUID ROCKET OPERATIONS
SACRAMENTO, CALIFORNIA

AUTHOR: J. D. Anderson

APPROVED: D. H. Clark
Manager
M-1 Test Program

Technical Management:

NASA LEWIS RESEARCH CENTER
CLEVELAND, OHIO

TECHNICAL MANAGERS: J. W. Norris
J. C. Presley

APPROVED: W. F. Dankhoff
M-1 Project Manager

ABSTRACT 23561

This report describes the Instrumentation and Data Acquisition Systems that were designed to be used for development testing of the NASA 1.5-million pound liquid oxygen/liquid hydrogen M-1 Engine in the Test Zone K facilities at Aerojet-General Corporation, Sacramento, California.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

I. SUMMARY

The instrumentation system described in this report for the NASA 1.5-million pound liquid oxygen/liquid hydrogen M-1 Engine development test facility, Test Zone K at the Aerojet-General Corporation, Sacramento, California has the capability for recording and automatically processing both steady-state and transient data. Because of funding limitations, the M-1 Engine Program was terminated prior to the completion of these facilities. The design phase of this effort was between 80% and 90% of completion and the pre-procurement of long-lead items was in process (i.e., the Digital Data System described in this report was completed). Primary data is recorded on magnetic tapes in both analog and digital forms. Transient data is then transferred from the analog tape to the oscillograph for final data review. Analog data is also taken through the digital system and recorded on magnetic tape and then processed by the digital computer. The system also permits the digital computer to have several on-line functions, including real time calculation and display of mixture ratio, Isp, and other engine performance parameters. Automatic engine balancing to a pre-set mixture ratio in one test instead of a typical average of 2.7 tests per engine, assuming availability of appropriate valves, could represent a savings in hundreds of thousands of dollars.

The instrumentation and control systems were designed to service four test stands. All four test stands would time-share the digital computer system, analog magnetic tape system, and oscillograph recording system. Test Stands K-1 and K-2 would share signal conditioning, strip chart recorders, and the patching system, Test Stands K-3 and K-4 would likewise share similar equipment. These systems were designed to operate with the test stand located 3500 ft from the control building.

The following tabulation is a summary of Test Stand K-1 instrumentation capabilities:

	Channels/Stand
Strain Gage (Pressure, Force, and Strain)	180
Thermocouple (Chromel-Alumel)	84
Resistive Temperature Transmitter (RTT)	60
Flow and Speed	12
Valve Position	24
Event (Switch Trace)	72
High Frequency	36
Leak Metering	24

CONTROL ROOM

Strip Chart Recorders	24
Visual Gages (Low Level)	48
Oscillographs	2 units, 36 Channels each
Analog Tape Recorders	3 recorders, 32 Channels each
36-Channel Event and 5 Analog Channels	1
Digital System (350 Low Level, 100 High Level)	

The K-Area test facility was to be equipped with an intercommunications system, four television systems per stand, an area warning and public address system for personnel safety, as well as a battery of motion picture stations and enclosures for complete movie coverage of the test stand. The facility was also to be equipped with an electrical control and process instrumentation system for loading and transferring propellants. All areas where liquid hydrogen was to be stored and used were to be equipped with a leak and fire detection system.

II. INTRODUCTION

This report covers the instrumentation system that was designed for the M-1 Engine static test complex. The ultimate configuration of this complex had not been made final at the time of termination; several options were under consideration.

The configuration for Test Stand K-1 was vertical firing of 30 sec duration with a capability for altitude start and environmental conditioning. Test Stand K-2 was intended to be a two-position stand providing for horizontal firing with an altitude long duration run (300 sec) capability, or a horizontal-vertical configuration with an altitude run in the horizontal position. Test Stand K-3 and K-4 were single position, full-duration (500 sec) vertical firing stands. An option to this latter configuration was the replacement of K-3 and K-4 with a two-position Test Stand K-3 (A and B). The total complex would provide five firing positions in any of the options considered. A plot plan of the proposed ultimate complex is shown as Figure No. 1.

The initial construction increment provided Test Stand K-1, the control building, and the other support facilities required for Test Stand K-1. Construction was stopped because of program termination and the systems and facilities were at various stages of completion. The Aerojet-General Corporation - funded control building was completed. Criteria for the facilities was provided by the Aerojet-General Corporation Test Operations Division with detail design and construction management provided by AETRON, the Architectural-Engineering Division of the Aerojet-General Corporation. Also, prefabrication and assembly of some instrumentation systems was performed by the AETRON Foothill Facility. The basic criteria established for this system are as follows.

The system must accommodate only one of the four test stands for hot-firing while any one or all remaining three test stands are simultaneously performing checkouts.

Test Stands K-1 and K-2 were to time share instrumentation signal conditioning, strip chart recorders, patching and checkout equipment located at the Control Room; test stands K-3 and K-4 (or K-3B depending upon the final configuration) would likewise share similar equipment.

The analog tape system, oscillographs, digital system, amplifiers and computer are to be time shared among all four stands.

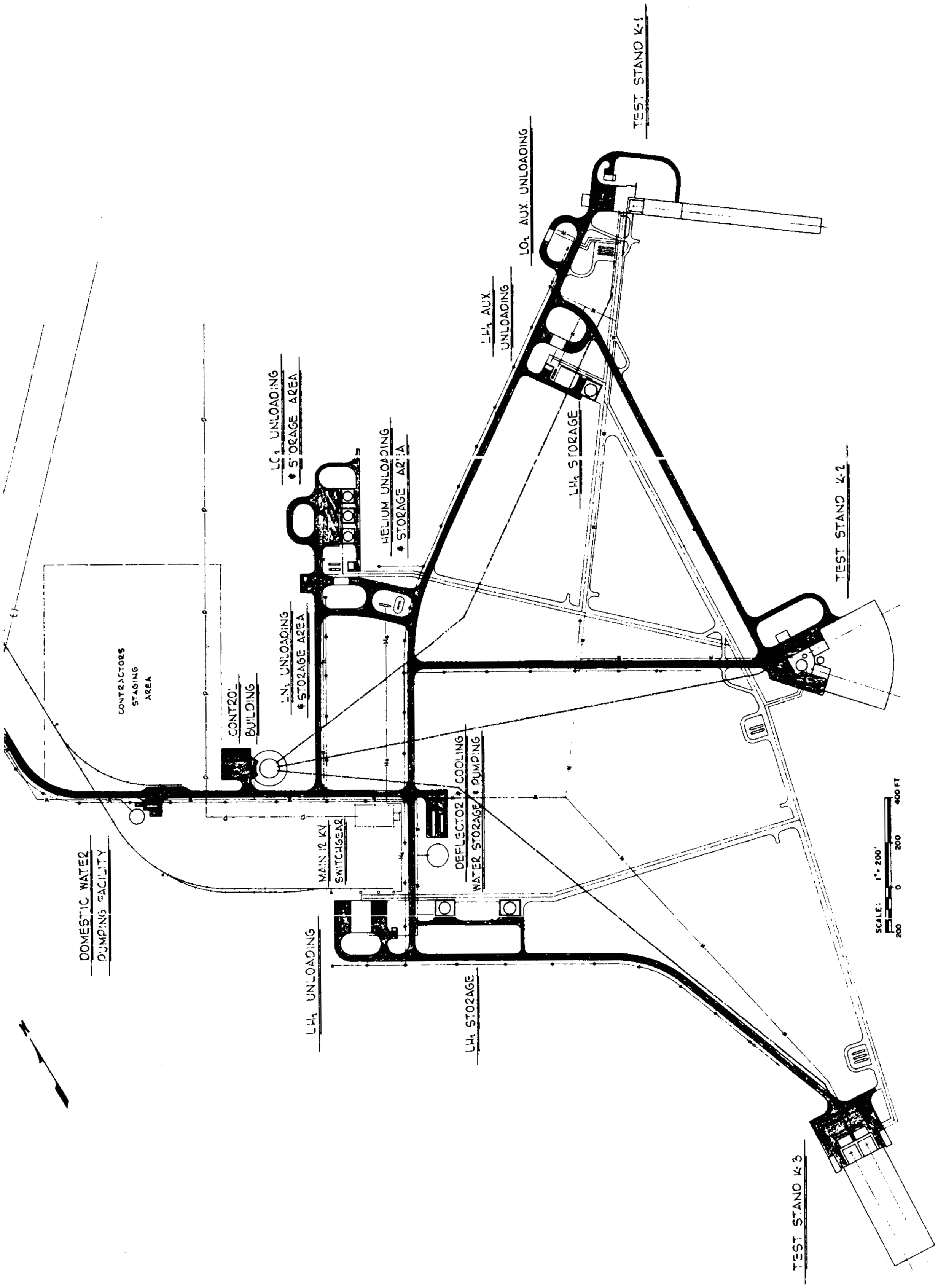

Figure 1
K-Zone Plot Plan

The control room is implemented with a special purpose digital computer with peripheral equipment. This computer is required to perform on-line calculations, on-line parameter limit monitoring, on-line control of engine, off-line data calculations and processing.

Typically, production engine testing requires approximately 2.7 tests per delivery (based upon Titan I and Titan II experience at Aerojet-General Corporation). The first test is a short (20 sec) duration for making balance adjustments in preparation for the final acceptance test. The on-line computer should be able to indicate to the test conductor data in formation which could conceivably reduce the number of tests to 2.0 or less with experience. It is estimated that a full duration M-1 test would cost approximately $350,000, including such considerations as the set-up, data reduction, and propellants. Several conditions occurring during acceptance tests could be minimized by the on-line computer, which represents a cost savings. These are:

A. The engine is within specification and there is no need to terminate the test at a shorter duration; the full-duration acceptance test can proceed.

B. The engine is out of specification and may require two more tests to produce an in-balance condition. Shutdown can be accomplished as soon as steady-state data is indicated.

In the first case, the computer could indicate that there is no need to terminate the test. In the second case, the computer could indicate the degree of adjustment required, and in the second test, it could indicate whether balance had been achieved.

It is conservatively estimated that the equivalent of 0.5 duration tests per deliverable engine could be saved through the use of the on-line computer, or approximately $175,000 per deliverable engine.

For uniformity in test operations, equipment calibration, equipment maintenance, and rapid channel conversions, the instrumentation system is implemented whenever practicable with modular construction.

III. TECHNICAL DISCUSSION

A. SYSTEM DESCRIPTION

Test Zone K was designed for M-1 Engine testing with the total complex consisting of four test stands or more and a two-position control room. The ultimate engine test program had the following goals:

Environmental engine conditioning from -260°F to +240°F.

Environmental engine tests at 95 to 100 percent humidity and two hours of rain.

Engine altitude start tests at -260°F and 0.025 psia.

Engine altitude full duration run tests.

Engine sea-level full duration run tests.

Test Stand K-1 was designed to fulfill the first phase of these test requirements. It was to have provided altitude/environmental conditioning and altitude engine start tests of 3 sec duration plus engine run tests at sea-level with 30 sec duration.[1]

The remaining program requirements for engine testing were to be designed into future K-Area test stands (i.e., K-2, K-3 etc.).

The basic facilities were designed to implement additional test stands. The K-Zone control room is designed with two separate control centers with a common computer center for all K-Area testing. Test Stands K-1 and K-2 were to time share instrumentation signal conditioning, patching, and checkout equipment located in Control Center 1.[2] Test Stand K-3 and future test stands were to have independent instrumentation signal conditioning, patching, and checkout equipment located in Control Center Number 2. The digital system amplifiers and computer would be shared among all of the test stands.

1. Test Stand K-1 Data Acquisition (see Figure No. 2)

Test Stand K-1 data acquisition is composed of the following systems:

a. Strain Gage

This system is composed of 168 channels with test and calibration capabilities, located in the terminal room, and 12 channels that are solely for K-1 propellant handling and common use.

b. Thermocouple

This system is composed of 84 channels of Chromel/Alumel utilizing 150°F reference junction. The system is equipped with test, selection, and calibration features located in the control room. Sixty channels are to be used for engine application and the remaining twenty-four are for the altitude environmental soak facilities.

(1) Rotter, L. L., Description of Test Stand K-1 Altitude and Environmental System, Aerojet-General Report No. 8800-30, 25 November 1965

(2) Criteria for "K" Zone Instrumentation and Controls, M-1 Program, Aerojet-General Corp. AETRON Division, April 1964

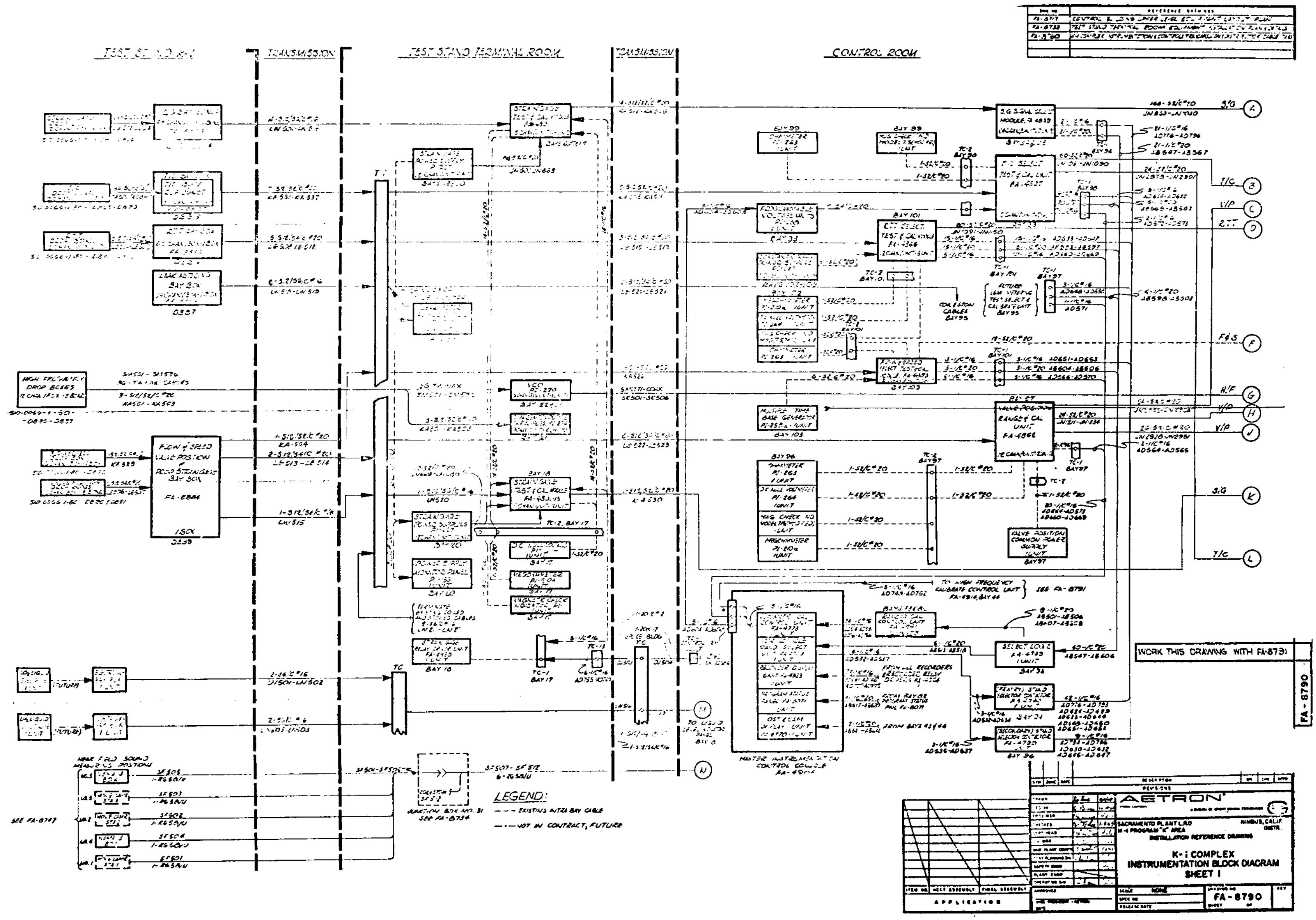

Figure 2

K-1 Complex Instrumentation Block Diagram

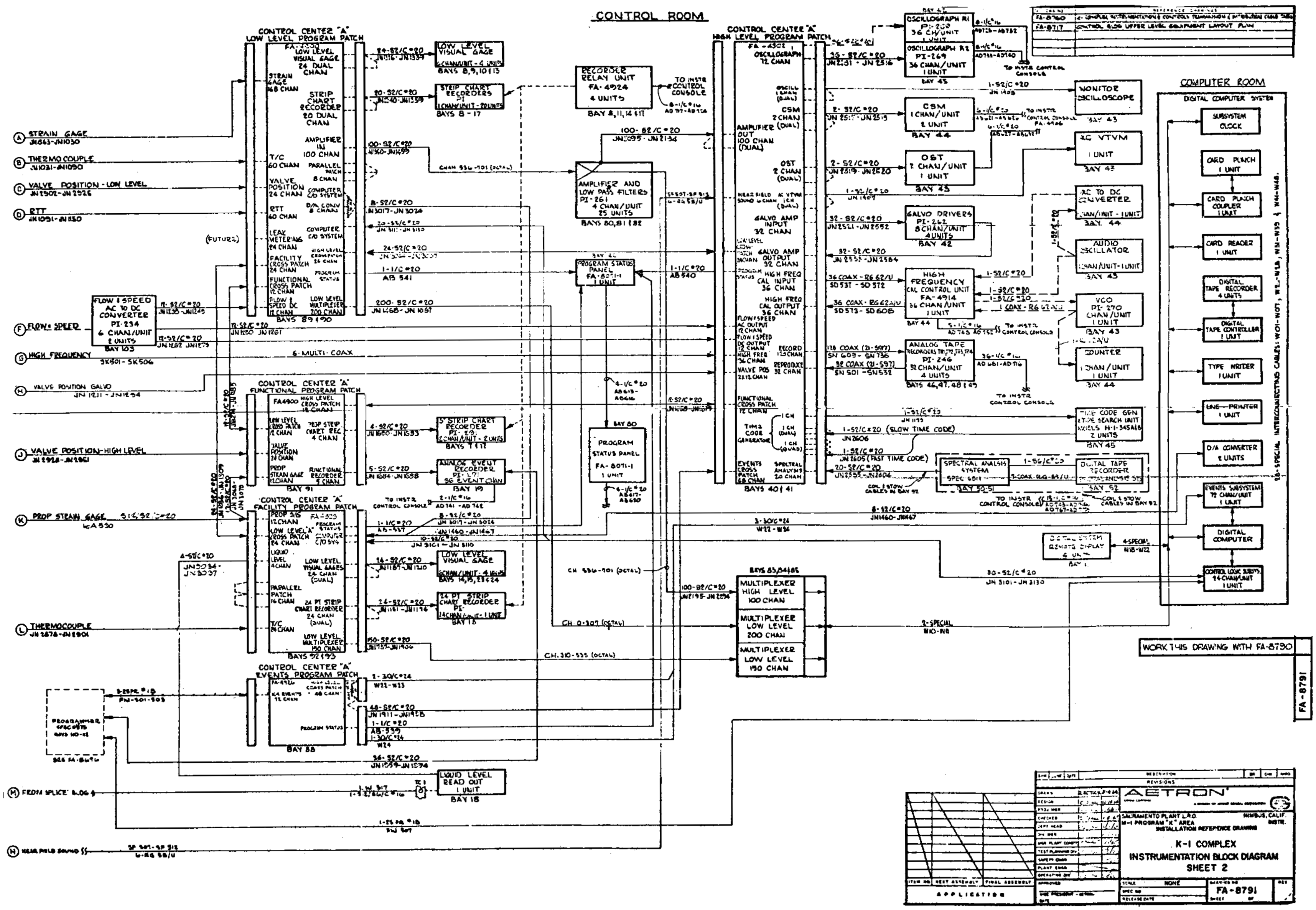

Figure 2

K-1 Complex Instrumentation Block Diagram

c. Resistance Temperature Transmitter (RTT)

The RTT System is composed of 60 channels of constant current signal conditioning, calibration, test, and selection equipment in the control room.

d. Flow and Speed

This system is composed of 12 channels with selection, test, calibration, and signal conditioning equipment in the control room.

e. Valve Position

This system is composed of 24 channels with calibration and signal conditioning in the control room.

f. High Frequency

This system is composed of 36 channels of signal conditioning units, voltage controlled oscillators, located in the terminal room.

Test Zone K, in addition to Test Stand K-1, is composed of four independent propellant storage areas and a flame deflector cooling system consisting of 2.5 million gallon water storage and a total pumping capability of 140,000 gpm. These propellant storage areas serve the following functions (see Figure No. 3).

The Liquid oxygen storage area provides liquid oxygen to the test stand through a fixed piping system. This storage area also contains the liquid-to-gaseous nitrogen conversion equipment and provides for the storage of gaseous helium. It has its own control room which is equipped with necessary controls and instrumentation for propellant handling.

The Liquid hydrogen storage and gaseous hydrogen conversion area is equipped with its own local controls and instrumentation. There are backup controls and instrumentation in the main control room.

The auxiliary liquid oxygen unloading area, which is adjacent to Test Stand K-1, has independent controls and instrumentation for the transfer of propellants to test stand tankage.

The high pressure gas storage area which is adjacent to Test Stand K-1, is used for nitrogen and hydrogen gas. Its controls and instrumentation are located in the main control room.

The test area is supported by a test area warning system consisting of a warning light and public address system to provide visual and vocal warning in all working areas as well as traffic control of all road ways through the K-Area complex.

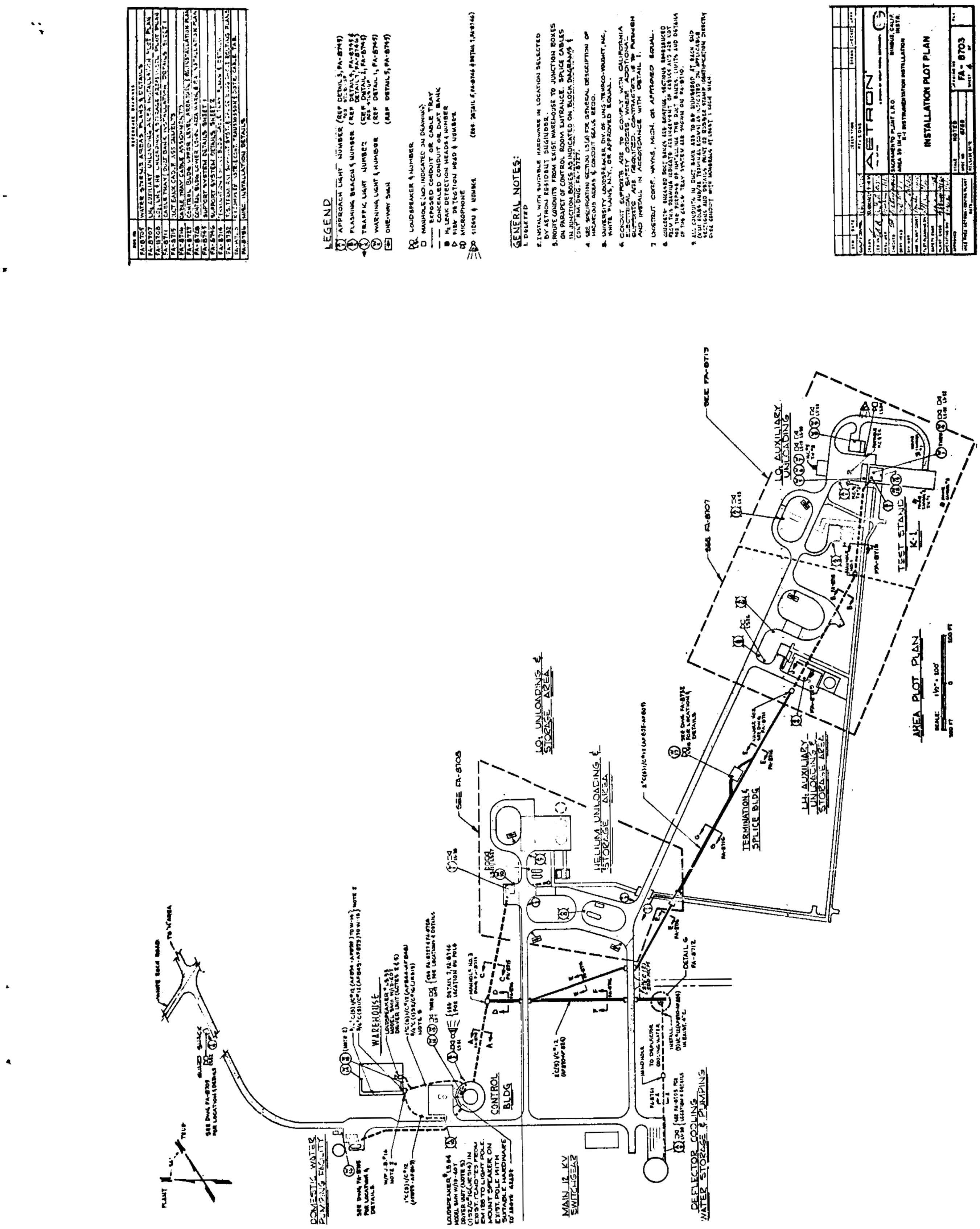

Figure 3
Installation Plot Plan

The test stand and areas where liquid hydrogen is handled or transferred is equipped with gaseous hydrogen detectors that will detect the presence of as little as 0.46% hydrogen in air, by volume. Those areas where hydrogen may be handled will also be equipped with ultra-violet flame detectors. Both the Hydrogen Gas Detectors System and the Ultra-Violet Hydrogen Flame Detector System provide audio as well as visual warning of a hazardous condition by means of a display board located in the control room.(3)(4)

The test stand is equipped with four closed circuit television systems (Figure No. 4). These four systems provide the control room with a means for visual monitoring of the test stand and its adjoining areas. The cameras, which are equipped with infrared vidicons, can provide necessary pin-point location of the invisible hydrogen flames that may be detected by stationary ultra-violet detectors.

2. Instrumentation Transmission Cabling

The instrumentation transmission cable designed for use in K-Zone is the standard multiconductor type cable with a polyethylene insulation. It has a unique feature in that copper-Mylar tape is used as the cable shield. The tape was applied with the copper face down against a drain wire with a minimum overlay of 50% and 100% coverage. The use of this Mylar insulation made it possible to reduce the over-all diameter of the cable by 20%, which made it possible to increase the cable packing density in the underground duct bank as well as the overland cable trays. The reduced cable diameter made it possible to obtain transmission cable in 3800 ft to 4000 ft lengths on one reel which facilitated its handling in shipment across country as well as by the standard contractor equipment during installation.

3. Instrumentation Remote Control System

The instrumentation remote control console contains control units for the following functions:

a. Calibration Control

Calibration steps for all instrumentation systems may be selected simultaneously as required from three points in the control room. A master calibration control unit is located in the instrumentation control console. Remote calibration control units are located in various bays throughout the control room. Manual or automatic modes of calibration sequences are provided.

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(3) Ultra Violet Sensors as Hydrogen Flame Detectors, Aerojet-General Engineering Report No. 9271-14, 17 March 1965

(4) Aerojet-General Memorandum 9110:0414, J. D. Anderson to G. R. Deppe, dated 1 February 1965, Subject: Television as Fire Detector for M-1 Facilities

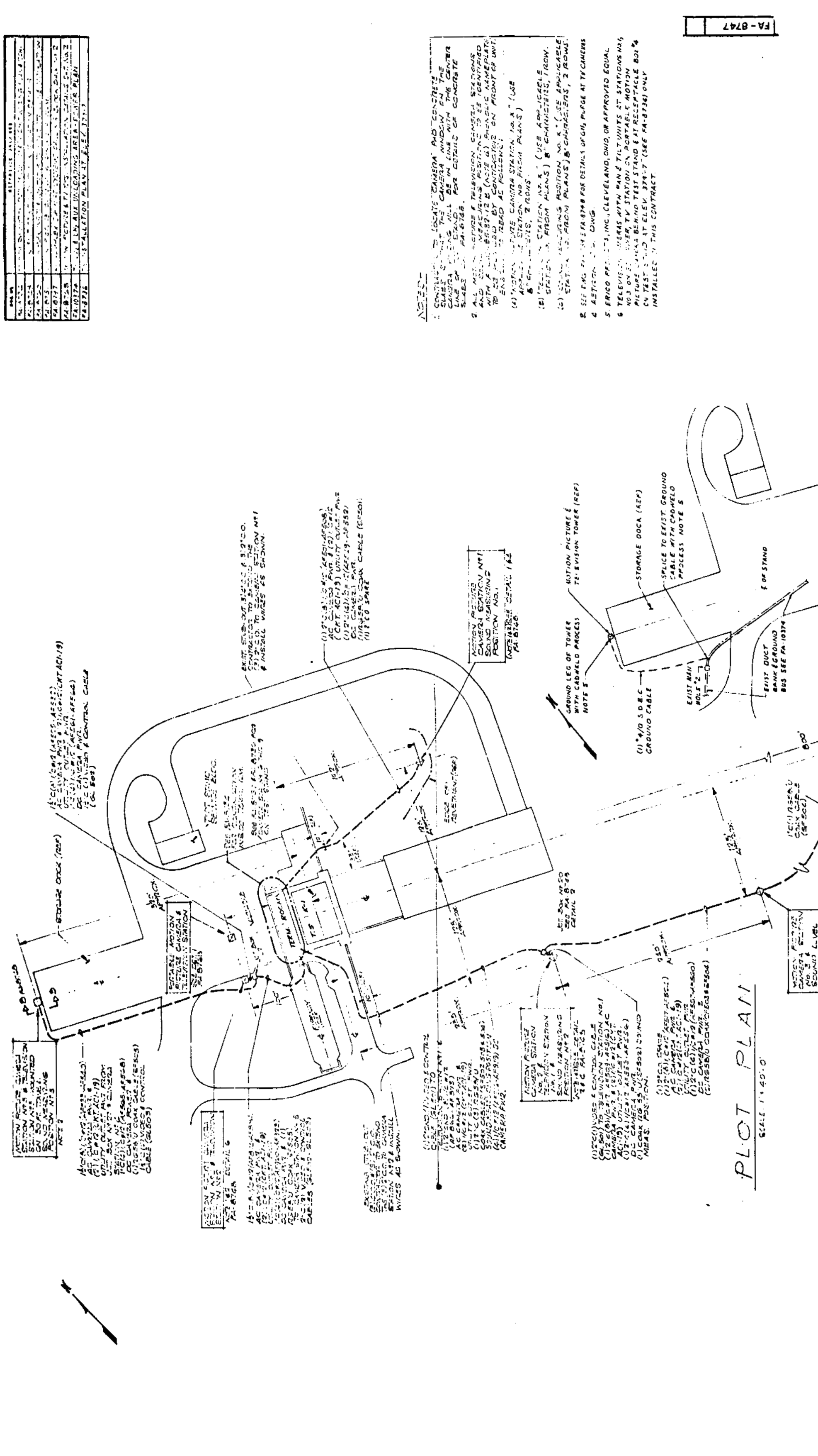


Figure 4
Test Stand Motion Picture and Television System Installation Plot Plan

In the manual mode, any step may be selected and in the automatic mode, a five-step sequence is provided. The dwell time for each step is adjustable from one to ten seconds.

The remote calibration control units are equipped with lamps that indicate the test stand selected.

b. Instrumentation Test Stand Selection

The strain gage system, resistance temperature transmitter (RTT) system, thermocouple system, as well as flow and speed system have a test stand select switching feature incorporated into the signal conditioning units. This allows the selection of any one of the three stands. The test stand select switches are of the remote operated rotary solenoid type. The instrumentation channels are selected in two groups as follows:

System	Primary Channels	Secondary Channels
Strain Gage	1 - 144	145 - 168
RTT	1 - 48	49 - 60
Thermocouple	1 - 48	49 - 60
Flow and Speed	1 - 12	---

The purpose of providing for the secondary selection is to allow long-term environmental testing in one stand while a simultaneous test setup is being accomplished at another stand.

The instrumentation console test stand selection unit provides stand selection control to the selector contactors, which provide the current to drive rotary solenoid switches. The rotary solenoid switches provide position data to a selection logic unit, which contains "AND" logic and generates signals to light the stand selection indicator lamps.

c. Recorder Display

The recorder display unit provides a central remote control for all control room recorders. Each record system, with the exception of the strip chart recorders, has provision for remote indication of operating mode. A "ready to record," "recording," or "no record" signal is sent to the recorder display unit, where it is indicated.

The recorder display unit is located in the instrumentation control console.

B. INSTRUMENTATION SYSTEMS

1. Strain Gage

a. Function

The 160-channel strain gage system will be used to detect physical stimuli, such as pressure, force, and strain. The detected stimulus is converted to an electrical analog signal, conditioned, and transmitted to the recording center. Twelve additional strain gage channels are provided for propellant handling exclusively.

This system is designed to be compatible with the large transducer pool available at Liquid Rocket Operations of Aerojet-General Corporation. Normally-standardized 350 ohm, six-wire, shunt-calibrated transducers will be used in this system; however, provisions are incorporated for strain gage bridge completion networks as required. Channel integrity and insulation checkout features are included with the system.

b. System Components

The system is composed of transducers, drop boxes, bay boxes, strain gage test and calibration units, power supplies, strain gage signal selection units, peripheral test equipment, and associated cabling.

The drop box is a 12-channel junction box placed near the test hardware to provide a convenient connection point for the individual transducer extension cable.

The bay box is a 48-channel junction box located on the test stand. Generally, the bay box is the terminus for four drop boxes and hook-up to the transmission cable is accomplished at this location.

Signal conditioning and channel checkout functions are performed with the strain gage test and calibration unit in conjunction with appropriate checkout equipment (Figure No. 5). This equipment is located in the test stand terminal room, which is adjacent to the test stand.

A 10V power supply is provided for each strain gage channel. A voltage check unit is available to permit checkout of these power supplies.

At the control room, strain gage signal selection units are provided to permit the selection of strain gage channels for future test stands.

c. Operation of Components

(1) Cabling

The strain gage system used is of the six-wire type, which means that a six wire shielded cable is required to connect the transducer to the signal conditioning equipment located at the test stand terminal room.

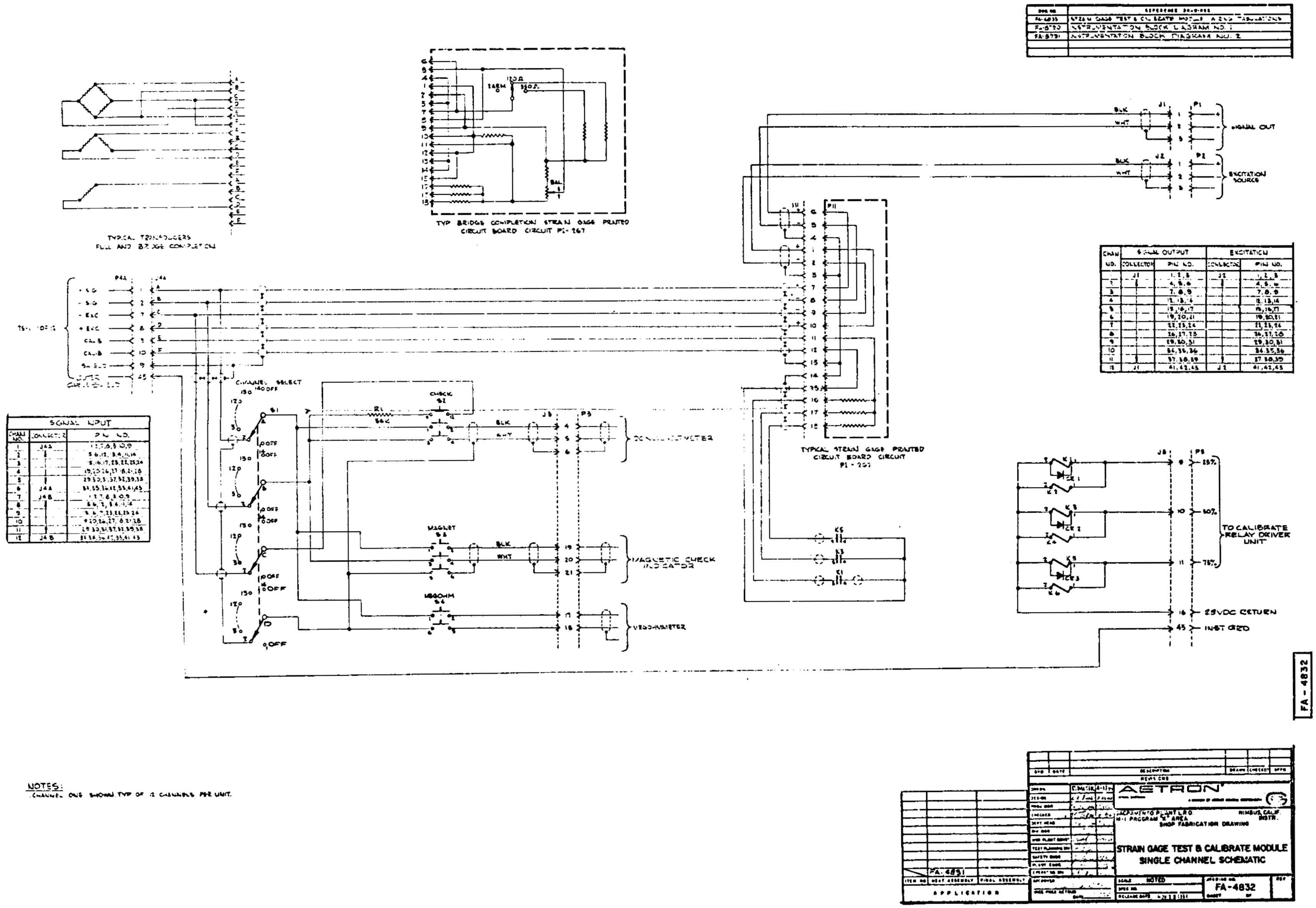


Figure 5

Strain Gage Test and Calibration Single Channel Schematic

Single channel shielded six wire cables are used from the transducer to the drop boxes. From the drop boxes to the bay boxes and running on to the signal conditioning unit (strain gage test and calibrate unit), 12-channel S12/S6/cables are used. From the signal conditioning unit, the transmission cable to the control room is a shielded two conductor per channel type. For installation convenience 12 channels (S2/C) are bundled to form a S12/S2/C cable in a polyvinyl chloride sheath.

(2) An individual 10 VDC isolated output power supply is provided for each channel. Twelve power supply units fit into a rack-mounted module. The required key electrical characteristics are as follows:

(a) Output voltage regulation: There shall be no more than 0.1% change in voltage output with a 2.0% change in load resistance and a simultaneous 10% change in AC supply voltage.

(b) Load Resistance: Resistance shall be 100 to 350 ohms.

(c) Ripple: Power supply output ripple voltage shall be less than one millivolt peak-to-peak with any rated load.

(d) Power Supply Noise: An AC component appearing between output terminals of a balanced 350 ohm bridge excited by the DC power supply operated at rated conditions shall not exceed five microvolts peak when one leg of the bridge is shunted to produce an output of 30 millivolts.

(e) Temperature Stability: Output voltage change shall be less than 0.1% with temperature change of 32°F to 115°F.

(f) Insulation Resistance: The resistance of the output leads to the case or to the AC supply shall exceed 10,000 megohm.

(g) Input Power: This power shall be 115 VAC ± 10% 60 cps, single phase.

Voltage check features as well as a means to adjust output voltage from 9 to 11 volts are included. Complete specifications are listed in AETRON Standard Specification PI-227, June 1962.

(3) Voltage Check Unit

The voltage check unit provides a means for checking the operation of the power supplies and to set the output voltage as required. The voltage check unit reference may be set to the desired voltage plus or minus one millivolt. By depressing a button on any strain gage power supply, the output voltage is compared with the reference voltage and read on a null meter located on the voltage check panel.

(4) Transducers

The transducers used with the strain gage system fall into the following general categories:

(a) Bonded Strain Gage Pressure Gages:

Standardized pressure gages are generally used for low frequency pressure measurements. The accuracy of these gages is either ± 0.3% or ± 0.5%, depending upon the requirements. The characteristics of these units are described in Aerojet-General Corporation Specification 32048/2.

(b) Unbonded Strain Gage Pressure Gages:

These transducers are purchased to conform to Aerojet-General Corporation Specification 42306.

(c) Load Cells:

Thrust measurements are not to be made at Test Stand K-1; however, standardized bonded bridge strain gage load cells are compatible with this system.

(d) Strain Patches:

Test hardware may occasionally be fitted with strain patches of several configurations. The system is designed to provide two- or three-leg bridge completion networks as required for 120 ohm or 350 ohm strain patches.

(e) Strain Gage Accelerometers:

Low frequency bridge strain gage accelerometers may also be utilized effectively in this system.

(5) Insulation Test Indicator

Cable and transducer insulation quality can be measured by a megohmeter with a capability for being conveniently switched to each channel through the strain gage test and calibrate unit. The megohmeter range shall be 1000 megohms at center scale and 50,000 megohms full scale with an accuracy of ± 3% at center scale. Test voltage shall be 10 volts. This unit is described in detail in AETRON Standard Specification PI-2102, July 1964.

(6) Null and Strain Indicator

A DC null multirange voltmeter is provided as part of the peripheral checkout equipment. The voltmeter may be switched to any channel output to check for proper channel functioning. The voltmeter is switched at the strain gage test and calibration unit. The strain gage test and calibration unit has provisions for applying a 50% shunt calibration resistor to the channel under test; thus, a 50% output voltage may be checked on the voltmeter.

(7) Strain Gage Test and Calibration Unit

The strain gage test and calibration unit provides switching for checking out each channel and the relay switching of the shunt calibration resistors. The channel test functions are performed through manual switching at the front panel. The channel checkout functions are insulation test, null and strain check, and channelization check. The shunt calibration resistor relays are remotely-controlled. A four-step calibration sequence in steps of 0, 25, 50, and 75% of full scale is simultaneously applied to all channels. The shunt calibration resistors and bridge completion networks, if required, are located on a plug-in printed circuit card for each channel. If a special type of transducer signal conditioning is needed, spare printed circuit cards can be set up as required.

(8) Deflection Check Indicator

The deflector check indicator is a sensitive AC voltmeter that can be siwtched to any channel output through the strain gage test and calibrate unit. A small AC signal can be induced magnetically on the transducer extension cable by a hand-held probe. Verification that this signal appears on the channel in question assures correct channelling for test preparations.

2. <u>Thermocouple</u>

a. Function

The thermocouple system is used to measure temperatures when a high degree of accuracy is not required. For uniformity, all channels are of the Chromel-Alumel type. Eighty-four channels are provided for general test stand use.

b. System Components

The system consists of transducers; drop boxes; reference junctions; transmission cabling; thermocouple select, test, and calibration units; and a programable voltage supply.

The drop boxes are 12-channel junction boxes placed near the test hardware to provide a convenient connection point for the transducer extension cables.

c. Operation of Components

(1) Cabling

The reference junction box is located on the test stand. The cabling from the junction box to the drop boxes consists of shielded pairs made up of a Chromel and an Alumel wire. Connector pins in the drop boxes are also made from the same thermocouple metals. Transmission cabling leading from the reference junction box through the test stand terminal room into the control room is copper-copper made up in a S12/S2/C#20 AWG configuration.

(2) Reference Junction

The reference junction box used is a 150°F type with provisions for 92 channels. Temperature stability of the reference junction oven shall be within ± 0.1°F. The individual junction accuracy shall be ± 0.2°F. The unit shall operate on 115 volts AC ± 10%, 60 cps, single phase power.

The reference junction box also provides termination points for the drop box cabling and the transmission cabling.

(3) Transducers

Any Chromel-Alumel thermocouple is compatible with this system.

(4) Thermocouple Signal Conditioning Units (Figure No. 6)

Thermocouple signal conditioning takes place at the reference junction and the thermocouple test selection and calibration unit.

The 12-channel per unit thermocouple selection of test and calibration facilitates the following operations:

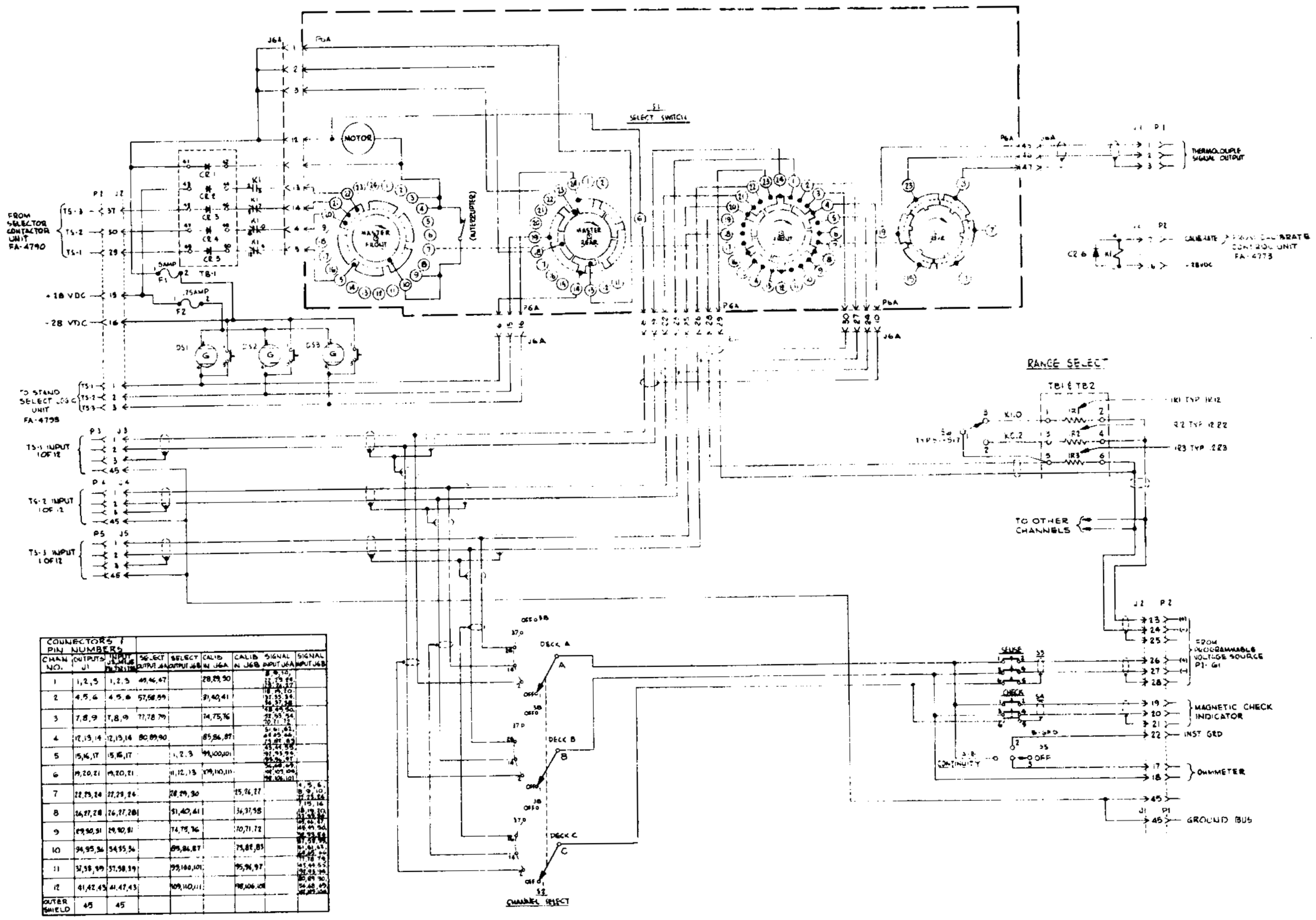
(a) Selection Function - Each unit provides an input capability for 12 channels from each of three test stands. Any one of the stand input groups may be selected remotely for the output.

(b) Test Functions - By selecting any one of the 36 input channels through a rotary switch, several checkout functions may be accomplished. A continuity check can be made, and either the line-to-ground resistance or the line-to-line resistance can be read on a remote ohmmeter.

The magnet check function can be performed to assure channelization. Operation is the same as that explained for the strain gage system.

A fixed 40 millivolt signal can be applied to any channel to provide a channelization check of the end instruments.

(c) Calibrate Function - During the remotely controlled calibration function, the output channels are switched to a calibration network. Precise voltage steps of 0, 2.0, 5.0, and 10.0 volts are applied to the network from a remote voltage supply that can be programed. The network contains a precision voltage divider for each channel. Division ratios of 200 to 1 or 1,000 to 1 are available as required by the usage of each channel. The ratio is selected by



CONNECTORS & PIN NUMBERS								
CHAN NO.	OUTPUTS J1	INPUT J3,J4,J5	SELECT OUTPUT J6A	SELECT OUTPUT J6B	CALIB IN J6A	CALIB IN J6B	SIGNAL INPUT J6A	SIGNAL INPUT J6B
1	1,2,3	1,2,3	45,46,47		28,29,30		[illegible]	
2	4,5,6	4,5,6	57,58,59		31,40,41		18,19,20, 37,35,34, 36,37,38	
3	7,8,9	7,8,9	77,78,79		74,75,76		48,49,50, 52,53,54, 70,71,72	
4	12,13,14	12,13,14	80,89,90		85,86,87		[illegible]	
5	15,16,17	15,16,17		1,2,3	99,100,101		[illegible]	
6	19,20,21	19,20,21		11,12,13	109,110,111		[illegible]	
7	22,23,24	22,23,24		28,29,30		25,26,27		4,5,6, 8,9,10, [illegible]
8	26,27,28	26,27,28		31,40,41		36,37,38		[illegible]
9	29,30,31	29,30,31		74,75,76		70,71,72		[illegible]
10	34,35,36	34,35,36		85,86,87		73,82,83		[illegible]
11	37,38,39	37,38,39		99,100,101		95,96,97		[illegible]
12	41,42,43	41,42,43		109,110,111		98,106,108		[illegible]
OUTER SHIELD	45	45						

NOTES:
1. SWITCH S1 SHOWN IN TS K-1 POSITION.

FA-4898

Figure 6

Thermocouple Select Test and Calibration Module Single Channel Schematic means of a switch for each channel. The resultant calibrate voltage steps are 0, 10, 25, 50 millivolts in the high (X1.0) range and 0, 2, 5, 10 millivolts in the low (X0.2) range. Upon completion of calibration operation, the channels are automatically switched back to the appropriate test stand.

(5) Programable Voltage Supply

The programable voltage supply provides precision voltages to the thermocouple test, selection, and calibration units. The supply provides a constant 40 millivolt DC output and a remotely programable output of 0, 2.0, 5.0, and 10.0 volts DC.

The absolute accuracy of the 40 millivolt DC output shall be within ± 0.5% with a load variance of from zero to 5 milliamperes and line variations of ± 10.0%.

The absolute accuracy of the programable output shall be within ± 0.02%. This accuracy shall be maintained with the load varying from zero to 200 milliamperes and line variations of ± 10.0%.

One programable voltage supply shall be capable of handling twelve thermocouple test, selection, and calibration units.

3. <u>Resistance Temperature Transmitter (RTT)</u>

a. Function

The prime function of the resistance temperature transmitter system is to provide precise temperature measurements in the cryogenic temperature region. System accuracies should be ± 0.1% of the span or ± 0.1°F whichever is greater. Four ranges of temperature measurements are provided as follows:

N Range	-300°F to -425°F
K Range	-400°F to -425°F
L Range	+75°F to -425°F
Y Range	-250°F to -425°F

Sixty RTT channels are provided for general test stand usage.

b. System Components

The RTT system consists of transducers, cabling, drop boxes, bay boxes, power supplies, and signal conditioning equipment.

c. Operation of Components

(1) Transducers

A standard precision platinum wire transducer is used with this system. The accuracy of the unit is ± 0.1°F in the range of -300°F to

-200°F and ± 0.2°F in the range of -200°F to +200°F. Complete descriptions and specifications of the transmitters are given in Aerojet-General Corporation Specification AGC-42114/6.

(2) Cabling

A four-wire, shielded cable is required for each channel from the transmitter to the signal conditioning units located in the control room. Drop boxes and bay boxes are used as they were in the strain gage system. The transmission cabling is S12/S4/C #20 AWG.

(3) RTT Power Supplies

A constant current power supply is provided for each channel. The power supply output current is adjustable from 0.2 to 2.0 milliamperes. Output regulation, with a simultaneous load variation of 5 to 5,000 ohms and line voltage variation of ± 10%, shall be within ± 0.01% of any selected operational point. Complete details are presented in AETRON Standard Specification PI-225c.

(4) RTT Signal Conditioning Units (Figure No. 7)

The RTT test, selection, and calibration unit provides the signal conditioning. This is a 12-channel unit with provisions for selecting 12 input channels from one of three stands to the outputs and power supplies. Any one of the input channels may be selected for checkout operations. Checkout is performed through switches in the RTT test, selection, and calibration unit as well as on external test equipment. The checkout functions are similar to those discussed in the procedure for the strain gage system.

Channel calibration is accomplished by switching the signal leads from the transmitter to precision resistors, which are in series with the transmitter power supply circuit. The four-step, remotely-controlled calibration sequence is 0, 25, 50, and 90% of full scale range. The precision resistors are on plug-in cards, and the calibration range is altered by changing the plug-in calibration resistor cards.

4. Flow and Speed

a. Function

The purpose of the flow and speed system is to provide analog and AC signals proportional to propellant flow rates and the pump turbine angular velocity. Twelve channels are provided.

b. System Components

This system is composed of transducers, drop box, bay box, cabling, a flow and speed selection, test, and calibration unit, and integrators. A two conductor shielded cable per channel is provided. In this system, the bay box is shared with the valve position system and propellant strain gage system.

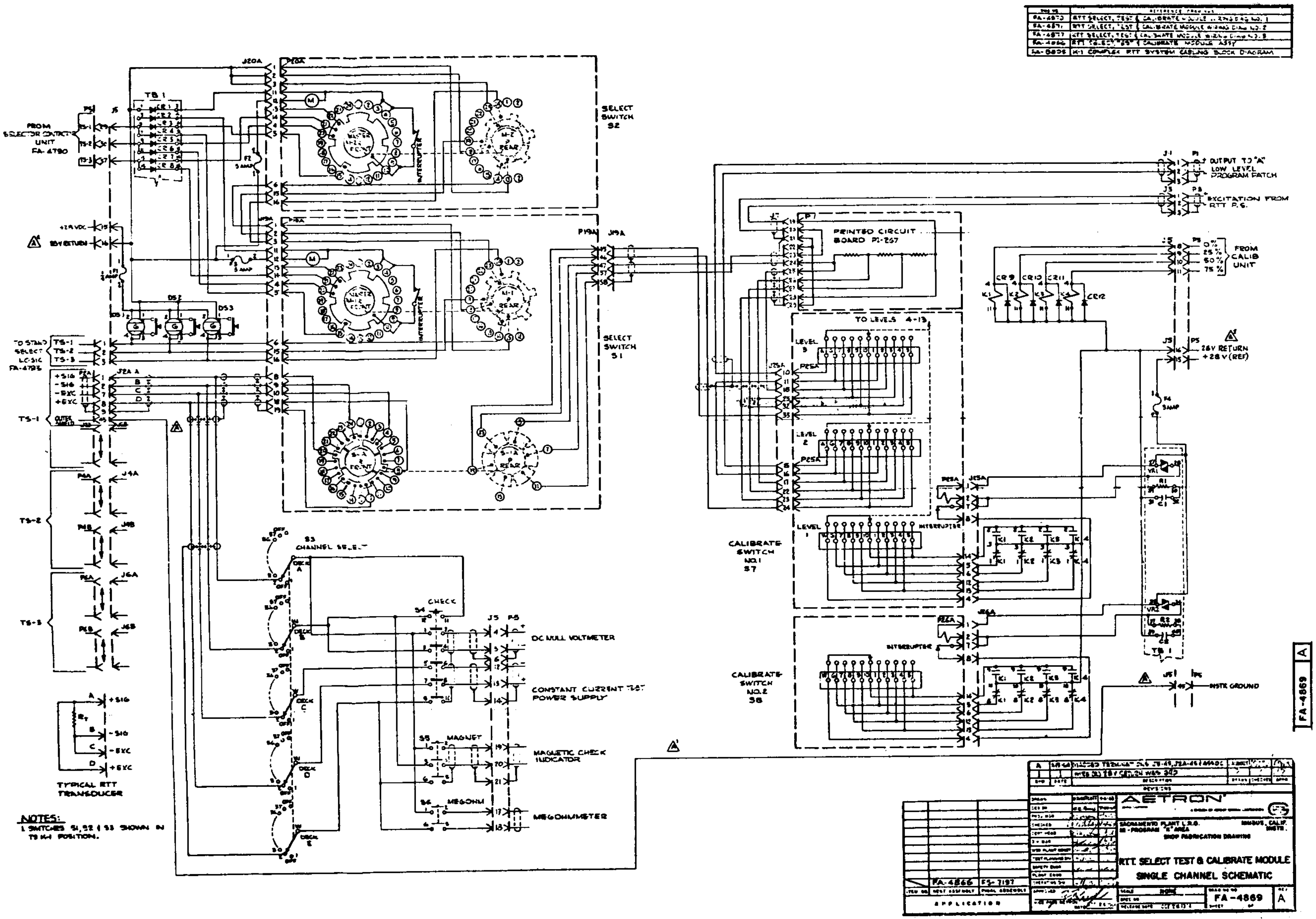


Figure 7

RTT Select Test and Calibrate Module Single Channel Schematic

c. Operation of Components

(1) Transducers

Turbine-type flowmeters that produce an AC signal with the frequency of the signal proportional to the flow rate can be used in this system. Pump turbine speed probes consist of a coil with a magnetic core placed near the teeth of a rotating gear. An AC signal, the frequency of which is proportional to the gear speed, is produced.

(2) Flow and Speed Selection, Test, and Calibration Unit (Figure No. 8)

The flow and speed selection, test, and calibration unit is capable of selecting 12 channels for one of three stands. The selector switch has a fourth position which allows the output to be selected in a group of calibration signals.

Three groups of calibration signals can be manually selected for each channel in the four-step, remotely-controlled calibration sequence. The calibration signals are:

Full-Scale Range	Calibration Frequencies
0.5 K cps	0, 100, 250, 500 cps
1.0 K cps	0, 250, 500, 1000 cps
20.0 K cps	0, 1K, 5K, 10K cps

Upon completion of the calibration sequence, the unit again selects the channels required for the correct test stand input.

The calibration frequencies are generated externally by the time base oscillator.

A manual input channel selector switch is provided to allow the checkout of all input channels. Flow and speed probe elements can be checked for continuity, insulation, and channelization. The required external test equipment consists of the magnetic check indicator and an ohmmeter. A channelization check of the end instrument can be made by applying a 500 cps signal to the channel in question.

(3) Integrators

The outputs of the flow and speed selection, test, and calibration unit are cabled to the integrators, which convert the AC signal to an analog DC voltage which is proportional to the frequency of the AC signal. A rectangular wave AC output is also generated for dynamic recording. One rectangular wave cycle is generated for each input cycle. Key items in the unit specification are:

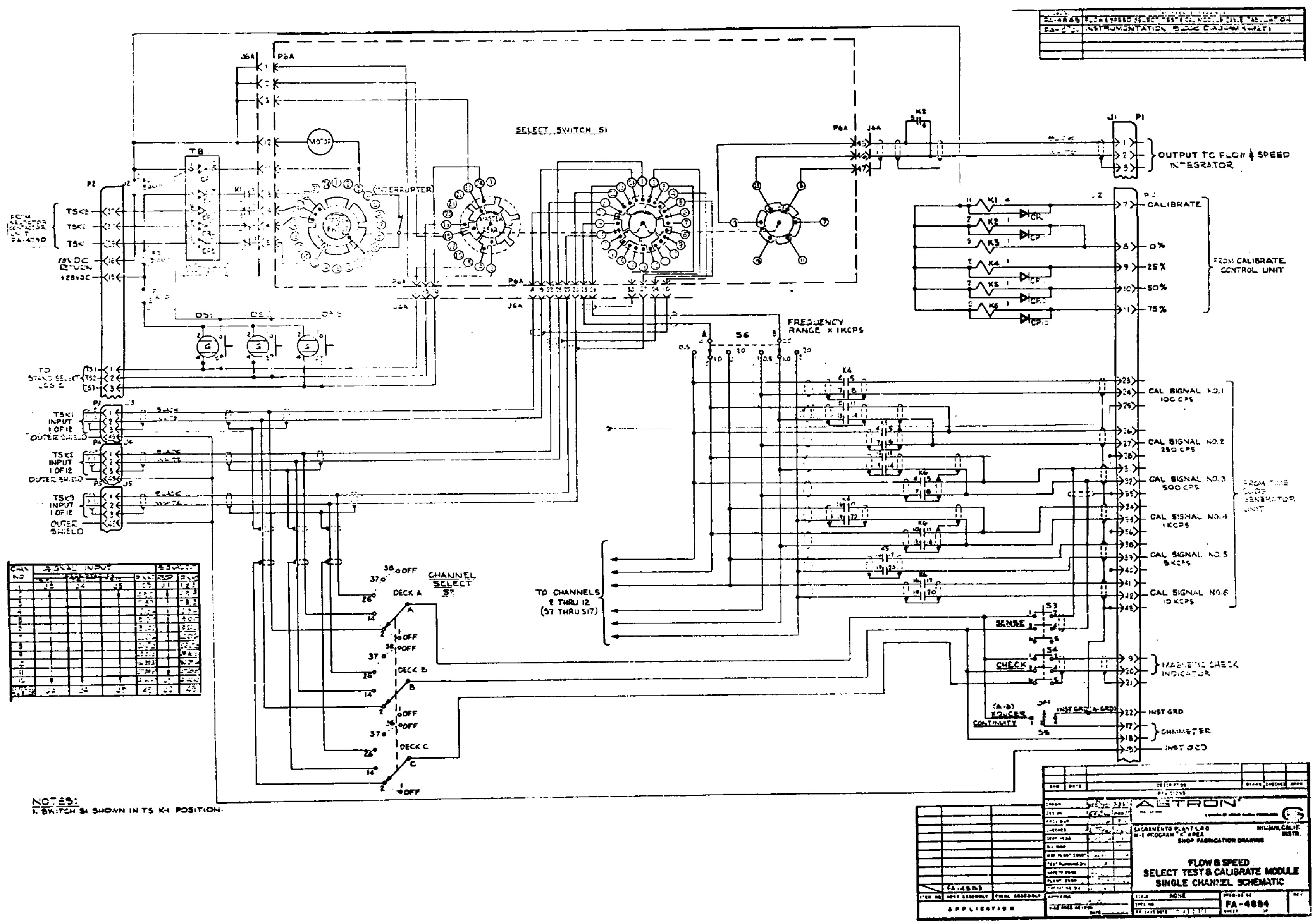


Figure 8

Flow and Speed Select Test and Calibrate Module Single Channel Schematic

(a) Full scale frequency ranges shall be 500, 1K, 2K, 5K, 10K, and 20K cps selectable by panel switch.

(b) Linearity shall be ± 0.1%.

(c) High Level DC Output

1 Impedance shall be 0.25 ohms or less

2 Ripple (peak-to-peak) shall be 0.7% or less of the output at the full scale input frequency indicated by the range selector.

3 Time constant shall be 7.5 divided by full scale frequency.

4 The full scale output voltage shall be 10 v at zero to 20 milliamperes.

(d) Low Level DC Output

A low level (zero to 50 millivolt) DC output shall be provided by means of a voltage divider.

(e) Pulse Output

The pulse output shall be a rectangular pulse for each cycle of input. The pulse shall be a one volt, positive, rectangular pulse for a 100 ohm or less source impedance.

Additional details are presented in AETRON Standard Specification PI-234a.

5. Valve Position

a. Function

The function of the valve position system is to provide analog signals that are proportional to angular or linear positions of the valve components or other hardware components where position data is required.

b. System Components

The 24-channel valve position system is composed of transducers, drop boxes, bay box, transmission cabling, valve position range and calibration units, and a DC power supply. The system is of the bridge-type; the transducer forms two legs and the other two legs are formed by the balance potentiometer within the valve position range and calibration unit. The required cabling per channel is three-conductor shielded; however, a four-conductor shielded cable per channel is used for the purposes of transmission cable uniformity and interchangeability.

c. Operation of Components

(1) Transducers

The transducers used in the valve position system are angular or linear motion potentiometers. The potentiometers should be the linear resistance taper versus motion types.

In most instances, the potentiometer will be included as an integral part of the valve. This system will accept potentiometers in the range of 500 to 10,000 ohms resistance; however, a nominal 2,000 ohm potentiometer is preferred.

(2) System Circuitry (Figure No. 9)

Signal conditioning and channel checkout is performed at the valve position range and calibration unit. Two units are provided; each handles twelve channels.

Excitation for all channels is provided by an adjustable zero to 15 volt DC power supply, which must be able to deliver up to five amperes. The set output voltage shall remain within $\pm$ 0.1% with 10% line voltage variation, 0.1% or 3 millivolts with zero to full scale output current variation, and 0.1% or 6 millivolts over a period of eight hours after warmup. Each channel is isolated from the power supply through 100 ohm resistors in each bridge excitation circuit.

The valve position range and calibration unit has provisions for four outputs for each channel. A high level output, a low level output, and two galvo outputs are provided. Galvo damping resistors are located within the unit.

A DC null voltmeter and an ohmmeter are mounted on a panel near the valve position and calibration unit. These are required for setup and checkout of this system during operation. A complete continuity check and an adequate insulation check can be made using the transducer test switch (momentary) and continuity test switch.

The balance, calibration adjustment, and range potentiometers are set-up using the following procedure:

With the valve closed, a nominal 10 V excitation, the channel select switch set to the desired channel, and the mode selection switch set to the balance position, the balance potentiometer is adjusted for a null reading on the DC null voltmeter.

With the switches set as indicated above, the valve is opened and the range potentiometer is adjusted to a five volt reading on the DC null voltmeter. Next, the mode switch is set to the calibration adjustment

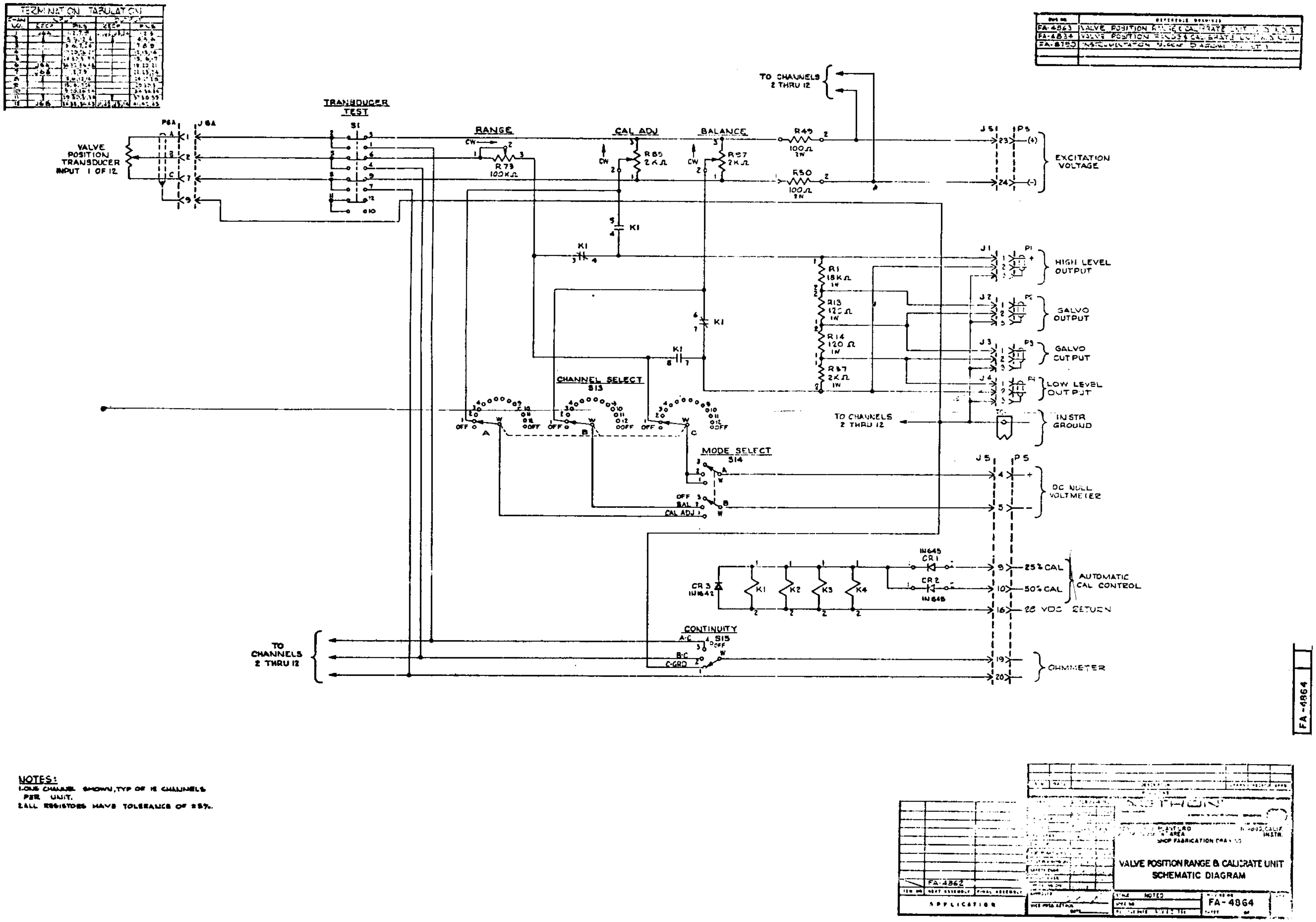


Figure 9

Valve Position Range and Calibrate Unit Schematic Diagram position and the calibration adjustment potentiometer is adjusted for a null reading on the DC null voltmeter.

The valve can then be closed and switches returned to the off position. This procedure is repeated for all channels after the valves are insulated.

To set up end instruments, the full-scale (valve open) signal can be attained by remotely selecting the second or third calibration step (25% or 50%). This procedure energizes relays that switch the output from the range and balance potentiometers to the calibration adjustment and range potentiometers, respectively.

The feature for test stand selection of other channels was not included in this panel. Thus, valve position indication is readily available for functional testing at any time.

6. <u>High Frequency</u>

a. Function

The high frequency system shall be capable of acquiring dynamic pressure, vibration, acceleration, and force data in the frequency range of steady state to 10,000 cps. A 36-channel system is provided.

b. System Components

The system is composed of transducers, cabling, voltage controlled oscillators, power supplies, a high frequency calibration control unit, an audio oscillator, an AC-to-DC converter, an event counter, FM recording units, and analog tape recorders. A block diagram of the system is presented in Figure No. 10.

c. Operation of the Components

(1) Transducers

Either the charge (piezoelectric) or the voltage (bridge) type transducers can be used in this system. For the bridge-type transducers, a constant voltage or constant current excitation is available. Transducers generally used in this system are not standardized for sensitivity. The system frequency response when using voltage producing transducers is DC to 10 KC maximum. Charge producing transducers are capacitively coupled, thereby diminishing the low end of the frequency response to 20 cycles per second. The system full scale charge sensitivity range is 50 to 50,000 picacoulombs. The system full scale voltage sensitivity range is 5 millivolts to 5 volts.

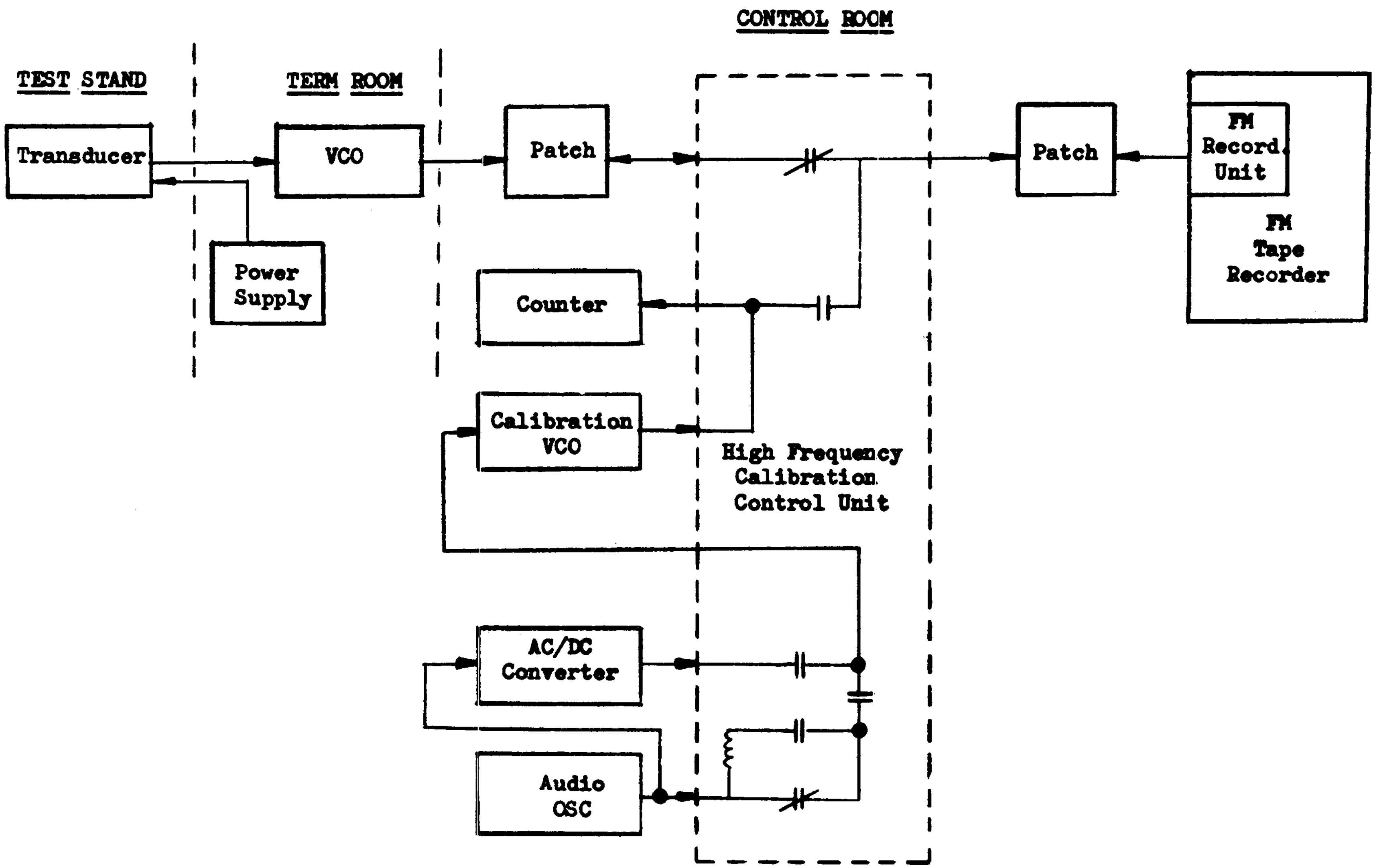


Figure 10

High Frequency System Block Diagram, Control Room

(2) Cabling

Low capacity coaxial cable is used throughout this system for signal transmission. A shielded two-conductor cable per channel provides excitation current as required.

(3) Signal Conditioning

(a) Voltage Controlled Oscillator

The voltage controlled oscillator (VCO) is the principal signal conditioning component in the high frequency system. The VCO is a bipolar input device that generates an FM signal with a center frequency of 216K cycles per second and a full scale frequency deviation of ± 40%. The FM signal is transmitted to the analog/FM tape recorder, amplified by a special plug-in FM recording unit, and recorded on tape.

The error of the VCO conversion to FM shall be no greater than ± 2.0% of full scale at 1000 cycles per second in the charge mode. In the voltage mode, the error of conversion shall be no greater than 0.25% of the VCO center frequency. Complete details of the VCO and FM recording unit are presented in AETRON Standard Specification PI-260, October 1964.

In the control room, the FM signal passes through the high frequency calibration control unit, which supplies a program of signals that are placed on the tape to aid in spanning the end instrument during playback of recorded tapes. The following FM calibration signals can be obtained:

Step 1	Lower Band Edge	
Step 2	Upper Band Edge	Manual or
Step 3	10% AC	Remotely-Controlled
Step 4	100% AC	

By manually controlling the steps, an additional center band FM signal is available.

The calibration signals are generated by an audio oscillator, an AC-to-DC converter, and a VCO. An electronic counter is used to establish the calibration signal levels. Through use of a voltage divider and switching in the high frequency calibrate control unit, the calibration sequence is generated as follows:

The audio oscillator is set to a nominal frequency (1000 cps). To adjust the audio oscillator amplitude control, the upper band edge calibration step is selected and the amplitude is adjusted for a reading of 302.4 K cps on the counter. No other adjustments are required. Selection of the calibration steps can be made as required.

The VCO used in the calibrate circuit is interchangeable with the units located in the terminal room.

The AC-to-DC converter was incorporated into the calibration circuit as a DC voltage supply and a precise method for setting the AC voltage calibration level. A conversion accuracy of ± 0.3% of full scale ± 1 millivolt is practical. Coupling this unit to the VCO and coupling the VCO to a-counter provides a precise method for measuring AC voltages.

(4) Power Supply

A constant voltage/constant current power supply is provided for each high frequency channel. A regulated constant current or constant voltage may be selected by a switch for the particular transducer requirements.

In the constant-current mode, the output current is 25 milliamperes. In the constant current-voltage mode, the output is 10 volts. The stability specification allows no more than a 0.05% drift for a 24 hour period. This power supply is described in detail in AETRON Specification PI-274.

7. Leak Metering

a. Function

The requirements for this leak metering system were established to measure the Conoseal[R] leakage rate of liquid oxygen and liquid hydrogen during the development phase of the M-1 Engine. Based upon these needs, a specification (AETRON Specification PI 260a) for leak metering transducers was written. The following are the general requirements of this specification:

Mass Flow Range (Oxygen or Hydrogen)	0 to 10 std cc
	0 to 100 std cc/min
Drift ± 0.2% (Environment Temperature Variation)	-250°F to 150°F
	20°F to 150°F
	40°F to 150°F
Stability ± 1% (Gas Temperature Variation)	-350°F to 150°F
	-100°F to 150°F
	0°F to 100°F
Accuracy	± 1% of full scale

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Response Time	1 sec or less to 63% response to a step flow change

One company proposed using a thermal conductivity bridge technique with the following exceptions: (1) Response time 5 to 6 sec, and (2) output drift resulting from environmental temperature variations - ± 1%.

Another company proposed using their standard Thermal Mass Flow Sensor with an exception of ± 0.8% if gas or ambient temperature is held to 150°F and could be ± 2% with temperature of -350°F.

No procurement action was taken concerning this specification and no system components were designed.

b. Operation

These transducers were to be located on the test hardware in the same manner as a regular transducer. The test stand would be equipped with drop boxes. The power supplies and selector units would be located in the control room. A voltage substitution system similar to that used in the thermocouple system would be used for calibration.

8. Analog Recording and Processing

a. Analog Tape Recorder

The analog tape system is composed of two units with 32 recording tracks and one machine with 32 recording tracks and 32 tracks for reproduction. The tape recorders intended for use are Ampex FR1200's and were procured in accordance with AETRON Specification PI 246a. These machines record and reproduce FM on a 1-in. tape. The frequency response at 60 cps is 0 to 10,000 cps with less than 2.0% harmonic distortion.

The analog recording system will accept all input data by means of the control room data patch system. This analog tape system will be the prime recording system for transient data requiring up to 10 KC response. Data taken on analog magnetic tape may be re-recorded on an oscillograph recorder for the purposes of analysis or manual data reduction. The systems that will provide data for recording on analog tape are: (1) strain gage system, (2) high frequency system, and (3) sound level pressure via microphones.

The analog machine with capabilities for reproduction can also be used with a tape loop for Dynamic Pressure Analysis System (see Section III,B,15).

b. Oscillograph Recording System

The oscillograph recording system is composed of two 36-channel combination direct writing-photo processing type machines. These machines were to be of the Minneapolis-Honeywell Model 1612 type.

The oscillograph would be used to record on-line static and dynamic data. Because the number of analog tape channels is limited, the oscillograph would be used primarily to record transient data and the AC output from functions such as flows and speeds.

One oscillograph could be used to record analog tape playbacks from one Ampex FR1200 by means of galvo driver amplifiers. This system would provide oscillograph records of data taken on analog tape. It would also provide for special filtering, expanding scales or range, and other techniques used in analyzing high frequency data.

c. Strip Chart Recorders

The strip chart recording system was to consist of 20 ten-inch single channel records, two five-inch single channel records, and one 24-point recorder. In addition to recording on-line analog data, the computer subsystem is equipped with eight digital-to-analog converters to display performance data on-line via the strip chart recorders.

d. Visual Gages

The visual gage system consists of 48 channels of low level indicators. This system would be used to monitor on- or off-line functions. Each channel will be equipped with its own amplifier. This visual gage system was designed by Aerojet-General Corporation and a single channel was fabricated and evaluated. The general specifications are as follows:

Input: 0 to 10 mv up to 0 to 100 mv DC
Span Adjustment: 9 to 110 mv DC
Zero Adjustment: $\pm$ 5 mv DC
Input Impedance: $>$ 100K ohms differential
Common Mode Rejection: $>$ 100 db (0 to 60 cps)
Source Impedance: Up to 500 ohms
Amplifier Linearity: $\pm$ 0.5%

e. Functional Graphic Recorder

The functional graphic recorder is a combination analog five-channel and event pin marker 36 channel direct-write recorder. The basic function of this recorder would be to provide off-line recording for pre- and post-fire electric functions of the valve and electric sequencing of the engine. The analog inputs are available through the instrumentation data acquisition patch system, while the event channels are patched through the engine sequence patch panel in the control room.

The following general specifications for this recorder are extracted from AETRON Specification PI-271:

(1) Channels - Five-channel analog; 36-channel event recorder presentation shall be inkless on pressure thermal chart paper in true rectilinear form.

(2) Analog Recorder - Signal Input shall be balanced and have a minimum isolation resistance of 500,000 ohms to ground for each input lead.

(3) Common Mode Rejection - A minimum of 60 db from DC to 100 cps.

(4) Linearity - $\pm$ 0.25 chart divisions or less at any gain position.

(5) Response Time - 4 millisec or less for a 4 centimeter deflection with overshoot of less than 4%.

(6) Event Recorder -

(a) Rise Time - 6 millisec with a resolution of 3 millisec.

(b) Solenoid Input Power - The solenoid event marker operates from 28 volts DC $\pm$ 20% at 70 milliamp maximum.

(c) Frequency Response - At any attenuator position and with a full scale input signal of any frequency from DC to 30 cps, the recorder output reading shall be within 2.0% of full scale.

9. <u>Digital Recording and Processing</u> (Figure No. 11)

a. System Description

The digital recording and processing system (Figure No. 12) is controlled by a digital computer which will operate on-line (real time) with the system during an engine test. During the test operation, the system will acquire, process, and record test data. The processing will consist of engine performance computations and data-limit checks. Event recording and system control functions will also be performed. All computer operations will be executed concurrently on a time-shared basis.

(1) Computer

The computer is a Scientific Data Systems (SDS) Model 930 general purpose digital computer with 16,384 words of memory (1.925 microsec cycle time), four input/output channels, and 16 priority interrupt channels. The Aerojet-General special subsystems use three of the input/output channels, and the standard Scientific Data Systems peripheral equipment share

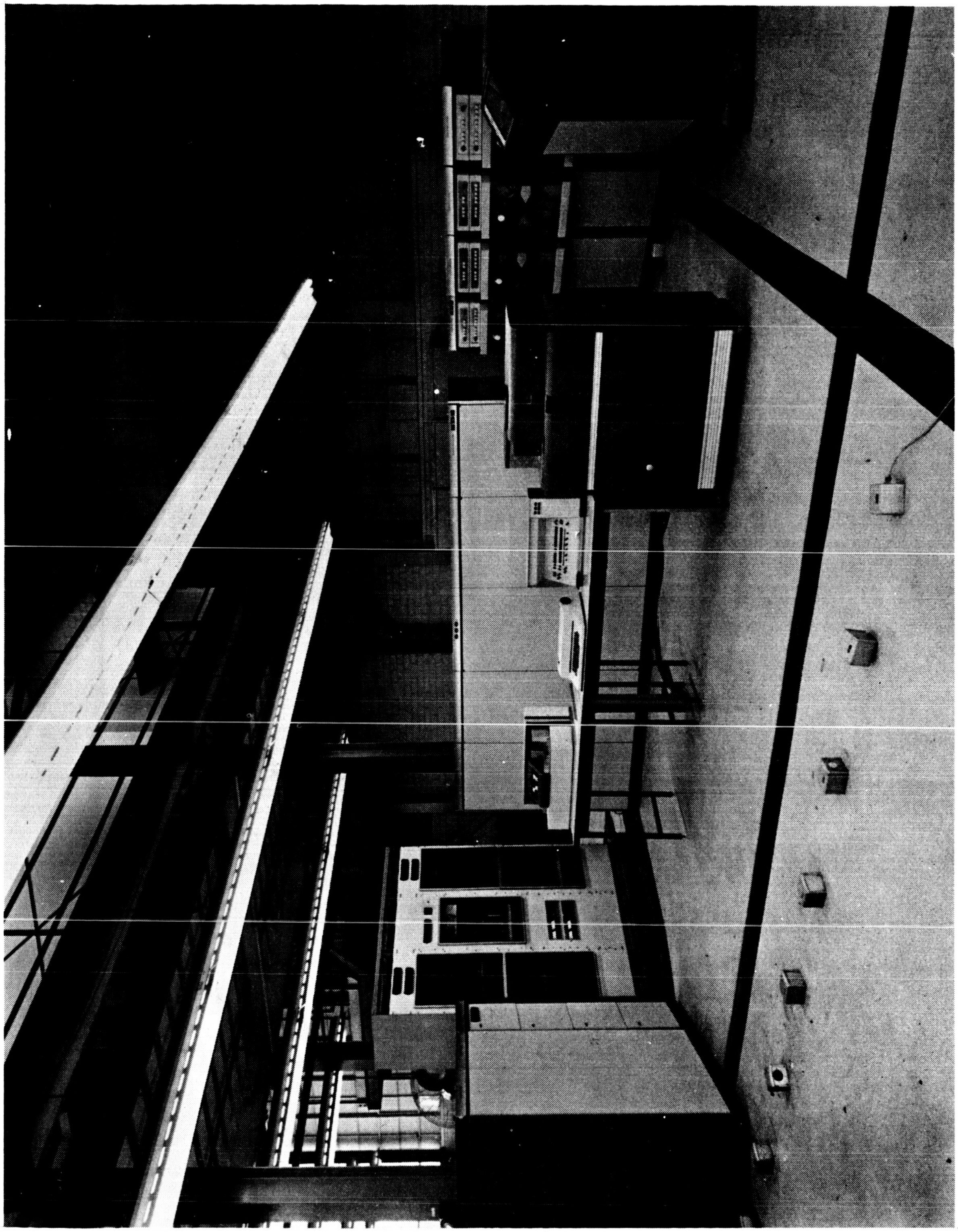

Figure 11

Digital Recording and Processing System

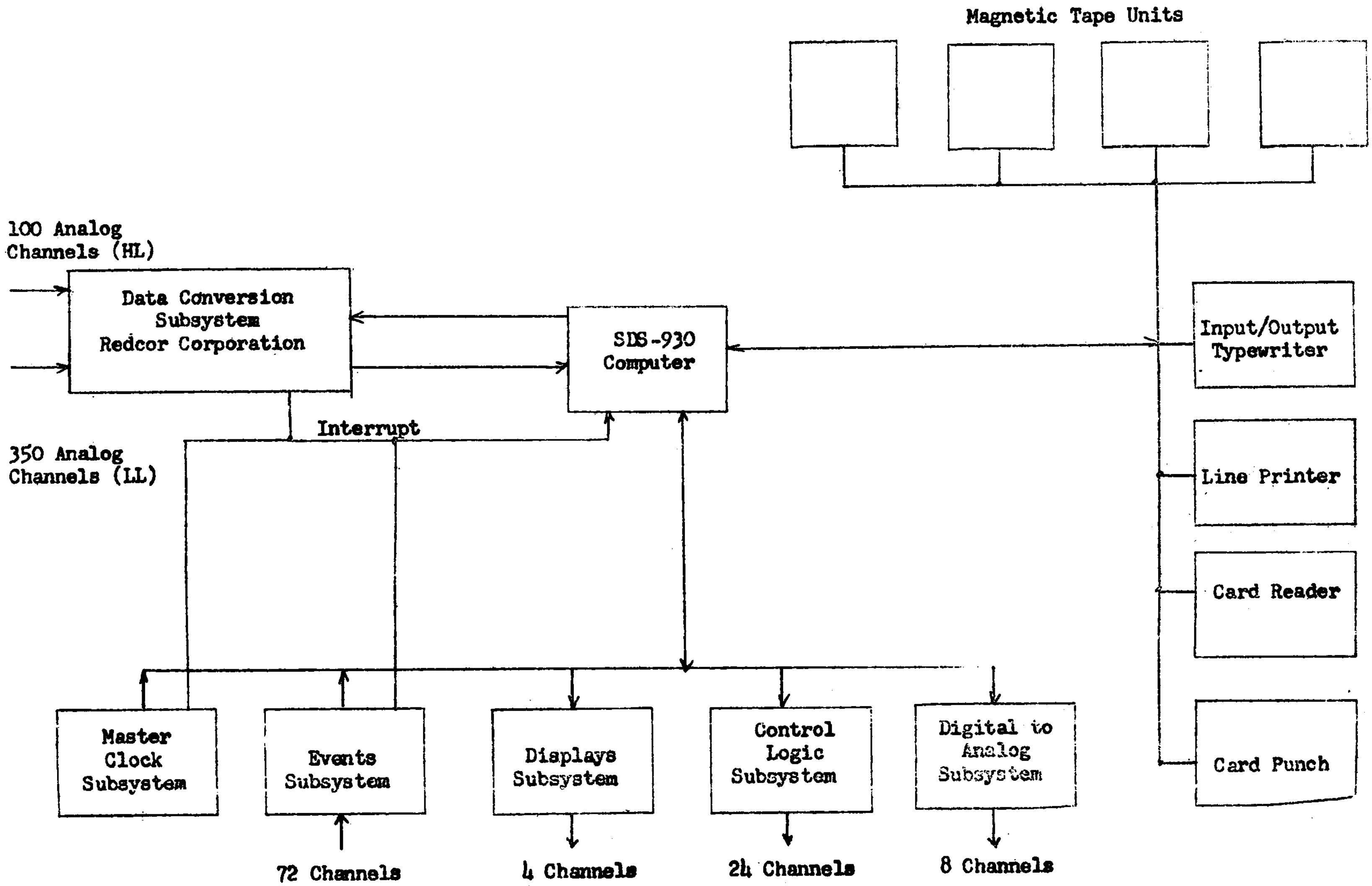

Figure 12

Digital System Block Diagram

the fourth channel (see Figure No. 12). The peripheral equipment specifications are as follows:

(a) Typewriter - IBM Selectric, wide carriage, 15 character/second output rate.

(b) Line Printer - Data Products Corporation, 600 lines per minute output rate.

(c) Card Reader - Burroughs Corporation, 200 cards per minute input rate.

(d) Card Punch - IBM Model 523, 100 cards per minute output rate.

(e) Magnetic Tape Units (Four) - Ampex Model TM-4, input/output rates of 60 kc, 41.7 kc, and 15 kc, at tape densities of 800, 556, and 200 bits per inch respectively.

(f) Watchdog Timer - An SDS timer device that will monitor correct computer operation by requiring reset pulses at minimum repetition rates of 10 milliseconds. (This device does not share the standard peripheral channel.)

(2) Data Conversion Subsystem

The data conversion subsystem, produced by Redcor Corporation, will multiplex and digitize high level and low level analog signals for computer entry and recording. The analog channel multiplexing is controlled by the computer by means of channel address list transmission. The address lists will contain channel addresses of selected channels for a given test where channel selection may be at random. All lists will be prepared in the form of computer input prior to a test. As the channel addresses are received by the subsystem from the computer via one channel, the corresponding data which has been acquired and digitized will be transmitted to the computer on another channel (see Figure No. 12). The channel address words are parity checked upon entry to the data conversion subsystem and the status is under interrupt control with the computer. Also the data words are parity checked upon entry to the computer under similar interrupt control.

There are 350 low level analog channels which are divided into four low level multiplexers (Redcor Model 625) with 96 channel capability per group (see Figure No. 13) There are 34 spare channel positions in this configuration. Each channel has sensitivity steps of plus and minus 10, 30, 100, 300, and 500 millivolts full scale. The channel errors, as determined during the acceptance tests, are equal to or less than the following specified values:

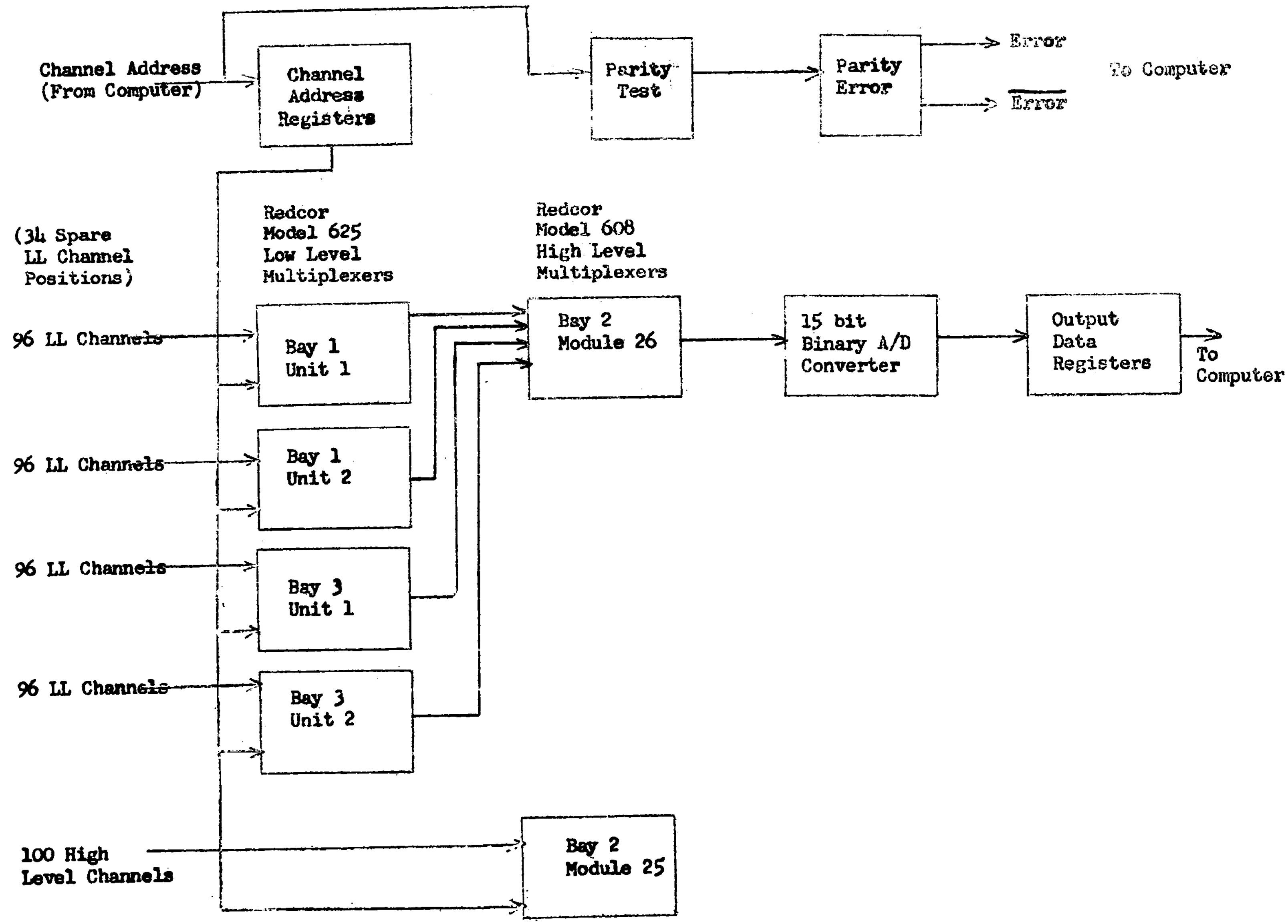

Figure 13

Data Conversion Subsystem Block Diagram

System Point Error ($\bar{e}$), $\pm$ 0.2%
Linearity Error (e_l), $\pm$ 0.5%
Precision Error (e_p), $\pm$ 0.1%

There are 100 high level analog channels which are supplied to a Redcor Corporation Model 608 high level multiplexer (see Figure No. 13). This multiplexer has a capacity for 28 additional channels. The high level channel errors, as determined during the acceptance test, are equal to or less than the following specified values:

System Point Error ($\bar{e}$), $\pm$ 0.1%
Linearity Error (e_l), $\pm$ 0.02%
Precision Error (e_p), $\pm$ 0.03%

The analog-to-digital converter produces a binary data word that has a format of 14 bits plus sign plus parity.

The maximum system sampling rate is 10,000 channels per second.

(3) Master Clock Subsystem

The master clock subsystem provides the computer with both clock pulse and time accumulation input. The clock pulses are fed into the computer priority interrupt system to provide the basic timing references for scanning and control. The time accumulator register provides a 24 bit time word upon command from the computer for recording and control purposes.

The pulse output of the master clock subsystem consists of computer-selectable repetition rates of 1000, 500, 100, and 50 pulses per secand for scan timing and a fixed one pulse per second rate for updating display.

The computer addressable time accumulator register provides for a maximum accumulated time work (millisecond resolution) of 16777.215 sec. The start, stop, and reset controls are addressed by the computer.

(4) Display Subsystem

The display subsystem provides four remote displays for visual readout of preselected parameters during a test. Each display consists of a decimal integer (000-999) plus sign with two limit indicators which are yellow and red. The indicator selection may be either red, yellow, or both.

Each display unit is addressable by the computer and will accept binary input data in the form of sign (1 bit) plus magnitude (10 bits) with limit indicators (2 bits). The data word is converted to decimal (BCD) by a binary converter that is shared by the four display units. The conversion time per word is less than 100 microsec, as determined during the acceptance tests. At the termination of each conversion process, a signal is generated and transmitted to the priority interrupt system.

(5) Control Logic Subsystem

The control logic subsystem provides a means for the computer to actuate selected relays by address control. There are 24 individually addressable relays. The addressing scheme is such that these relays may be either addressed singly or multiple addressed in any combination. The relay set or reset status are accomplished by computer transmission of a 24 bit word, wherein each bit position controls a single relay. Zero is equivalent to reset and one is equivalent to set. The relay pull-in and drop-out times do not exceed 5 millisec.

(6) Event Subsystem

The event subsystem provides the computer with the facility of acquiring on/off data by means of interrupt control. When any of the 72 input channels of the event subsystem experience a change of state, a priority interrupt will be generated. Upon receipt of the interrupt, the computer will consequently acquire and record the data and time and will provide the necessary process control.

The event channels are arranged in three groups, wherein each group consists of a 24-bit input buffer register with an interrupt line. An interrupt pulse is generated for a group of 24 channels when a bit change occurs in the group register.

(7) Digital-to-Analog Subsystem

The digital-to-analog subsystem converts digital data output from the computer to an equivalent analog voltage. Eight digital-to-analog units are included in the subsystem. Each unit accepts an eight bit plus sign (2's compliment) word from the computer. The digital word is converted to a-voltage in the range of $\pm$ zero to 5 volts DC.

b. System Function

(1) On-Line

All digital data system functions will be controlled by the computer through the use of a computer program. This program will cause the computer to continuously accept and record data during a test. Concurrently with the data acquisition process, the computer will compute engine performance parameters, monitor data, and execute test control functions.

The computer will acquire data from the data conversion subsystem by selected channel addresses at a maximum rate of 10 kc. The data conversion subsystem will transmit the corresponding data words back to the computer at the same rate. For processing purposes, the data will remain in the computer memory for a short period and then will be recorded on magnetic tape (gapped) at a 20 kc word rate. The channel sampling rate and address selection will be determined by computer input prior to a test. Individual channel sampling rates of 5, 25, or 50, will be used normally; however, other rates are available through program modification.

The events data (on/off data) will be detected by the computer by means of a priority interrupt signal that will be generated by the events subsystem when a channel state change occurs. The computer, upon receipt of an interrupt, will immediately acquire and record the data status with the time-of-state change. The computer will also process any necessary control functions after receipt of certain event information as defined by computer input prior to a test.

The on-line computations will include the determination of propellant densities (from curve fit data), weight flow rates, mixture ratios, specific impulse, thrust and net positive suction pressure (NPSP). The calculated results can be displayed on strip chart recorders through the use of the digital-to-analog subsystem and/or printed with time data in tabular form by the line printer. The steady-state conditions will be determined by the computer to assist in engine balance (mixture ratio) adjustments. Computer controlled fuel flow adjustments can be incorporated in the future as on-line engine balancing experience is developed.

The computer will monitor data from selected channels by limit checking with fixed or variable limit values as specified by program input prior to the test. At the time of each comparison, the variable limits will be determined by evaluating limit-time functions at a point. Out-of-limit conditions will be indicated by use of the control logic subsystem, display subsystem, or the line printer. The selection will be specified by program input.

The visual displays of the display subsystem will be normally used for the altitude diffuser temperature instrumentation at Test Stand K-2. The computer will select a series of channels representing temperature measurements of a common diffuser zone. The highest temperature value of a selected block will be determined once a second, limit checked, and converted to engineering units and displayed. If an out-of-limit condition exists, the yellow or red indicator light can give warning of the condition depending upon the degree of the exceeded limit. The control logic may be used to actuate an alarm in conjunction with the indicator lights. The system will handle four blocks, one for each display unit of the display subsystem.

Control functions can be initiated through the use of the control logic subsystem at fixed times and/or following a sequence or single event. Any determined out-of-limit condition can be indicated through relay contact closure to actuate audio or visual alarms.

Data from selected channels can be converted to engineering units and supplied to strip chart recorders through the use of the digital-to-analog subsystem.

(2) Off-Line

Between tests (off-line), the computer will be available as a general purpose computer. During this time, the computer will process and tabulate recorded and calculated data stored on tape during the on-line test period. Prior to, as well as after the tests, the computer will check the instrumentation and control systems. It will also control the calibration of the data acquisition system.

The computer will be available for solving engineering problems and processing of business, inventory, and reinspection data. A complete library of software is available with the computer for these off-line programing tasks. Included are a monitor system, assembler, Fortran II, sort routine, and a file managment system.

10. Time Code Generator/Tape Search and Master Time Base

The time code generator/reader will be used in the data acquisition system. The unit will provide timing for correlating data to be recorded on Ampex FR-1200 tape recorders and strip charts or oscillograph recorders. The time code generator/reader, in the run mode, will provide a modulated time code to be recorded simultaneously with the data. In addition, a level shift slow code will be provided for recording on oscillographs and strip charts. The unit will also have provisions for selecting either a 24-hour time of day code or an elapsed time code. In the reproduce mode, it will be capable of accepting the modulated carrier time code from the analog tape recorders and display the time at playback speeds up to 200 times the record speed, in both forward and reverse modes. The tape read mode or reproduce mode will be used to reach tape using the time code recorded on the tape. The search mode will be used to locate and reproduce segments of data without reviewing the entire test by manual means.

The master time base generator is a separate piece of equipment and is composed of a crystal-controlled oscillator with a time base of one megacycle. The time base provides a common frequency device for all control room recording equipment and signal conditioning equipment requiring either a sine wave or square wave frequency.

Equipment such as the frequency-to-dc-converters used in the flow system, the overspeed trip unit, the control sequence and timing system, the digital computer, and the time code generator requiring discrete frequency for timing and other operations.

The time base generator was procured in accordance with AETRON Specification PI-258a, which provides for:

a. Stability of one part per million in any 24-hour period and long term stability of ten parts per million in any 30-day period.

b. The oscillator shall be capable of being adjusted to an accuracy of at least one part per million.

c. Square and sine wave output with an amplitude of 15 volts.

Square Wave Frequencies	Sine Wave Frequencies
1000 cps	20 kc
100 cps	10 kc
10 cps	5 kc
1 cps	1 kc
	500 cps
	250 cps
	100 cps

11. Program Data Patch

The instrumentation data patch system for the K-1 Control Room was designed to handle as the data acquisition channels for Test Stand K-1 and K-2 by means of the program board type patch system. This patch system consists of the following types of boards.

a. Low Level Program Patch ("Amp" 4896)

This patch board contains all raw signal inputs directly from the test stand or via a signal selection system, amplifier inputs, low level digital input, low level visual inputs, strip chart records, as well as cross-patch entries to the other patch boards.

b. High Level Program Patch ("Amp" 4896)

This patch board contains high level raw signals such as valve position and high frequency outputs and AC signal inputs from flowmeter and turbine pickups, oscillograph inputs, amplifier outputs, spectral analyzer inputs, analog tape inputs and output, test equipment input output signals, and high level digital inputs.

c. Facility Program Patch ("Amp" 3264)

This patch panel provides the operational ability to perform checkout and long-term conditioning of the secondary test position while other activities such as a test setup or a hot firing is performed on another test stand. This patch board was designed into the system because of Test Stand K-1 and K-2 altitude diffuser capabilities as well as the long-term temperature soak period required. The board contains raw thermocouple inputs, low level digital inputs, low level visual inputs, and multipoint strip chart recorder inputs.

d. Event Program Patch ("Amp" 1632)

The event patch board provides entry into the digital event system (computer) and the oscillograph for recording voltage event functions originating from the engine sequence control system.

e. Functional Patch

This patch system, unlike the low level, high level patch boards, is not of the AMP type patch panel. This patch panel uses individual patch cords in a fixed patch panel configuration. The patch system was designed so changes could be made without disturbing setups in process and checkout of control systems could be made for one or more test stands while the other stand was being set up for hot firings.

12. Digital Overspeed Trip Unit

a. Function

The digital overspeed trip unit was designed primarily to meet the test requirements of the M-1 turbopump assembly development program. Existing overspeed trip devices did not exhibit the accuracy, resolution, and speed necessary to answer the demands of the M-1 Program. In designing this unit, performance capabilities were broadened to permit its use for engine testing as well as its use in other existing test programs.

b. Performance Requirements

(1) Input Signal Range

Input signal level to the overspeed trip will normally range from 10 V PP to 30 V PP during test runs. Wafeform is often irregular with, in some instances, secondary pulses present at as high as 10% of signal level. Depending upon the particular combination of hardware, signal level may approach 100 V PP or be as low as 2 or 3 V PP at normal rpm. The overspeed trip unit (OST) must be capable of operating over this range; however, the trigger threshold requires adjustment to a point midway between the anticipated noise and signal levels.

(2) Trip Response

To prevent hardware damage in the event of turbine overspeed under conditions of high acceleration, such as pump cavitation, shutdown must be physically initiated within 10 millisec after trip speed is reached. Relay sequencing subsequent to the overspeed trip absorbs between 7 millisec and 9 millisec, leaving a requirement of approximately 2 millisec for OST action time.

(3) Frequency Response

The hardware, for which the digital overspeed trip unit was developed requires that the unit exhibit a frequency response of from approximately 500 cps to 2500 cps. To extend its capabilities and versatility to cover the majority of other possible applications, overspeed trip should be available over a range of 100 cps to 15,000 cps.

c. Equipment Description

(1) Mechanical

The digital overspeed trip is a dual channel unit mounted on a sliding type chassis which may be pulled out for servicing or adjustment. All circuitry, with the exception of the power supply, is mounted on plug-in cards.

Thumb switches on the front panel are separately adjustable on each channel for the number of gear teeth and for the "kill" or limit settings. A four-digit BCD readout displays the period of revolution at trip. The digital overspeed trip unit dimensions are: width, 24 in. (19 in. optional); height, 10.5 in.; depth, 23 in.; and weight, 30 lb.

(2) Electrical

All circuitry is composed of Packard-Bell germanium logic modules with the exception of the input amplifier/shaper which is an Aerojet-General design using solid state components. The power supply is a Packard-Bell Type PS-4 and is contained in the same chassis. The BCD register lamps are in-line Amperex indicators.

Input signals to each overspeed trip channel are transformer-coupled into an amplifier shaper circuit through a level control, which permits trigger level adjustment from 60 millivolts to 100 V PP.

An input pulse initiates a timing period which starts advancing a four-digit register at the time base clock rate of 100 kc. Subsequent input pulses enter a "teeth setting" decade counter which divides the input frequency by the number set into the "teeth setting" thumb switches. When that number of input pulses has been counted by the decade, an output pulse is generated which signifies that one complete turbine revolution has been completed. If, in the meantime, the register has been filled to the setting of the "kill" setting thumb switches, this indicates that the turbine speed is slower than the preset trip point. For this condition, the output pulse from the teeth setting decade resets the register and initiates another timing period. On the other hand, if the pulse occurs before the register fills to the "kill" setting, clock input to the register is suspended, the trip relay is energized, and sampling is suspended until the channel is manually reset.

d. Circuit Description

(1) Input Amplifier/Shaper

Signals are coupled into the input of the amplifier/shaper through an isolation transformer terminated in a 20k trigger level adjust potentiometer. Three emitter followers with "bootstrap" feedback through a Zener diode provide a stable DC platform from which the bias for a Schmidt trigger is adjustable through a single-stage amplifier and emitter follower. Two low-pass networks at the input to the Schmidt trigger lessen susceptibility to spurious triggering as a result of power supply or line noise. A transistor switch driven by the Schmitt trigger applied the shaped signal to subsequent logic circuitry.

(2) Logic (Figure No. 14)

With the unit in the reset condition, an input pulse sets a control toggle switch through an "AND" gate, which enables the "teeth setting" counter (two digit) and the "kill setting" register (four digit). Also, a gate toggle is set which enables one leg of an "AND" gate controlling the trip toggle and relay driver. The "kill setting" register starts filling at the 100 kc clock rate and each input pulse from the amplifier/shaper advances the "teeth setting" counter one step until it is filled to the number set into the Digiswitch (one revolution). At this point, an output pulse from the Digiswitch circuitry resets the control toggle through a clocked gate. If the control toggle resets before the register fills to the number set into the "kill setting" Digiswitch, the toggle controlling the trip relay driver is set through the enabled "AND" gate. The input gates to the register and reset drivers are inhibited and the trip relay is picked. However, if the register fills to the Digiswitch kill setting before the control toggle is reset, output from the kill setting Digiswitch resets the gate toggle previously set by the control toggle which inhibits the trip gate and enables the reset drivers. The next clock pulse triggers the reset one shot and all circuits are reset to their original condition. The next signal input pulse initiates another cycle.

If overspeed trip has taken place, manual reset must be used to reset the logic. The manual reset switch triggers a one shot which, in turn, triggers a reset driver to reset all circuitry.

(3) Operational

Basically, setup and functional checks are straightforward, although the kill setting is not made directly in rpm, but rather is the number of 10 microsec increments in the period of one revolution. The formula used to establish the kill setting is:

$$\text{KILL SETTING} = \frac{6 \times 10^6}{\text{RPM}_{\text{TRIP}}}$$

The additional circuitry required to permit setting RPM directly was deemed too expensive for the function performed.

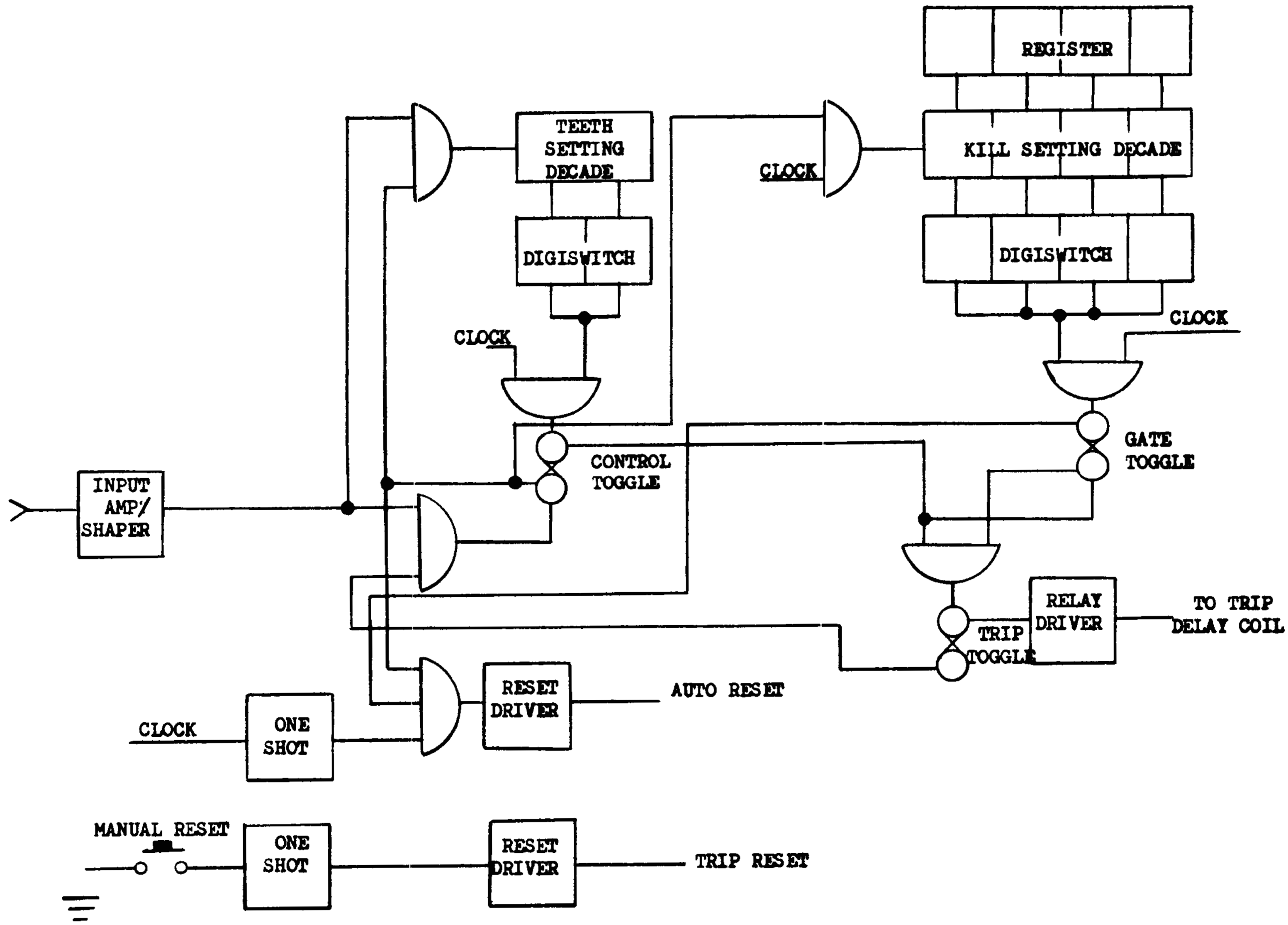

Figure 14

Basic Logic Diagram for Digital Overspeed Trip Unit

(4) Performance

PARAMETER	TARGET	ACTUAL	COMMENT
Frequency Range (+3 db)	10 cps to 40 KC	100 cps to 15 KC	500 cycles to 5 KC adequate for all expected applications.
Input Z	20K (minimum)	5K (minimum)	5K Z acceptable for expected applications.
Input Threshold (Adjustable)	50 mv to 30v PP	50 mv to 100v PP	
Accuracy	Time Base Accuracy	Time Base Accuracy	
Resolution	+10 microsec	+10 microsec	
Sample Period	$\frac{60}{RPM_{TRIP}}$ sec/2 Rev	$\frac{60}{RPM_{TRIP}}$ sec/1 Rev	
Output	SPDT Relay Contacts	SPDT Relay Contacts	
Trip Delay	$(\frac{2 \times 10^3}{f_{in}} + 2)$ MS	$(\frac{10^3}{f_{in}} + 1)$ MS	
Register Display	4 Digit BCD	4 Digit BCD	
Input Power	115 v AC + 10%	115 v AC + 10%	

13. Combustion Stability Monitor

The combustion stability monitor (CSM) was designed as a control device to detect the presence of instability in the combustion processes of a rocket engine or gas generator and to automatically initiate a shutdown. It is necessary to terminate unstable burning operation by automatic methods because human reaction time is insufficient to obtain the millisecond judgement and action required to minimize possible damage.

Signals are received from pressure transducers in the combustion chamber, although it is preferable to measure chamber pressure directly, it is not always feasible to mount high-frequency transducers directly into the chamber. It may be necessary to measure injector pressure instead. This signal is not smooth, but is characterized by random oscillations superimposed upon a quasi-static level. The combustion stability monitor is sensitive only to the oscillation position of the signal. Engines may exhibit unstable burning characteristics during the start transient period and then smooth out. To prevent a premature shutdown, it is necessary to time the instability portion and delay the shutdown for a predetermined interval.

There are three basic functions in the combustion stability monitoring system. These are: (a) determination of the input signal level in relationship to the desired critical level, (b) determination of the frequency of the incoming signal in relationship to the critical frequency, and (c) timing of the interval in which the critical levels of amplitude and frequency have been simultaneously exceeded. These steps are sequentially accomplished by the combustion stability monitor in the order listed above and are shown diagramatically in Figure No. 15. Signals can appear at the output of the signal level sensor only when the input level exceeds the critical level. Signals can appear at the output of the high-pass filter only when the frequency is above the cutoff value of the filter. Timing action starts whenever a signal appears at the input to the time delay.

Elimination of signals beyond the field of interest is accomplished by the use of an active band-pass filter. This unit provides a roll off of 12 db per octave below 500 cps and above 9 kc. The response is flat between 600 cps and 7000 cps.

To determine when the incoming signal is above the critical value, a circuitry is needed that will respond in a positive manner whenever it is excited by a signal whose magnitude is equal to or greater than some predetermined level. This device must respond in both directions (i.e., turn off when the voltage drops below the critical level and turn on when the voltage rises above the critical level). Further, the spread between the "ON" and "OFF" points must be narrow. Such circuitry is found in the Schmidt trigger, a bilevel output device whose output state is "ON" when the input voltage is below critical level. With an alternating signal of sufficient magnitude, a series of pulses is formed at the output of the Schmidt trigger with the pulse width equal to the time that the signal value remains above the critical level, and whose repetition rate is equal to the frequency of the signal.

Because of the action of the signal level sensor, signals will appear at the input to the high-pass filter only when the incoming signal is large enough in magnitude. Signals may also appear because of the action of the series of pulses whose repetition rate corresponds to the frequency of the input signal. The high-pass filter is designed to deliver a signal only when the pulse repetition rate is above the critical rate. The cutoff point must be as sharp as possible. The filter concept that was used resulted in a pass band that was fully "OFF" up to the critical frequency and fully "ON" above that point, with an uncertainty of approximately $\pm$ 5 cycles out of 1000. There are three components in this filter: a bistable circuit, a monostable circuit, and a phase comparator.

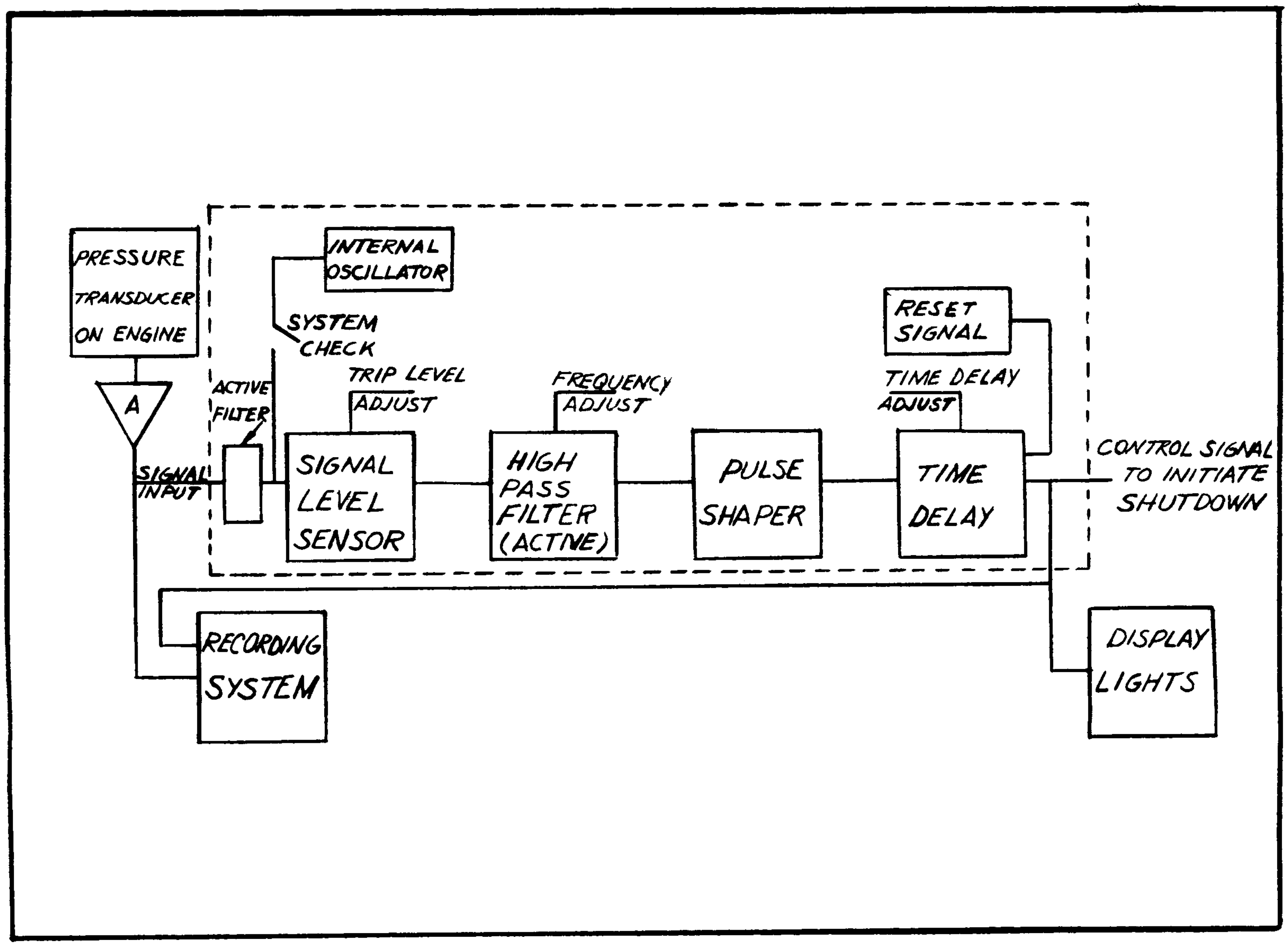

Figure 15

ɔmbustion Stability Monitoring System Block Diagram

Filter action is achieved by comparing a pulse whose width is a function of the signal frequency with a standard pulse whose width is set to equal the reciprocal of the frequency at which it is desired to start passing signals. By this method, signals come through the filter only when the critical value is exceeded.

To obtain a pulse whose width is a function of the signal frequency, use is made of the bistable circuit. This circuitry switches state every time it receives an input pulse going in the negative direction, or from 1 to 0; it remains at that state until the next pulse is received. The output of the circuit is designed to deliver two signals of opposite polarity; these are called Phase A and Phase B. When Phase A is zero, Phase B is 1 and vice versa. At both Phase A and B, one pulse will be formed going from 1 to 0 for every two input pulses going from 1 to 0. These 1 to 0 pulses will be separated by the period of the incoming signal. If the incoming signal frequency is 1 kc, the pulse separation will be 1 millisec. The Phase A signal goes directly to a phase comparator and the Phase B signal goes to the monostable circuit.

Monostable circuits deliver a pulse when excited by a pulse. The output pulse width is determined by the constants used in designing the circuit, not by the input pulse width. This particular circuit is designed to respond only to pulses going from 1 to 0 and to produce a 1 to 0 pulse for each pulse received. The output pulse width is set to equal the period of the signal which is to be passed. For instance, if it is desired to pass frequencies over 1 kc, the pulse width is set to one millisec. These output pulses are fed into the phase comparator.

Phase relationships of the pulses of Phase A and those of the monostable circuit are such that the pulse states are 180 degrees out of phase when the period of the incoming signal is greater than the period of the monostable pulse, and the pulse states are in phase when the incoming signal period is equal to or less than the period of the monostable pulse. To automatically detect this phase relationship, a phase comparator was designed to respond when both inputs were zero. An analysis of pulse relationships at the phase comparator for signals above and below the critical point is presented in Figure No. 16. This analysis also shows that the output pulse from the phase comparator has a width which is a function of the input frequency. To be usable, the pulse was standardized by use of another monostable circuit called a pulse shaper.

The techniques described previously result in pulses being present at the output of the pulse shaper only under conditions where the incoming signal amplitude is greater than the critical level and where the incoming signal frequency is greater than the critical frequency. The absence of either condition will block the signal from reaching this point.

When a pulse does appear, it is an indication that a signal with the frequency and amplitude characteristic of instability is being monitored by the CSM. This first pulse could be used to initiate the shutdown sequence. However, engine testing is expensive and unnecessary shutdowns cost a great deal

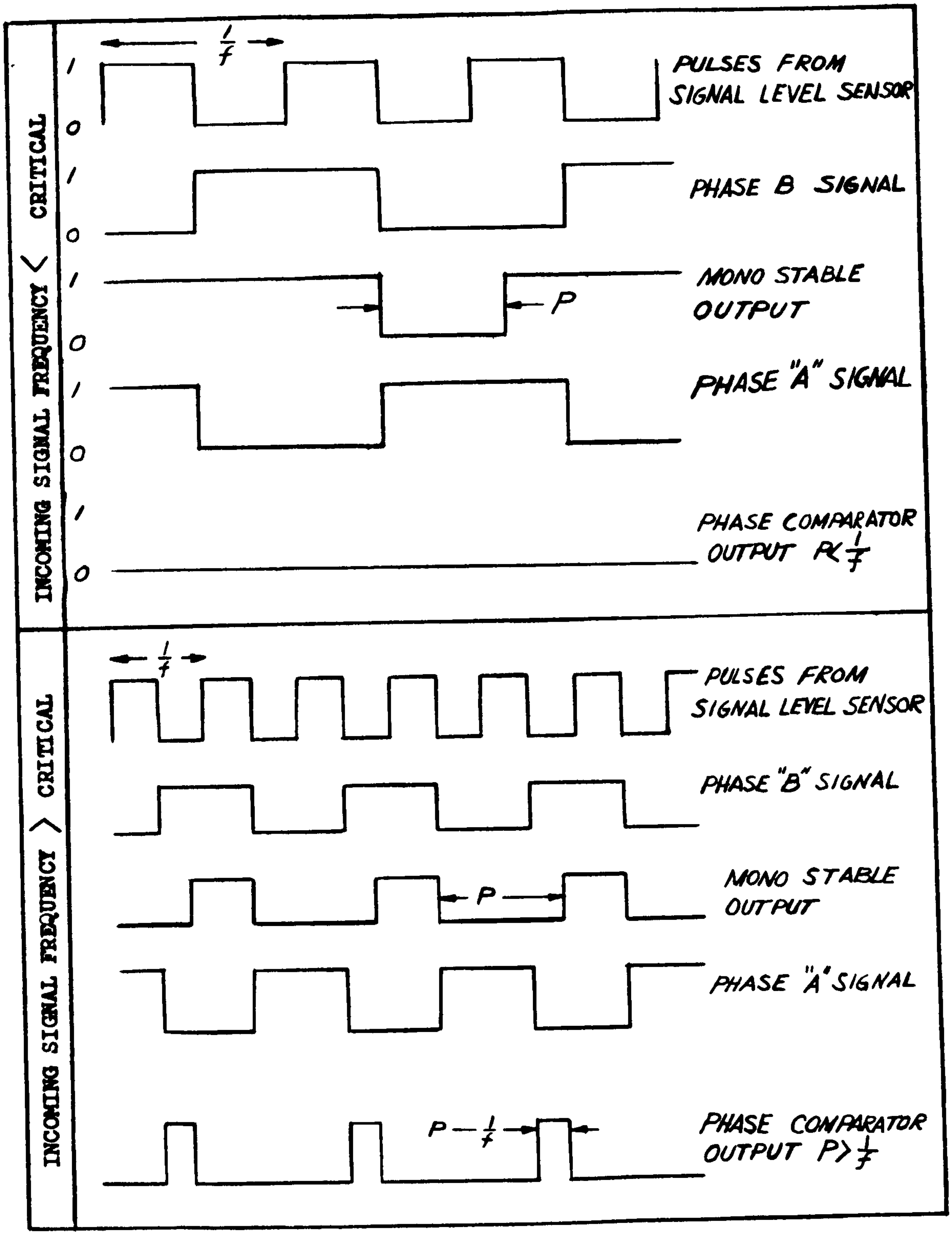

Figure 16

High-Pass Filter Signal Comparisons

in wasted time and material. Therefore, it is necessary to have a high confidence level to assure there is a bonafide case of combustion instability. Two steps are taken to increase this confidence level: (a) a time delay is introduced between the first pulse from the pulse shaper and the initiation of the shutdown sequence, and (b) circuitry is incorporated to ensure that the series of pulses from the pulse shaper is continuous with no gaps greater than 3 millisec in the pulse string. The 3 millisec time interval is introduced to prevent a recycle of the timer in the event of jitter, which may occur at the threshold points.

When there is no signal, the gate emits a positive signal that prevents the time from reacting and which charges the resistance-capacitance (RC) network across the timer. The input resistance of the timer is low so that the RC circuit charges rapidly. This approach provides a very fast recycle time if the timing cycle must be started again.

The heart of the timer is a transistor which is biased to saturation by the positive output of the gate. When a pulse is put into the gate, the gate-supplied bias is removed. However, the transistor is still biased to saturation by the charge on C and is held in this condition until the charge voltage drops to the switching point of the timer. The time interval is determined by the elements of the RC circuitry. When the voltage to the gate is removed, the gate-supplied bias immediately saturates the timer and again recharges C.

Another RC circuit is placed across the input to the gate transistor to hold the gate "OFF" for a period of 3 millisec after the last pulse comes into the gate. In this manner, a series of approximately three missing pulses will not cause the timing cycle to start over again. If more than three pulses are missing, it can be assumed that the conditions of instability are no longer present and that the timing cycle should restart.

After the required delay period, as determined by the RC network of the timer, a positive voltage will appear at the output of the timer. This voltage is used to drive a transistorized relay. Once the relay is activated, it is attached through its own contact to the 28V DC supply. In turn, a 28V DC signal initiates the engine shutdown sequence.

Complementary circuitry consists of a unijunction transistor wired as an oscillator with the frequency and output voltage matching that generated during engine instability. In this way, the operation of the control and over-all circuitry can be verified.

14. Hybrid Dynamic Data Spectral Analyzer

The hybrid (combination of analog and digital computer techniques) analyzer is an automatic, high speed electronic data processing system capable of accurately analyzing and processing transient as well as steady-state energy in relationship to frequency information from complex dynamic test data. A block diagram of the total system is shown in Figure No. 17. The hybrid analyzer system offers an almost unlimited number of spectral analysis ranges

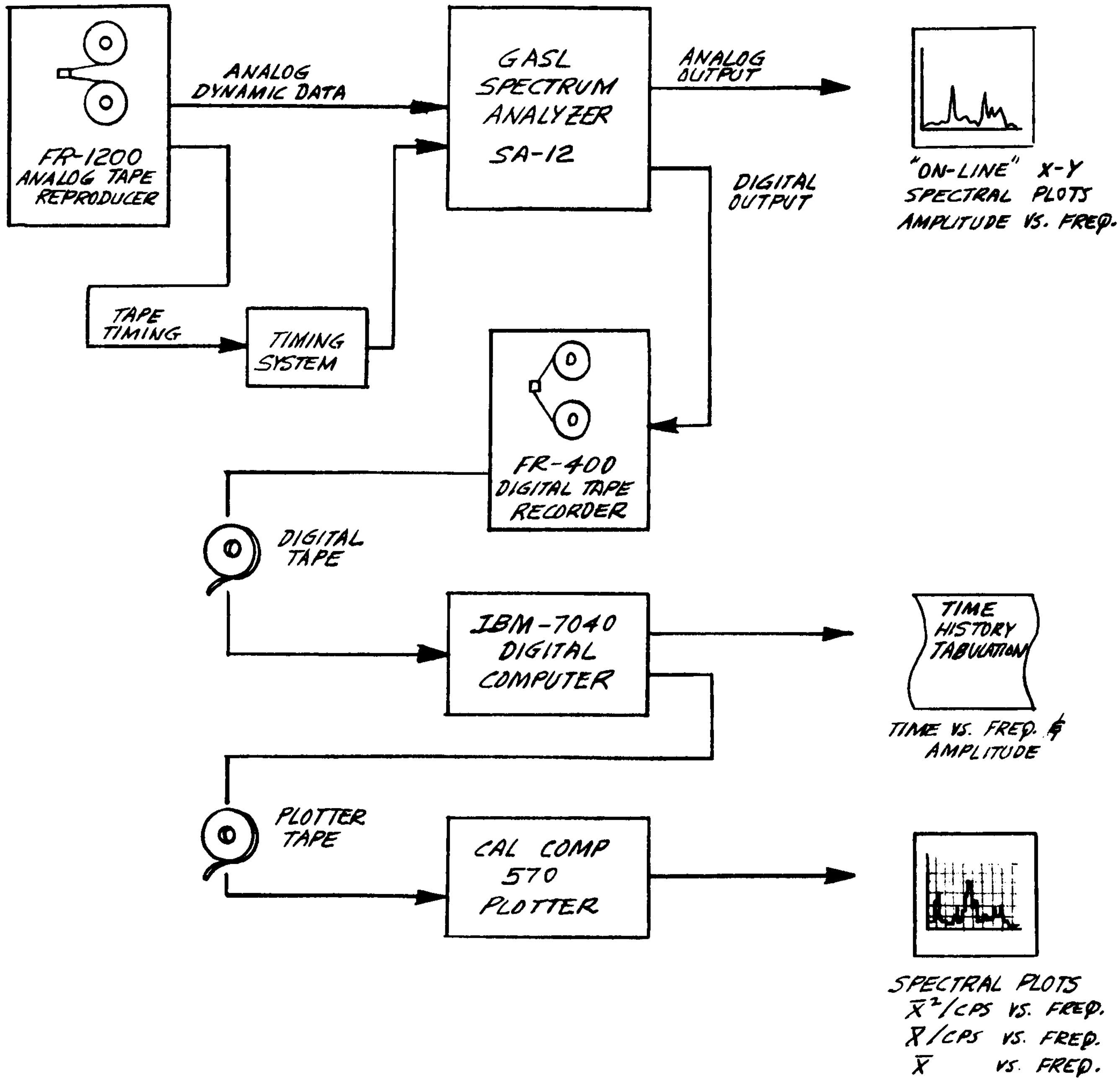

Figure 17

Hybrid Analyzer System Block Diagram

(0.01 cps to 40,000 cps) and effective analysis bandwidths (0.01 cps to 800 cps) for the analysis of dynamic data. By selecting the proper combinations of tape reproduction speed and digital sampling rate, as little as 12 millisec of real-time transient data can be accurately analyzed. (The pre-hybrid system utilized a Hetrodyne Wave Analyzer which required a minimum of 2.0 sec of real-time data for analysis.)

a. Operational Description

In the hybrid analyzer system, the analog dynamic data is fed from an FR-1200 Tape Recorder into a Model SA-12 Spectrum Analyzer manufactured by General Applied Science Laboratory (GASL). An external gating circuit (timing system), operated by the 17-bit time code recorded on the analog tape, is used to select the required data sample time period from the input tape.

The Model SA-12 Spectrum Analyzer, which is the heart of the hybrid system, consists basically of two sections. The first is a digital loop section wherein the analog data are digitized with 8-bit resolution at a rate at least four times the highest frequency of interest (see Figure No. 15). This digitized data is then inserted into a recirculating magnetostrictive delay-line storage system and effectively "sped-up" (compressed in time) by a large factor. The data sample may be stored in the delay-line digital storage system and recirculated continuously for analysis, or incremented progressively in time throughout the data run wherever a frequency-amplitude-time profile is desired. Data stored in the "digital loop" is reconverted to analog data in its "sped-up" form and the actual data frequencies translated upward in frequency by the speed-up factor.

The "compressed" analog data is then fed to the second basic section of the analyzer which is a conventional sweep spectrum analyzer. This analyzer operates at a carrier frequency of 600 kc, and is equipped with both a crystal lattice filter for narrow band analysis and a stagger-tuned amplifier for wider band survey work.

The output from the SA-12 Spectrum Analyzer is available in both analog and digital form (see Figures No. 17 and No. 18). The analog output is generally used when an "on-line" X-Y spectral plot of a stored, recirculated data sample is desired for the analysis of short-duration transient data.

The digital output, in the real-time mode, is generally recorded on an FR-400 tape that is compatible with computer format. The computer can manipulate the data in many ways for presentation, the most common being the complete tabulation of time versus frequency and amplitude.

Summaries can be made of any selected portion of the processed data and plotted automatically using a Cal-Comp tape plotter system.

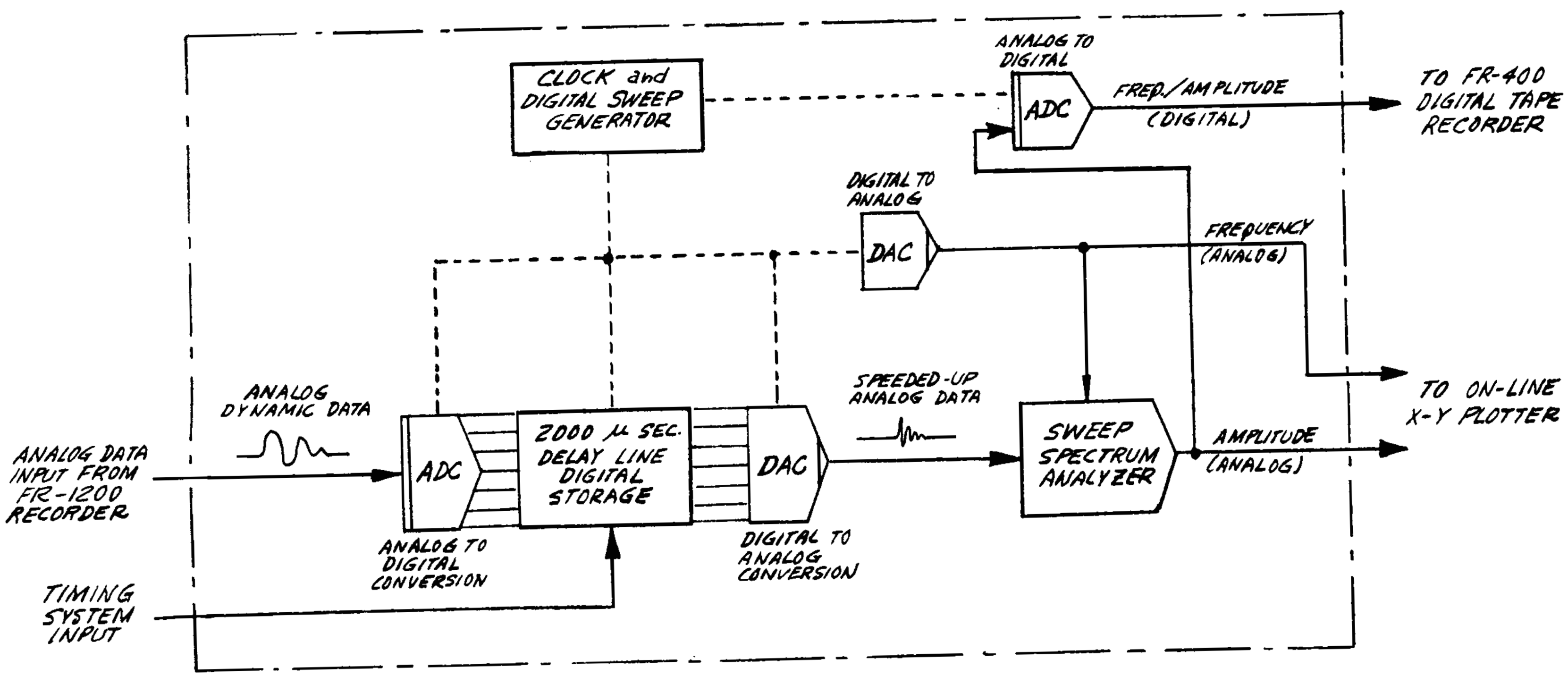

Figure 18

GASL Spectrum Analyzer SA-12 Block Diagram

b. Data Formats

The existing hybrid system at the Aerojet-General Sacramento facility processes data in two basic formats: it presents "on-line" spectral plots of short duration transient data, or creates a digital tape containing spectral time history data for computer processing. The most significant operational difference between the two formats is that the transient data for "on-line" plots of energy versus frequency is stored in digital memory for processing while the spectral time history data is processed with the system operating the real-time continuous mode.

(1) Short Duration Transient Data

This data appears in the form of X-Y spectral plots as shown in Figure No. 19. The energy amplitude, in engineering units, is found on the ordinate and the frequency on the abscissa.

(2) Computer-Processed Data

The hybrid system generates a digital tape which contains amplitude, frequency, and time information which is in a form compatible for computer processing. With digital tape input, the computer is then directed to process and re-format the data using one or more of the mathematical programs available as tape input. Some of the computer-processed data formats are:

(a) Time History Tabulations

These listings provide a three-dimensional time history survey of the dynamic data encompassing the complete test run. Table I shows a portion of a 20 cps to 10,000 cps time history computer tabulation. Frequency appears across the top; time in the left-hand vertical column; and the energy (amplitude) values in the center field. By establishing a minimum energy value for printout on the tabulation (i.e., on Table I only amplitudes of 25 psi or greater are shown,) the predominant frequencies and their time of occurrence are readily identified. Note that the system reads out a complete line of spectral information every 50 millisec commensurate with a 20 cps to 10,000 cps frequency analysis (Table I).

(b) Computer-Generated Plotter Tape

Several of the computer programs provide a statistical treatment and re-formating of the analyzed data, which is recorded on a plotter tape. This plotter tape is then installed on an automatic plotting system (Cal-Comp Plotter), which scales, annotates, and plots the required data in one operation. The three main plotter formats are:

1 Power Spectral Density in the form of $\overline{X}^2$/cps versus Frequency (see Figure No. 20).

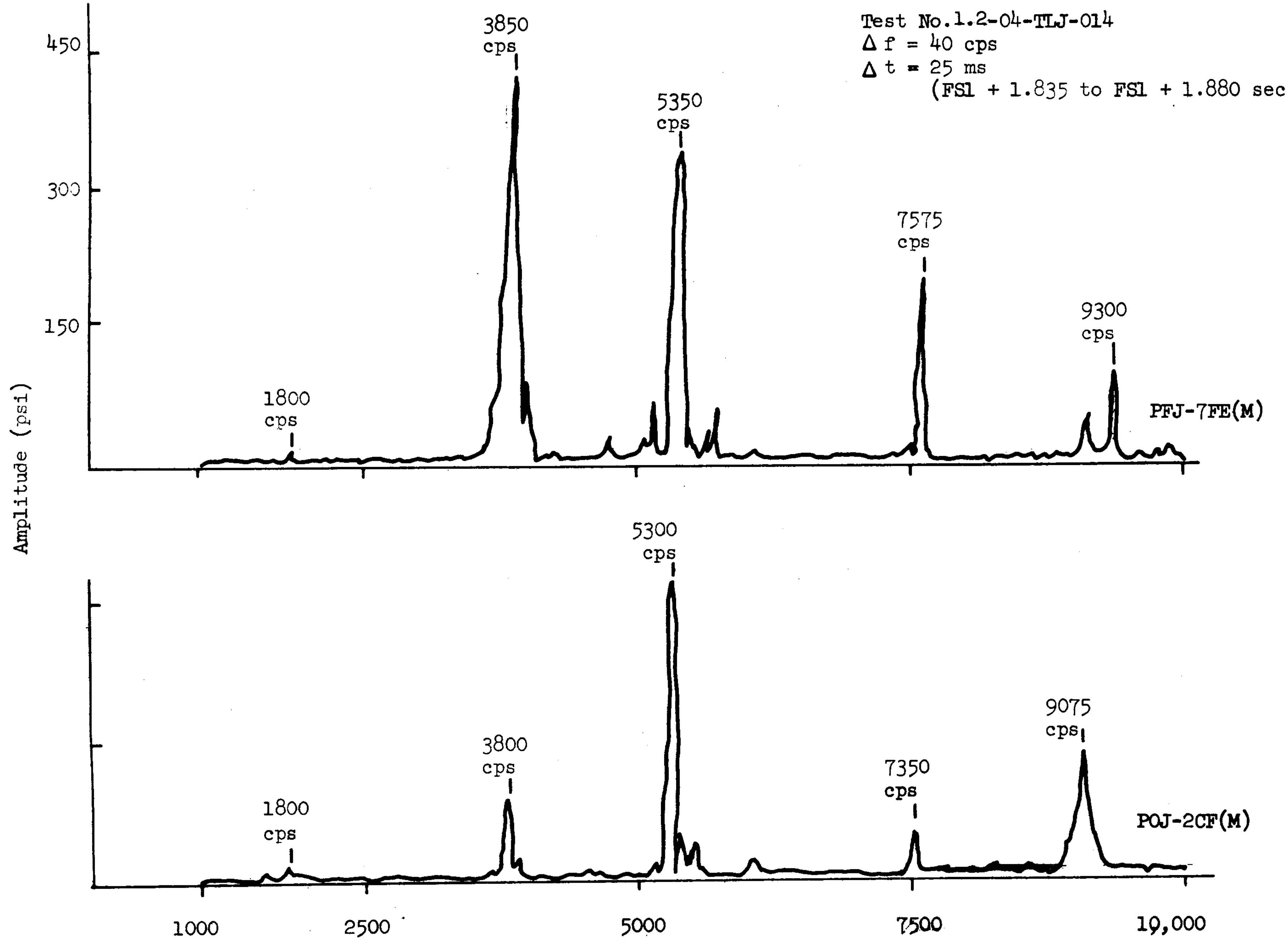

Figure 19

Delay Line Digital Storage Analysis

TABLE I

SPECTRUM ANALYZER DATA TABULATION

1.2-04-TUJ-014   C-1   05   64 FS2   2.097TRACK 13 PC4E-F(K)   S.F. 1.0   025   025

	510	530	550	570	590	610	630	650	670	690	710	730	750	770	790	810	830	850	870	890	910	930	950	9
000.005																								
000.057																								
000.108																								
000.158																								
000.209																								
000.260																								
000.311																								
000.362																								
000.414																								
000.464																								
000.515																								
000.567																								
000.618																								
000.668													027											
000.719																								
000.770																								
000.821																								
000.872																								
000.924																								
000.975																								
001.025																								
001.076																								
001.127																								
001.178																								
001.230																								
001.281																								
001.332																								
001.383																								
001.434																								
001.484																								
001.535																								
001.586																								
001.637																								
001.688																								
001.700																								
001.790	026	027	065									025	126	104				025			071	067		
001.841	041	089	053										088	198	029									
001.893		042										026	111	093							054			
001.944	026	041											058	095					031	073				
001.995	053												065					028	078					
002.046	030																050							
002.097											046													
002.143																								
002.199																								
002.250																								

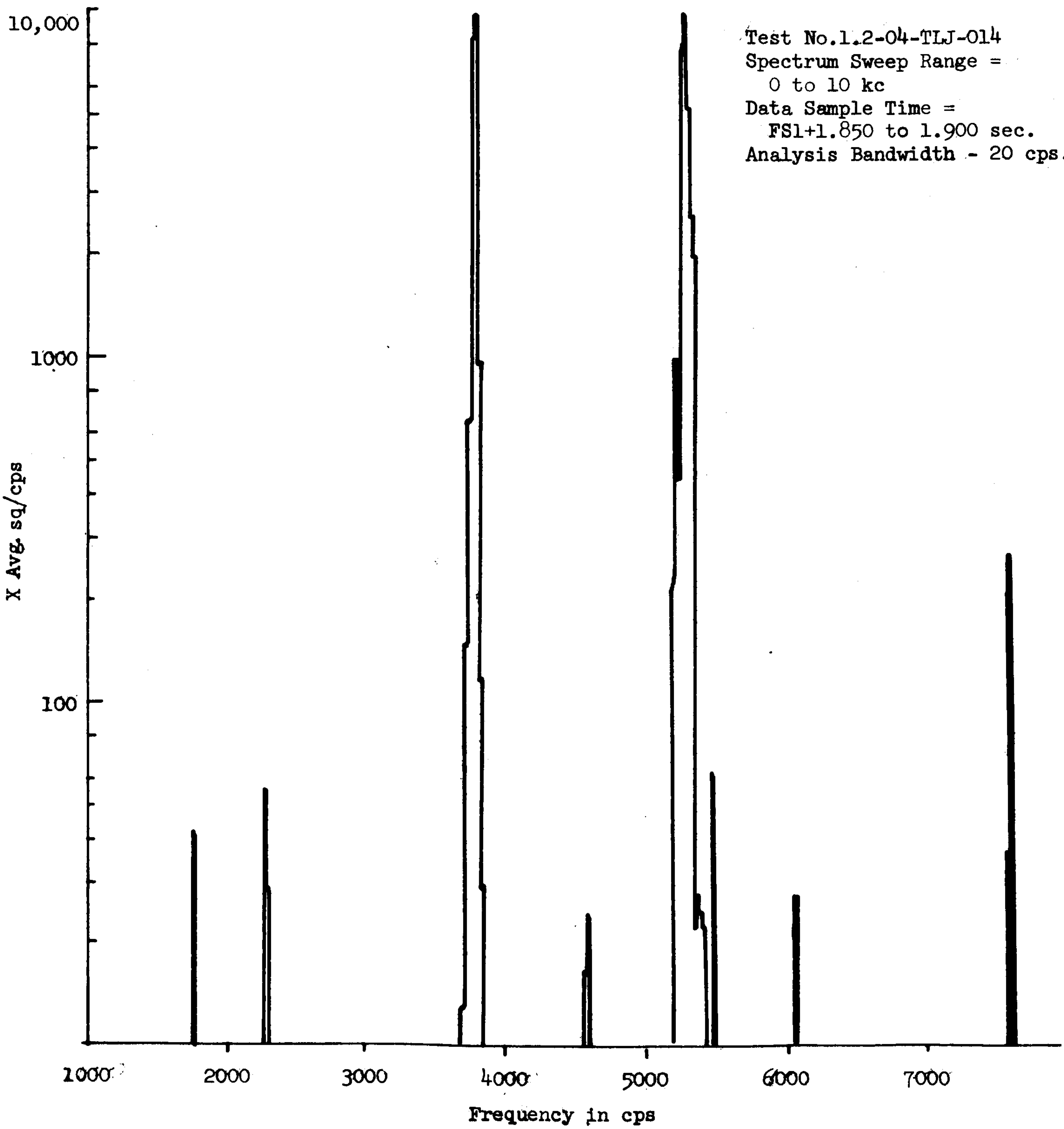

Figure 20

Power Spectral Density Analysis

2 Mean Spectral Density in the form of $\overline{X}$/cps versus Frequency

3 Spectral Distribution in the form of $\overline{X}$ versus Frequency

Note: $\overline{X}$ = Average amplitude in psi. In the spectral plot formats of 1 and 2, $\overline{X}^2$ and $\overline{X}$ are divided by the analysis bandwidth in cps.

c. Processing Speed and Accuracies

The processing speed of the hybrid system is significantly faster than the analog-type systems such as heterodyne wave analyzers using tape loop storage. The hybrid system will process and digitize dynamic data in real-time when operated in any one of its five basic spectral ranges. For example, 20 sec of data for a 10 to 5000 cps analysis may be processed in 20 sec, as compared to 8,000 sec required for a heterodyne analyzer set for the same degree of statistical confidence. Computer processing time required for the 20 sec of digitized data is approximately three minutes in any data format mode, and the automatic plotting system requires approximately 3 minutes per plot, plus tape handling time. This represents a time savings of approximately 16:1.

The amplitude statistical error for the SA-12 analyzer is dependent upon the mode of operation and input data characteristics. For transient data, which have periodic components that are continuous throughout the system storage time, the amplitude reconstruction accuracy is within $\pm$ 10%. If the transient duration is less than the system storage time, or if there are components that are not continuous throughout the storage time, the statistical error increases proportionally.

When the hybrid system is operated in the continuous digital analysis mode, the system amplitude accuracy is within $\pm$ 5% for sinusoidal or complex periodic data that are continuous throughout each spectrum sample period.

For random data, which may be assumed to approximate a Gaussian probability density function, the statistical error of the system is expressed as confidence intervals based upon the number of degrees of freedom. Typical data of this type is processed with a 90% confidence that the actual mean square energy value is between 0.8 and 1.3 times the processed values.

15. Cable Conveyance

Because of K-Zone topography and the safety requirement to locate the control outside the 2 psi over-pressure area, the mean distance to any of the K-Zone stands is approximately 3800 ft. To provide channel-for-channel transmission cabling and to implement these test stands with the necessary instrumentation and controls, it was necessary to undertake several studies of various types of cable conveyance systems.

A preliminary study indicated that a signal conditioning center located at some optimum distance between stands K-1 and K-2 would provide a common switching point and would make it necessary to provide only one set of transmission cables to the control room. Because the digital system and amplifiers would be common and located in the signal conditioning center, only transmission for such items as strip charts records, visual gages, computer inputs, and oscillograph inputs were necessary between the signal conditioning center and the control room. With the advance of concepts and the design of systems, the number of interconnecting cables between the signal conditioning center and control room increased. All transmission cable between the test stand and signal conditioning center (a distance of 1000 ft) and the signal conditioning center and control room (a distance of approximately 2800 ft) was in duct bank. With the increase in the number of cables between the signal conditioning center and the control room, a second study was undertaken to reduce the cost of the cable conveyance system.

The second study indicated that the signal conditioning center could be eliminated and the majority of the transmission cable installed in cable trays; the last 500 ft of cable at the test stand end would be installed in a duct bank for protection. In the plan for signal conditioning centers, two digital machines and two sets of amplifiers would be required for the four test stands. With the signal conditioning centers eliminated, a common digital system with amplifiers could be provided in the control room. With these trade-offs in cable length and the elimination of the signal conditioning center and cost savings in cable tray over duct bank, it appears that a greater operational system was being provided with a considerable savings to the program by eliminating the signal conditioning center.

The cable tray system is of a low silhouette type, whereby the cable trays are laid side by side, approximately one foot above the ground, providing easy access over the trays if conditions so arise. Also, this low silhouette will make cable installation much easier, in that the cables may be taken directly off the reel and laid into the trays.

The duct banks are of a standard design, the only major change is the use of plastic pipe to make the total installation job easier and less expensive.

IV. CONCLUSIONS

The criteria established for the data acquisition facilities for M-1 engine development testing in Test Zone K was an attempt to incorporate two basic design approaches. It was to take advantage of the existing extensive experience both in instrumentation operations and in actual rocket testing operations. It also was intended to make this experience current by using the best technology and hardware available.

In attempting to meet these criteria, costs were a significant influence. The operational savings that can be realized with an optimum system must be compatible with budget limitations. Also, other factors must be considered, such as the flexibility for adapting to program variations and the obsolescence of equipment.

It is believed that the prime objectives of these criteria have been met in the design of the K Zone data acquisition facilities by designing the system around a modern computer, which is capable of providing on-line real-time data and off-line computing service functions.

The significant cost trade-off is the ability to provide the test conductor with improved data during the test so that the optimum test duration can be achieved while providing sufficient data for engine analysis and control.

The digital data system performed as designed during checkout.[5] It is believed that this system would have contributed to a significant advancement in rocket test facility utilization. The potential reduction of the number of acceptance tests in a program where one duration test may cost $175,000, was the basis for including approximately $300,000 in specialized computer equipment. The computer can also terminate a test, which conserves many thousands of dollars in propellants costs, in the event that the design point operation is not being met.

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(5) Acceptance Test Report for SDS Computer Controlled A to D Conversion System (Including Acceptance Test Procedure), Aerojet-General Report No. 9270:33, 29 June 1965

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