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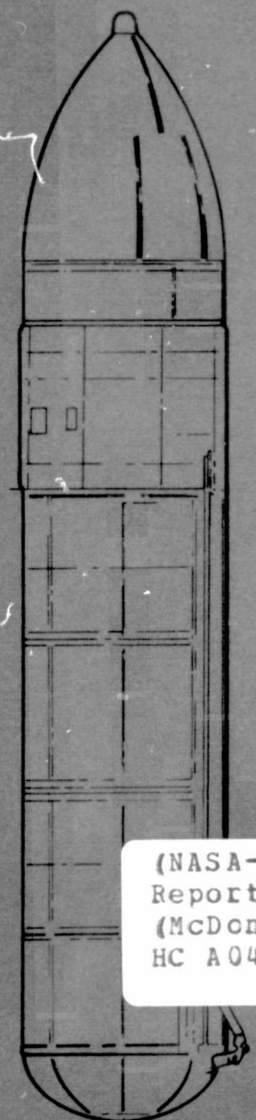

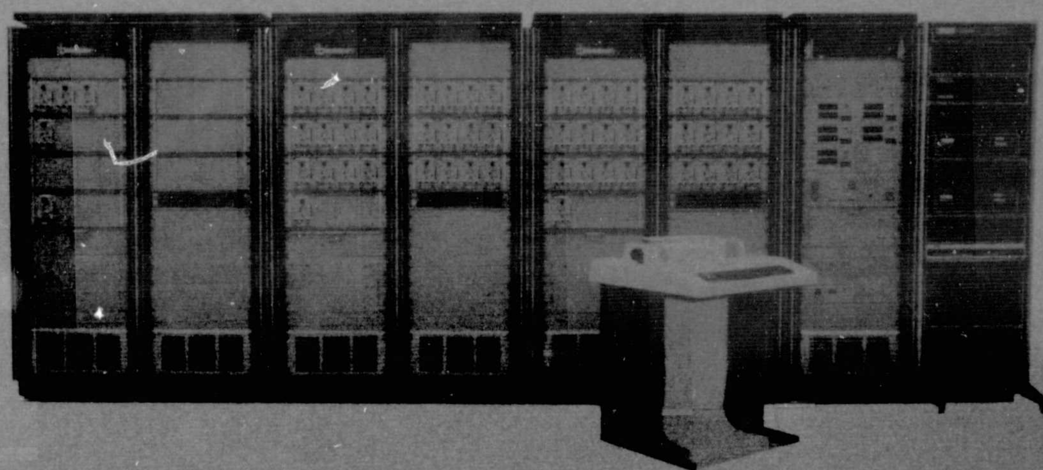

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LOAD CONTROL SYSTEM FINAL REPORT

MCDONNELL DOUGLAS ASTRONAUTICS COMPANY

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MCDONNELL DOUGLAS CORPORATION

MCDONNELL DOUGLAS

LOAD CONTROL SYSTEM FINAL REPORT

JUNE 1977

MDC G7038

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CONTRACT NAS8-31669

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PREFACE

This final report is submitted to the National Aeronautics and Space Administration, George C. Marshall Space Flight Center, Alabama as authorized by Contract NAS8-31669. It documents the work performed by McDonnell Douglas Astronautics Company (MDAC) during the period November 1975 through June 1977, for the contract entitled Design, Fabrication, Installation Support and Checkout Support of Load Control Systems for Shuttle External Tank Major Ground Tests, and SRB Load Control System Design.

INTRODUCTION

This is the final report on MDAC Contract NAS8-31669, entitled: DESIGN, FABRICATION, INSTALLATION SUPPORT AND CHECKOUT SUPPORT OF LOAD CONTROL SYSTEMS FOR SHUTTLE EXTERNAL TANK MAJOR GROUND TESTS AND SRB LOAD CONTROL SYSTEM DESIGN. This program consists of the design, fabrication, installation, checkout and field service for an automatic load control system for structures static load testing of the Space Shuttle External Tank - Intertank Section, LOX Tank Section and the External LH_2 Section. The SRB load control system design was deleted by Change Order No. 2.

The load control system for the external tank consists of a computer, with electronic hardware, servo controllers and an uninterruptible power source for controlling up to 58 load lines. The system design and hardware provides hydraulic system components for eighty (80) load cylinders, one-hundred (100) solenoid operated hydraulic dump valves, and sixteen (16) hydraulic pressure distribution/pressure regulation panels. In addition, one man year of field service is provided at the Marshall Space Flight Center to install and check-out the load control system and train personnel in its operation and maintenance.

The load control system meets all of the requirements for controlling the Space Shuttle External Tank tests as defined in Contract NAS8-31669. The system is currently located in Building 4619 at MSFC in a test readiness status for the upcoming Intertank tests that are to begin in late July 1977.

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1.0 GENERAL

An award contract was made by the George C. Marshall Space Flight Center (MSFC) to the McDonnell Douglas Astronautics Company (MDAC) on November 14, 1975 to design, fabricate and checkout a load control system (LCS) for Space Shuttle External Tank structural tests. The contract period of performance initially covered eighteen (18) months; however, at MDAC request a forty-five (45) day extension was approved in order to complete the calibration, testing, and delivery of hydraulic valve components.

A schedule of major tasks is shown in Figure 1.0-1. The system was completed in October 1976, at which time MSFC personnel received training at MDAC facilities using the equipment in a test mode. Shipment of the system to MSFC was completed on November 23, 1976 without the hydraulic servo valves. These valves were subsequently shipped over a four-month period starting in February 1977. Interim checkout at MSFC was accomplished using servo valves of the same type loaned to MSFC from MDAC.

Load control system performance checkout on the load fixture for five channels (NAS8-31669 - paragraph 15 of Exhibit A, SCOPE OF WORK) was successfully completed by February 17, 1977. The subsequent qualification testing of the system per MSFC Hydraulic/Load Control Procedure SST-G-FAP-006, dated February 3, 1977 was successfully completed on April 8, 1977.

2.0 SYSTEM DESIGN DESCRIPTION

The load control system developed by MDAC for the MSFC Shuttle External Tank structural tests consists of two subsystem modules: 1) the load programming/display module, and 2) the load control module along with the following hydraulic system components: (a) servo valves, (b) dump valves, (c) hydraulic system pressure reducing stations, and (d) servo valve manifold blocks. One load programming/display subsystem module can support multiple load control subsystem modules.

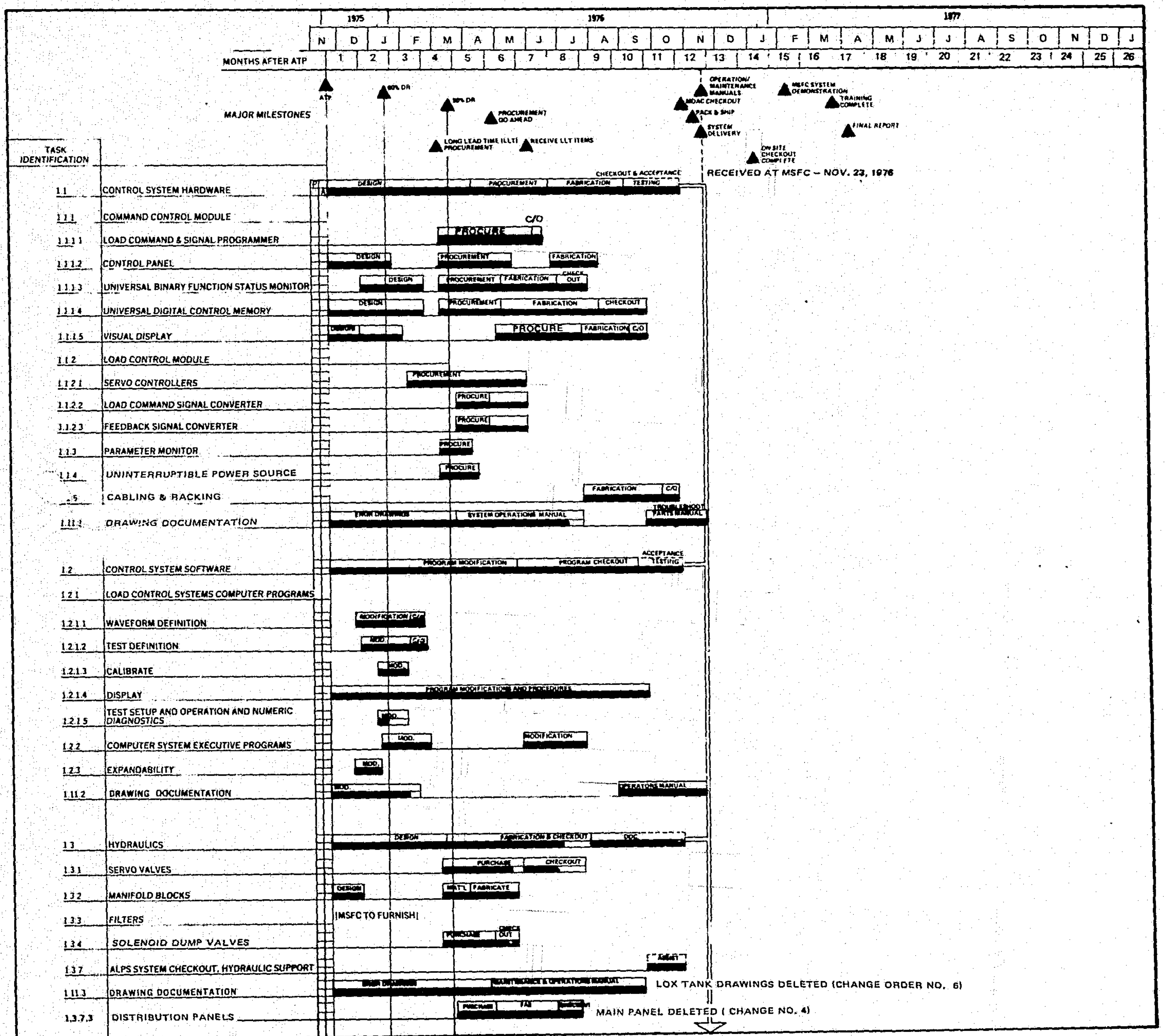


Figure 1.0-1 Program Summary Schedule

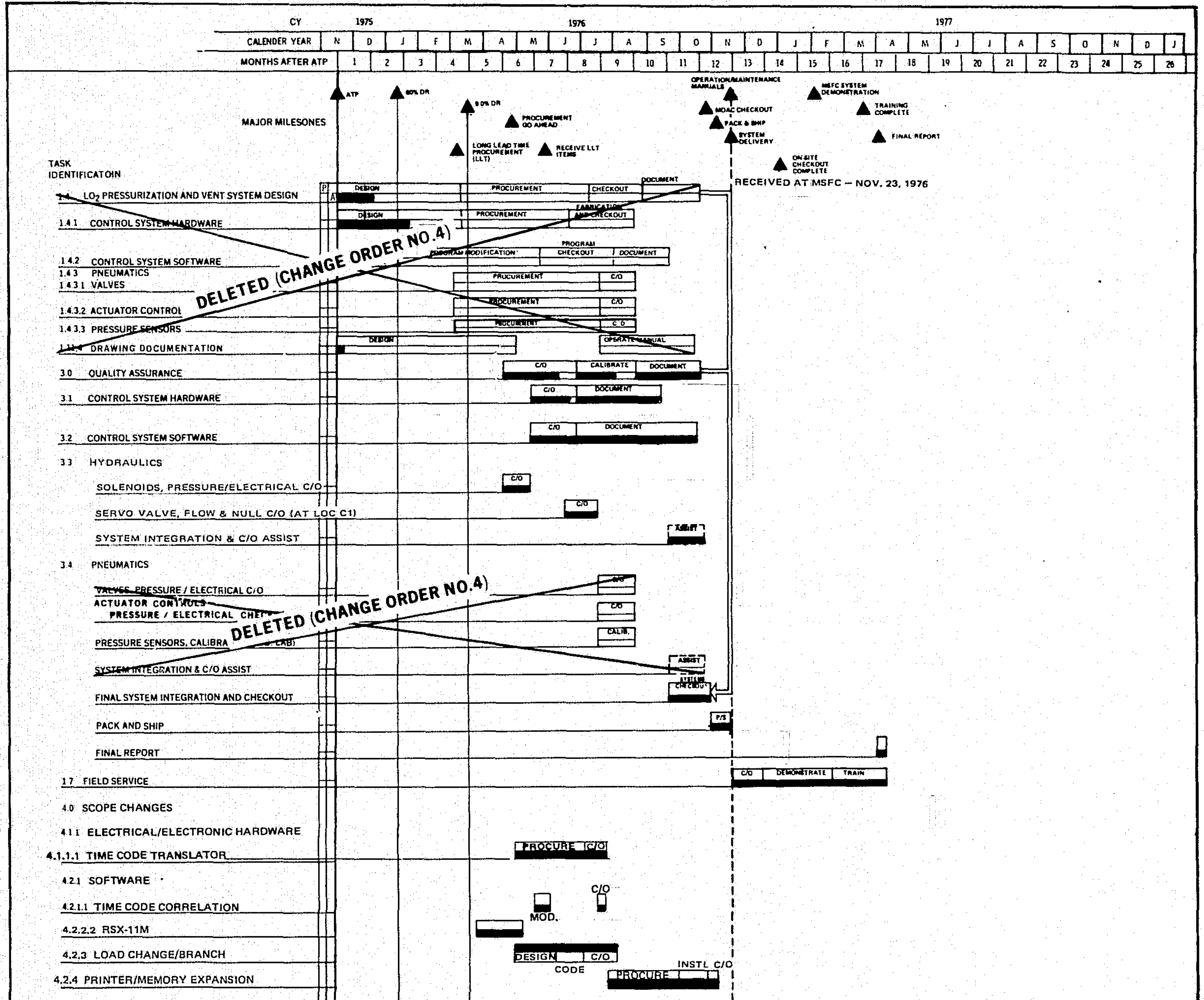


Figure 1.0-1 Program Summary Schedule (Continued)

The system hardware delivered to MSFC consists of one (1) load programming/display subsystem, three (3) load control subsystems, eighty (80) servo valves, one-hundred (100) dump valves, sixteen (16) pressure reducing stations, eighty (80) servo valve manifold blocks, and two (2) actuator positioners. The delivered hardware presently can control fifty-eight (58) load actuators and is configured to control seventy-five (75) load actuators with the addition of servo controllers only. A photograph of the load control system for Shuttle External Tank tests is presented in Figure 2.0-1.

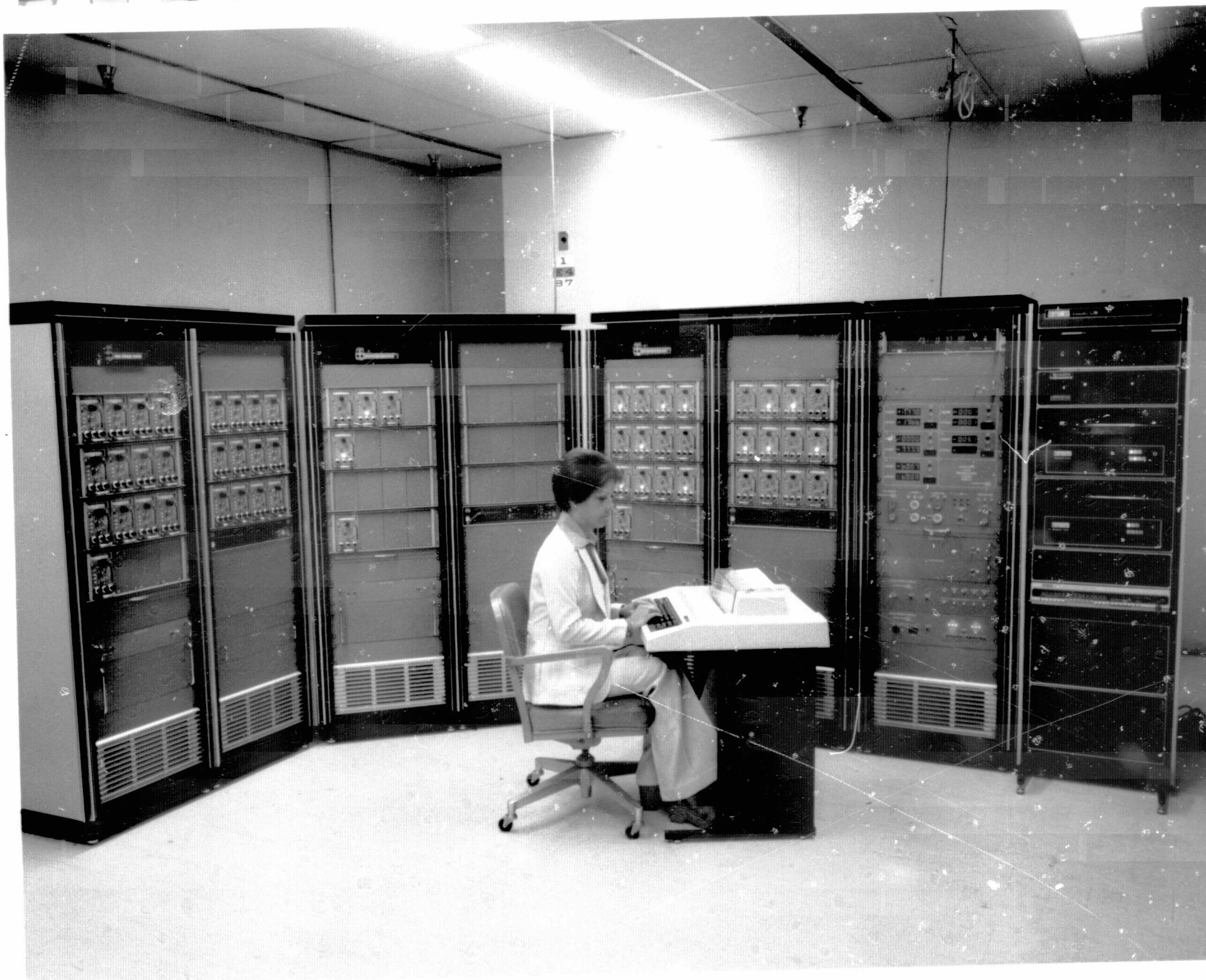
2.1 Load Programming/Display Subsystem

The load programming/display subsystem provides: 1) the media for inputting and storing the load programming scenario for each of the load actuators, 2) the communications paths for all inputs and outputs to the load control computer, 3) interfaces with the user to operate the system, 4) outputs of message and load information on numeric displays and printing devices, 5) control of the load system functions, and 6) correlation of loads data with test time-of-day. A photograph of this subsystem is presented in Figure 2.1-1.

2.1.1 Load Program Input and Storage

The load programming/display subsystem is formed around a Digital Equipment Corporation Model PDP-11 minicomputer wherein the loads are programmed to digital to analog converters (DAC). The DAC's in turn output analog voltage commands to the corresponding servo controllers that drive the hydraulic actuator servo valves.

The load command scenario is entered into the computer via a keyboard or magnetic tape cassette and stored on a mass storage removable disk pack device. The scenario, in general, describes the load segment end points, includes load channel calibration data and provides the load control computer with various operators that are used to: 1) control loading and unloading rates, 2) define load system actions when error conditions are detected, 3) define emergency safe test backout information for each load segment, and 4) indicate the load points that require hardcopy printout.



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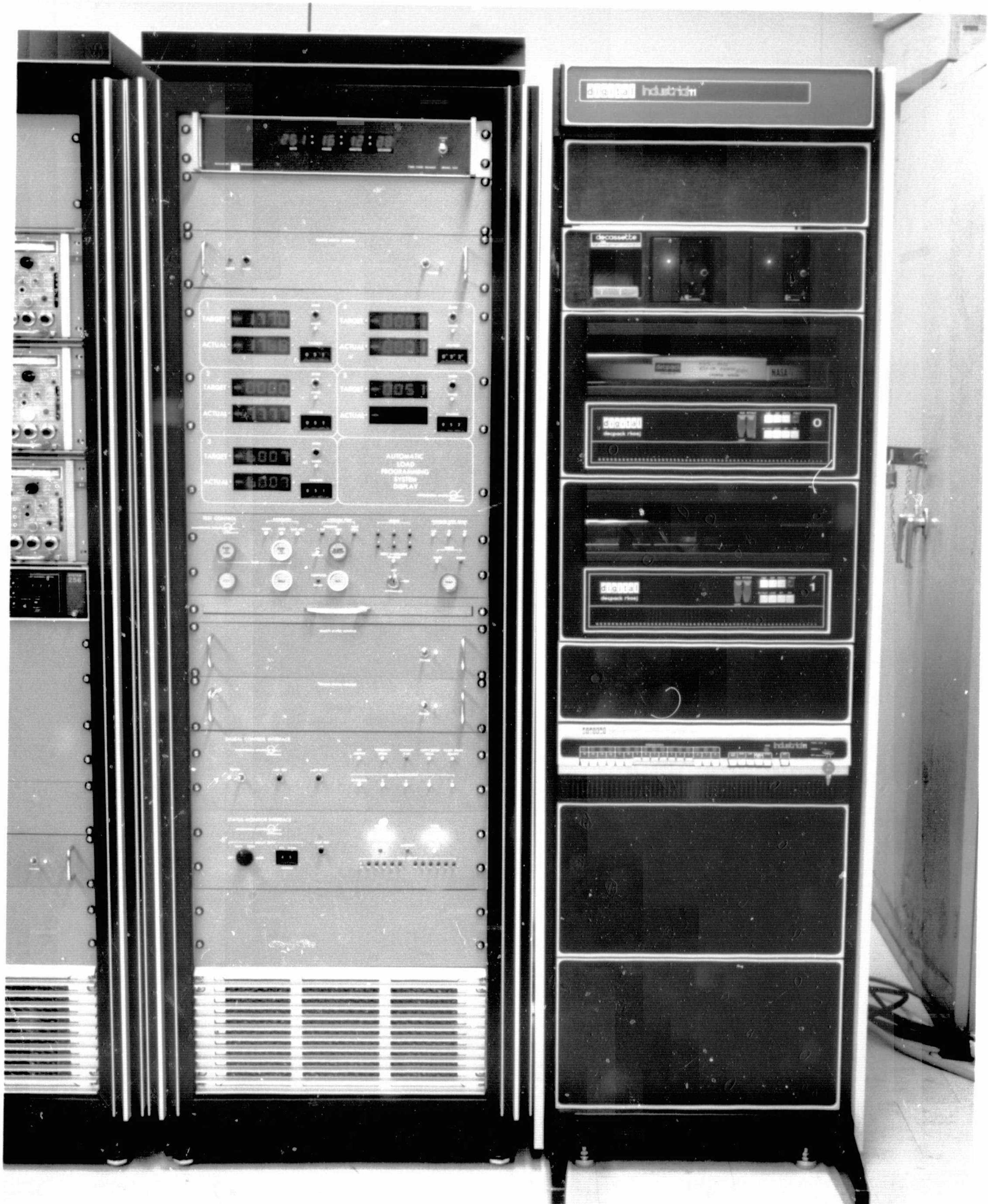

The load program scenario can be modified before and during test. These modifications to the loads scenario are permitted prior to test following the creation of a test file and during test at any hold point (end of a load segment end point).

2.1.2 Input and Output Communications

The load programming/display subsystem communicates with all other devices and equipment through a common parallel data bus. Each device connects to this bus in a "daisy chain" manner through an appropriate interface compatible with the load control computer. Each device is managed on this bus through a priority interrupt structure established within the computer operating system (RSX-11M).

Binary inputs and outputs that: 1) light the five channel display unit and the control panel functions, and 2) monitor the error detection functions of the servo controllers, the control panel, five channel display unit, and A-D and D-A converter operator functions are provided by Digital Control Memory (DCM) for outputs and Status Monitors (SM) for inputs. These devices are modularized as central and remote units. The central units, located in the load programming/display subsystem, communicate with the computer via the common bus and communicate with the remote units through independent wire cables.

2.1.3 Operator Interfaces

The user interfaces to the load programming/display subsystem through the following devices:

- Computer front panel switches for computer start up
- Keyboard/Printer for data entry and message output
- Line printer for loads data output
- Control panel for test command entries
- Engineering unit display panel for continuous monitoring of any selectable five loading channels

A conversational English language dialog has been developed to aid the user in communicating with the load control computer when using the keyboard/printer with the load control applications programs.

2.1.4 Displays and Printing Devices

Visual displays are incorporated into the load programming/display subsystem to provide the user with the capability to monitor continuously any selectable five loading channels and the corresponding end segment target loads. These displays present the loads data in engineering unit form.

Data used by the computer to display loads originates as an analog signal from the load cell attached to the load actuator and the load reaction structure. This analog output, conditioned in the servo controller and digitized by the multiplexer/analog digital converter of the load control module, is transmitted to the computer over the bus.

An additional capability built into the display panel permits the user to select any display to view the current loading segment number in execution and the next loading segment number to be executed.

There are two printing devices used in the load programming/display subsystem. One printing device is integral with the keyboard and is used to print the information input by the user and also to output all of the messages that originate from the load control programs or computer operating system. The second printing device is used exclusively to print the loads data. Consequently, the two printers in combination provide two continuous, uninterrupted logs of: 1) the message inputs and outputs emanating from one device, and 2) the printed loads data from the other.

2.1.5 System Control

The load programming/display subsystem provides the timely control and operation of the loading functions through software developed for the load control system computer. This software operates from the load program scenario input by the user.

The software is supplemented with a manual control panel interfacing to the computer to provide the operator with the functions to start and stop the load command outputs, and calibrate the system. The panel also includes switches to initiate emergency safe actions (i.e., Ramp-To-Load, Ramp-To-Zero, Load Dump), and provides monitors and alarms of control conditions (hydraulic oil pressure low, oil temperature high, slow down, inner error).

Under normal operations the load programming/display subsystem conducts the control functions automatically between load segment end points with only an action required by the operator at the control panel to initiate the start. However, the functions on the control panel provide the manual "override" in the event operator intervention is desired.

2.1.6 Loads Correlation

The test universal master time, originating from an IRIG-B time code generator, is input to the load programming/display subsystem and output with all messages and loads data appearing on the message and loads printers. A time code translator with a visual display is incorporated into the system for operator use.

2.2 Load Control Subsystem

The load control subsystem modules provide closed loop control with the servo valves and, in addition, house the following equipment: 1) the digital to analog conversion systems which transform the digital load control command to an analog signal, 2) the analog to digital conversion systems which convert the analog load cell feedback signals to a digital form for processing by the digital computer, and 3) the servo controllers which operate the hydraulic servo valves.

Each of the three load control subsystem modules furnished in the NASA MSFC system is wired to accommodate twenty-five (25) servo controllers and twenty-five (25) load cell feedback channels. A photograph of a load control subsystem module is presented in Figure 2.1.2-1.

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2.2.1 Analog to Digital Conversion

The electrical analog signals generated from the load cell transducers are multiplexed and converted to digital form by the analog to digital conversion system (ADC). The ADC, housed in the same chassis as the DAC's, shares the common bus interface to the computer with the digital to analog converters. The digitized load cell data are utilized by the computer to compare against acceptable tolerance values established for the test as well as display and print load values in engineering unit form for operator and analyst interpretation.

2.2.2 Digital to Analog Conversion

The load control digital command signals generated in the computer of the load programming/display subsystem are transmitted over the common bus to addressable digital to analog converters (DAC). The converters transform the digital command into analog electrical signals scaled to the acceptable range of the servo controllers. The output of each DAC is hardwired to the respective servo controller command input terminal.

2.2.3 Servo Controllers

As many as twenty-five (25) servo controllers can be installed in each of the load control subsystems. Each servo controller is independently hardwired to: 1) the servo valve for command control, 2) the load cell for load signal feedback, 3) the digital to analog conversion system for command control input and update, and 4) the analog to digital conversion system for load cell feedback input to the computer.

The servo controllers (DATUM Model 2116) provide the closed loop electrical control of the hydraulic actuator servo valves. All adjustments and setup of the servo controller with the servo valve are performed manually, using the adjustments, switches and meter provided with the instrument.

Signal conditioning and calibration circuitry for the load cell is also contained within the servo controller.

2.2.4 Actuator Positioner

Two MDAC designed actuator positioners are provided with the load control system. This equipment, operating on batteries, allows the user to control the servo valve to manually position the load actuator extension rod independently of the load control system. A photograph of this device is shown in Figure 2.2.4-1.

2.3 Hydraulic System Components

The hydraulic system components delivered with the load control system provide flow regulation, pressure reduction and pressure dump to the hydraulic loading system. This equipment includes eighty (80) servo valves, one-hundred (100) hydraulic pressure dump valves, and sixteen (16) pressure reducing stations. Although these components are located in the hydraulic system they interface to the load control system electrically and/or provide hydraulic system safety. Eighty (80) servo valve mounting block manifolds are also provided.

2.3.1 Servo Valves

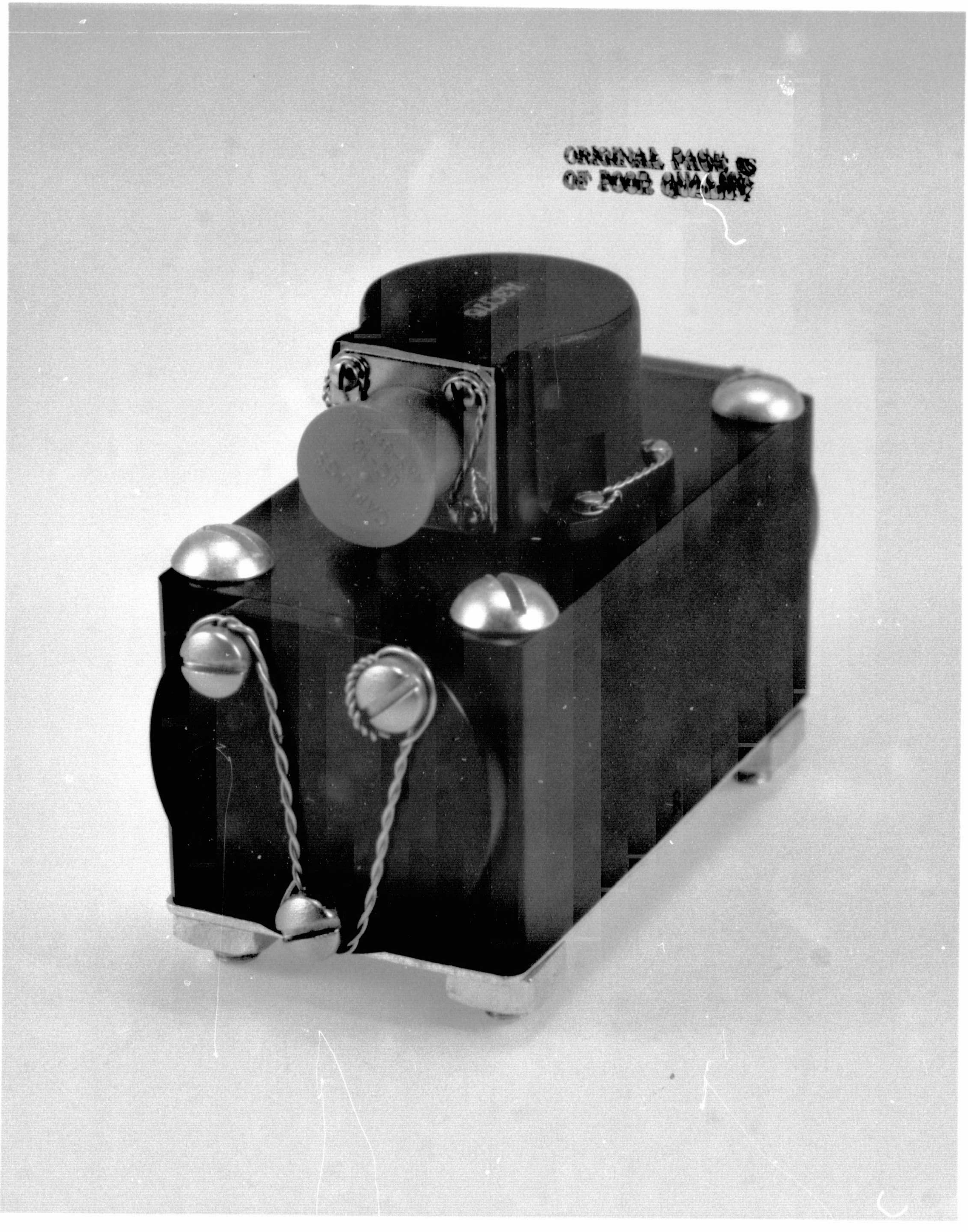
Fifty-four 10 GPM and twenty-six 25 GPM servo valves are provided with the system. The servo valve regulates the flow of hydraulic fluid to both sides of the load actuator piston. These valves are mounted on manifold blocks (also a delivered end item) that deliver and distribute the hydraulic oil source to the proper devices. A photograph of a typical ABEX servo valve is shown in Figure 2.3.1-1.

Each servo controller in the load control subsystem is hardwired electrically to a servo valve, and through this hardwired electrical connection the servo valve is operated.

2.3.2 Pressure Reducing Stations

Sixteen pressure reducing stations, provided with the load control system, are utilized to regulate and maintain a reduced hydraulic system pressure (< 5000 PSI) at distributed points in the hydraulic oil lines near the test load line locations. Each pressure reducing station feeds a group of


ACTUATOR POSITIONER
TENSION
COMPRESSION
LOAD
INCREASE
RATE



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load lines all of which require approximately the same maximum pressure to obtain the required test maximum load. A drawing of the pressure reducing station is presented in Figure 2.3.2-1.

2.3.3 Pressure Dump Valves

One-hundred solenoid operated normally closed hydraulic oil dump valves are delivered with the load control system. These valves can electrically interface to the load control system through a single relay closure that activates all valves simultaneously. The dump valves provide a measure of safety for the test article and they can be activated manually from the load control system control panel or automatically from the computer. A photograph of a typical solenoid dump valve is shown in Figure 2.3.3-1.

2.4 Software Design

The software that has been implemented in the load control system consists of: 1) computer vendor supplied systems software, and 2) MDAC developed applications programs.

2.4.1 System Software

The system software provided includes the Operating System (RSX-11M), compilers, assemblers, utility programs and the diagnostic test programs. This set of software (itemized in Figure 3.5-1) was provided by the computer supplier.

The general purpose nature of the system software permits the user to develop the applications programs and operate these programs under the control of a real time multiprogramming operating system.

RSX-11M Version 2 is the real time operating system installed in the load control system computer. The RSX-11M operating system has been built to contain the specific program partitions, address pointers and common routines required to operate the load control system.

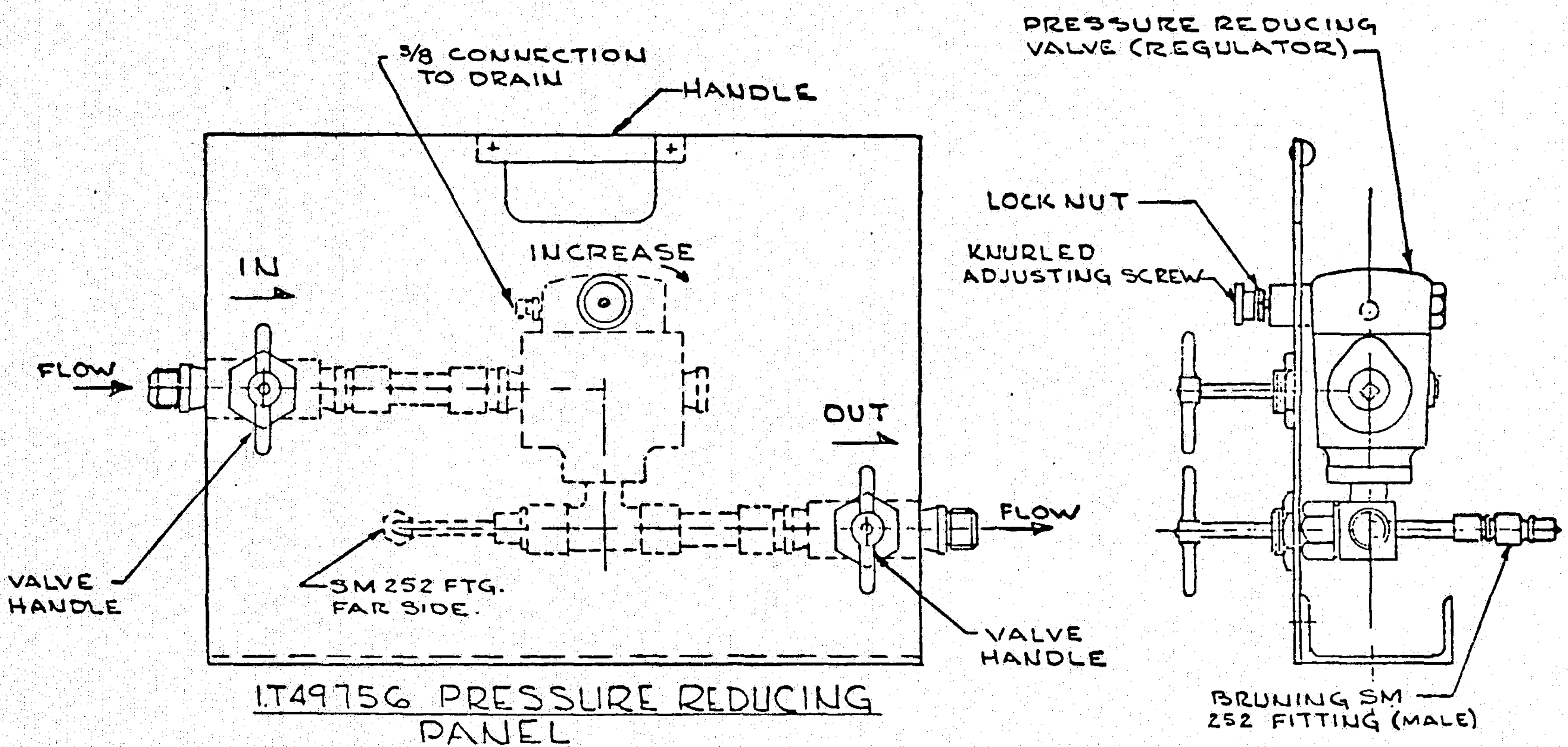
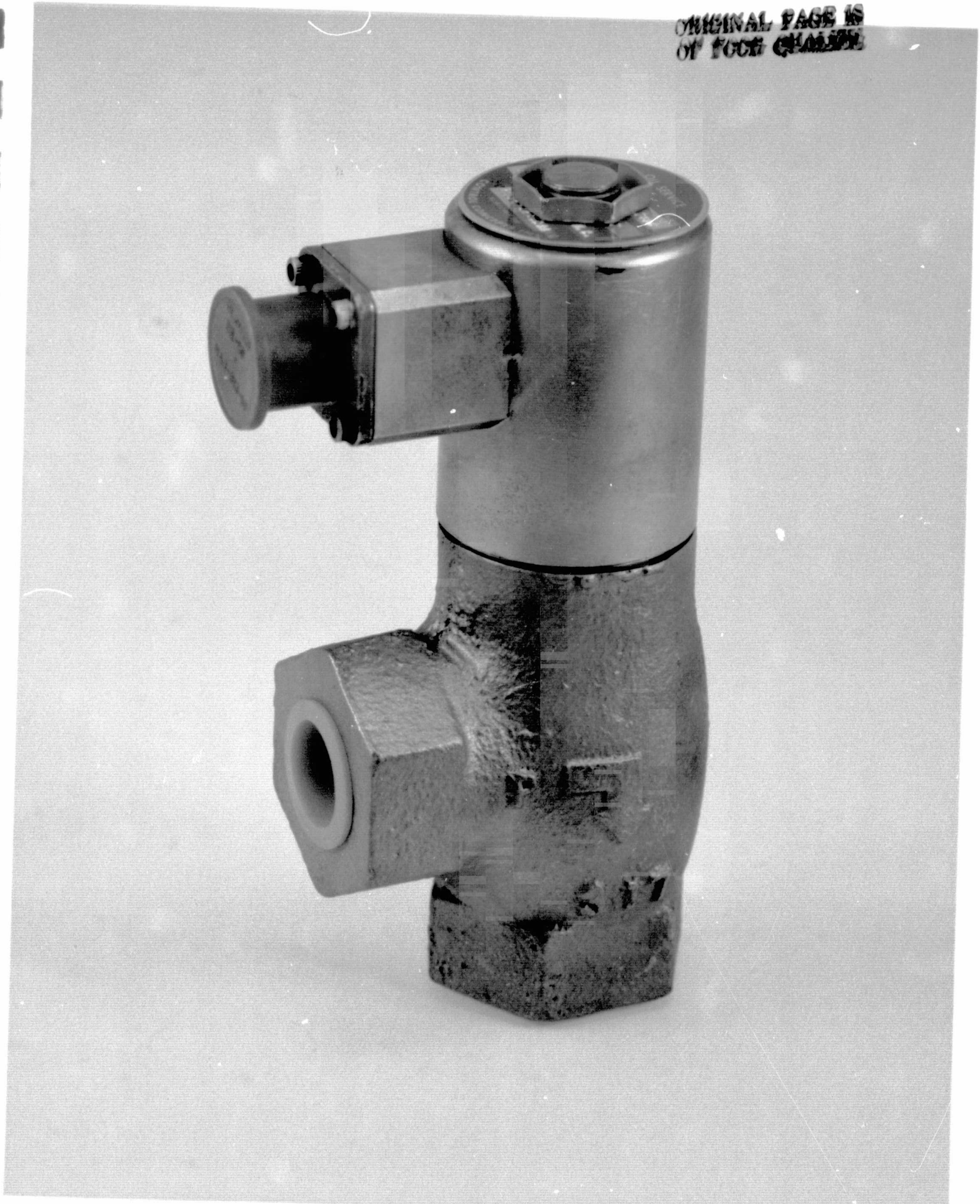


Figure 2.3.2-1 Pressure Reducing Station



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The current baseline version of this system, along with the applications programs is stored on disk packs. Several disk copies of the baseline version are retained as backup both at MSFC and MDAC.

2.4.2 Applications Programs

The load control system applications programs were written in MACRO 11 assembly language. Seven main programs were generated to provide the user with the capability of conducting a static structural test using the MDAC Load Control System. These seven basic programs, documented in the Operations/Documentation Manual Test Software (MDC G6590), are identified as follows:

M001 - TEST MAKE
M002 - TEST MODIFY
M003 - TEST PRINTOUT
M004 - TEST RUN
M005 - DATA PRINTOUT
M006 - BRANCH
M007 - TEST SAVE AND RESTORE

Two additional programs were developed. A diagnostic program called CHECK was written to test the analog to digital converters as well as the manual operator settings of the servo controller inner and outer error. The other program, called DACT, allows the user to calibrate the analog to digital converters.

All of the applications programs reside on disk and are callable automatically by other programs during test and also callable by the user from the console keyboard/printer. An English language interactive dialog provides communication between the user and each of these programs.

2.4.2.1 M001 - TEST MAKE Program

M001 was written to allow the user to create a test definition file on the disk. All of the static structural test parameters are entered via the console keyboard using this program.

2.4.2.2 M002 - TEST MODIFY Program

M002 was written to allow the user to change information in a test file that has previously been generated.

2.4.2.3 M003 - TEST TYPEOUT Program

M003 allows the user to obtain a line printer listing of all the parameters in the test definition file. This program was designed to run while a test is in a run status.

2.4.2.4 M004 - TEST RUN Program

M004 initializes the test run, opens the test definition file, starts the calibration procedure, runs the test and disarms all functions and exits at the end of a test.

2.4.2.5 M005 - DATA PRINT Program

M005 reads the digital data input by the analog to digital converters, calibrates the data and prints the data scan on the line printer.

2.4.2.6 M006 - BRANCH Program

M006 allows the operator to branch to any previously defined load segment in the test definition file. This program can also end a test, calculate the largest excursion for all channels (% of design limit) when a branch is requested and print the largest excursion data for user evaluation.

2.4.2.7 M007 - TEST SAVE AND RESTORE Program

M007 allows the user to save a copy of the test file on a cassette tape or restore a test file to disk from a cassette tape.

3.0 SCOPE OF WORK PERFORMED

The scope of work defined under Contract NAS8-31669 initially specified the following two major efforts:

a. Provide a load control system for Marshall Space Flight Center to be used in performing structural load tests on various sub-assemblies of the Shuttle External Tank (ET).

b. Design a load control system to be used in performing structural load tests on various sub-assemblies of the Space Shuttle Solid Rocket Booster (SRB).

Subsequent modifications to the contract that changed the scope of work are outlined in Section 3.4.

3.1 30% Design Review

Work commenced on the LCS contract on November 14, 1975. An informal design review (30%) was conducted at MSFC on December 1 and 2, 1975. The minutes of this review were documented in NASA Letter ET27-75-27, dated December 5, 1975.

New requirements were discussed in this informal design review and MDAC was directed to propose methods at the next design review (60%) for providing: 1) time of day correlation between control functions and the data system, and 2) control of the SRB attach point load beam so that it would not rotate more than $\pm$ 1.5° during application of loads.

Drawings and documentation for the Intertank and LH_2 Tank tests were provided to MDAC at this time and MDAC was directed to make calculations for line and valve size requirements for the LOX Tank pressurization system as well as loading and unloading time for each hydraulic actuator based on line and valve sizes MSFC expected to use on the LH_2 and Intertank tests. These calculations were presented at the 60% design review.

Concept changes were discussed at the 30% design review with regard to location of the servo valve off of the actuator, the regulation of pressure for each load line using a simpler version of the pressure reducing station than originally proposed by MDAC, and configuring the solenoid dump valves to operate on 28 VDC, be hermetically sealed and normally closed (power required to open the valve).

3.2 60% Design Review

The 60% design review was conducted on January 19 and 20, 1976 at MSFC. Technical comments on the design review are contained in NASA Letter ET27-76-2, dated January 27, 1976.

The calculations of the hydraulic system loading and unloading times, summarized in Figure 3.2-1, were presented. A sketch of the pressure reducing station (MDAC 1T49756) was submitted and not approved. MSFC requested that MDAC provide a simplified version of the secondary pressure reducing station that did not contain the pressure switch or pressure gage.

By MSFC request, MDAC stopped all design work on the primary hydraulic distribution panel. MSFC would supply the dump valves for the main system as well as the pressure regulation system.

Minor changes were requested to the manual control panel that included: 1) provisions for external stimuli to interface with the STOP, HOLD, RAMP TO LOAD, and RAMP TO ZERO functions, 2) separate external relay contact closures for dump and outer error in place of a common relay closure, and 3) a squelch switch for the audible alarm.

MDAC proposed a time code translator installation that obtains the code from the time code generator supplied by the data system. Time of day would be tagged to each message and data printout and would appear on a visual display.

A design concept was presented to MSFC for the control of the SRB attach point load beam within $\pm$ 1.5° of horizontal. This proposal, diagrammed in Figure 3.2-2, used two displacement transducers, one at each end of the load beam. These transducers output signals, forming two legs of a bridge, are inputs to a summing amplifier which in turn is coupled to the two load beam load cell excitation voltage sources. Any difference signal would cause a change in the excitation voltage to the load cells, causing a proportionate change to the servo controller feedback signals and appropriate adjustments to each of the two load actuators.

LH$_2$ TANK TEST

TIME TO UNLOAD FROM 140% TO 100% (CALCULATED VALUES)

LOAD PT	ACT IN	MODE T-C	AREA SQ. IN	DEFL IN	PMAX PSI	VALVE SIZE	FLOW THRU VALVE GPM	PRESS LOSS					PRESS FINAL PSI	TIME SEC
								LINE SIZE IN	ΔP LINE	JACK ORIF	ΔP ORIF	TOTAL		
FB1	12	T	89.34	.3	3093	10	17.8	3/4	218	3/8	100	318	2209	.13
FB2	12	T	89.34	.4	3144	10	17.9	3/4	218	3/8	100	318	2246	.17
FB3*	12	C	113.1	.5	3222	10	18.1	3/4	220	3/8	100	320	2301	.26
FB4*	12	C	113.1	.5	3014	10	17.6	3/4	217	3/8	100	317	2217	.25
FB5A	33	T	701.4	.8	955	25	20.1	1	64	1/2	44	108	682	2.41
5B	33	T	701.4	.8	955	25	20.1	1	64	1/2	44	108	682	2.41
6A	33	T	701.4	.8	955	25	20.1	1	64	1/2	44	108	682	2.41
6B	33	T	701.4	.8	955	25	20.1	1	64	1/2	44	108	682	2.41
FB7A*	14	C	153.4	4.8	2659	25	33.6	1	182	3/8	250	432	1899	1.96
FB8A*	14	C	153.9	4.17	2659	10	16.7	3/4	183	3/8	100	283	1899	3.23
FB8B	10	T	62.64	4.17	1683	10	13.8	3/4	134	3/8	60	194	1202	1.60
FB9A*	12	C	113.1	5.5	2821	10	17.1	3/4	186	3/8	100	286	2015	3.05
FB10A*	12	C	113.1	5.7	2821	10	17.1	3/4	186	3/8	100	286	2015	3.16
FB9B*	14	T	115.5	5.0	3323	10	18.3	3/4	220	3/8	115	335	2374	2.64
FB10B*	14	T	115.5	4.7	3323	10	18.3	3/4	220	3/8	115	335	2374	2.48
FO1*	12	C	113.1	2.1	1728	10	13.9	3/4	134	3/8	65	199	1231	1.45
FO2A&B	8	C	40.65	.9	2074	10	15.0	3/4	144	3/8	75	219	1481	.20
FO3*	16	C	201.1	4.3	2892	25	35.0	1	186	3/8	270	456	2066	2.20
FO4*	16	C	201.1	4.4	3133	25	36.5	1	210	3/8	280	490	2238	2.16
FO5*	10	C	78.54	5.7	1939	10	14.6	3/4	141	3/8	70	211	1385	2.58
FO7	30	C	706.9	1.5*	1366	25	24.08	1	71	1/2	65	136	976	3.74
FO8	30	C	706.9	1.5*	1353	25	24.08	1	71	1/2	65	136	966	3.77
FSS2Y A&C	7	T	28.86	.4	2377	10	15.9	3/4	180	3/8	90	270	1698	.06
FSS3Y A&C	7	T	28.86	2.9	2377	10	15.9	3/4	180	3/8	90	270	1698	.44
FSS4Y A-C	7	T	28.86	.6	2377	10	15.9	3/4	180	3/8	90	270	1698	.09
FSS4Z A&C	7	T	28.86	2.8	2425	10	16.0	3/4	180	3/8	90	270	1732	.43

*DOUBLE ENDED

140% - 100%
MAX. UNLOADING TIME - 3.77 SEC FO8
MDAC RECOMMENDATION - 7.54 SEC.

LH$_2$ TANK TEST TABLE 1

Figure 3.2-1 Calculations of System Loading and Unloading Times

INTERTANK TEST

TIME TO UNLOAD FROM 140% TO 100% (CALCULATED VALUES)

LOAD PT.	ACT. IN.	AREA SQ. IN.	MODE T-C	DEFL. IN.	PMAX. PSI	VALVE SIZE	FLOW THRU VALVE GPM	PRESS LOSS					FINAL PRESS PSI	TIME SEC
								LINE SIZE	ΔP LINE	ORIF SIZE	ΔP ORIF	ΔP TOTAL		
1 thru 24	12	113.1	C	.739	1989	10	14.8	3/4	144	3/8	75	219	1421	.48
25-27	6	18.65	T	.84	1817	10	14.2	3/4	136	3/8	70	206	1298	.09
26-28	6	18.65	T	.84	3158	10	17.9	3/4	214	3/8	112	326	2256	.07
29-31	12	89.34	T	1.162	2017	10	14.9	3/4	144	3/8	75	219	1441	.59
30-32	12	89.34	T	1.162	1104	10	11.5	3/4	93	3/8	45	138	789	.76
33	12	89.34	T	.42	3268	10	18.2	3/4	220	3/8	115	335	2334	.17
34	8	34.37	T	.42	2962	10	17.5	3/4	203	3/8	110	313	2116	.07
35	12	89.34	T	.398	3268	10	18.2	3/4	220	3/8	115	335	2334	.16
36	8	34.37	T	.398	2756	10	16.9	3/4	191	3/8	100	291	1968	.07
37	12	113.1	C	.262	2082	10	15.1	3/4	144	3/8	77	221	1487	.17
38	12	113.1	C	.64	2104	10	15.1	3/4	144	3/8	77	221	1503	.40
39	30	552.9	T	.87	2257	25	30.9	1	150	1/2	110	260	1612	1.35
40	30	552.9	T	.87	2257	25	30.9	1	150	1/2	110	260	1612	1.35
41	30	552.9	T	.605	1854	25	28.0	1	126	1/2	90	216	1324	1.03
42	30	552.9	T	.605	1854	25	28.0	1	126	1/2	90	216	1324	1.03
43	8	50.26	C	.442	3184	10	18.1	3/4	218	3/8	115	333	2274	.10
44	7	28.86	T	.360	3234	10	18.0	3/4	219	3/8	115	334	2310	.05
45	7	28.86	T	.360	3333	10	18.3	3/4	222	3/8	116	338	2381	.05
46	10	62.64	T	.253	1653	10	13.7	3/4	136	3/8	65	201	1181	.10
47	10	62.64	T	.253	1653	10	13.7	3/4	136	3/8	65	201	1181	.10

MAX. TIME = 1.35 SEC. LOADS 39 & 40
MDAC RECOMMENDATION = 2.20 SEC.

INTERTANK TEST TABLE 2

Figure 3.2-1 Calculations of System Loading and Unloading Times (Continued)

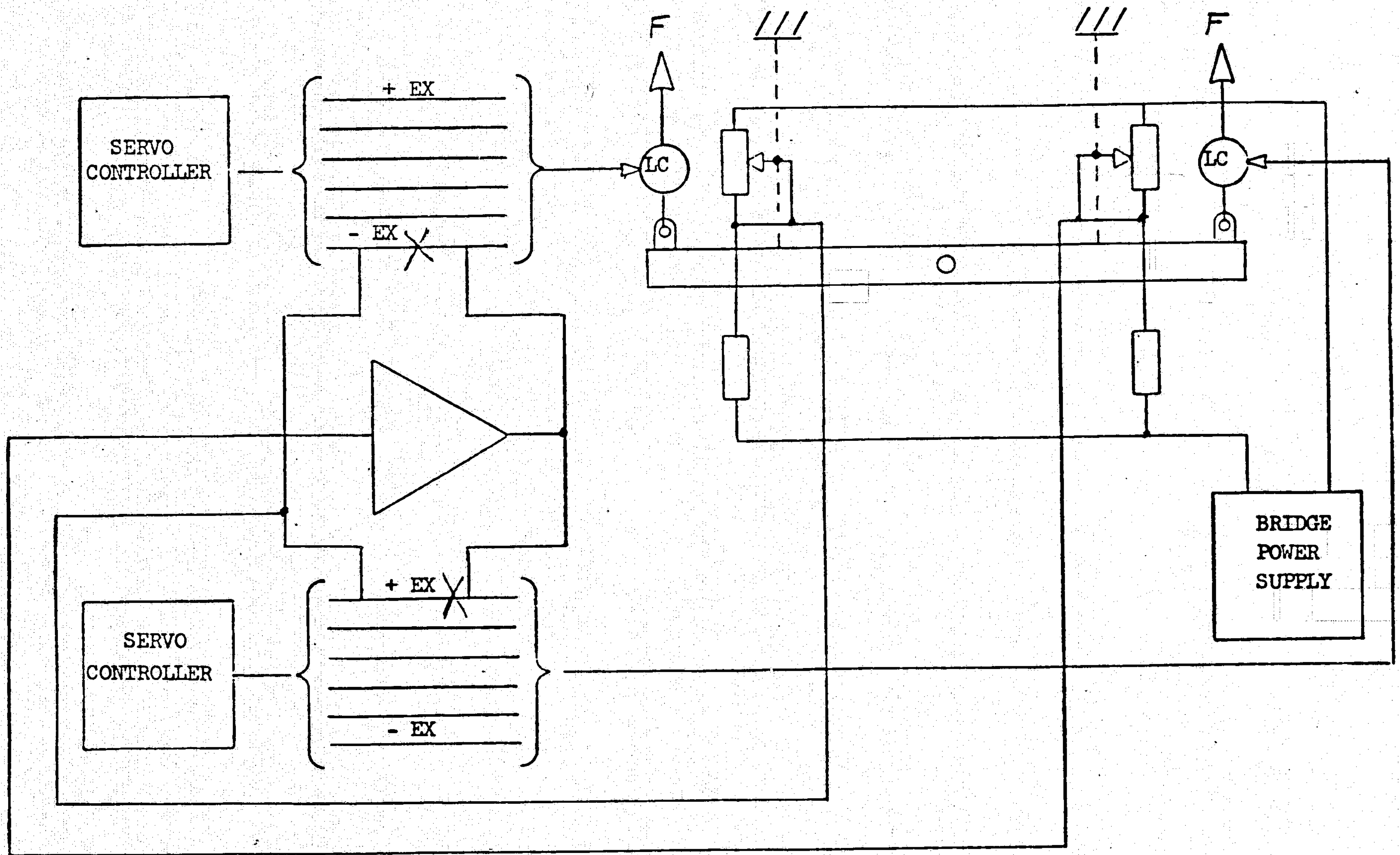

Figure 3.2-2 Diagram of Load Beam Control System

3.3 90% Design Review

The 90% design review occurred on March 15 and 16, 1976 at MSFC. Salient design concepts and changes reflected in the design review that affected the scope of work on the overall load control system design included the following:

1. Sixteen (16) simplified pressure reducing stations were proposed by MDAC in lieu of the original five (5) stations previously quoted.
2. A selectable upper limit load warning feature was proposed by MSFC as a safeguard feature for the load control system.
3. Greater flexibility was requested by MSFC in changing the load programming for each actuator during test. These changes would: (a) allow new load values to be inserted in a test segment, (b) allow new segments to be inserted into the test profile, and (c) permit branching from any segment to any other segment.

3.4 Contract Change Orders and Supplemental Agreements

The basic contract underwent twenty (20) amendments or modifications during the contract lifetime. These modifications are identified as follows:

AMENDMENT/ MODIFICATION	DESCRIPTION
#1	Deleted International System of Units.
#2	Deleted load control system design for the Solid Rocket Booster.
#3	MDAC to loan MSFC ABEX servo valves.
#4	a. Deleted the main hydraulic distribution panel. b. Added requirement to furnish time correlation with test data using a time code translator. c. Replaced proposed computer operating system (RSX-11A) with more current version (RSX-11M).

AMENDMENT/ MODIFICATION	DESCRIPTION
	d. Deleted all LOX tank pneumatic pressurization system requirements.
	e. Added SRB attach point load beam control requirement.
#5	Deleted SRB attach point load beam control requirement.
#6	Agreed that estimated cost and fee will not be affected by changes 1 and 3.
#7	a. Deleted LOX tank hydraulic system schematic.
	b. Added requirement to modify software that allows: (1) new load values to be inserted in a test segment, (2) new segments to be inserted in a test load profile, and (3) branching from any segment to any other segment.
#8	Agreed to cost adjustments for modifications 4 and 5.
#9	Added servo valve training course.
#10	Correction of an administrative error on modification #8.
#11	Agreed to cost adjustments for modification #7.
#12	Added line printer and additional computer memory.
#13	Amended the wording of modification #12.
#14	Agreed to cost adjustments for modification #9.
#15	Correction to cost adjustments stated in modification #14.
#16	Agreed to cost adjustments for modifications #12 and #13.
#17	Amendment to general provision clause for financial reporting of Government-owned/Contractor-held property.

AMENDMENT/ MODIFICATION	DESCRIPTION
#18	Agreed to cost adjustments to fund projected overrun.
#19	Amendment to Article XVIII - Contents of Contract.
#20	Agreed to extend contract end date to June 30, 1977.

3.5 Documentation

The documentation provided with the load control system consists of a combination of MDAC and Vendor supplied engineering drawings and manuals. A list of the documentation package provided with the load control system is shown in Figure 3.5-1.

Other documentation provided to MSFC during the contract period included:

a. ALTERNATE WIRING METHOD FROM LOAD CELL TO SERVO CONTROLLER - MDAC Letter A3-13E-118, dated 27 January 1976.

b. TRANSMITTAL OF MDAC SILKSCREENING PROCESS - DPS 40250 - MDAC Letter A3-13E-479, dated 19 April 1976.

c. PRELIMINARY DESIGN DOCUMENTATION FOR SELECTIVE LOAD CHANGE - MDAC Letter A3-13E-622, dated 14 May 1976.

d. RECOMMENDED CLEANING SPECIFICATION FOR HYDRAULIC COMPONENTS - MDAC Letter A3-13E-447, dated 12 April 1976.

e. PROCEDURES FOR TEST ADJUSTMENT AND CHECKOUT OF HYDRAULIC ASSEMBLIES - MDAC Letter A3-130-RCE-1667, dated 30 July 1976.

f. DATUM MODEL 2116 SERVO CONTROLLER BURN IN PROCEDURE - MDAC Letter A3-13E-1218, dated 4 October 1976.

LOAD CONTROL SYSTEM DOCUMENTATION

SOFTWARE - MDC G6590 - OPERATING/DOCUMENTATION MANUAL TEST SOFTWARE - REVISED APRIL 1, 1977

System Software

DEC-11-UDEBA-A-D - DOS/BATCH Debugging Program (ODT-11R) Programmers Manual

DEC-11-UEDAA-A-D - DOS/BATCH Test Editor (EDIT-11) Programmers Manual

DEC-11-UPPAA-A-D - DOS/BATCH Utility Package (PIP) Programmers Manual

DEC-11-OCCMA-A-D - DOS/BATCH Concepts and Capabilities

DEC-11-LASMA-A-D - DOS/BATCH Assembler, (MACRO) Programmers Manual

DEC-11-OBUGA-A-D - DOS/BATCH, Batch Users Guide

DEC-11-ULKAA-A-D - DOS/BATCH, Linker (LINK) Programmers Manual

DEC-11-IRSAA-A-D - RSX11A Programmers Reference Manual

PRELIMINARY DOCUMENT - RSX-11A Plus FORTRAN

HYDRAULICS - MDC G6591 - OPERATING MAINTENANCE MANUAL HYDRAULICS - NOVEMBER 1976

Hydraulics System Schematic

MDAC 1T49750 - ALPS Hydraulic Schematic (General)

MDAC 1T49751 - Intertank Test Schematic - Hydraulic & Electrical

MDAC 1T49752 - LH_2 Tank Test Schematic - Hydraulic & Electrical

Pressure Reducing Panel

MDAC 1T49755 - ALPS Main Pressure Distribution Panel

MDAC 1T49756 - ALPS Pressure Reducing Station

MDAC 1T49757 - Actuator Positioner, ALPS

Servo Valve Assembly

MDAC 1T49759 - Manifold Block, Servo Valve - 10 GPM

MDAC 1T49760 - Manifolf Block, Servo Valve - 25 GPM

MDAC 1T49762 - Cleaning Specifications - Hydraulic Components & Assemblies

MDAC 1T49763 - Procedures, Proof & Operation Test - ALPS Hydraulic Assemblies

MDAC 1T49764 - Procedures, Adjustment & Checkout - ABEX Servo Valves

ABEX - Model 415-1756 Servo Valve Schematic

ABEX - Model 425-1757 Servo Valve Schematic

Figure 3.5-1 LCS Documentation List

Control Hardware

MDAC 1T49700 - Logic Flow Schematic, ALPS
MDAC 1T49701 - Load Control Module Assembly, ALPS
MDAC 1T49702 - Relay Panel Assembly, ALPS
MDAC 1T49703 - Schematic, Relay Panel, ALPS
MDAC 1T49704 - Command Controller Assembly, ALPS
MDAC 1T49724 - Installation Drawing, ALPS
MDAC 1T49725 - Rack Cabling, Load Control Module, ALPS
MDAC 1T49726 - Rack Cabling, Command Control Module

Visual Display

MDAC 1T49705 - Display Panel Assembly, ALPS
MDAC 1T49708 - Display Drill and Silkscreen, ALPS
MDAC 1T49729 - Wire List, Display Panel, ALPS

Control Panel

MDAC 1T49706 - Control Panel, Drill and Silkscreen, ALPS
MDAC 1T49707 - Control Panel Assembly, ALPS
MDAC 1T49709 - Schematic, Control Panel, ALPS

Status Monitor/Digital Control Memories

MDAC 1T49710 - Status Monitor Central Station Assembly, ALPS
MDAC 1T49711 - Status Monitor Central Chassis, ALPS
MDAC 1T49712 - Status Monitor Panel, Drill and Silkscreen, ALPS
MDAC 1T49713 - Status Monitor Remote Station Assembly, ALPS
MDAC 1T49714 - Diagram Status Monitor, ALPS
MDAC 1T49715 - Module Layout, Status Monitor, ALPS
MDAC 1T49732 - Front Panel Remote Stations, ALPS
MDAC 1T49723 - Status Monitor and Digital Control Assignments, ALPS
MDAC 1T49716 - Digital Control Central Station Assembly, ALPS
MDAC 1T49717 - Digital Control Central Chassis, ALPS
MDAC 1T49718 - Digital Control, Panel Drill and Silkscreen, ALPS
MDAC 1T49719 - Digital Control, Remote Station Assembly, ALPS
MDAC 1T49720 - Logic Diagram, Digital Control Memory, ALPS
MDAC 1T49721 - Module Layout, Digital Control Memory

Figure 3.5-1 LCS Documentation List (Continued)

Power

MDAC 1T49727 - Power Distribution, Load Control Module, ALPS

MDAC 1T49728 - Power Distribution, Command Controller, ALPS

MDAC 1T49730 - UPS Power Distribution, ALPS

MDAC 1T49731 - Power Supply Panel Assembly, ALPS

ELGAR - UPS Remote Alarm Schematic

ELGAR - UPS Remote Alarm Assembly

Computer

DEC Not Numbered - PDP-11/05-10-35-40 Processor Handbook

DEC Not Numbered - PDP-11 Peripheral Handbook

DEC Not Numbered - LA180 Maintenance Manual

DEC Not Numbered - LA180 Users Manual

D/A - A/D Converter

DATEL 2561 - PDP-11-1-2 - D/A Data Register and Unibus Buffer

DATEL 2561 - PDP-11-1-2 - A/D Final and Start Channel Register

DATEL 2561 - PDP-11-1-2 - D/A Final and Start Channel Register

DATEL 2561 - PDP-11-1-2 - A/D Data Register and Unibus Buffer

DATEL 2561 - PDP-11-1-2 - Address Select Gating

DATEL 2561 - PDP-11-1-1 - S256 Control (2 Sheets)

DATEL 2561 - PDP-11-2-1 - Block Transfer Interface (5 Sheets)

DATEL Not Numbered - Unibus Bus Data and Buffered Data (Option)

DATEL Not Numbered - Unibus Mem. Addr. Lines (Block Trans. Option)

DATEL Not Numbered - S-256 I/O Connector Data and Address (Basic Option)

DATEL Not Numbered - Back Panel PDP-11 Interface Control Signals (2 pages)

DATEL Not Numbered - BR and NPR Level Wiring and Modification Guide (M7821

DATEL MCMBM0401 - System 256 Combination A/D - D/A Instruction Manual

DATEL MDABM01401 - System 256 Data Distribution Instruction Manual

DATEL MADEM01401 - System 256 Data Acquisition Manual Instruction Manual

DATEL Not Numbered - PDP-11 Cable

Servo Controllers

DATUM Pub. No. 3028.3 - Instruction Manual for Model 2116 Hydraulic Servo Controller

Figure 3.5-1 LCS Documentation List (Continued)

3.6 Training

Three categories of training were provided for the load control system. These training categories consisted of: 1) operation of the load control system, 2) programming the load control system PDP-11 computer, and 3) maintenance/overhaul of ABEX servo valves. All of the training used classroom lectures followed by demonstration and user participation with the equipment.

3.6.1 Operation Training

MSFC personnel received formal operation training on the load control system at MDAC facilities for a period of four days during the month of October 1976. This training consisted of classroom instruction and demonstration of the applications software and equipment operation followed by MSFC personnel participation in making and executing a structural test profile on the load control system.

Continued informal training has been conducted at MSFC following system installation and during the field engineering period as the mutual need has dictated.

3.6.2 Computer Programmer Training

Two training course credits were provided with the system and used by MSFC for PDP-11 computer programmer training. The courses were selected from the Digital Equipment Corporation Educational Catalog and attended in Washington D.C.

3.6.3 ABEX Servo Valve Training

MDAC and Douglas Aircraft Company (DAC) provided a servo valve maintenance and overhaul course at DAC facilities from October 18 thru October 22, 1976. This course included classroom and bench instruction followed by student participation in all phases of assembly, disassembly and calibration of ABEX servo valves.

A technical manual was provided in this course that included calibration and overhaul procedures, together with a technical facility description. The course and material contained information unique to DAC's long term (20 years) experience in servicing this type of servo valve.

3.7 System Checkout and Qualification Testing

Load control system checkout was accomplished initially at the MDAC facilities prior to shipment to MSFC. Final checkout and qualification testing was performed at MSFC from the period December 1976 through May 1977.

3.7.1 MDAC Checkout and Testing

Checkout and testing of the load control system at MDAC consisted of hardware component tests and a hardware/software systems checkout. Hardware component tests were performed on the servo valves, solenoid dump valves servo controllers and digital computer. The systems checkout was an integrated electronic hardware and software test using a six actuator hydraulic test fixture. Documentation of the component testing results was transmitted with the hardware.

3.7.1.1 Servo Valve Test

Eighty (80) servo valves were tested and calibrated by the Hydraulics Laboratory of the Douglas Aircraft Company. Fifty-four (54) model 415 ten GPM valves and twenty-six (26) model 425 twenty-five GPM valves underwent test and calibration. Each valve has been tested and qualified to manufacturers specification and calibrated for use on the Shuttle Intertank test. A summary chart of servo valve test and calibration anomalies is shown in Figure 3.7.1.1-1.

3.7.1.2 Solenoid Dump Valve Tests

One-hundred Control Concept Model 502 solenoid valves were tested at MDAC. Each valve was electrically tested to check solenoid operation. Ten valves, picked at random, were subjected to a cycle open and close test in a hydraulic system and at a pressure of 5000 PSIA. There were no failures from the tests performed.

SER. NO.	1ST DAC CHECKOUT OK/ADJ.	DATE	TO ABEX REASON	DATE	ABEX ACTION	2ND DAC CHECKOUT OK/ADJ.	DATE	TO ABEX REASON	DATE	ABEX ACTION	SHIPPED TO MSFC
19	OFF MECH NULL	2/25/77	OFF MECH NULL	3/1/77	WITHIN MFG. SPEC	NULL ADJ	4/26/77				5/2/77
22	EXCESS LEAKAGE	2/25/77	EXCESS LEAKAGE	3/1/77	REPAIRED UNIT	OK	4/26/77				5/2/77
23	OFF MECH NULL	2/28/77	OFF MECH NULL	3/1/77	UNIT WITHIN MFG. TOL.	NULL ADJ	4/26/77				5/2/77
30	NO CURVE	2/17/77	UNABLE TO CONTROL	3/1/77	REPAIRED UNIT	NULL ADJ.	4/12/77				4/15/77
34	OFF NULL	2/17/77	OFF MECH NULL	3/1/77	UNIT WITHIN TOL.	NULL ADJ.	4/12/77				4/15/77
51	OFF NULL	3/7/77	OFF MECH NULL	3/11/77	WITHIN MFG. TOL.	ADJ. NULL	5/4/77				5/9/77
53	NO CURVE	3/7/77	EXCESS HYSTERESIS	3/11/77	ABEX REPAIR	EXT. LEAKAGE	5/5/77	EXT. LEAKAGE	5/9/77		7/14/77

Figure 3.7.1.1-1 Servo Valve Test Anomally Summary

3.7.1.3 Servo Controller Tests

Fifty-eight servo controllers were subjected to a "burn in" test (described in MDAC procedure transmitted to MSFC in Letter A3-13E-1218, dated 4 October 1976) and a functional closed loop control test using the load control system hardware and software with hydraulic load lines assembled in the test fixture. Results of these tests were transmitted to MSFC with the hardware on DD250 HBC003, dated 12 November 1977.

3.7.1.4 Digital Computer Test

An acceptance test was conducted on the Digital Equipment Corporation (DEC) Model PDP-11 computer at MDAC. This test consisted of running the manufacturers diagnostics on the equipment for a period of forty (40) contiguous hours without obtaining a hardware failure. This test was successfully completed following installation at MDAC.

3.7.1.5 Integrated Systems Test

The integrated systems test performed at MDAC included the electronic load control system hardware and the systems and applications software.

A sample test profile, shown in Figure 3.7.1.5-1, was designed to operate and control simultaneously five (5) actuators installed in the hydraulic load fixture. The test was repeated until fifty-four (54) load control channels successfully completed the test. Four controllers and one rack adapter were previously shipped to MSFC at MSFC request and were to undergo test and checkout with the system at MSFC.

3.7.2 Qualification Testing at MSFC

Qualification testing of the load control system at MSFC spanned the period from December 1976 through May 1977. A five channel test fixture, supplied by MSFC, was utilized in the testing of the hardware and software capabilities and components of the control system. The servo valves were tested with this fixture, however, the solenoid dump valves underwent leakage and functional tests in the MSFC Hydraulics Laboratory.

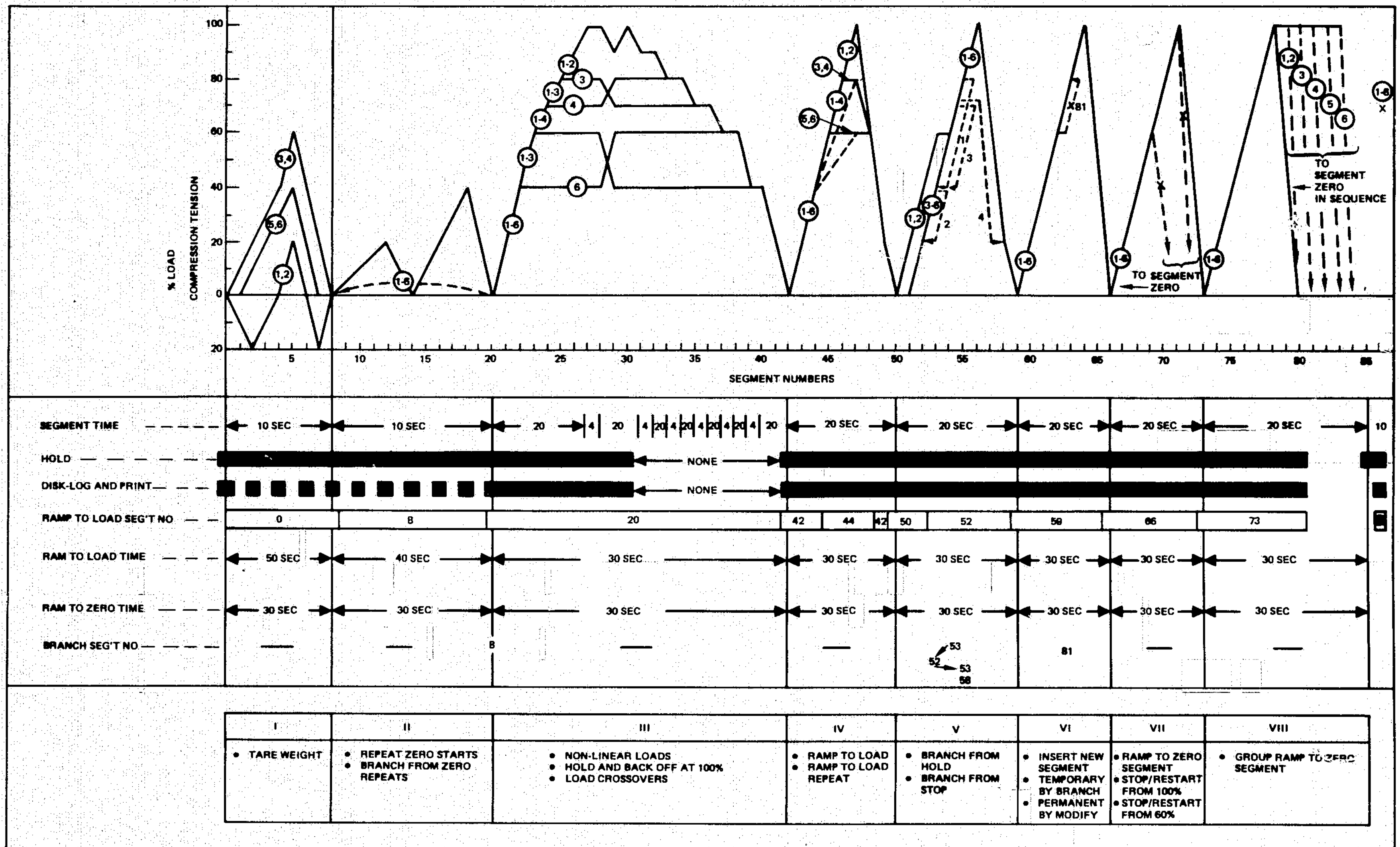

Figure 3.7.1.5-1 Sample Test Profile

By February 17, 1977 the LCS was demonstrated on five load channels. The completion of this effort satisfied the contract requirement of Paragraph 15, Section E of the contract Scope Of Work. The testing that followed the 5 channel demonstration qualified all fifty-eight channels of the load control system per NASA Hydraulic/Load Control System Checkout Procedure SST-G-FAP-006, dated February 3, 1977.

The qualification testing at MSFC included the following system and component tests:

a. LCS Hardware Performance
b. LCS Software Performance
c. Servo Controller Functional
d. Servo Valve Verification
e. Solenoid Dump Valve Functional

Items a, b and c above were accomplished as an integrated checkout, using NASA Procedure SST-G-FAP-006, dated February 3, 1977. Testing of items d and e was accomplished independent of the integrated LCS qualification test.

3.7.3 Qualification Testing Anomalies

During the qualification testing at MSFC, hardware and software anomalies occurred. However, all of these anomalies have been corrected and the load control system is operational, in readiness for the Space Shuttle Intertank structural testing.

3.7.3.1 LCS Hardware Performance Anomalies

LCS hardware anomalies occurred in the computer and the load control system during the test and system qualification period at MSFC. Computer failures occurred with magnetic tape cassettes, the disk storage devices, and the extended arithmetic element. A history of the computer anomalies is presented in Figure 3.7.3-1.

DATE	DEC SERVICE REPORT NO.	PROBLEM	REMEDY
1/25/77	009591	Module Failure	Replaced Module 54-0973 OYA
2/28/77	009614	LA180 Printer Malfunction	Adjusted printer cover.
		BA11-KE Power Supply Low	Replaced harness and power control diagnostics run.
1/31/77	009616	TA11-AA Failure	No repeat failure found.
2/1/77	009617	LA36-CE Keyboard had sticky Key	Repaired key.
2/1/77	00918	Disk RK05-J light out.	Replaced light bulb.
2/9/77	009509	Computer failed	Replaced fuse in MDAC equipment.
		LA180 Failure	Replaced logic module.
4/6/77 4/15/77 4/20/77 5/15/77 4/26/77 5/17/77	084673 084994 076707 009511 077097 452941	KE11 fails randomly	Failed on diagnostics. Replaced KE11. System operates satisfactorily.

Figure 3.7.3-1 Computer System Anomalies

The five Amp power supplies servicing the interface electronics of the analog to digital and digital to analog converters of the three load control subsystems were not adequate to carry the current load (5.2 Amps) observed. These units were replaced with power supplies capable of carrying a ten Amp load.

The digital to analog and analog to digital conversion systems experienced the following types of failures:

a. A voltage slew rate offset was present in digital to analog converters.
b. Loss of a bit in the analog to digital converter.
c. Unable to address the analog to digital/digital to analog conversion unit.
d. Digital to analog converter out of calibration.
e. Noisy potentiometer on an analog to digital converter circuit board.

These anomalies were corrected through the replacement of circuit boards.

Servo controller anomalies are presented in Figure 3.7.3-2. In addition to the functional tests a potentiometer check was performed on each servo controller independent of the qualification tests and either set point, span, or loop gain potentiometers were replaced by MSFC personnel on twelve servo controllers. A summary of these test results is shown in Figure 3.7.3-3.

A fixed resistor was added to the inner error detection/interrupt circuit to increase the inner error hysteresis and inhibit repeating the same interrupt to the computer when an inner error occurred. This installation was performed by MSFC personnel.

Testing of the servo valves was accomplished on the five channel load fixture using the load control system to operate the valve. MSFC tested a total of sixty-nine valves with no failures. The remaining eleven valves were to be checked out when they were installed in the test system.

SERVO CONTROLLER SERIAL NUMBER	ANOMALLY	RESOLUTION
424	OUTER ERROR SET - 1/20/77	FACTORY WARRANTY REPAIR - SERVICE REPORT #7295 RETESTED
	OUTER ERROR SET INHIBIT SWITCH FAILURE - 3/2/77	SAME AS ABOVE NO SERVICE REPORT
459	FUNCTION SELECT SWITCH - 1/20/77	SAME AS ABOVE NO SERVICE REPORT
472	SPAN POT. - 2/8/77	SAME AS ABOVE SERVICE REPORT #3190
	OUTER ERROR FAILURE - 4/4/77	SAME AS ABOVE NO SERVICE REPORT
423	BLOWS FUSE - 2/8/77	SAME AS ABOVE SERVICE REPORT #3192
441	BLOWS FUSE - 2/17/77	SAME AS ABOVE SERVICE REPORT #3181
451	SET POINT POT. - 2/17/77	SAME AS ABOVE NO SERVICE REPORT
464	DOES NOT POWER UP - 2/17/77	SAME AS ABOVE SERVICE REPORT #3179
428	INNER ERROR LIGHT STAYS ON - 2/21/77	SAME AS ABOVE NO SERVICE REPORT
432	BLOWS FUSES - 2/25/77	SAME AS ABOVE SERVICE REPORT #7274
433	DOES NOT POWER UP - 2/22/77	SAME AS ABOVE SERVICE REPORT #3180
436	BLOWS FUSE - 2/22/77	SAME AS ABOVE SERVICE REPORT #7272
456	INNER ERROR LIGHT STAYS ON - 2/22/77	SAME AS ABOVE SERVICE REPORT #7273
465	DOES NOT POWER UP - 2/22/77	SAME AS ABOVE SERVICE REPORT #3183
429	INHIBIT SWITCH STAYS ON - 2/25/77	SAME AS ABOVE SERVICE REPORT #3090
448	DOES NOT POWER UP - 2/25/77	SAME AS ABOVE SERVICE REPORT #3089
457	INHIBIT LIGHT STAYS ON - 3/4/77	SAME AS ABOVE NO SERVICE REPORT

Figure 3.7.3-2 Servo Controller Anomalies

SERVO CONTROLLER SERIAL NUMBER	POTENTIOMETER ANOMALLY	RESOLUTION
426	SPAN POT. - ONE POSITION	REPLACE POTENTIOMETER
430	SET POINT - SIX POSITIONS	REPLACE POTENTIOMETER
434	SET POINT - TWO POSITIONS	REPLACE POTENTIOMETER
435	SET POINT - ONE POSITION	REPLACE POTENTIOMETER
443	SET POINT - ONE POSITION	REPLACE POTENTIOMETER
445	SPAN - ONE POSITION	REPLACE POTENTIOMETER
453	SET POINT - ONE POSITION	REPLACE POTENTIOMETER
455	SET POINT - ONE POSITION	REPLACE POTENTIOMETER
458	SET POINT - TWO POSITIONS	REPLACE POTENTIOMETER
469	SPAN - ONE POSITION LOOP GAIN - TWO POSITIONS	REPLACE POTENTIOMETER " " " "
474	LOOP GAIN - ONE POSITION	REPLACE POTENTIOMETER
479	SPAN - ONE POSITION	REPLACE POTENTIOMETER

Figure 3.7.3-3 DATUM Servo Controller Potentiometer Check Test Results

Solenoid dump valves were functionally tested by MSFC personnel. A total of 29 valves exhibited a mode of unacceptable operation. These valves were repaired, tested by the vendor, and returned to MSFC. A summary of the valve test anomalies is presented in Figure 3.7.3-4. MSFC assumes the responsibility to verify the functional operation of these valves.

3.7.3.2 LCS Software Anomalies

During the qualification testing of the LCS at MSFC, several software anomalies were identified in the applications software. These anomalies and the remedies are summarized below.

	Anomally	Remedy
1.	Cassette tape read/write program using the DEC supplied program FLEX will not read random access files stored on disk.	Write special program named M007 to read and write cassette tapes.
2.	The displays and printout contain erroneous numbers.	Save register contents of extended arithmetic element (EAE) processes when the program function using the EAE is interrupted by higher priority.
3.	Error message does not always print on console TTY.	Provide common program to be used by all loads programs to print messages instead of individual programs printing messages.
4.	Loading program execution stalled while messages are printed on slow TTY.	Incorporate ring buffer in common message print programs allowing load programs to deposit message in buffer and continue with program execution.

VALVE SERIAL NO.	CONTROL CONCEPTS	MDAC			NASA - MSFC							CONTROL CONCEPTS	NASA - MSFC			NASA - MSFC		
	10/1976	11/3 - 11/9, 1976			1ST TEST 3-5-77			DISASSEMBLED AND CLEANED	2ND TEST 4-19-77			REWORKED FAILED VALVES	RETEST			RETEST		
	OPERATIONAL PRESSURE CHECK	OPERATIONAL CHECK			OPERATIONAL CHECK				OPERATIONAL CHECK				OPERATIONAL CHECK			OPERATIONAL CHECK		
		ELECT	PRESSURE	CYCLES	PRESSURE	CYCLES	REMARKS		PRESSURE	CYCLES	REMARKS		PRESSURE	CYCLES	REMARKS	PRESSURE	CYCLES	REMARKS
2323	X	X	-	-	X	0	Failed to Open					4-6-77 Checked OK	X	25	OK			
2326	X	X	-	-	X	5	OK But Fast Leak					4-6-77						
2327	X	X	-	-	X	15	OK But Slow Leak					4-6-77						
2329	X	X	-	-	X	10	OK	X	X	0	Failed to Open	5-19-77 Replaced Parts						
2333	X	X	-	-	X	10	OK	X	X	0	Failed to Open	5-19-77 Replaced Parts						
2337	X	X	X	1	X	20	Leaked After 20th Cycle					4-6-77 Replaced Bent Oriface						
2339	X	X	-	-	X	20	OK - But Slow to Close After 3 Cycles	X	X	0	Failed to Open	5-19-77 Replaced Parts						
2340	X	X	-	-	X	25	Open Normal Slow to Close					4-6-77 Replaced Bent Stem						
2343	X	X	-	-	X	3	Failed to Close After 3 Cycles					4-6-77 Replaced Stuck Valve	X	25	OK			
2350	X	X	-	-	X	10	OK	X	X	0/10	Failed 1st Cycle - Changed O-	5-19-77 Replaced Parts						
											Ring - OK 10 Cycles							
2351	X	X	-	-	X	20	OK	X	X	0	Failed To Open							
2353	X	X	-	-	X	1	Failed To Open					4-6-77 Checked OK	X	25	OK - But Leaks			
2354	X	X	-	-	X	10	OK	X	X	10	OK (Sluggish)							
2356	X	X	-	-	X	5	Opens Normal Slow To Close					4-6-77 Checked OK	X	25	OK			
2361	X	X	-	-	X	11	Failed To Open After 11 Cycles					4-6-77 Checked OK						

Figure 3.7.3-4 Solenoid Dump Valve Anomally Summary

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VALVE SERIAL NO.	CONTROL CONCEPTS 10/1976 OPERATIONAL PRESSURE CHECK	MDAC 11/3 - 11/9, 1976 OPERATIONAL CHECK ELECT	PRESSURE	CYCLES	NASA - MSFC 1ST TEST 3-5-77 OPERATIONAL CHECK PRESSURE	CYCLES	REMARKS	DISASSEMBLED AND CLEANED	2ND TEST 4-19-77 OPERATIONAL CHECK PRESSURE	CYCLES	REMARKS	CONTROL CONCEPTS REWORKED FAILED VALVES	NASA - MSFC RETEST OPERATIONAL CHECK PRESSURE	CYCLES	REMARKS	NASA - MSFC RETEST OPERATIONAL CHECK PRESSURE	CYCLES	REMARKS
2366	X	X	-	-	X	10	OK	X	X	10	Failed To Open	5-19-77 Replaced Parts						
2368	X	X	-	-	X	0	Stuck Fully Open					4-6-77 Checked OK						
2375	X	X	-	-	X	0	Failed To Open					4-6-77 Parts Inst. Backwards	X	25	OK			
2376	X	X	-	-	X	10	OK	X	X	0	Failed To Open							
2385	X	X	-	-	X	5	Slow To Close Opens Normal					4-6-77						
2391	X	X	X	1	X	10	OK	X	X	0	Failed To Open	5-19-77 Replaced Parts						
2396	X	X	-	-	X	10	OK	X	X	10	OK - But Can't Shut Off	5-19-77 Replaced Parts						
2397	X	X	-	-	X	10	OK - But Drip Leaks					4-6-77 Checked OK						
2403	X	X	X	1	X	10	Opens OK Slow To Close - Leaks					4-6-77 Changed Stripped Body	X	25	OK			
2404	X	X	-	-	X	10	OK	X	X	0	Failed To Open	5-19-77 Replaced Parts						
2409	X	X	-	-	X	10	OK 1st Cycle Leaked After 2nd Cycle					4-6-77 Leaked	X	25	OK			
2410	X	X	-	-	X	20	OK	X	X	10	OK - But Slow To Close	5-19-77 Replaced Parts						
2413	X	X	-	-	X	10	Slow To Open Close Normal					4-6-77 Checked OK						

Figure 3.7.3-4 Solenoid Dump Valve Anomally Summary (Continued)

VALVE SERIAL NO.	CONTROL CONCEPTS	MDAC			NASA - MSFC							CONTROL CONCEPTS	NASA - MSFC			NASA - MSFC		
	10/1976	11/3 - 11/9, 1976			1ST TEST 3-5-77			DISASSEMBLED AND CLEANED	2ND TEST 4-19-77			REWORKED FAILED VALVES	RETEST			RETEST		
	OPERATIONAL PRESSURE CHECK	OPERATIONAL CHECK			OPERATIONAL CHECK				OPERATIONAL CHECK				OPERATIONAL CHECK			OPERATIONAL CHECK		
		ELECT	PRESSURE	CYCLES	PRESSURE	CYCLES	REMARKS		PRESSURE	CYCLES	REMARKS		PRESSURE	CYCLES	REMARKS	PRESSURE	CYCLES	REMARKS
2414	X	X	-	-	X	5	Slow To Close Opens Normal					4-6-77 Changed Stripped Body	X	25	OK			
2415	X	X	-	-	X	20	OK	X	X	0	Failed To Open	5-19-77 Replaced Parts						
2419	X	X	-	-				X	-	10	Leaks Badly, No Test	5-19-77 Replaced Parts						
2420	X	X	-	-				X	X	5	OK, But Leaks							
2342	X	X	-	-	X	10	OK	X	X	100	OK	5-19-77 Replaced Parts						

Figure 3.7.3-4 Solenoid Dump Valve Anomally Summary (Continued)

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Anomaly	Remedy
5. Messages say "continue" instead of "begin".	Put in timing delay of two ticks in order to allow time to deposit first message of sequence in common message program.

3.7.4 System Test Readiness Status

The Load Control System (LCS) is presently installed in Building 4619 at the Marshall Space Flight Center. Qualification testing with a closed loop hydraulic system per NASA Procedure SST-G-FAP-006, dated February 3, 1977, has been completed. The LCS performed satisfactorily throughout this operational checkout of all loading channels.

All hardware has been delivered and all changes to LCS documentation have been made and revised drawings and manuals have been transmitted to MSFC.

MDAC has completed all of the contractual requirements of contract NAS8-31669 and the system is in a test readiness status.