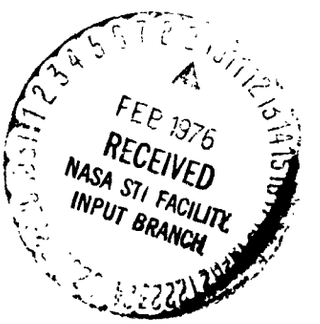
MCR-75-457
Contract NAS8-31615

November 1975

Revitalizing the Hydrodynamic Support for Space Shuttle



MARTIN MARIETTA

MCR-75-457
Contract NAS8-31616

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REVITALIZING THE HYDRODYNAMIC SUPPORT FOR SPACE SHUTTLE

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FOREWORD

This report is submitted to the George C. Marshall Space Flight Center, National Aeronautics and Space Administration, Huntsville, Alabama, by Martin Marietta Aerospace, Denver Division, in accordance with contract number NAS8-31616.

CONTENTS

CONTENTS (continued)

SUMMARY

Martin Marietta Aerospace has completed the inventory, inspection, preliminary layout drawing, list of spare parts required, and an implementation plan for adapting the Saturn V Hydrodynamic Support (HDS) to the Space Shuttle Mated Vehicle Ground Vibration Test (MVGVT).

The major HDS components which have been saved are generally in good condition and can be readily adapted for Space Shuttle MVGVT. Approximately 73% of the Saturn V equipment has been saved and is equivalent to 60% of the value of the original Saturn V equipment.

I. INTRODUCTION

This report describes the condition of the equipment retained from the Saturn V HDS and defines the work necessary to supplement, modify and refurbish it for the Space Shuttle MVGVT. The HDS equipment provided a six degree of freedom soft suspension system for the Saturn V-Apollo dynamic test (see Figure I-1). Major elements of the system were preserved to varying degrees and saved for future use. The HDS will be used to test the Space Shuttle Launch and Solid Rocket Booster burnout configurations.

Section II of this report describes the design changes necessary to adapt the Saturn V HDS design for Space Shuttle.

Section III gives the results of the inventory and inspection.

Section IV describes the work necessary to revitalize the HDS for Space Shuttle.

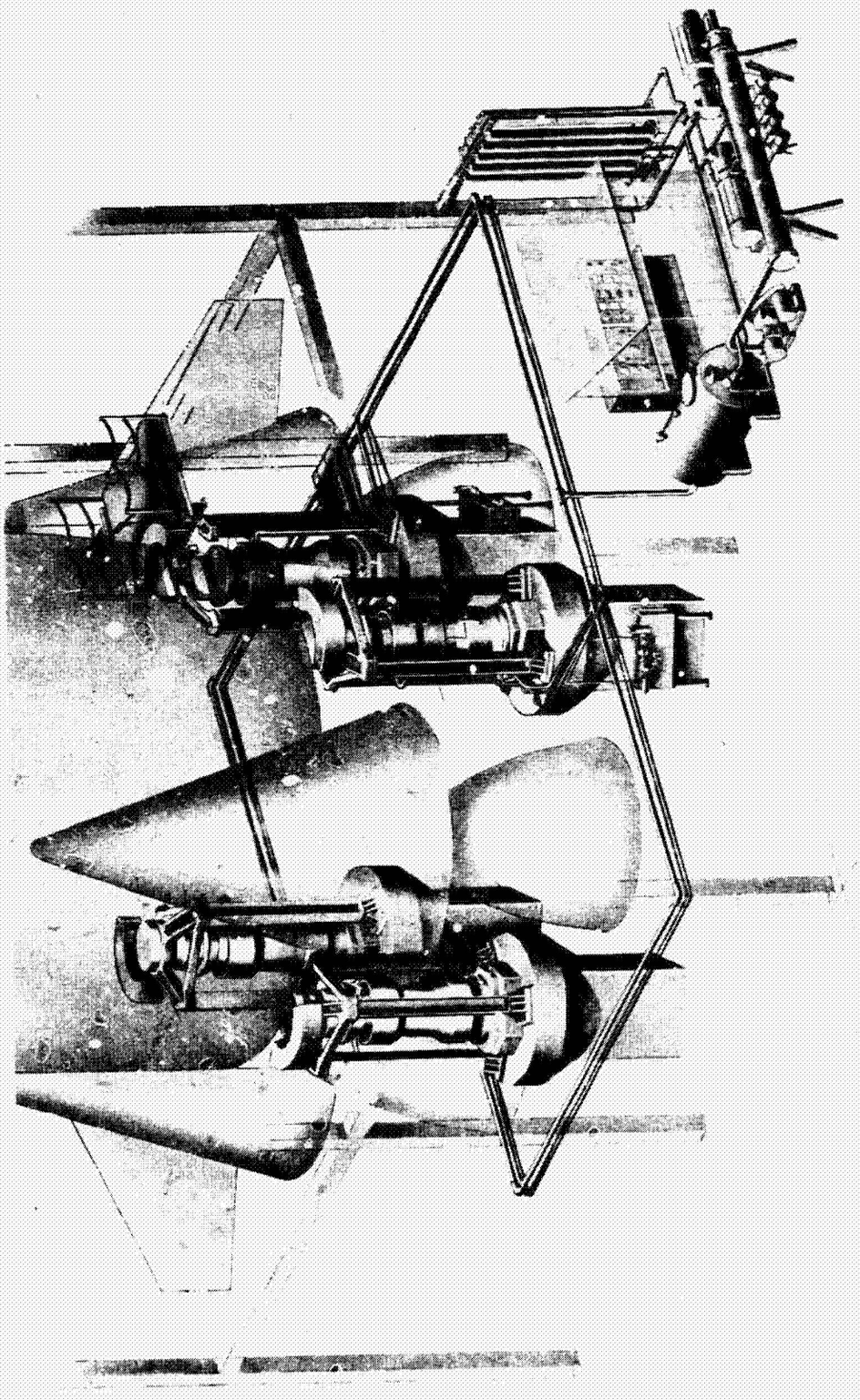


Figure I-1. Saturn V Dynamic Test Support

II. DESIGN CHANGES REQUIRED

The HDS used for Saturn V can be readily adapted for testing the Space Shuttle Launch and SRB burnout conditions. Figure II-1 shows the configuration required for Space Shuttle. The principal differences between it and the Saturn V configuration (Figure I-1) are that the pedestals are relocated in a rectangle 15-1/2 x 42 feet instead of a 32 foot circle and they are approximately 10 feet lower.

A. MODIFICATIONS

1. Return Pumps

Additional oil return pumps will be required since with the supports at the lower elevation the oil will not flow back to the reservoir by gravity as was the case with the Saturn V configuration. One pump and sump tank can be used for each pair of supports. Necessary flow rate controls and liquid level switches will be required. The sump tank should be baffled to provide for separation of dirt and water.

2. Auxilliary Control Panel

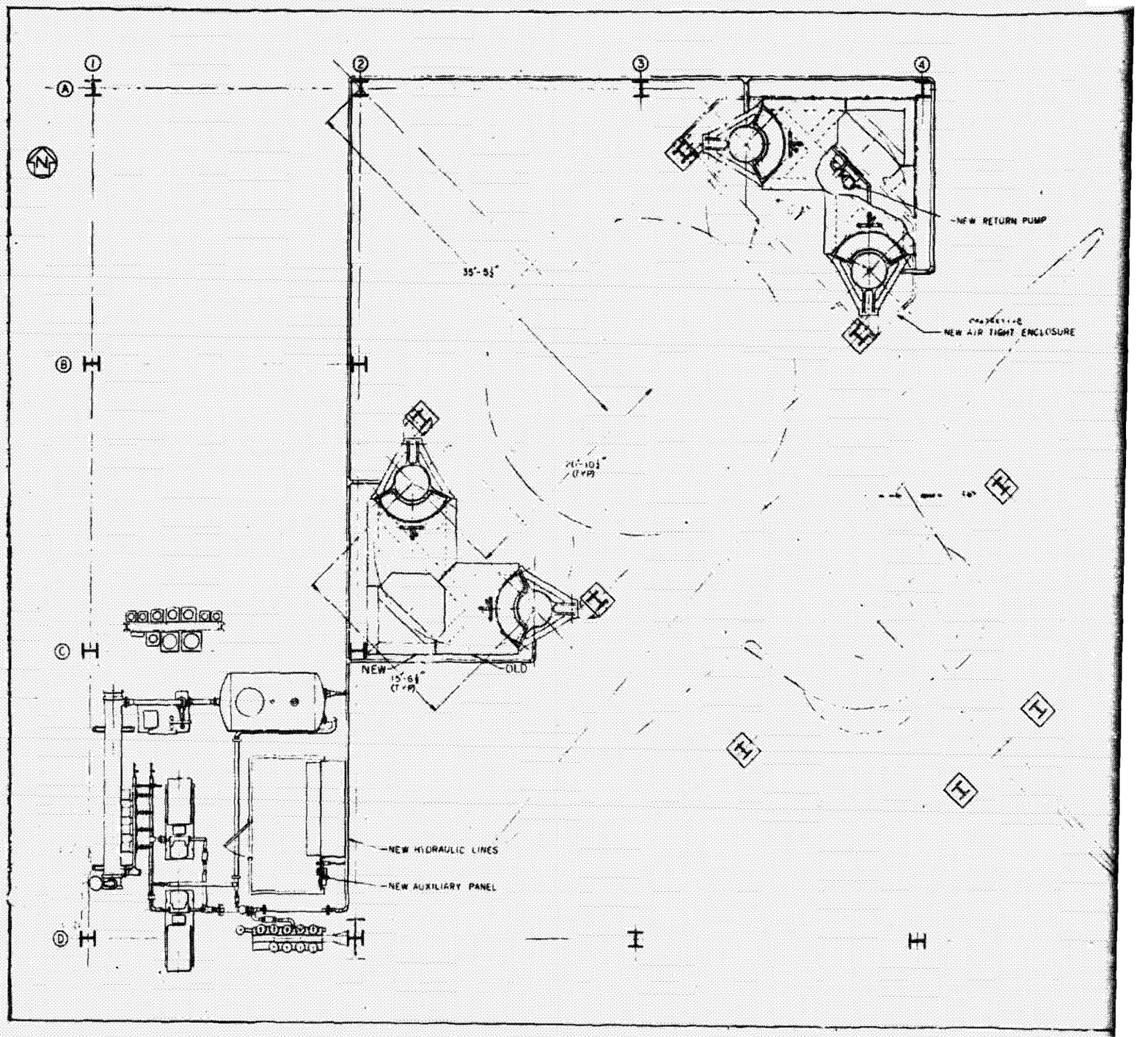
An auxiliary control panel will be required to mount the additional controls required by the unequal loading of the supports. These are comprised of the additional flow modulation controls required for stability due to the unequal loading.

3. Bumpers and Brace Structure

The bumpers and bumper moving mechanism can be the same as the Saturn V configuration (see Figure II-1). The brace structure must be adapted to the new location in the test tower possibly using the platform columns shown in Figure II-1 for some lateral support.

B. IMPROVEMENTS

A number of improvements can be made to the Saturn V design to assure that the MVGVT can be completed without any significant down time due to the HDS malfunction. Subsystems which were troublesome or marginal should be improved so as not to require a high degree of skill and ingenuity to keep the system in operation. Some of the improvements are facilitated by the absence of design constraints of the Saturn V; e.g., lighter load, the space restriction required to remove F-1 engines, less variation in magnitude of the mass of the test article. Feasible changes are as follows.



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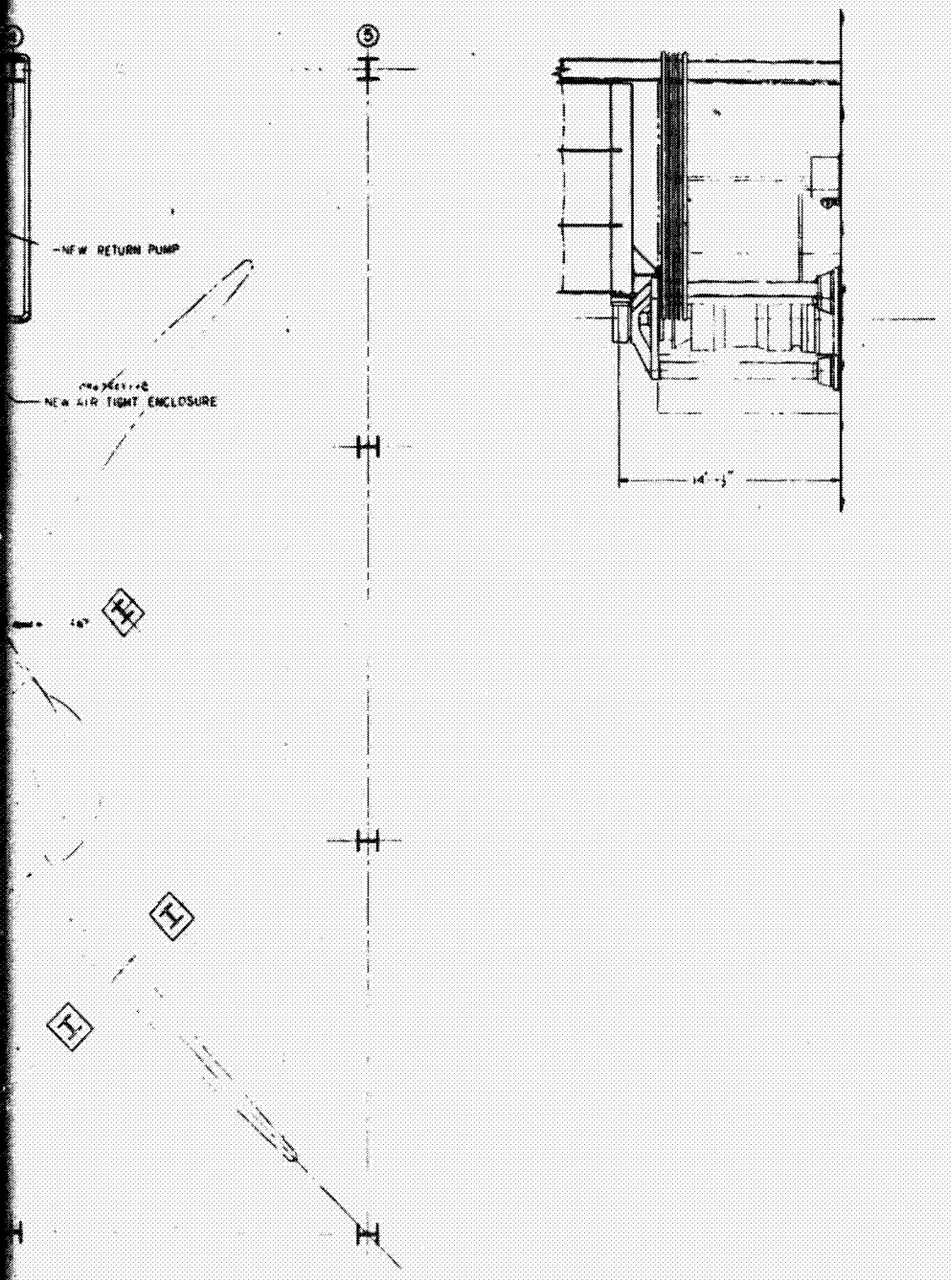
FOLDOUT FRAME 1

NOTES
1. CONTROL CONSOLE & HYDRAULIC EQUIPMENT REMAINS IN THE SAME LOCATION.



MVGVT
MDS GENERAL ARRANGEMENT

Figure II-1.

FOLDOUT FRAME 2

1. Pedestal Enclosures

Each pair of supports should be enclosed in a room similar to the one which previously enclosed the control console. This enclosure is made of prefabricated steel panels of the type frequently used for shop offices. This will provide much greater protection against dirt and water entering the hydraulic system, protect the supports and instrumentation systems against cold and rain, which was a principal cause of component failures during the Saturn V test.

2. Light Weight Oil

The viscosity of the oil used in the hydraulic system can be reduced to about 1000 SSU, approximately 1/2 that used for the Saturn V launch configuration but 50% greater than that used after removal of the S-1C stage. This will require a five gallon per minute increase in flow to the flat bearing which is within the capacity of the existing pumps at the reduced pressures needed for the Space Shuttle vehicle. The lighter oil will work substantially better with the filters, boost pump, return pumps, alleviate cold start up problems and make the float sunk sensor operation less critical.

3. Instrumentation

The following instrumentation subsystems which were marginal can be improved:

a. piston height indication and warning system;
b. float height indicating system;
c. float sunk warning system.

4. Float Seal

The hemispherical float inside the piston (see Figure II-2) seals the high pressure nitrogen use for the air spring when the vehicle is parked on the supports and the oil pressure goes to zero. During the Saturn V tests, the float on the number two support would fail to seal intermittantly causing operating problems. The float and sealing ring should be inspected and the seal design can be modified as required.

5. Boost Pump

A positive displacement boost pump was used on the Saturn V HDS to pump oil through the heat exchanger and to provide a high precharge pressure for the high pressure pumps. This type pump was selected instead of a centrifugal pump normally used in the application because of the concern about the affect of the unusually viscous oil in the high pressure pumps.

The pump used and the associated bypass pressure controls required extensive maintenance and adjustment. The boost pump can be replaced with a centrifugal pump which would alleviate the operating problems.

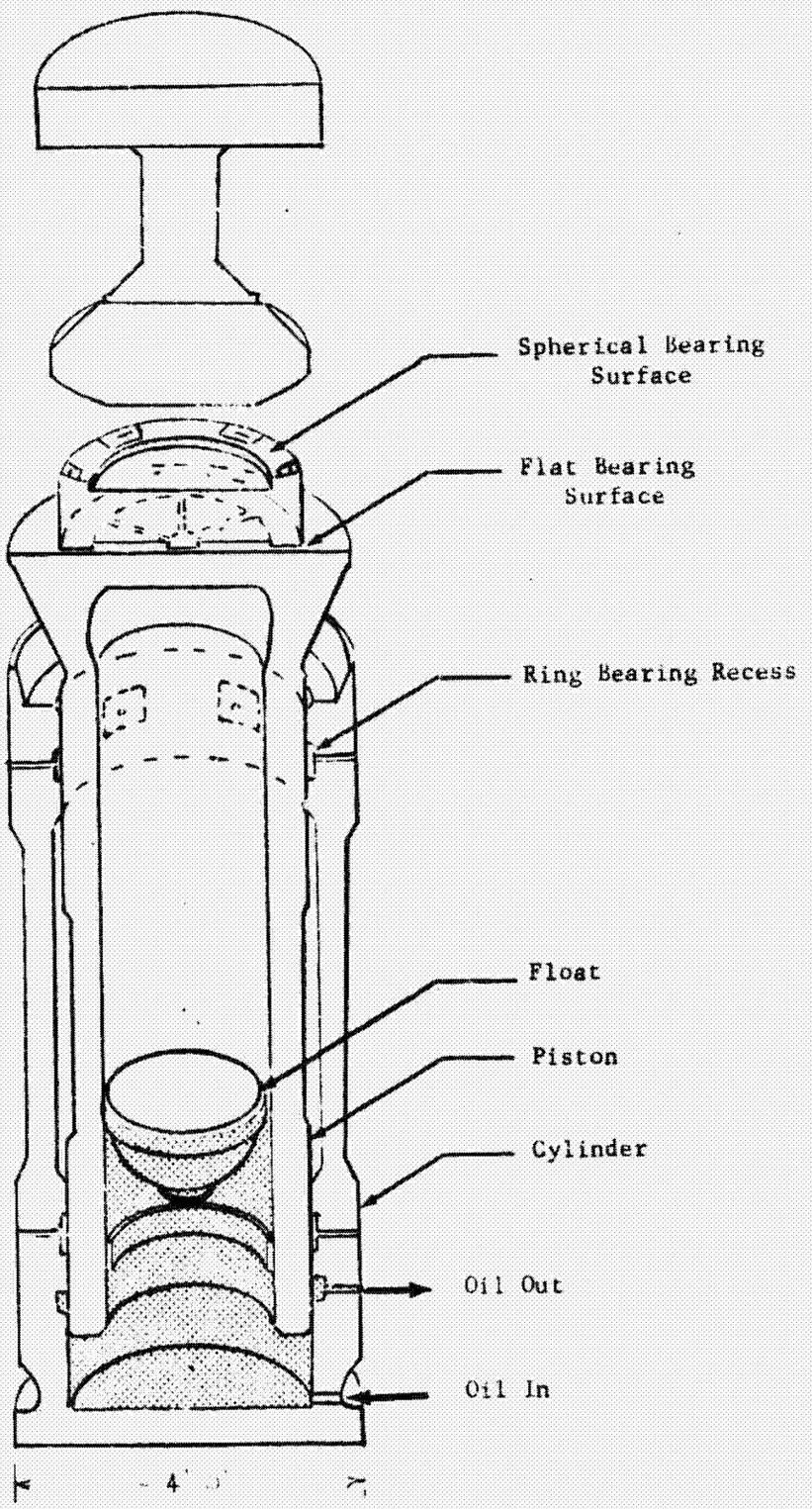


Figure II-2. Hydrostatic Bearings and Air Springs

6. Flow Modulation Control

Due to the characteristics inherent in the design of the pistons and cylinders, the piston height tends to vary with load in a different manner than a simple spring. This must be corrected for proper operation of the support by modulating the input oil flow to the bottom of the piston. The flow modulation required depends on several factors including the piston spring rate and supported load. Since these factors are different for the two pairs of supports, the flow modulation system must be redesigned to provide the different flow modulation required for each pair of supports.

III. INVENTORY AND INSPECTION

The results of the inventory and inspection are listed in Appendix A. A summary by subsystem is shown in Table III-1. Inspection of the pistons, cylinders and bearings is described in detail in Appendix B.

Table III-1. Inventory and Inspection Summary

Subsystem	% of Saturn V System	% Present	% Good	% of Original Value
Control Console	10	100	85	8.5
Park Structure	6	100	85	5.1
Piston	10	100	85	8.5
Cylinder	10	100	90	9.
Piston and Cylinder Auxiliary Equipment	8	0	--	0.
Flat and Spherical Bearing	7	100	95	6.7
Bearing Valves and Manifold	2	0	--	0.
Instr. Trailer Panel	1	0	--	0.
Brace Structure	4	100	50	2.
Bumpers	3	100	35	1.
Capillary Panels	2	50	80	.8
Hydraulic Pumping Station	10	90	80	7.2
Misc. Equipment on Pedestals	7	5	50	.2
Electrical Power Distribution	7	80	90	5.
Instrumentation	6	10	50	.3
Installed Piping, Wiring, Conduit	6	25	90	1.4
Disassembly Handling Equip.	1	95	75	.7
Calibration Console	1	0	--	0.
Spares	5	80	85	3.4
Weighted Average		73	81.9	
TOTAL	100			59.8

IV. IMPLEMENTATION PLAN

A. ENGINEERING PLAN

1. Design and Analysis

The following design and analysis tasks are to be accomplished.

a. Revise hydraulic schematic including all line sizes and define all components by part number.

b. Document revisions to hydrostatic bearing design for Space Shuttle.

c. Design Auxiliary Control Panel required for unequally loaded supports in space shuttle configuration. Define the flow modulation required for the two test conditions.

d. Design return pumping system:

1) pump selection,
2) sump design,
3) flow control system design,
4) control panel indicators and controls.

e. Redesign piston height indication and warning system:

1) new piston height potentiometer installation,
2) new piston height warning switches.

f. Redesign float height indicating system including the hydraulic fuse 88A4100853 (an automatic shutoff). Define test.

g. Select new thermistor in float sunk system to take advantage of lighter oil and lower pressures. Define test.

h. Redesign float seat seal and define test of new seal.

i. Layou bumpers and brace structure.

j. Define HDS interface with facility and STE:

1) bumper loads,
2) park disc to SRB adapter frame,
3) remote indicators; e.g., support height, part indication,
4) support pressures,
5) park height shims.

k. Define overall acceptance test of the completed system.

2. Drawings

Detail drawings must be prepared for the HDS Space Shuttle configuration. Maximum use can be made of the Saturn V drawings by making changes on reproducible copies for modified parts and those with minor changes. The following is an estimate of the scope of changes to the drawings:

New drawings	35
50% modified drawings	75
Minor modifications	125

3. Reports

The following reports must be prepared or supplemented as indicated:

a. flow modulation and vertical dynamic response of the individual supports,
b. reliability analysis,
c. hazard analysis,
d. hydrostatic bearing design analysis,
e. hydraulic system analysis,
f. stress analysis, a supplement to ER14034, "Detail Stress Analysis, Hydrodynamic Support for Saturn V".

4. Engineering Support

Engineering support must be provided to solve problems occurring during manufacture, test, installation and operation of the HDS.

B. FABRICATION OF REPLACEMENT AND NEW PARTS

1. Piston and Cylinder Assembly

The piston and cylinder assemblies must be completed per drawing 88A4100410. Parts needed to complete the assembly generally consist of flow control valves, covers, heaters, guide bearings, plumbing, float sunk warning system, piston height potentiometer installation, guide blocks, park blocks. Only the following parts are available:

Piston - 88A4100417,
Cylinder - 88A4100418,
Float - 88A4100465,
Float Seat - 88A4100456,
Bailing Tube - 88A4100467,
Float Sensor Details - 88A4100866,
Hoist Fittings - 88A4100492.

3. Flat Bearing Assembly

The flat bearing assembly 88A4100423 consists of the bearing block, ten flow control valves, six orifices, a manifold and associated plumbing (see Figure IV-1). The only parts present are the cylindrical block 88A4100405-13 and the six orifices. The bearing assembly must be completed to the requirements of the original drawings with the exception of the hole in the orifices which may be enlarged if lighter oil and greater flow is used.

4. Bearing Disc

A thin Teflon coated disc is placed between the top of the spherical bearing and the steel stem supporting the vehicle. Its function is to reduce the coefficient of friction to between .05 and .1 to provide a slip plane and prevent damage to the vehicle should the bearings fail. These discs 88A4100455 must be replaced with new ones.

5. Linear Flow Control Valve 88A4100483

Three valves must be fabricated to replace the missing ones.

6. Access Platforms

Four sets of platforms similar to 88A4100480-029, 039 and 049 must be fabricated to replace the missing ones.

7. Auxiliary Control Panel

The auxiliary panel must be built new but can use existing components as indicated on the inventory list.

8. Bumpers and Brace Structure

The existing bumpers and brace structure may be used with some added structure. The corners of the existing platforms can be cut and splice plates added to accommodate the new configuration. New cover plates must be fabricated. The rubber on the pitch and yaw bumpers 88A4100466-29 and the roll bumpers 88A4100464 must be replaced with new rubber.

9. Piston and Cylinder Installation Hardware

One piston and cylinder assembly may be installed in a Park Structure assembly off-site in order to prefabricate and develop installation hardware (see Figures IV-2 and IV-3). The equipment to be developed and installed is similar to that on drawing 88A4100488 and consists of the following:

a. tubing installation 88A4100488,
b. revised float height sensors similar to 88A4100875-001,

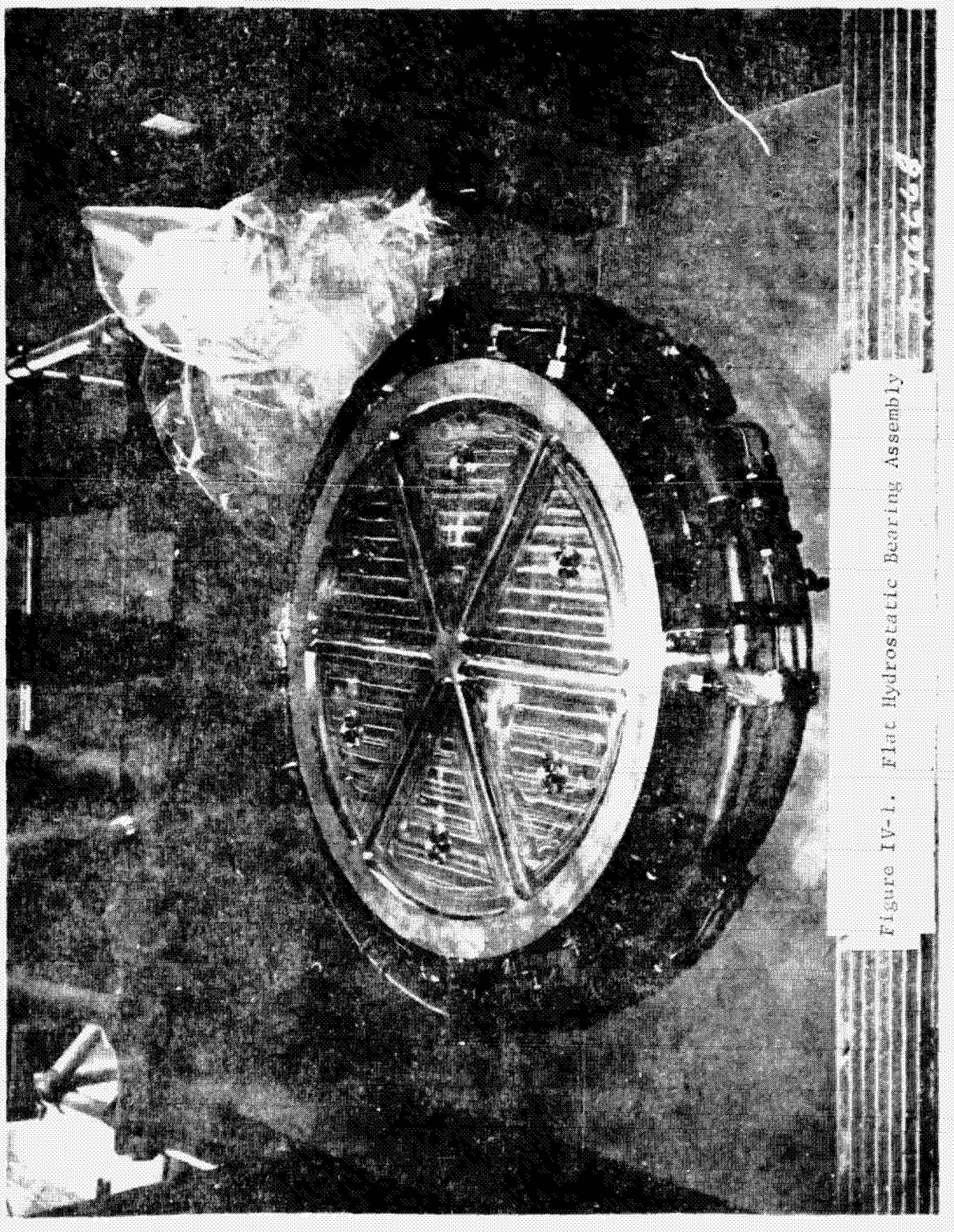


Figure IV-1. Flat Hydrostatic Bearing Assembly

Figure IV-2. Piston and Cylinder Installation on Pedestal

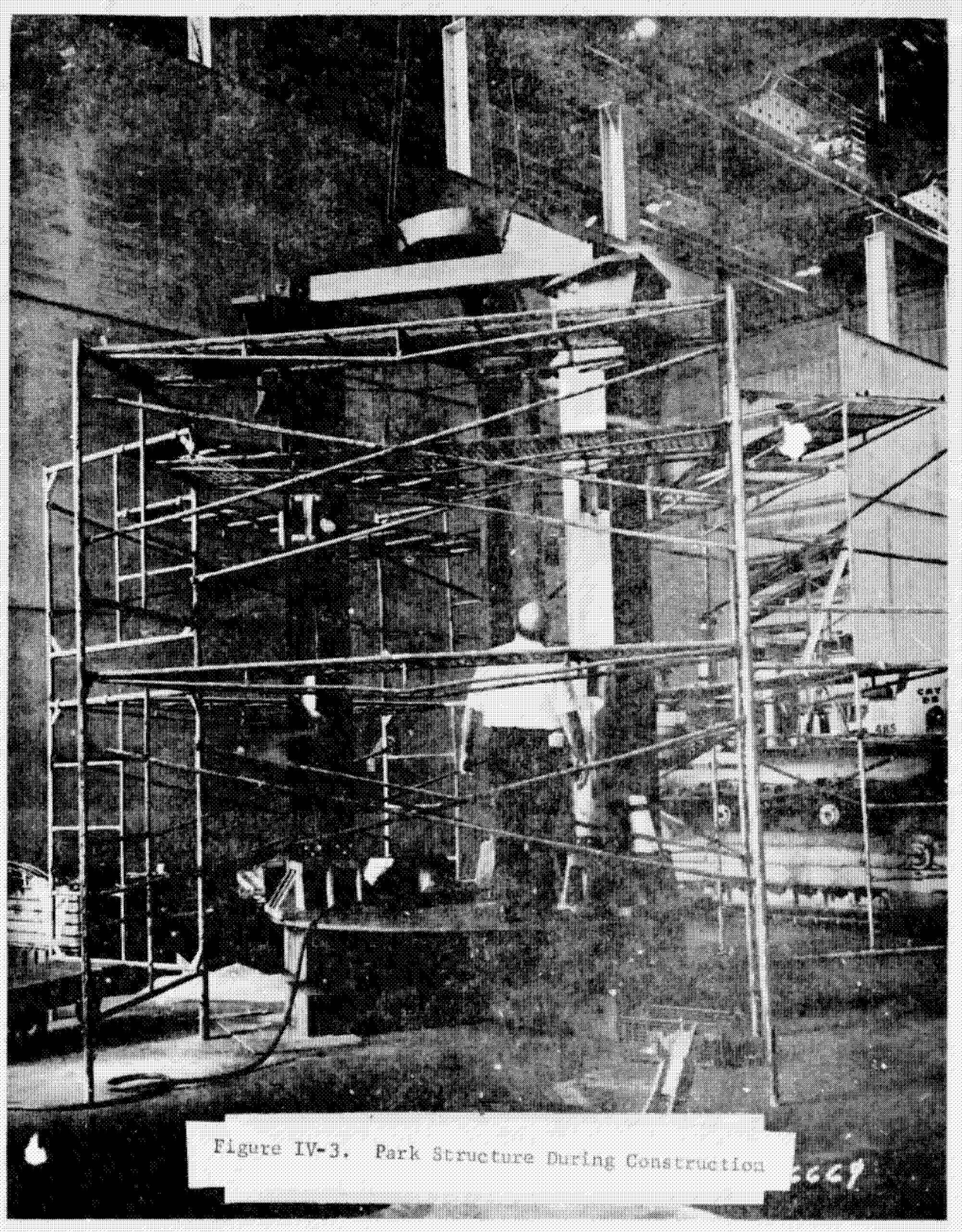


Figure IV-3. Park Structure During Construction

c. covers per 88A4100898,
d. bellows to seal between park disc and tripod 88A4100430 (new design),
e. scupper boot installation - see 88A4100400, sheet 18,
f. plumbing to return pump.

C. TEST PLAN

1. Piston and Cylinder Spin and Bounce Test

The piston and cylinder should be tested as described in Appendix C. The test will determine the piston/cylinder gap, measure the damping, verify the float has proper clearance and verify that the top of the piston is sufficiently flat for proper flat bearing operation.

2. Verification Tests

Development tests of the following new or modified systems should be conducted:

a. float seal,
b. float height indicating system,
c. float sunk warning system,
d. piston height indicator,
e. return pump and controls,
f. auxiliary control panel.

3. Hydraulic Pumping System

The modified hydraulic system should be tested in accordance with "Hydraulic Unit Test Specification", 88A4100870 with minor revisions for the Space Shuttle application.

4. Test of the Completed System

The system should be tested after completion but before installation of vehicle in accordance with "Post Installation Test Procedure", 88A4100855 revised as necessary for the Space Shuttle configuration. This test procedure will include tests to verify that hazards (including vehicle damage) from hardware failure or operator error have been eliminated or controlled.

D. SAFETY ANALYSIS

The "Reliability Analysis and Corrective Action Summary for the Saturn V HDS" ER14038 must be supplemented to meet the Space Shuttle safety requirements.

E. INSPECTION PLAN AND QUALITY CONTROL

The Quality Assurance Program will be in general conformance with the applicable portions of NHB 5300.4 (ID-1) and will include the following:

1. newly fabricated or modified parts will be inspected to verify that they comply with the requirements of the drawings;

2. purchased components which are generally industrial components will be inspected to verify conformance with the vendors published data, workmanship and cleanliness. Special inspection requirements will be specified on engineering drawings;

3. the results of all functional tests will be verified by inspection and documented;

4. the installed equipment will be inspected to verify compliance with installation drawings;

5. failure analysis will be performed on all failed items critical to the safe and efficient operation of the HDS.

F. SYSTEM INSTALLATION

The installed system is shown in Figure II-1. The installation work will be less than Saturn V due to the fact that the concrete pedestals are not required and the hydraulic pumping system, electrical power system and the control console are in place. Most of the instrumentation and control wiring must be replaced. It may not be necessary to replace the wiring inside the control console.

The hydraulic pressure lines can be made of stainless steel instead of the carbon steel used in the Saturn V HDS. Plastic or aluminum pipe for the return lines may be used instead of carbon steel. The return lines can be smaller in diameter due to the use of return pumps and lower viscosity oil.

The hydraulic lines and most components must be heated and insulated. The lines and components within the pedestal enclosure may not require heating.

G. OPERATING PROCEDURE

An operating procedure similar to the "Technical Manual, Saturn V Hydrodynamic Support System" must be prepared. This document should contain about 160 pages.

H. REFURBISHMENT PLAN

The primary consideration in refurbishment of the HDS equipment is the maintenance of the reliability of the system. The mean time between failures (MTSF) which could stop or delay the test was about 1000 hours on the Saturn V system. The refurbishment required is summarized below.

1. Hydraulic Pumping System

All critical components should be put in "good as new" condition.

a. High pressure pumps - The pumps will be overhauled and tested to original specifications (at a small fraction of replacement costs).

b. Boost pump - Replace with new pump.

c. Heat exchange - Clean and chemically treat the inside of case, "rod out" tubes, proof pressure test.

d. Bladder accumulators - Clean, replace bladders and seals.

e. Piston accumulators - Replace seals, hone inside diameter as necessary.

f. Miscellaneous valves - Inspect, replace seals as required, bench test.

g. Pipe manifolds - Remove, clean and chemically treat inside of pipe.

2. Electrical Power System

Test insulation, functional test under full load.

3. Structural Castings

Dye check for cracks.

4. Instrumentation

Existing instruments that will be reused must be removed for recalibration and necessary repair.

5. Hydrostatic Bearings

The hydrostatic bearings should be checked for the condition of plating on the spherical bearing and for nicks and dents on all bearings. Critical dimensions must be checked to see that they are within tolerance.

6. Hoses

All hoses must be replaced with new ones.

I. SCHEDULE AND LONG LEAD ITEMS

The schedule for the Space Shuttle HDS is shown in Figure IV-4. All material and equipment requirements must be determined by December, 1976, anticipating a maximum lead time of 26 weeks which is the current lead time on high pressure pipe.

J. GOVERNMENT FURNISHED PROPERTY AND SERVICES

This plan assumes that the property and services listed below will be furnished by the Government.

1. Government Furnished Property

   a. Saturn V HDS equipment listed in the inventory

   b. Hydraulic test bench suitable for calibrating and testing hydraulic components.

2. Government Furnished Services

   a. Instrument calibration.

   b. Hydraulic oil contamination measurement (particle count).

   c. 8-ton hoist proof tests.

K. COSTS

The cost of modifying and installing the Saturn V HDS for the Space Shuttle MVGVT as described herein is estimated to be $995,000.

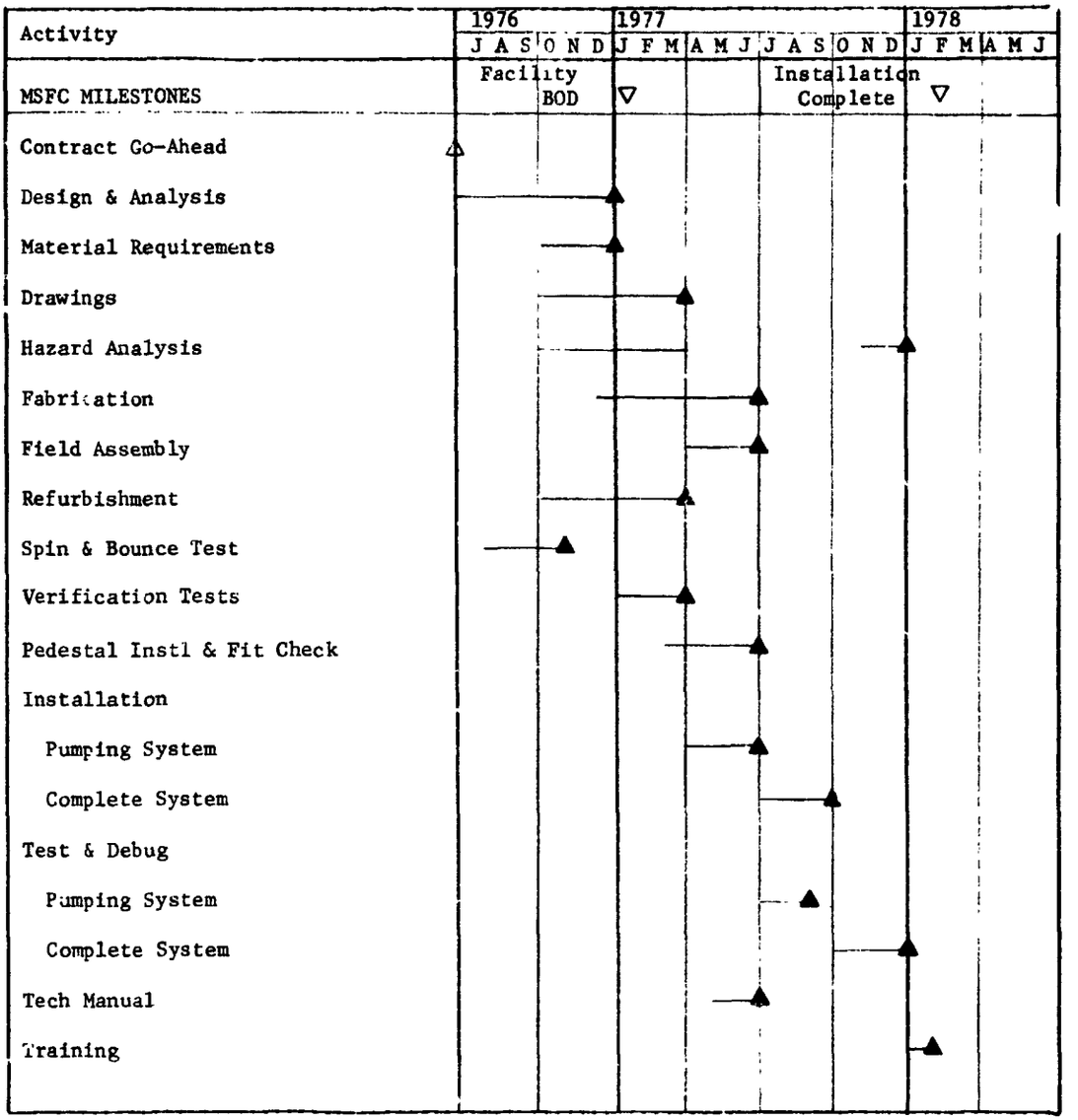


Figure IV-4. Program Schedule

APPENDIX A

INVENTORY AND INSPECTION

INVENTORY AND CONDITION ASSESSMENT NOTES

A. Inventory Notes

1. The "no. Req'd." is for the Saturn V configuration and is generally applicable to the Space Shuttle configuration.

2. "Spares Req'd" are complete units. Additional parts such as seals, lamp bulbs, gaskets, springs and diaphragms are required.

3. Equipment totally missing is not included in the inventory.

4. Parts which are present but appear impractical to refurbish are marked "Replace".

5. Missing hardware such as bolts, washers, shims, chain, etc., is not indicated.

6. Assemblies which are "called out" on the top drawing 88A4100400 are underlined, e.g., 412-009. Equipment is listed in the order that it appears on the drawing tree. Note that on the list, the numbers 88A4100 are omitted as they are common to all drawings.

B. Condition Assessments Notes

1. Where "Good" or "Fair" appear in the "Condition Assessment" column, the equipment appears to be restorable to like new performance. "Poor" indicates marginal for reuse.

2. Suggested refurbishment and test are shown for the purpose of more fully indicating the condition of the equipment.

Table A-1. Inventory and Inspection

Item No.	88A4100 Drawing Suffix	No. Req'd	Spares Req'd	On Hand	Part Name	Condition Assessment and Notes
1	400 Sht 8	1	0	1	Hydraulic Equipment Mounting Rails	Good
2	400 Sht 11 & 12	1	0	1	Electrical Power Installation	Good
3	400 Sht 9,10, & 13	1	0	-	Hydraulic and Pneumatic Piping	Replace
4	400 Sht 14,15 & 16	1	0	-	Oil Line Heating Installation	Replace
5	400 Sht 17	4	0	-	Oil/Air Separator Piping Installation	Replace
6	400 Sht 18	4	0	-	Scupper Boot Installation	Replace
7	412-009	1	0	1	Control Panel Assy	Fair, essentially complete. Remove parts added for later tests. Repair holes in console.
8	443-009	1	0	1	Bearing Contact Junction Box	Good
9	-	12	2	12	12XA Simpson Meter Relay	Fair
10	444-009	1	0	1	Transformer Junction Box	Good
11	899-009	12	0	12	Power Transformer	Good
12	461	1	0	1	Control Panel Junction Boxes	Good
13	472-009	1	0	1	Pipe and Tubing Installation	Good
14	472-019	1	0	1	Pipe and Tubing Installation	Fair
15	832-01	1		1	200 psig Hydraulic Press. Ga.	Good
16	832-003	1	1	2	5000 psig Hydraulic Pressure Gauge	Good
17	833-001	1	1	1	10,000 psig N_2 Pressure Gauge	Good
18	833-002	4	1	2	5000 psig N_2 Pressure Gauge	Good
19	833-003	6	2	8	3000 psig N_2 Pressure Gauge	Good

Table A-1. (continued)

Item No.	88A4100 Drawing Suffix	No. Req'd	Spares Req'd	On Hand	Part Name	Condition Assessment and Notes
20	840-001	20	4	24	1/2 Globe Valve	Good
21	840-002	6	2	8	1/2 Angle Valve	Good
22	840-003	4	1	5	3/8 Angle Valve	Good
23	840-004	7	2	9	3/4 Globe Valve	Good
24	847-001	1	1	2	Temperature Indicator	Good
25	875-001	4	1	*	Differential Pressure Transmitter	*Manufacturer no longer in business. Replace with new equipment.
26	875-002	4	1	*	Indicator	
27	875-003	1	0	*	600' of Cable	
28	885-001	4	2	2	Resistance Bridge Indicator (Piston Height)	Good
29	887-001	4	1	4	Oil Level Sensor	Replace Recalibrate System
30	887-003	1	0	1	Oil Level Control Unit	Fair
31	890-001	1	0	1	Temperature Control Transmitter	Fair
32	890-002	1	0	1	Temperature Control Controller	Fair
33	890-003	1	0	0	Temperature Control Valve	Missing, Replace.
34	890-004	1	0	1	Temperature Control Regulator	Fair
35	890-009	1	0	1	Temperature Control System	Fair
36	893	*1	*1	*1	Control Panel Indicators and Switch Operators	*1 Set on hand, 1 Set of recommended spares per drawing are not on hand.
37	906-009	1	0	1	Electrical Component Assy	Good
38	907-009	1	-	1	Relay Assembly	Good
39	908-009	1	-	1	Rectifier Assembly	Good
40	909-009	1	-	1	Indicator Assembly	Good
41	910-009	1	-	1	Transformer Housing	Good
42	416-009	1	0	1	Support Equipment Set	

Table A-1. (continued)

Item No.	88A4100 Drawing Suffix	No. Req'd	Spares Req'd	On Hand	Part Name	Condition Assessment and Notes
43	416-019	2	0	2	Rail Assy	Good
44	416-029	1	0	1	Support Assy	Good
45	416-035	2	0	0	Link	
46	416-039	2	0	0	Support Assy	
47	416-049	2	0	2	Guide Assy	Good
48	416-055	1	0	0	Disc	
49	416-059	1	0	1	Sling Assy	Good
50	416-089	1	0	0	Wood Assy	
51	416-099	1	0	0	Shelf Assy	
52	416-109	1	0	0	Pallet Assy	
53	416-119	4	0	4	Roller Assy	Poor
54	416-129	2	0	2	Tackle Assy	Fair
55	416-139	2	0	2	Hoist Fitting	Good
56	416-159	2	0	2	Hoist Fitting	Good
57	416-169	2	0	2	Jack	Good
58	-	2	0	2	Yale 8 Ton Chain Hoist	Clean and proof test.
59	432-009	4	0	4	Park Structure	Remove sight glass assy. Remove welded channels and grind smooth. Sand blast, dye check support casting for cracks, check alignment to drawing tolerances, repaint.
60	433-009	1	0	1	Piston and Bearing Assy	
61	405-011	4	0	4	Spherical Bearing	Clean, check condition of surfaces, check for condition of plating, replate if necessary.
62	405-017	4	0	4	Stem	Fair

Table A-1. (continued)

Item No.	88A4100 Drawing Suffix	No. Req'd	Spares Req'd	On Hand	Part Name	Condition Assessment and Notes
63	410-009	2	0	*2	Piston and Cylinder Assy	*All parts missing except: Piston 88A4100417 Cylinder 418 Float 405 Float Seat 456 Bailing Tube 467 Float Sensor Details 866 Hoist Fittings 492
64	410-019	2	0	*2	Piston and Cylinder Assy	
65	417-009 & -019	4	1	5	Piston Assy	Clean, remove corrosion, replace epoxy.
66	418-009	4	1	5	Cylinder Assy	Clean, remove corrosion, pain.
67	465-009	4	1	5	Float Assy	Clean, check tolerance on 21.970" diameter.
68	456-001	4	1	5	Float Seat	Good
69	866	4	0	4	Float Sensor Details	Good
70	423-009	4	0	*4	Bearing and Manifold Assy	*All parts missing except: Flat Bearing 88A4100405-013 Orifices 484-001
71	405-013	4	0	4	Flat Bearing	Good
72	455-009	4	0	*	Bearing Disc	*Replace
73	462-009	4	0	4	Brace Structure	Some small components missing--general condition, poor.
74	466-029	4	0	*	Rubber Bumper Assy	*Replace rubber.
75	464-009	4	0	0	Bumper (Roll)	Replace rubber.
76	469-001	4	0	4	Plate	Fair, check tolerances.
77	486-009	1	0	1	Equipment and Piping Installation	
78	475-009	1	0	1	Heat Exchanger Support	Good
79	476-009	1	0	1	Accumulator Rack	Good
80	494-009	1	0	1	Manifold Assy	Good

Table A-1. (continued)

Item No.	88A4100 Drawing Suffix	No. Req'd	Spares Req'd	On Hand	Part Name	Condition Assessment and Notes
81	495-009	1	0	1	Breather Assy	Good
82	496-009	1	0	1	Manifold Assy	Good
83	825-001	9	0	9	20 Gallon Accumulator	Hone inside as required, replace O-rings.
84	826-001	1	0	1	Heat Exchanger	"Rod out" tubes, clean to meet contamination spec, sand blast exterior, repaint, and proof test.
85	828-001	1	0	1	Variable Volume Pump	Rebuild and test to original specification.
86	828-002	1	0	1	Variable Volume Pump	
87	878-001	2	0	2	Motors, 200 hp	Clean and repaint, retest motors and starters underload.
88	878-002	2		2	Starters, 200 hp	
89	830-001	1	1	2	4" Ball Valve	1 new, clean and replace seals in both.
84	830-003	2	0	2	3" Ball Valve	Good
90	431-001	4	0	4	Filter Housing	Fair
91	431-002		-	12	Filter Element 200-F-250	Good (use for initial cleanup only).
92	431-003	4	8	6	Filter Element 8-13-S-20 (throw away type)	Good (use for initial cleanup only).
93	Vendor P/N	4	6	*0	Improved Filter Element	*Improved filter elements are available.
94	834-001	9	0	9	2" Ball Valve	Good
95	835-001	1	0	1	Unloading Valve	Good
96	836-001	3	0	3	2" Check Valve	Good
97	837-001	1	0	1	1" Shutoff Valve	Good
98	838-001	1	0	*	Booster Pump	Replace with centrifugal pump.
99	845-001	1	0	1	5 Gal Accumulator	Clean, replace bladder and anti-extension ring.
100	846-001	1	0	1	Reservoir	Good, clean cosmolene from interior.
102	877	1	0	1	Reservoir Oil Heater	Good

Table A-1. (continued)

Item No.	88A4100 Drawing Suffix	No. Req'd	Spares Req'd	On Hand	Part Name	Condition Assessment and Notes
103	880-001	1	0	1	1-75 psi Adjustable Press Sw	Fair
104	880-002	1	0	1	400-3000 psi Adjustable Pressure Switch	Fair
105	488-009	4	0	*	Tubing Installation (Pedestal)	The only usable part of this installation is the sight glass 841-001 and filter 60HP-250-M-20-YY3.
106	841-001	4	1	*4	Sight Glass	Overhaul sight glass per mfg specification. *12 B8 glass segments with gaskets are on hand.
107	Vendor P/N	8	0	6	Rosaen 60HP-250-M-20-YY3 Filter Housing	Fair
108	Vendor P/N	-	-	18	Rosaen 60HP 250 Filter Element	Good (use for initial cleanup only).
109	Vendor P/N	8	10	*0	Improved Filter Element	*Improved filter elements are available.
110	480-049	4	0	2	Capillary Panel	2 panels missing, 2 are in good condition.
111	483-009	4	1	2	Linear Flow Control Valve	Good
112	499-001	4	0	2	Regulator	Fair
113	429-004	4	2	2	Flow Control Valves	Poor
114	841-002	4	1	1	Sight Glass	Unused
115	842-001	4	1	2	Relief Valve	Good
116	849-001	4	1	3	Flow Control Valve, Variable	Good
117	849-002	4	0	2	Flow Control Valve, Variable	Good
118	871-009	1	0	*	Control Center Enclosure	*East wall only in place. This design may not meet OSHA requirements for noise attenuation.
119	889	1	0	1	Oil Line Heating System	Replace
120	901-019	1	0	1	Distribution Control Center	Good

APPENDIX B

INSPECTION OF PISTONS, CYLINDERS AND BEARINGS

Preservation Plan

The pistons, cylinders and hydrostatic bearings were stored in accordance with "Hydrodynamic Suspension System Preservation Plan", Boeing Document D5-15785, dated 12-18-68.

The pistons, cylinders, flat and spherical bearings were stripped of all components, cleaned, coated with cosmolene and wrapped in plastic sheets. The spare piston and cylinder were also preserved. These elements were then packed in 10 plywood boxes, approximately 10' x 5' x 6', each containing a single cylinder or a single piston and bearings. See Figure B-1 for a photograph of the piston and cylinder when new.

Boxes

The large plywood box that contained piston number 3 was partially rotted. One other box was slightly decayed. The remaining plywood boxes were in good condition. The defective parts of these boxes were replaced prior to repacking.

Cylinders

The interior of all cylinders were inspected. The results are shown in Table B-1.

Table B-1. Condition of Cylinders

Cylinder Number	Condition	Affect on Function
1	Slight rust spots	None
2	OK	None
3	Very slight rust spots	None
4	OK	None
5	OK	None

The cylinders were resealed and placed in boxes; the box tops were covered with black 6 mil polyethelene.

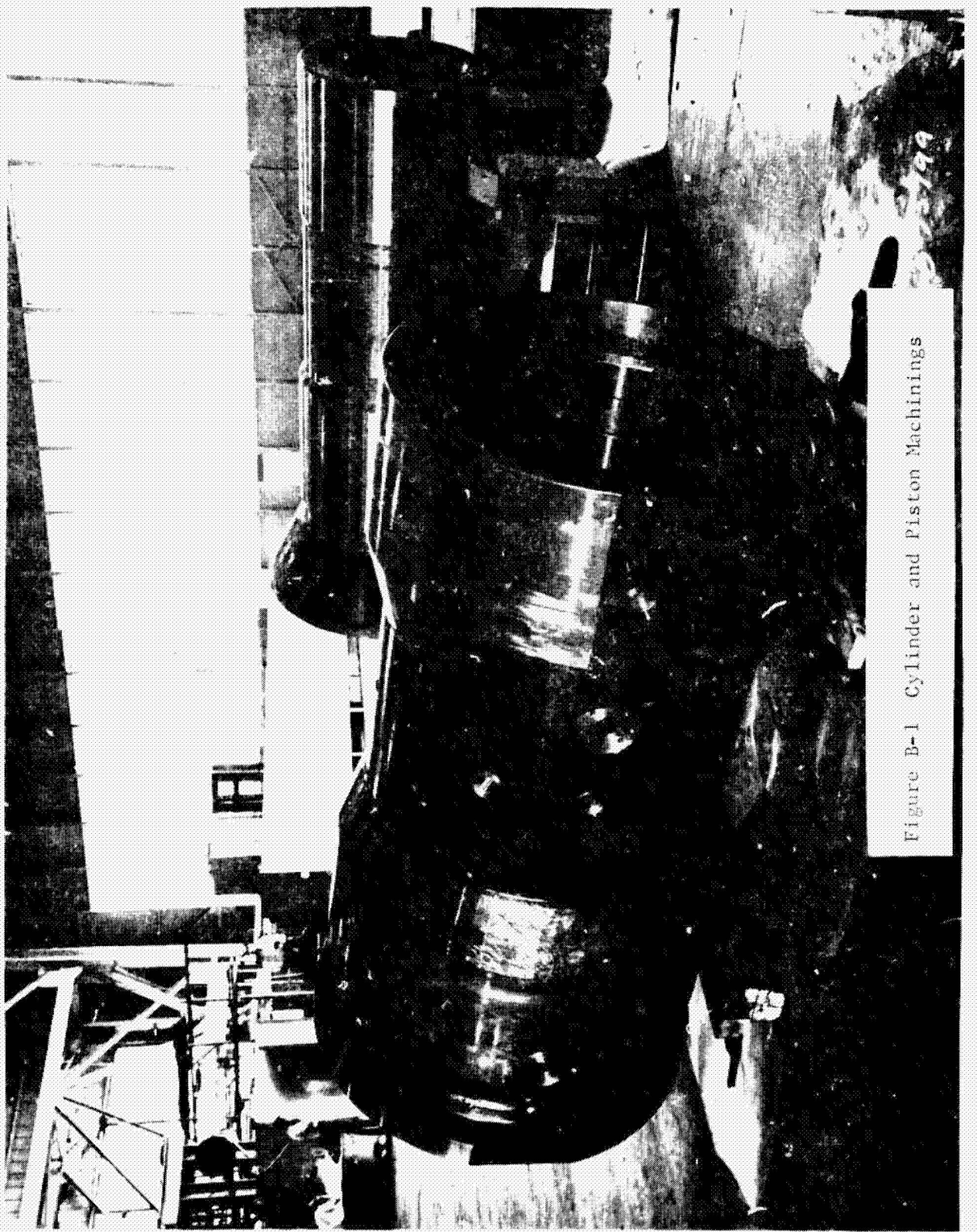


Figure B-1 Cylinder and Piston Machinings

Pistons

The number 3 piston was removed from the partially rotted box. It proved to be in the worst condition. The plastic wrapping contained about a gallon of water. About 20% of the critical surfaces were rusted. The preservative was removed from the outside of the piston. The loose rust was removed with steel wool and number 240 carborundum paper. Rusted areas were treated with inhibited phosphoric acid (Duro branc "Naval Jelly"). Not withstanding the initial bad appearance of the piston, the damage was minimal. The damage will increase the flow conductivity by a maximum of 5% in the area of the worst rusting.

The interior of the piston was examined and no rust was found.

The groove around the circular plug in the top of the piston was initially filled with epoxy (reference drawing 88A4100418). This epoxy was partially missing, perhaps due to erosion during use. The missing epoxy substantially reduces the ability of the flat bearing to resist tilting moments due to horizontal oscillatory motion. The epoxy must be replaced in a manner that will preclude its deterioration in use.

The float, flat and spherical bearing which were packed with the piston were in good condition. The piston was coated with cosmolene, wrapped in plastic and reboxed. The remaining pistons and bearings were examined through the transparent plastic. The results are summarized below.

Table B-2. Condition of Pistons

Piston Number	Condition	Affect on Function
1	OK	None
2	OK	None
3	20% rusted, 1 gal water under wrapping	Minimal
4	Moisture under wrapping	None
5	OK	None

Piston/Cylinder Radial Clearance

The "Affect on Function" in Tables B-1 and B-2 for the pistons and cylinders is based on the assumption that the piston/cylinder clearance has not changed significantly during storage or handling. This assumption is based on a comparison of the data taken during the head-to-head test and the data taken about nine months later during operation of the HDS. There is a decrease in the clearance based on diametral measurements taken during manufacture and those derived from test. It seems most probable, however, that this difference is due either to the difficulty in accurately measuring the cylindrical surfaces of the piston and cylinder or to the correlation of the fluid flow rate to the actual gap. See Table B-3 and Figure B-2 for quantitative data.

Table B-3. Piston-Cylinder Gap Change

	Support Number				
	1	2	3	4	Average
Manufactured Gap	.007" .009"	.007" .009"	.007" .009"	.007" .009"	.008"
Head-to-Head Flow, gpm	6.8	4.0	6.2	4.4	
Head-to-Head Computed gap	.0072"	.006"	.007"	.0062"	.0066"
Saturn V Capillary Valve, Turns Open	2.15	1.80	2.10	1.85	
Saturn V Computed gap	.0071"	.0058"	.007"	.0059"	.00645"
Indicated Change	-.0001"	-.0002"	0	-.0003"	-.00021"

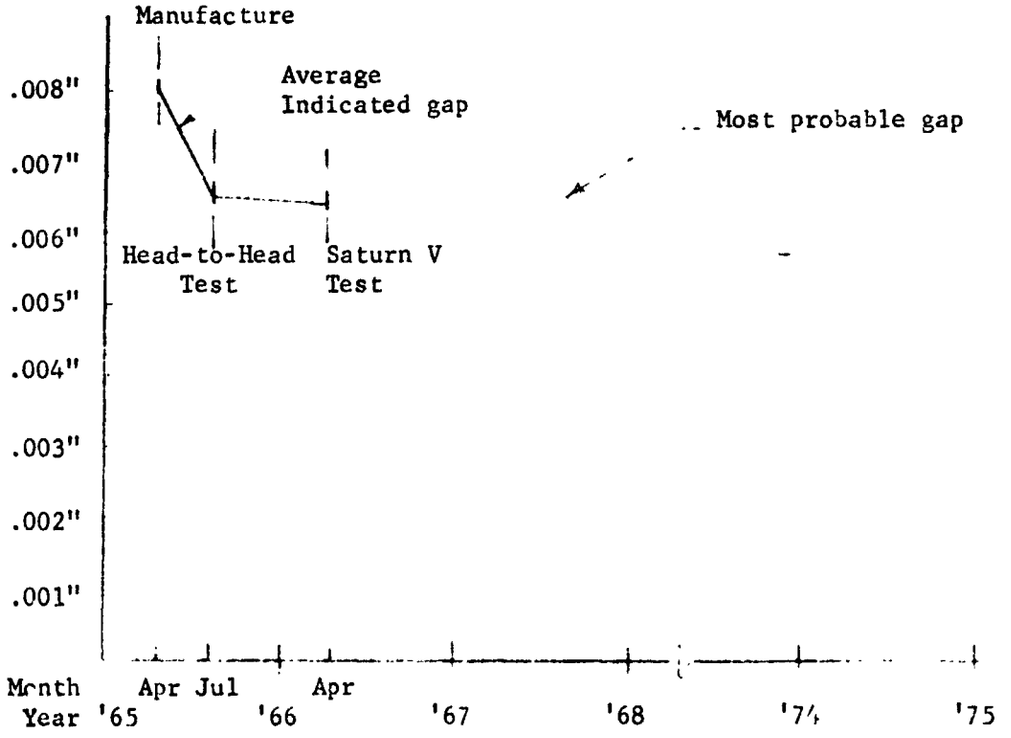


Figure B-2. Piston-Cylinder Gap Change vs Time

APPENDIX C

PISTON-CYLINDER TEST (SPIN & BOUNCE)

PISTON-CYLINDER UNIT TEST (SPIN & BOUNCE)

A. Test Objective:

1. Determine piston/cylinder gap from pressures at the 12 ring bearing recessed;
2. measure piston/cylinder damping;
3. determine that float has adequate clearance;
4. proof test piston;
5. measure flatness of top of piston at operating pressure and verify that it is adequate for proper bearing operation.

B. Test Preparation:

1. remove preservative and clean rust spots from pistons, cylinders and floats;
2. install float in piston;
3. install plumbing flow control valves and pressure gauge on cylinder;
4. install piston in cylinder using procedure shown in 88A4100410, sheet 5;
5. prepare accelerometer and strip recorder;
6. install platform for access to top of piston;
7. connect hydraulic supply (see Figure C-1).

C. Test Procedure:

1. measure bearing recess pressures;
2. oscillate piston vertically (by hand), measure logarithmic amplitude decay;
3. rotate piston and measure velocity decay;
4. measure piston top flatness at 0 and 1600 psi.

D. Test Analysis:

1. compute piston-cylinder gap at 12 recesses based on Saturn V test data;

2. compute piston-cylinder gap based on damping tests and compare with Saturn V data.

F. Equipment Required:

1. 3000 psi, 7.5 gpm hydraulic supply;

2. accelerometer and strip chart records;

3. guide pins per 88A4100410, sheet 5;

4. miscellaneous plumbing for test setup;

5. 12 flow control valves and tube assemblies per 88A4100410;

6. miscellaneous cleaning equipment and supplies;

7. special spanner wrench to remove and install float seat ring.

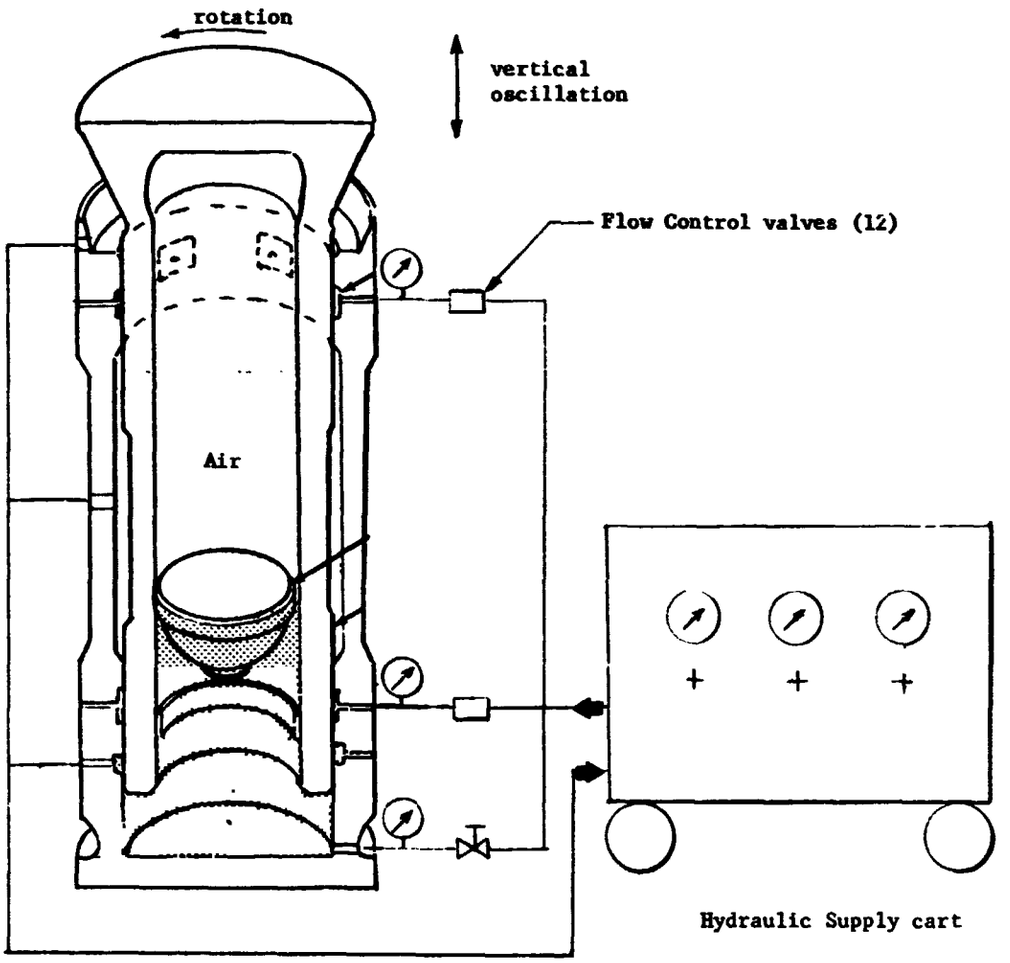


Figure C-1. Piston-Cylinder Unit (Spin & Bounce) Test

APPENDIX D

NOTES FROM CONFERENCE

WITH

GEORGE HOCH

Conferences were held with George Hoch, the former Martin Marietta supervisor for the installation and operation of the Saturn V HDS.

A. Recommendations

The following recommendations are made to improve the reliability ease of operation, and facilitate maintenance.

1. Improve sound level in control panel enclosure. It may not meet OSHA requirements.

2. Replace instrumentation wiring because of problems with shorts.

3. Replace boost pump with one that requires less adjustment and maintenance.

4. Provide protective enclosure for pedestals to prevent water and dust from entering the hydraulic system and the electrical and instrumentation conduits.

5. Run high pressure pump motors at less than full load to prevent overheating on hot days.

6. Use more reliable return line heaters.

7. If shims are added to the top of the part structure increase the park block height an amount equal to the shim thickness so that the flat bearing will remain in contact with the spherical bearing when the vehicle is in the park position.

8. Relocate the bearing contact warning meters inside the control room.

9. Install a protective housing over the area where the filters are changed to keep wind from blowing dust into the filler housings and cartridges.

10. Add the following to the periodic inspection requirements.

Item	Frequency	Procedure	Corrective Action
Hydraulic Reservoir	2 Months	Take sample from bottom near outlet to boost pump	Drain and Clean
Cylinders	2 Months	Remove fitting and clean bottom with suction pump	

11. Change the needle valves on the control panel which have only an on-off function to quarter turn valves to improve speed of operation in emergency situations.

12. Increase the size of AN200KP8 bearing in the brace structure assembly to improve ease of bumper operation.

13. Check the .005" flatness tolerance on 88A4100469-001 plates.

14. Move pressure gauges PI-11 and PI-12 so that they are visible from the control console enclosure.

B. Documents

The following pertinent documents were obtained and were forwarded under separate cover.

1. "Hydrodynamic Suspension System Preservation Plan", Boeing document D5-15785, dated December 18, 1968.

2. "Technical Manual, Saturn V Hydrodynamic Support", revised May 1, 1967, prepared by Martin Marietta Corporation.