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FINAL REPORT

F SERIES

STAGING

MOCK-UP INVESTIGATION

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FINAL REPORT

F SERIES

STAGING

MOCK-UP INVESTIGATION

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REVISIONS

NO.	DATE	BY	CHANGE	PAGES AFFECTED

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E. E and F Staging Investigation Dynamics Report (1962) AD1558

F. Jettison Rail Dynamic Response Investigation - (F Series Mock Up) 27A3437

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1.0 INTRODUCTION

This report is presented as a portion of the Computer, Launch and Separation Problem (CLASP) Program. Reports for the other phases of the program are not covered, except as necessary to define the subject herein.

Project CLASP was an extensive investigation of "E" and "F" Series Atlas Missile System failures in order to analyze, isolate and define the critical areas associated with staging, guidance and other problems that may have been defined and to devise and prepare design fixes to correct the problems.

An investigation of possible problem areas in the staging of Atlas "E" and "F" missiles was conducted as a portion of the program in order to determine the mode of failure of 71E, 6F, and 136F. The failure of the three missiles was directly attributed to loss of sustainer hydraulic pressure after initiation of staging.

As an aid to the staging investigation, the "F" Series Mock-up Test Program was performed in Building 1, Plant 19, General Dynamics/Astronautics, San Diego during the period 3 February 1964 through 3 March 1964.

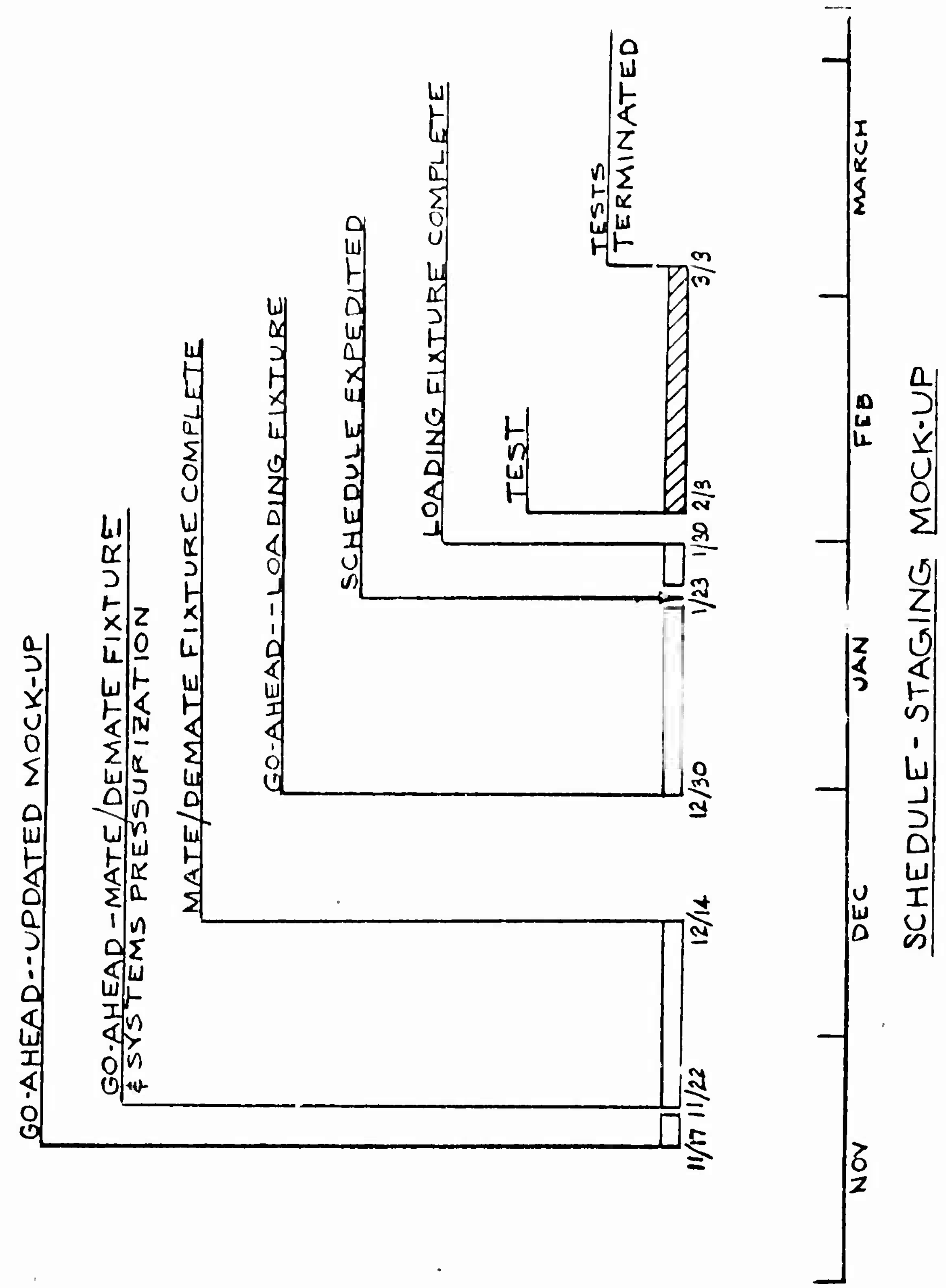
The mock-up program began with a requirement generated on 17 November 1963 to provide an updated "F" Series mock-up to facilitate the "E/F" Series staging investigation. This requirement was fulfilled by reassembly of the specimen which had been used earlier that year in the Thrust Section Vibration Test. Prior to that test the specimen had been updated to "F" Series configuration.

During the subsequent investigation, requirements were formulated for the performance of such tests as could be expeditiously accomplished on the mock-up. The mating/demating fixture, the loading fixture, facilities for the pressurization of airborne systems and other loading and instrumentation fixtures were provided to meet these requirements.

Nine tests were accomplished during the available test period. Eight of these tests were successful. One test, the Sustainer/Thrust Section Deflection Test was unsuccessful with respect to acquisition of Load/Deflection Data. This was due to the flexibility of the jettison slide/jettison track structure, which permitted the thrust section to interfere with the sustainer section before the required test condition had been attained.

In January 1964, the program was expedited to assure availability of the specimen by 4 March 1964 for the Point Loma test program. The major result of this speed up was the loss of lead time for the preparation of formal test procedures. This deficiency was compensated by the provision of continuous engineering support during the testing.

2.1.0 SCHEDULE



SCHEDULE - STAGING MOCK-UP

PREPARED BY	DATE	CHECKED BY	DATE	REVISED BY	DATE
P.C. Bandow	4-30-64				

3.0 SUMMARY

The primary objective of this program was to investigate possible problem areas involved in staging using a completed "F" Series thrust section.

Test Program

The following tests were planned:

Phase I

Test	5.1	Mate/Demate Check-out
	5.2	Sustainer/Thrust Section Deflection Test
	5.3	Helium Bottle Interference Test
	5.4	Q IV Jettison Track Vibration Test
	5.5	Jettison Track Deflection Test
	5.6	LOX Bottle Area Deflection Tests
	5.7	Solo LOX Bottle Deflection Tests
	5.8	Jettison Slide Pedestal Tests
	5.9	Sustainer Droop Tests
	5.10	Sustainer Gimballing Test
	5.11	Fuel Disconnect Test
	5.12	Separation Strap Calibration

Phase II

Test	1.	Separation Latch Tests
	2.	Sustainer/Thrust Section Deflection
	3.	Sustainer Gimballing
	4.	Dynamic Separation

Only Tests 5.1 through 5.9 of Phase I were performed. The remainder of the tests were not accomplished due to the termination of the test program on the staging mock-up at General Dynamics/Astronautics Air Force Plant 19.

CONCLUSIONS AND RECOMMENDATIONS

The conclusions and recommendations of the nine tests performed are outlined below:

Test 5.1 - Mate/Demate Check-out

The test results, considered in conjunction with the production mating procedure, indicate that appreciable loads may be induced in the jettison slides in the last 5 inches of motion.

Test 5.2 - Sustainer Thrust Section Deflection Test

The test results show that for the first few inches of motion the jettison slide/jettison track structure is not sufficiently stiff to prevent the forward edge of the thrust section from striking the sustainer tank when staging loads are applied statically. (The significance of this under dynamic conditions will be determined during dynamic testing at Point Loma.

Test 5.3 - He Bottle Interference Test

The Q III - Q IV helium bottles are supported by adjacent plumbing, etc., to such an extent that interference with the sustainer is improbable even after failure of the support structure. No further testing in this area is necessary.

Test 5.4 - Q IV Jettison Track Vibration Test

The transmissibility of vibration from the jettison track is so low that the excursion of the Lox bottle vent control valve due to flight vibrations is unlikely to be of sufficient magnitude to cause interference with the hydraulic system.

Test 5.5 - Jettison Track Deflection Tests

Deflection test provided necessary information to predict track deflection due to flight loads. The load/deflection characteristics are linear up to the test load level. The effect on track deflection due to the low test fuel tank pressure is negligible. X

Test 5.6 - Lox Bottle Area Deflection Tests

Results indicate no further testing is required.

Test 5.7 - Solo Lox Bottle Deflection Tests

The flexibility of the Lox bottle support structure is sufficient to ensure that undue strain is not imposed due to known deflections of the jettison track and "A" frame.

Test 5.8 - Jettison Slide Pedestal Tests

The failure load of the Q IV pedestal is less than the anticipated load in the Point Loma program applied statically.

The flexibility of the forward slide pedestals should be considered as a contribution to the overall flexibility of the jettison track/jettison slide system.

Instrumentation of this area should be considered for Point Loma test and a flight article. This would aid in resolving necessity of a redesign effort.

Problems Encountered During Testing

The hydraulic reservoir failed during a routine fill and bleed operation. The mode of failure indicated an overpressurization of the hydraulic return system, probably related to the manual throttle control on the pumping system. Since the reservoir was a prime suspect area, a recommendation was made for further testing and analysis including consideration of possible overpressurization in all fill and bleed procedures.

The Q IV jettison slide pedestal failed while attempting to achieve a given flight load on the jettison rails during Test 5.2 - Sustainer/Thrust Section Deflection Test, at 12 inches of booster separation.

A series of pedestal deflection tests were conducted (Test 5.8). The failure load was 2200 pounds while anticipated flight load could reach 2900 pounds in the same direction.

One test was conducted on a pedestal which was redesigned to add an intercostal between two attach points. It increased the pedestal strength enough to react a 3800 pound load. At the 3800 pound load the pedestal bolt holes for attaching the slide failed. It is felt that further instrumentation on Point Loma tests and possibly a flight article would reveal the maximum load to fix a value to use in a redesign effort, if required.

Revised loads to be used at Point Loma will apply the load on the Q II pedestal in the direction of least structural resistance. This may cause a repeat of failure in the same mode as the Q IV pedestal failed in these tests.

Incompleted Test Program

With the decision to continue testing of the staging mock-up at the Point Loma Test Facility, the last three tests of Phase I and all of the Phase II tests were deleted. One of these tests, the Fuel Disconnect Test, was deemed unnecessary while another, the Separation Latch Test, was made into a separate investigation.

While the intent of the Point Loma testing is not to complete this program as outlined, it is similar enough to the Phase II portion that the intent of these tests will be accomplished.

4.0 DESCRIPTION OF TEST FIXTURE AND SPECIMEN INSTALLATION

The tests were performed on the "E" and "F" Series Staging Mock-up in Building 1, Plant 19. A diagram of the test set-up is presented in Figure 4.2.1.

The test specimen consisted of the "E" stub tank/sustainer specimen and booster section specimen previously updated to "F" Series configuration for the "E" and "F" Series thrust section vibration test.

The test fixture consisted of:

A. A track support structure comprised of two horizontal "I" beams suitably supported on pedestals from the floor.

B. A booster section support carriage capable of manual translation along the track support structure and provided with adjustment to align the thrust section with the jettison tracks.

C. A loading fixture supported on a system of jacks from the track support structure. The stub tank was attached to the loading fixture around the periphery of the sta. 1049 "Battleship Bulkhead" and at the crown of the forward pressure dome. An auxiliary support, provided at sta. 1133, was disengaged during loading tests.

D. Two vertical hydraulic jacks, remotely controlled individually by hand pumps and monitored individually by pressure gages. This system was calibrated prior to testing. These jacks were supported on a lateral horizontal beam, the position of which could be varied along the "Z" axis. Roller bearings were provided between the jacks and the loading fixture to effectively prevent lateral loading.

E. An auxiliary hydraulic jack to facilitate adjustment to the required test condition. This jack was disengaged when the test condition was attained.

F. Two yaw loading jacks, one located on the forward left hand side, the other on the aft right hand side of the loading fixture. These jacks were individually remotely controlled by hand pumps and individually monitored by pressure gages. This system was calibrated prior to testing.

G. Four screw jacks for leveling and supporting the loading fixture. These jacks were disengaged during loading tests.

H. A turnbuckle/cable hold down for the booster section and carriage on each side of the test fixture. (For safety precaution)

The test fixture is illustrated in Figure 3.1.

Loading Fixture

No provisions were made for the simulation of flight conditions by the application of local flight loads. The tests were designed to obtain data on the effect of the summation of these loads on the jettison track slide structure. The loading fixture was designed to apply the correct summation o of loads and moments while minimizing the effects of test fixture load inputs and reactions.

During the loading tests, the sustainer section was attached to the fixture only around the periphery of the forward "Battleship" bulkhead and at the crown of the pressure dome. Thus the sustainer/load fixture assembly was in equilibrium under the load system shown in Figure 4.2.2.

The load "V" in the vertical jacks was chosen such that the difference between "V" and the weight "W" induced the required vertical load in the four jettison slides.

The location "D2" of the vertical jacks was determined by the required moment in the jettison slides.

The net result when the test condition was attained is shown in Figures 4.2.2, the sustainer section being in equilibrium under the system of loads illustrated.

The two yaw jacks could be used to induce yaw loads into the jettison slides in a manner similar to the vertical loads.

INSTRUMENTATION

Strain Gages

A. On all four jettison slides to read shear and axial strains on an SR4 Budd strain indicator.

B. On all six jettison rail attach struts, taped on oscillograph recorders.

C. On the hydraulic lines at the staging disconnect, taped on oscillograph recorders.

D. On the drag links of the staging disconnects, taped on oscillograph recorders.

Linear Motion Transducers

A. On the jettison tracks to measure deflection relative to the sustainer. Taped on oscillograph recorders.

B. On the solo Lox bottle pilot valve to measure deflection relative to the hydraulic reservoir. Taped on oscillograph recorders.

C. For the 12 inch separation test, on various internal components to measure deflection relative to the booster. Taped on oscillograph recorders.

Dial Indicators

A. At Station 1133 on the sustainer to measure motion in three planes and diametrical distortion.

B. At the vertical load jacks to measure vertical displacement relative to the ground.

Test Method

The stub tank was leveled using the four vertical leveling screw jacks. The thrust section was then engaged with the jettison tracks, misalignment being corrected by the adjustment on the booster section support carriage.

The thrust section was separated from the stub tank by the requisite separation distance measured at Sta. 1133. The intent was to conduct static load/deflection tests at the following increments of separation: 6 inch; 12 inch; 30 inch; 48 inch; 56 inch. The aft end of the booster section was then tied down to the track support fixture.

The distance from the common C.G. of the sustainer specimen and loading fixture to the vertical loading jacks was adjusted as required for the specific test. This distance is set to induce in the jettison slides a moment equal to the summation of all pitching moments encountered in flight at the relevant separation distance.

The load to be applied by the vertical loading jacks is such that the difference between this loading and the weight of the sustainer specimen and loading fixture is equal to the summation of flight vertical loads applied to the jettison slides at the relevant separation distance.

The following procedure was executed to ensure that:

A. This predetermined moment and load would be imposed on the jettison slides by attaining a condition in which the sustainer specimen/loading fixture assembly is balanced solely by its own weight, the load in the two vertical jacks, and the load on the jettison slides.

B. That the correct load distribution between the fwd and aft jettison shoes is attained by allowing the stub tank to rotate in the pitching plane until limited by the jettison shoe reactions.

Vertical Loading Procedure

1. Raise the auxiliary hydraulic jack until the loading fixture lifts off the fwd screw jacks.

2. Adjust the two vertical hydraulic loading jacks to the required test load.

3. Disengage all screw jacks and ensure that motion of the loading fixture is restrained only by the two vertical load jacks, the auxiliary jack, and the jettison slides.

4. Adjust the two vertical jacks to slightly below the test load. (The auxiliary jack will register an increase due to load transfer).

5. Adjust the auxiliary jack to zero load. (The load in the two vertical jacks will increase to greater than the test load).

6. Repeat steps 4 and 5. The increase in load in the two vertical jacks in step 5 will progressively diminish. Continue repeating steps 4 and 5 until the load registered in the vertical jacks in step 5 is equal to or less than the test load.

7. Disengage the auxiliary jack.

8. Adjust the two vertical jacks to slightly below the test load.

9. Raise the two vertical jacks to the test load. Monitor deflections at the two vertical jacks to ensure that a nominal reduction in deflection occurs.

A condition has now been attained at which the correct moment and load, as functions of weight, the vertical jack loads, and the vertical jack location, is resisted by the jettison shoes.

Linear motion transducers, dial indicators, and strain gage readings were taken at each of the above steps.

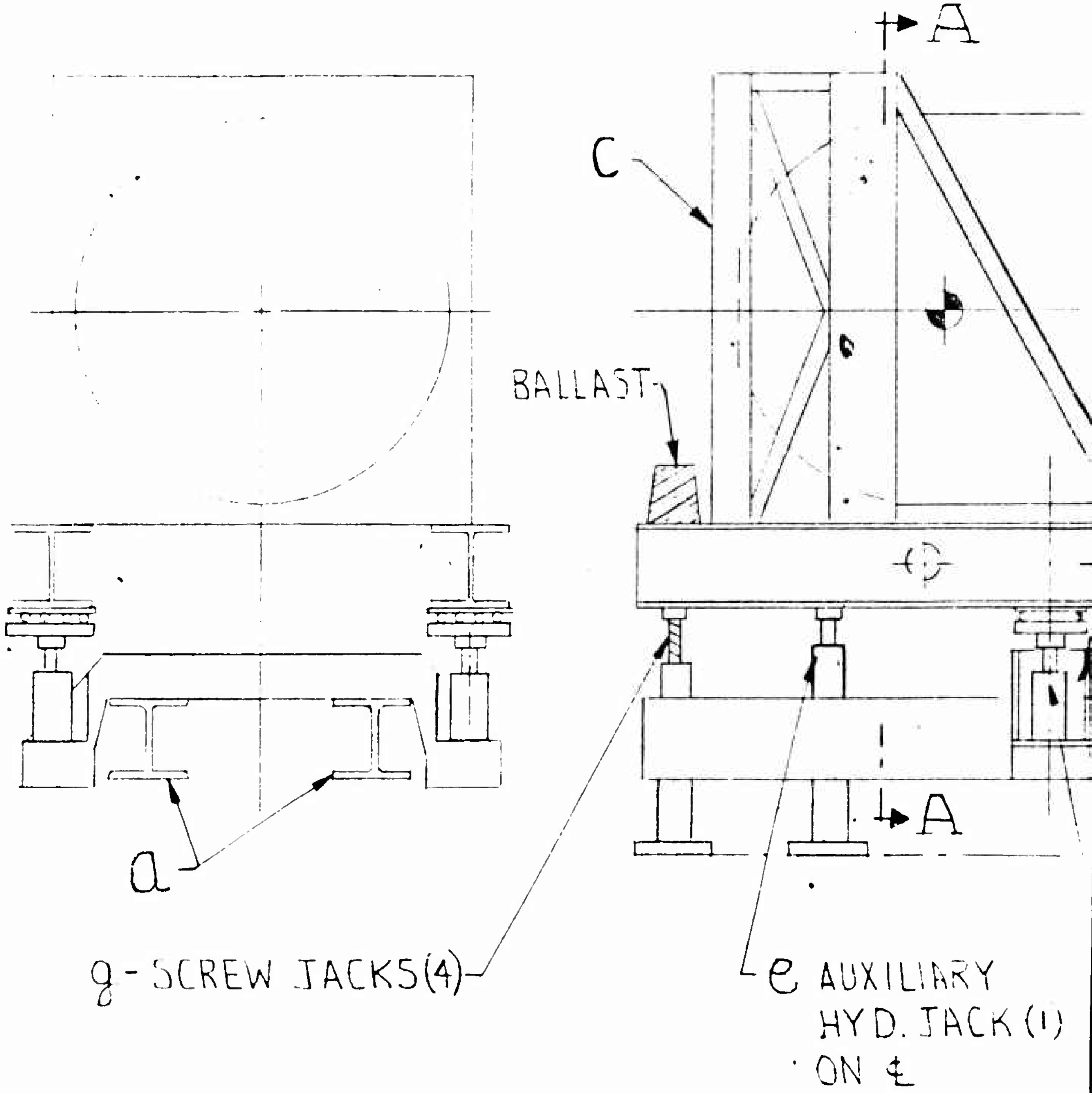


DIAGRAM-STAGING MOCK

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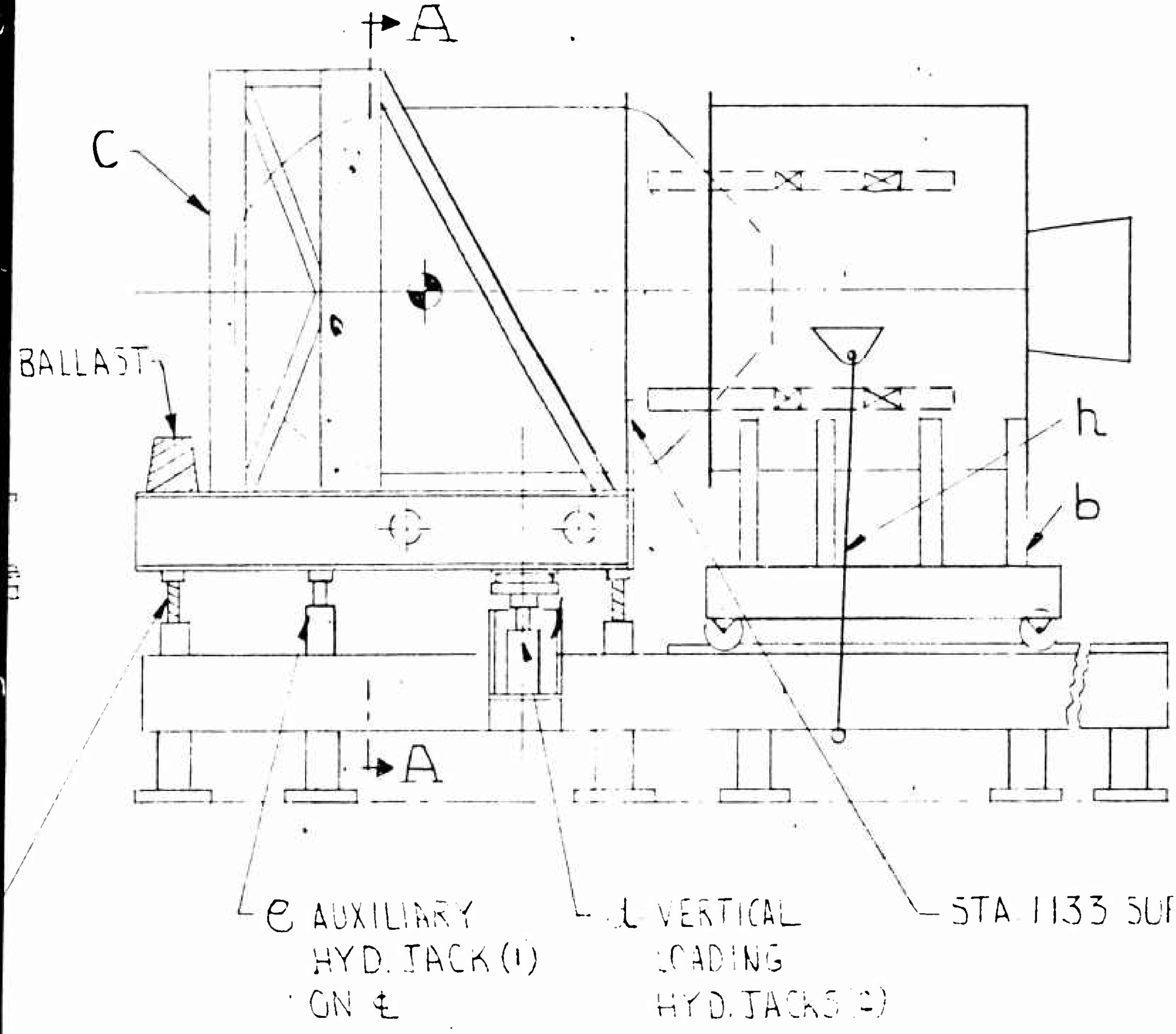
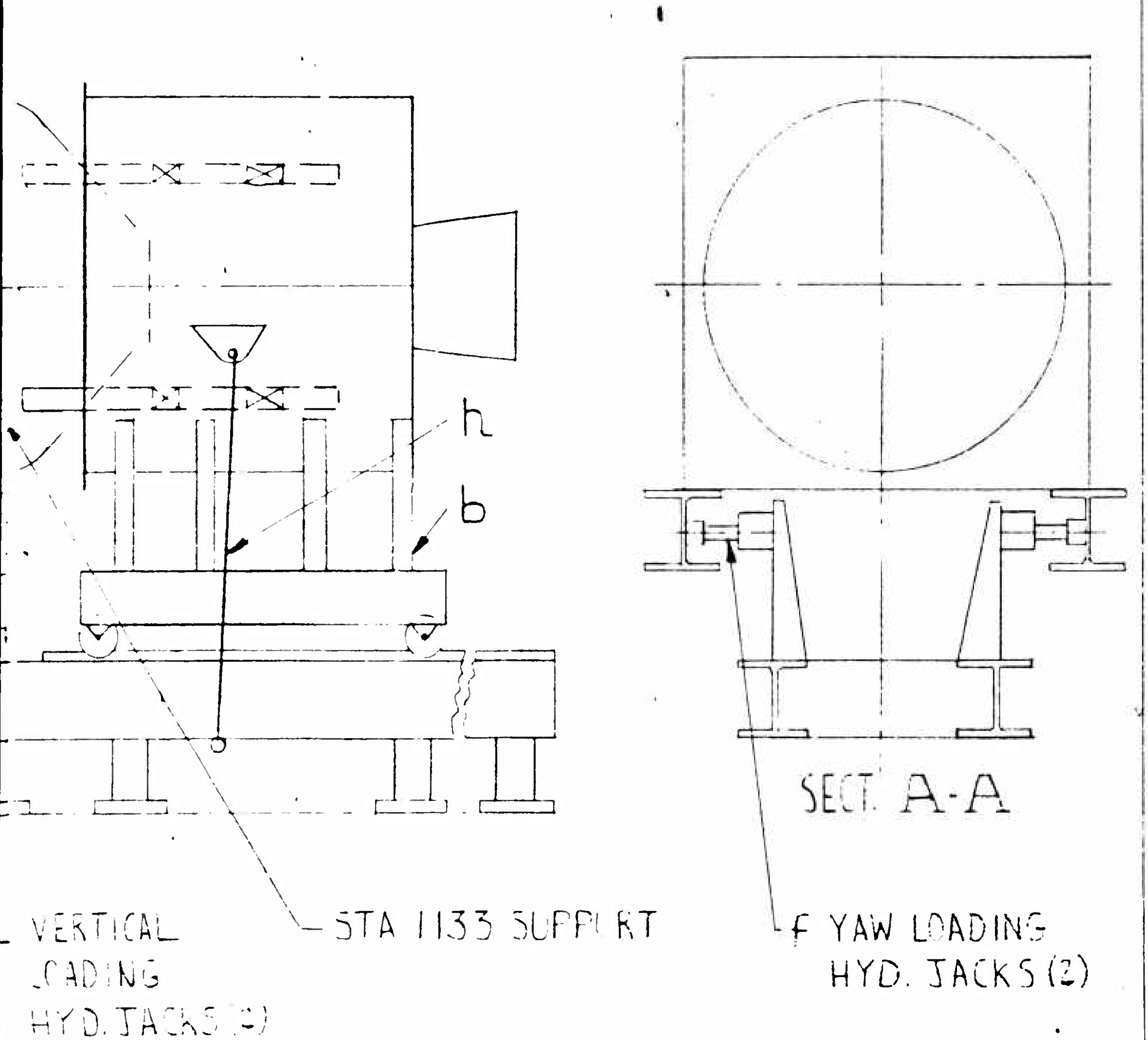


RAM-STAGING MOCK UP TEST STAND

PREPARED BY K.R. Fowler DATE 4-30 CHECKED BY



TEST STAND

FIGURE 4.2.1

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B.

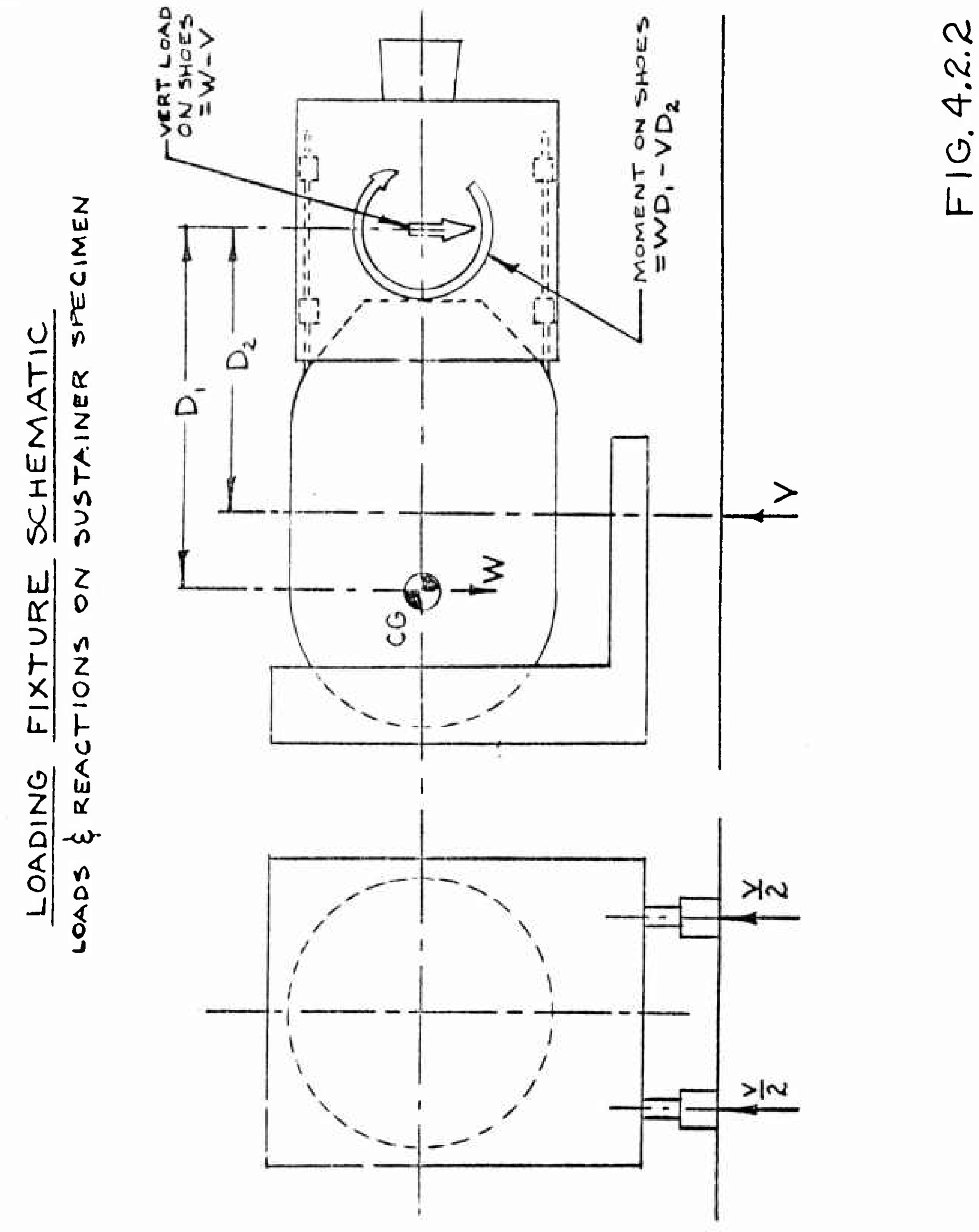

FIG. 4.2.2

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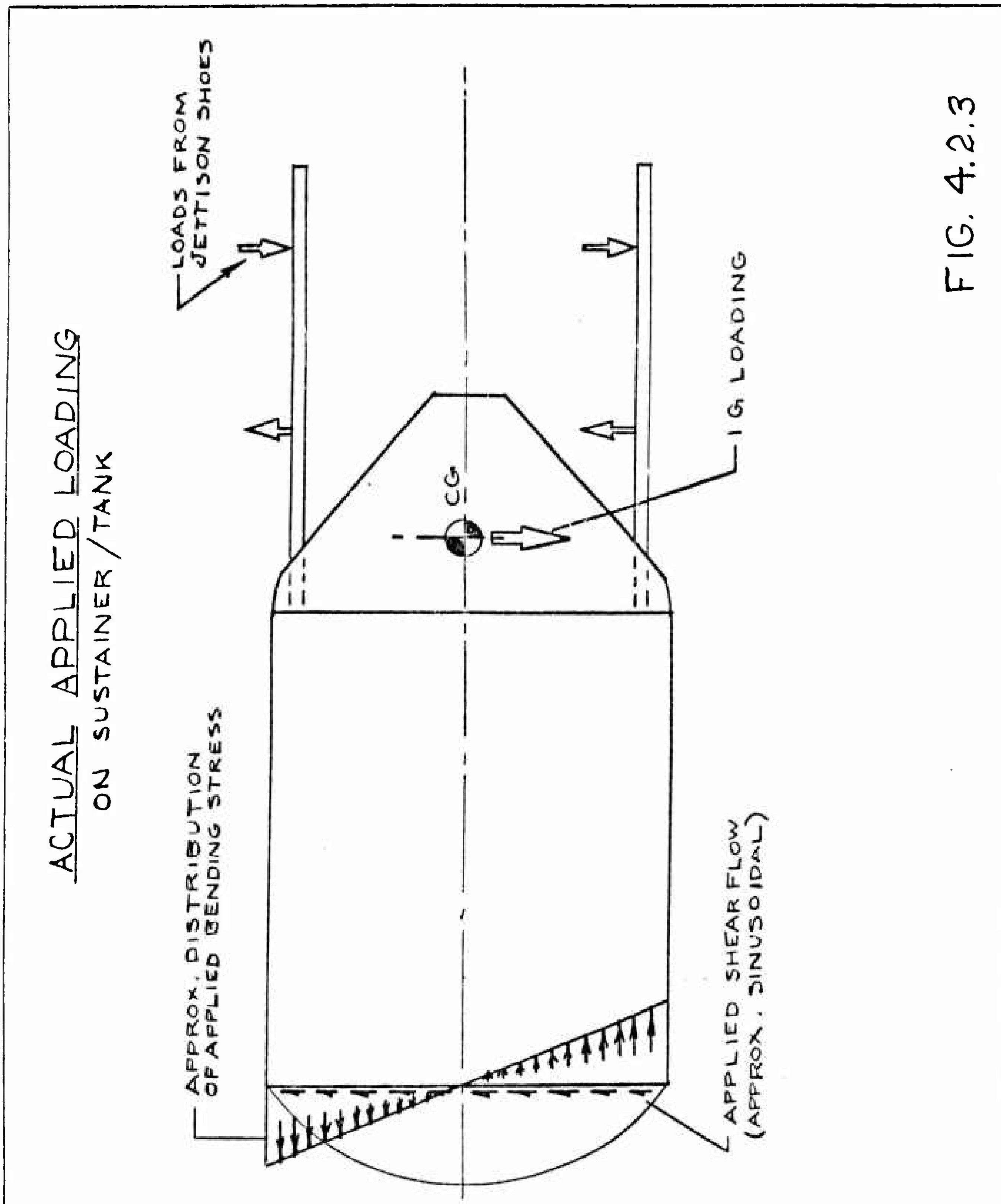

FIG. 4.2.3

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PC Bandow	4-29-64	R.R. Fowler	4-30-64		

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5.1.0 Mate/ Demate Test

5.1.1 Test Objective

To check out the alignment of the test fixture and test specimen and perform a mating per production procedures measuring mating loads.

5.1.2 Test Set-up

Test specimen was installed in test fixture and carriage as described in section 4.0.

5.1.3 Instrumentation

Strain gages on all four jettison slides to read radial and tangential strains. All four slides were of production configuration. Strain reading were read manually on an SR 4 Budd Strain Indicator through a Baldwin Switch Z Balancer.

5.1.4 Test Method

The sustainer section axis was leveled using the loading fixture leveling screw-jacks. The booster section was leveled in relation to sustainer axis optically by means of the adjustment on the booster support cradle.

The only alignment requirements of EOP 345.1.3, booster section mating, may be summarized: "Adjust the booster carriage as and when required to allow the forward jettison slides, the disconnect rollers and the aft slides to enter the tracks. In the latter stages of mating correct misalignment continuously as required - alignment being considered as parallelism (no tolerance specified) of the gap between the STA 1133 mating flanges, and equalization (no tolerance specified) of the radial gap between the mating ring and the tank cone skin."

Per EOP 345.1.3 the booster carriage is moved by hand winches, but 3 "set up bolts" per quandrant may be used to pull the mating flanges together for "the last few inches".

This EOP was followed on the staging mock-up except that "set-up" bolts were not required except for the nominal non-parallelism at first contact of the mating rings.

At significant increments before, during and after mating strain gage readings were taken, the results being presented in Figures 5.1.1 and 5.1.2.

5.1.5 Test Results

Figure 5.1.1 presents the strain gage readings in micro inch/inch for the significant locations of the booster during mating. This table shows that Quad II shoes carried ten times as much load as the Quad IV shoes. Because the booster was mated in accordance with EOP 345.1.3, this load distribution may be considered representative of possible load distributions obtained on the assembly line. It may be observed that the loads in the shoes remained low until the booster was within 5 inches of the fully mated position.

Figure 5.1.2 gives the load in the shoes in pounds. Because of the difficulty in attaining a good strain gage installation on the jettison shoes, the loads in this table must be considered qualitatively only. The shear load in the aft Quad II shoe should be treated as being a high value.

5.1.6 Discussion

As outlined in paragraph 5.1.4, there is no requirement in the production booster section mating procedure to check the alignment of the jettison slides relative to the track for the last few inches of motion.

This test indicated that loads may be introduced into the shoes during the mating procedure. There loads may be as much as 50% of the flight loads. The following observations may be made from the test results:

(a) The readings for all slides are effectively insignificant until approximately 5 inches from mated, at which point the readings for all alides increase significantly.

(b) The readings for both the forward and aft Q-II slides are of a significantly greater than for the Q-IV slides.

(c) The differences in loads between the forward and aft slides are consistent with the relative stiffnesses.

(d) The load was not significantly reduced after latch engagement.

The shoe preloads observed in this test may be caused by interferences between sustainer tank and booster due to missile tolerances or assembly support structure tolerances.

Preloads caused by tolerances in the jettison track installation and jettison shoe installations are sensitive to deformations in the tank and thrust barrel. It is likely that the shoe preload would be entirely modified after the missile was fully loaded and pressurized. Deformation in the booster barrel due to booster engine loads will cause variances in preload. A comparison of preloads at tank pressures at 4 psig and 12 psig show some difference in preload, however, it is impossible to extrapolate this data to a flight condition because of the difference in fuel weight and system restraints. Separation strap loads should not be effected by this preload at installation. Variances in shoe preload due to tank deformation will be reflected by the separation straps. Because of the high stiffners of the separation strap and booster combination, the magnitude of the variance should be small when compared to the total strap load.

Preloads caused by tolerances in the tooling supporting the missile tank and the carriage supporting the booster barrel will have a greater effect on the separation strap load. The shoe preloads will be again effected by changes in external loads and tank pressures.

Because of the complexity of the thrust structure and the tolerances in the track and shoe installations, it is impossible to determine analytically the changes which external loads cause in jettison shoes loads. This information is best attained during flight tests and the Point Loma Tests in which the booster thrust loads will be simulated. Strain gaging the Quad II fwd pedestal will provide some flight data concerning variance of preload during flight. Point Loma tests will provide a complete set of data including the effect on the separation strap loads. The Point Loma data should provide the key to extrapolate the data obtained in this test to flight conditions.

5.1.7 Conclusions

While the booster thrust section is being mated to the sustainer section, shoe preloads may be minimized by alignment of the booster section to the sustainer. However, when the structures are mated, and latched, the booster 1133 ring must conform to the sustainer 1133 ring. This will precisely locate the booster section in relation to the sustainer tank and may introduce new preloads in the jettison shoes. Point Loma tests and flight tests are required to determine the effects of these preloads and if further investigations are required.

JETTISON SLIDE LOADS

MATE/DEMATE TEST

FIGURE 5.1.1

INCHES FROM MATING	CONDITION	JETTISON SLIDE STRAIN-MICRO INCHES/INCHES							
		FWD				AFT			
		QUAD II		QUAD IV		QUAD II		QUAD IV	
		SHEAR	AXIAL	SHEAR	AXIAL	SHEAR	AXIAL	SHEAR	AXIAL
-	COMPLETELY DEMATED	0	0	0	0	0	0	0	0
105	FORWARD SLIDE JUST ENGAGED	150	10	0	0	185	0	0	0
74	DISCONNECT ROLLERS NOT ENGAGED	94	0	0	0	58	-2	0	0
67	DISCONNECT ROLLERS JUST ENGAGED	242	-15	0	-2	74	-5	0	0
53	AFT SLIDE JUST ENGAGED	44	-15	0	0	10	-5	10	-20
5	STAGING DISCONNECT NOT ENGAGED	-935	60	-30	-7	-780	15	-64	-64
2	FULLY MATED MINUS 2 INCHES	-685	0	-19	-19	-3112	70	-52	-18
0	FULLY MATED - UNLATCHED	-925	19	-88	-16	-2575	165	-35	-48
0	FULLY MATED - LATCHED	-860	0	-100	-22	-2658	155	-48	-48
0	FULLY MATED - LATCHED 1	-870	0	-125	-21	-2665	105	-41	-50
0	FULLY MATED - LATCHED 2	-855	0	-100	-20	-2748	158	-40	-351

1 SYSTEMS PRESSURIZED (EXCEPT FUEL & OXIDIZER)

2 FUEL TANK PRESSURE RAISED FROM 4 PSI TO 12 PSI

375-1-64/286

JETTISON SLIDE LOADS-LBS

MATE/DEMATE TEST

Figure 5.1.2

INCHES FROM MATED	CONDITION	FWD				AFT			
		QUAD II		QUAD IV		QUAD II		QUAD IV	
		SHEAR	AXIAL	SHEAR	AXIAL	SHEAR	AXIAL	SHEAR	AXIAL
	DEMATED	0	0	0	0	0	0	0	0
53	AFT SLIDE ENGAGED	20	-60	0	0	5	-20	10	-150
5	DISCONNECT NOT ENGAGED	-185	730	-10	0	-675	-175	-100	-405
2	MATED MINUS 2 INCHES	-215	145	-5	-20	-3800	740	-110	-75
0	MATED AND LATCHED	-270	185	-20	-20	-3500	400	-70	-300
	Positive	Up	Inboard	Up	Inboard	Up	Inboard	Up	Inboard

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5.2.0 SUSTAINER/THRUST SECTION DEFLECTION TEST

5.2.1 Objectives

To obtain data on the load/deflection characteristics of the Jettison Track and Slide System.

To determine the effect of structural deflections at specified staging separation distances on critical clearances.

5.2.2 Test Set Up

The tests were performed on the staging mockup using test fixture and specimen. Loading was accomplished per method described in section 4.0. Separation distances of 6, 12, 30, 48 and 56 inches were planned.

Test loads and reaction moment loads used were per Figure 5.2.1 for each setting.

5.2.3 Instrumentation

Installed as described in Section 4.0 for tests 1 through 2C. Test 2D was instrumented to provide linear motion readouts on the two axis of the tank relative to the booster. Linear motions were placed to read relative motion of tracks to booster and rail forward end to sustainer tank.

The linear motion of the pneumatic step on quad 2 rail in relation to booster was included.

Optical scale readings were made at discreta points on the booster to determine deflection of the booster relative to the ground.

Dial indicators were positioned to give relative movement of tank and fixture to the ground at the Station 1133, jack reaction point. Optical scale readings taken at forward end of fixture relative to ground.

The three struts which attach the jettison rail to the tank were strain gaged. These gages were recorded during each deflection test.

5.2.4 LOAD/DEFLECTION TESTS

5.2.4.1 6" Separation Series

Test 1 and 1A

These tests were considered inconclusive since the large structural deflections encountered were beyond the capability of the loading fixture. Interferences were encountered between fixture and the base.

Test fixture clearances were modified and linear motion pickup points on booster enlarged for clearance.

Test 1B

This test was terminated when deflection caused the forward edge of the booster to contact the skin of the fuel tank cone.

Figure 5.2.2 gives the significant deflections attained. The tabulated values for total slide loads, B_t and C_t are the required test loads.

Figure 5.2.3 compares the calculated shoe loads against those obtained from strain gages mounted on the shoes and on the forward attach struts. The shoe loads determined from strain gage mounted on the shoes gave loads which differ greatly from the calculated values. Shoe loads obtained from strut data were more consistent in sign and distribution with the calculated values. Subsequent testing of the jettison rail assembly with shoes positioned equivalent to six (6) inch separation has revealed that shoe loads calculated from strut data are lower than true values. This fact plus the tank - booster interference may account for the shoe loads determined by this method.

5.2.4.2 12" Separation Series

Test 2A, 2B and 2C

Deflections encountered caused Interference of Linear Motion probes with booster entrance ports. At each new attempt deflections increased beyond each previous modification made to fixture. The deflections in the system resulted in abortive attempts each time. Specified test loads were not

5.2.4.2 (Cont'd.) achieved.

The fixture and jack reaction points were then modified to allow maximum capability within the limits of existing support structure.

Test 2D

12 Inch Separation

This test was terminated primarily by a failure of the QIV forward jettison slide pedestal. However, at this point, the limitation encountered in the six inch separation test had again been reached, - the lower forward edge of the booster was in contract with the fuel tank skin. The upper forward edge of the booster was also contacting the LOX staging valves.

The jettison slide pedestal failed at the upper forward corner. Similar specimens described in section 5.8 failed in the same manner.

Linear motion at the LOX bottle pilot valve and QII step was nominal for this condition. .06 in pilot valve relative to the hydraulic reservoir and .03 in step relative to the adjacent booster structure.

Figure 5.2.6 compares the calculated shoe loads against those obtained from strain gages mounted on the shoes and on the forward attach struts. Again the data obtained from jettison shoe data differs from calculated values in both distribution and sign. The shoe loads obtained from the strut data shows better agreement in sign but the magnitudes are quite large. These loads occurred after the pedestal failure. The Quad IV shoe after failure was shown to be capable of taking only 800 lb. shear (see Section 5.8). This capability was augmented, however, by an instrumentation plate which caused interference between the pedestal and booster. The 2530 pound recorded load is not as great an error as would first be assumed. It may be concluded that the required moments and shears had been introduced in the test specimen but that the pedestal failure and interferences caused differences in distribution.

5.2.4.2 (Cont'd.)

Figure 5.2.4 demonstrates graphically the contribution of the pedestal and booster deflections to the total deflection seen at MS1133 during Test 2D.

Figure 5.2.5 shows the interference of the booster with the fuel tank cone skin and the LOX staging valve.

5.2.5 DISCUSSION

The original intent of this test was to obtain data on the effect of the jettison guide system on possible interferences, such as:

a. The Vernier Solo Lox Bottle Pilot Valve with the Hydraulic Reservoir.

b. The Sustainer G. G. Valve with the Q IV Helium Bottles.

c. The step on the Q II Staging Disconnect with the Booster Yaw Actuator Beam.

d. Any other possible interferences noted in the test.

The data was to be obtained by direct observation, by linear motion transducers, and/or by extrapolation for other loading conditions using the data on the overall spring constants obtained from the test.

Since the objective was the rapid acquisition of data on the effects of the flexibility of the jettison guide system, no attempt was made to simulate the system of externally applied loads on the booster and sustairer. However, the loading fixture was designed to minimize the effects of any test loads which did not simulate actual loads.

The loading fixture enabled the application of any combination of pitch, yaw and roll moment, vertical load and lateral load on the jettison slides. The distribution of loads between the four jettison slides was not known. This would be dependent on relative stiffnesses, jettison slide friction, mechanical fits, and to a slight extent by the method of support of the booster. The distribution obtained, however, could reasonably be assumed to be representative. The rela-

5.2.5 (Cont'd.)

tive severity of non-uniform distribution was unknown.

The first attempts to use the loading fixture were abortive due to fixture interferences caused by the large deflections between the sustainer and booster. The fixture was revised to accommodate larger deflections and test runs at six and twelve inch separation were performed successfully up to the limits of the airborne structure.

Proposed test runs at wider separation distances 30, 48, and 56 inches were delayed pending a better understanding of the cause of the large deflection phenomena. The need to avoid hazard to the specimen and to ensure its availability for the Point Loma program by 4 March 1964 then resulted in the elimination of these test runs.

In both of the last test runs, at six inch and twelve inch separation, the loading system performed satisfactorily. The procedure outlined in Section 4.0 permitted controlled adjustment to the test load with only a nominal overload in the last adjustment step.

The required test loading conditions were therefore attained at six inches and twelve inches separation. The test results show, however, that in both cases the stiffness of the jettison track/slide system was insufficient to prevent interference between the booster and sustainer. In this case, the jettison slide loads may have been redistributed and relieved by reactions between the booster and the sustainer at the points of interference.

The six inch separation test 1B was limited by structural interference between booster and lower section of the sustainer tank. The nominal radial clearance at this point of separation is 0.3 of an inch. The sustainer tank cone at this point is a developed radius. A small rotation of the tank due to deflection of track system would allow interference to occur.

The twelve inch separation test 2D encountered more severe interferences as illustrated by Figure 5.2.5. The nominal radial clearance at this point of separation is 1.3 inches. The

5.2.5 (Cont'd.)

sustainer tank cone area is still along the developed radius.

Linear motion devices indicated the clearance between SPGG valve and helium bottles reduced from 2" to 1.4.

No significant deflections at any of the other possible critical clearance points were noted or recorded, however, the elimination of the remaining test runs prevented a rigorous investigation in these areas. Subsequent planned tests would have added sustainer gimbal and loading.

Consideration was given to the possible effect of the low pressure (12 psi) used in the fuel tank on the flexibility of the jettison track structure. Subsequent tests, however, indicated that the difference between 12 psi and flight pressure is negligible in this respect.

5.2.6 CONCLUSIONS

1. The final six inch separation test and the final twelve inch separation test were valid test runs for the specified test loading conditions, except that the specified yaw loading was not applied.

2. The stiffness of the jettison guide system is insufficient to prevent booster/sustainer interference under the specified static loads. The significance of this in the dynamic case requires additional analysis and/or test.

3. The structural deflections under the attained test conditions are insufficient to cause Pilot Valve/Reservoir interference.

4. Sustainer engine gimballing with tank to booster in deflected position would reduce critical clearances substantially. Since static load testing was stopped prior to the planned test of this condition no data was collected.

   Further investigation and testing in this configuration would be beneficial.

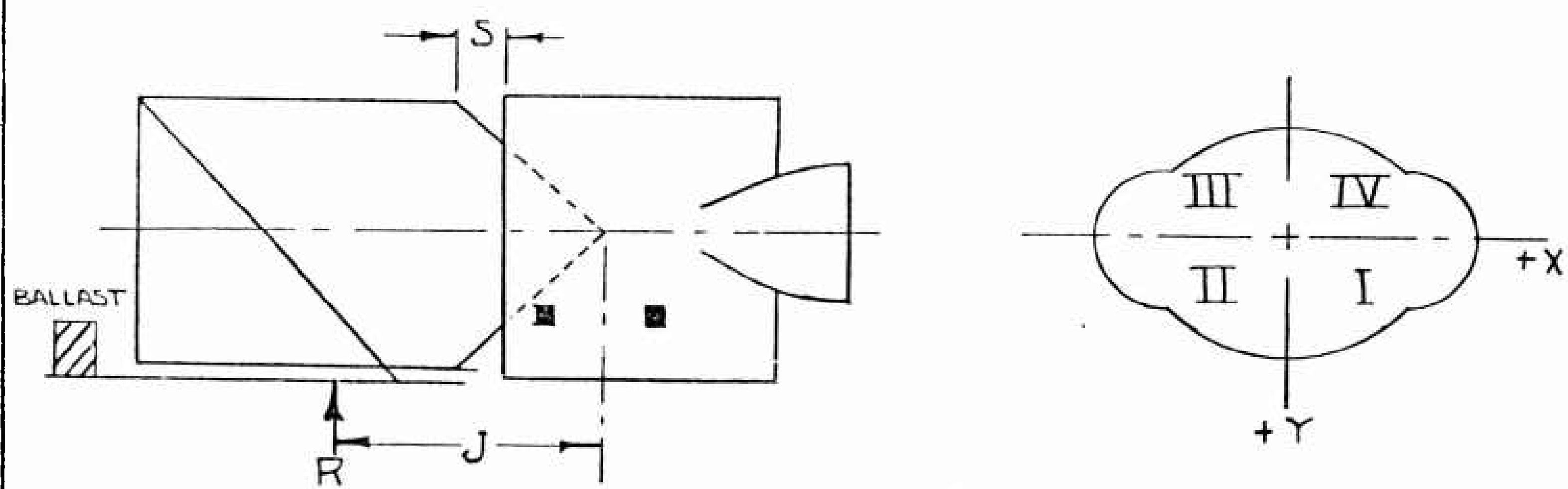
5.2.6 (Cont'd.)

The Pt. Loma test program will essentially accomplish this.

5. Visual and instrumentation data review indicated the clearances monitored were adequate. (Without additive reduction that would occur if sustainer engine were full gimballed.)

BOOSTER LOADS AND JACK REACTIONS

SEPARATION DISTANCE "S"	BOOSTER LOADS: SHEAR PARALLEL TO X-AXIS (#)	BOOSTER LOADS: SHEAR PARALLEL TO Y-AXIS (#)	M_{Y-Y} (IN-LB)	M_{X-X} (IN-LB)	JACK REACTION (#) "R"	JACK DISTANCE "J" (IN)	BALLAST (#)
6"	494	285	185,000	0	15,936	103.9	0
12"	3,750	285	185,000	0	21,195	98.7	2,000
30"	3,260	0	185,000	0	20,705	116.8	2,000
48"	3,260	0	185,000	0	21,205	134.7	2,500
56"	1,800	0	185,000	0	19,244	152.7	2,000

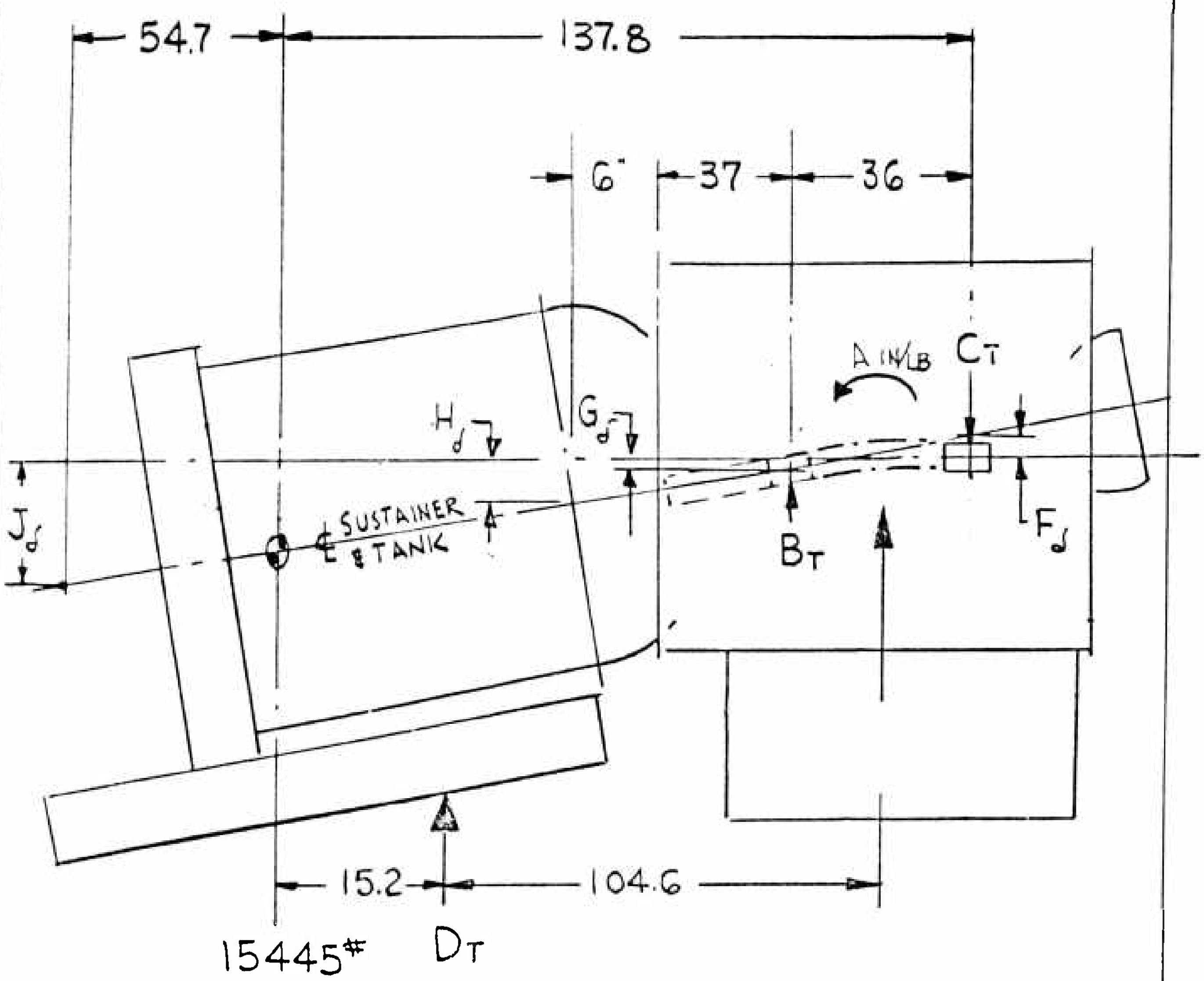


WT. OF MOCKUP STRUCTURE AND TANK = 15,445#

FIG. 5.2.1

PREPARED BY P.C. BANDOW DATE 5-6-4 | CHECKED BY WAKFER DATE 5-6-64 | REVISED BY DATE

6" SEPARATION LOAD / DEFLECTION TEST
TEST IB FIG 5.2.2



CONDITION	A	B_T	C_T	D_T	E	F	G	H	J
INITIAL LOAD (STEP 1.10)	.18 10^6	4755 CALC	5245 CALC	15936	—	.22	+.05	.00	.40
FINAL LOAD (STEP 1.12)	.18 10^6	4755 CALC	5245 CALC	15936	—	.30	-.06	.33	1.66 CALC.

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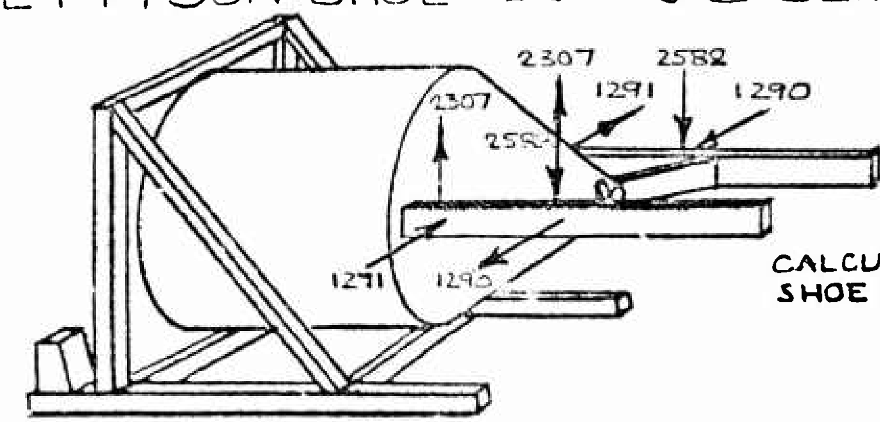
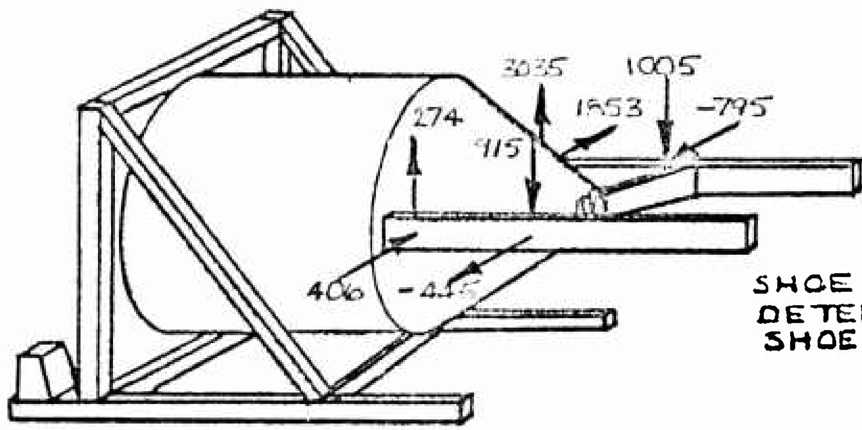
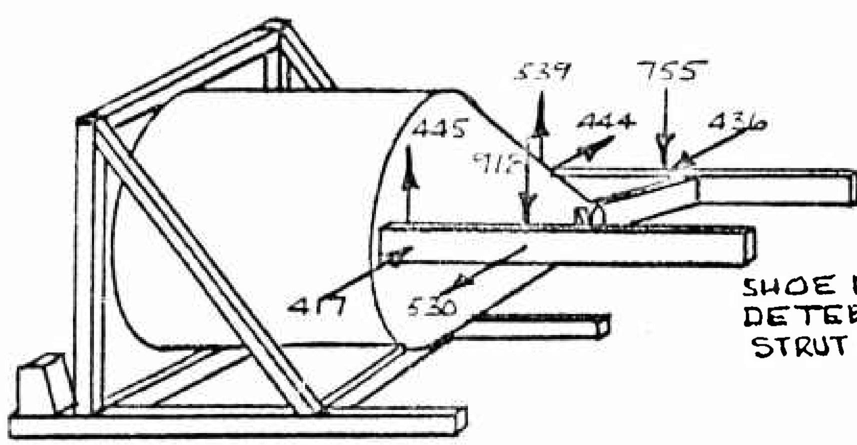
JETTISON SHOE REACTIONS–6" SEPARATION



CALCULATED SHOE REACTIONS



SHOE REACTIONS DETERMINED FROM SHOE STRAIN GAGES



SHOE REACTIONS DETERMINED FROM STRUT STRAIN GAGES

FIG 5.2.3

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P C BANDOW	5-7-64	[illegible]	5-7-64		

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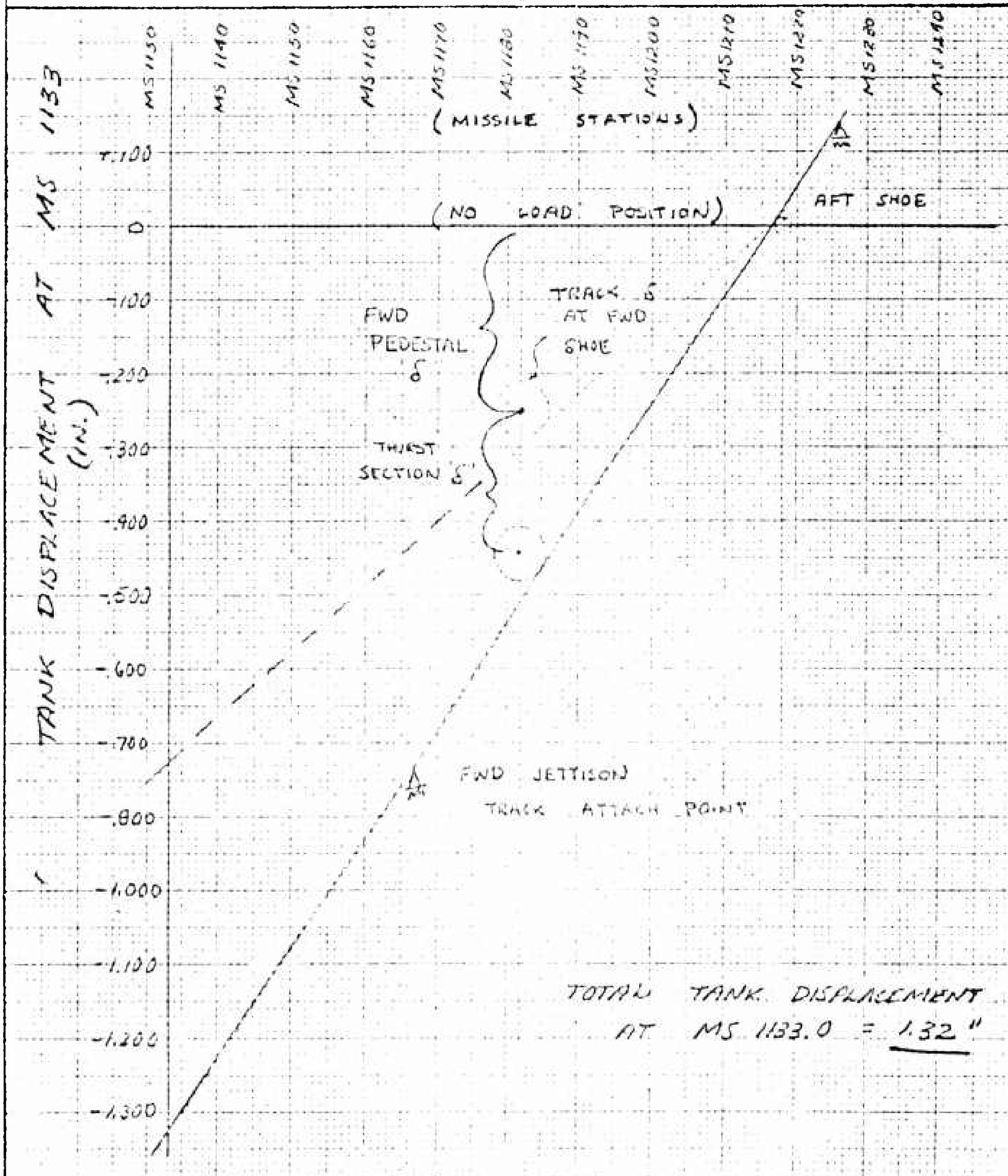
FIGURE 5.2.4 DISPLACEMENT AT MS 1133 DURING TEST 2 D.



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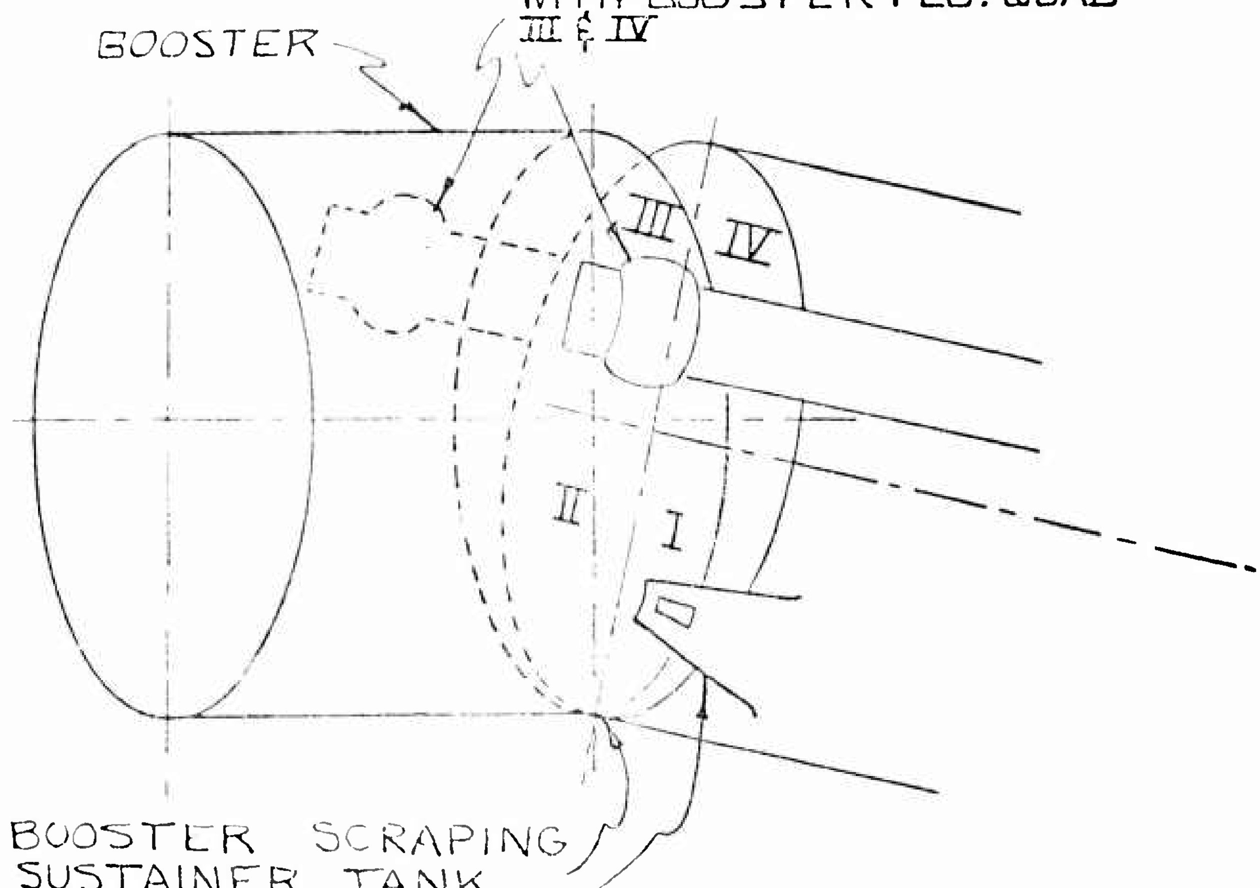
W A Kuu	5/13/64				

FORM NO. A707-1

12" SEPARATION LOAD/DEFLECTION

INTERFERENCES AT LOADING
(AFTER FAILURE OF QUAD. IV
PEDESTAL.)

FIG 5.2.5



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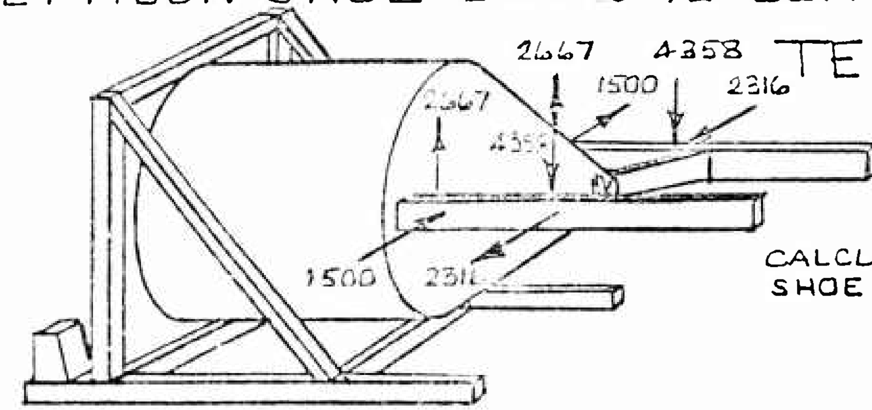
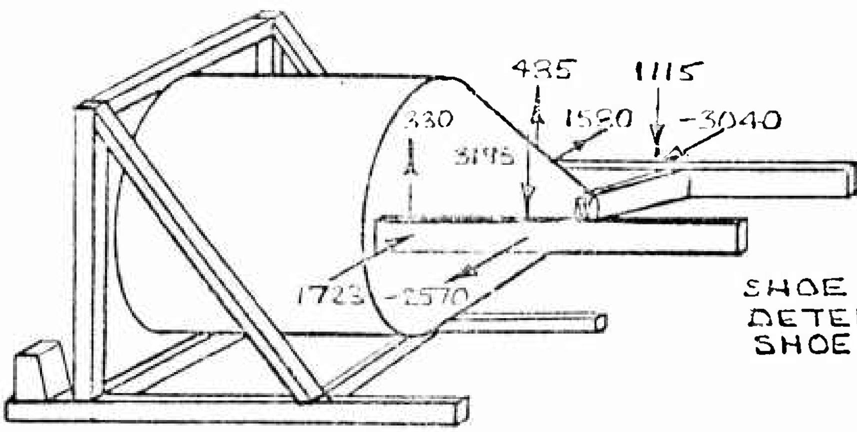
JETTISON SHOE REACTIONS - 12" SEPARATION

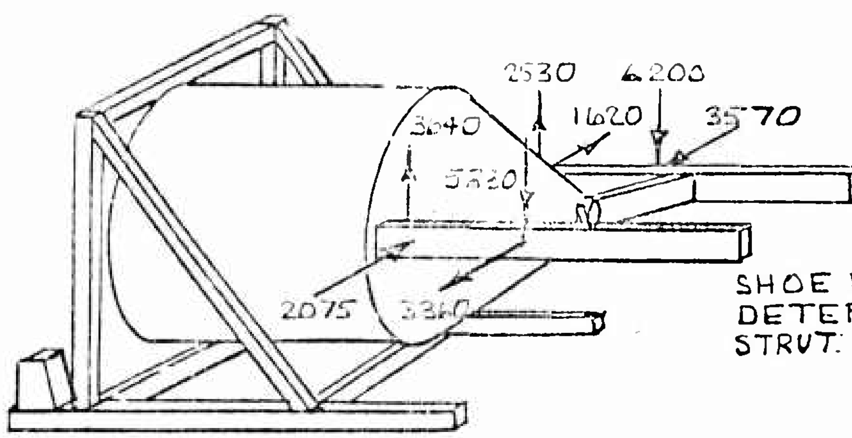
TEST 2D



CALCULATED SHOE REACTIONS



SHOE REACTIONS DETERMINED FROM SHOE STRAIN GAGES



SHOE REACTIONS DETERMINED FROM STRUT STRAIN GAGES

FIG 5.2.6

PREPARED BY P. BANDOW	DATE	CHECKED BY WAK	DATE 5-8-4	REVISED BY	DATE

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5.3.0 HELIUM BOTTLE INTERFERENCE TEST

5.3.1 Objective

Due to the possibility of interference between the helium bottles and the sustainer engine and associated lines during staging if the bottle structure had failed, it was necessary to determine the force required to move the bottles against the resistance of the associated lines, ducts, etc and to determine the mode of impact of the bottles in the hydraulic pump area. A check was also to be made to see if the helium lines would break during bottle displacement so that a correlation of events could be made by flight test data of the helium bottle pressure prior to staging. A determination of wedging action or other possible effects of loose bottles during staging was also intended.

5.3.2 Test Set-Up

The helium bottles were installed in the staging mockup and were at ambient temperature and pressure throughout the test. A hydraulic cylinder was installed in the booster diametrically opposed to the forward Quad III helium bottle. A cable was strung between the hydraulic cylinder and the helium bottle. The cable was attached to the helium bottle at the bottle to strut attach points. A load cell installed at the hydraulic cylinder end of the cable was used to record load. An extensometer was attached to the booster just aft of the hydraulic cylinder. A wire between the extensometer and the bottle paralled the loading cable and attached to the bottle at the same points as the loading cable. A fixture was built to lock the bottle in position after it had been rotated inboard.

5.3.3 Instrumentation

An extensometer was used to record the inboard travel of the helium bottle. A load cell determined the amount of load applied.

5.3.4 Testing

The forward Quad III helium bottle struts were disconnected from the 1206.19 bulkhead brackets. The forward bottle was then loaded to rotate it inboard. After a bottle deflection of approximately .6 inches inboard, the forward magnesium strut came in contact with the LO_2 topping line. This line is attached to the aft side of the 1206.19 bulkhead just inboard of the strut attach brackets. Due to the attachment of the magnesium strut to the helium bottle shroud anti-rotation clip, the strut could not rotate outboard with respect to the helium bottle and the strut could not pass by the LO_2 topping line. This forced an increase in load per unit deflection. The test was stopped at a load of 2500 pounds.

5.3.0 HELIUM BOTTLE INTERFERENCE TEST (contd)

5.3.4 Testing (contd)

The aft struts of the forward bottle were then disconnected from the brackets on the forward side of the 1237.08 bulkhead. This left only two struts (the two struts parallel to the Z-Z axis that connect the two bottles), the shroud interconnecting bellows, the forward bottle shroud vent line and the forward bottle helium line holding the bottle in place. The aft bottle shroud was connected to the aft magnesium strut by the shroud anti-rotation clip and therefore was not free to rotate.

The forward bottle was again loaded by the hydraulic cylinder and the deflection of this bottle inboard was recorded.

The remainder of the test, checking clearances between the bottles and the sustainer engine with the mock-up mated and at various stations during demate was not accomplished due to possible damage to the mock-up and due to lack of time.

5.3.5 Test Results

During the first part of the test, the load increase due to interference between the strut and the LO_2 topping line occurred at about 900 pounds load and .6 inch deflection. The total deflection was 1.4 inches at 2500 pounds load.

With the forward bottle detached from the bulkheads a permanent deflection had occurred, due both to the first test and to the weight of the bottles, of .8 inch. The loading on this portion of the test continued smoothly until 1025 pounds at 4.6 inches deflection when the shrouds interconnecting bellows broke loose. This unloaded the bottles to about 700 pounds. As the loading continued, the LN2 vent line to bottle strut clip broke at 850 pounds and 5.4 - 5.9 inches of deflection. This dropped the load to 200 pounds. The test was stopped at 8.0 inches of deflection. The load at this point was 525 pounds.

The helium lines were severely bent but did not break with this displacement.

5.3.6 Discussion

The 2500 pounds required to displace the forward bottle through the 1.4 inches for the first part of the test probably should be discounted since the amount of interference with the LOX topping line could vary greatly with the direction of load, structural deflection, fits and tolerances, etc.

However, for the second part of the test, with the forward bottle restrained only by the attached plumbing, etc., a load

5.3.0 HELIUM BOTTLE INTERFERENCE TEST (contd)

5.3.6 Discussion (contd)

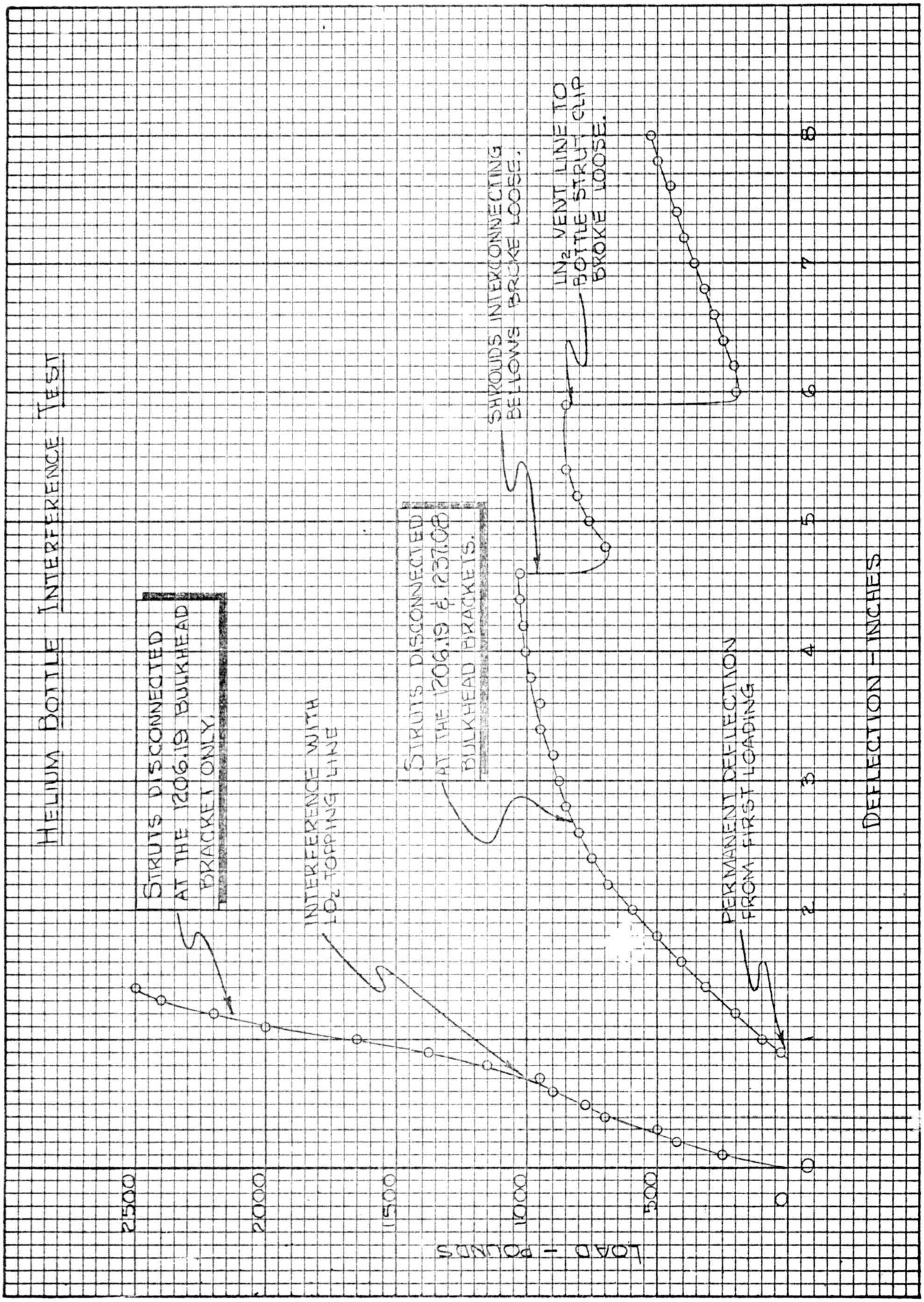
of 1000 pounds (10 G) was needed to displace the bottle past 4 inches. The displacement required for bottle interference with the hydraulic system is approximately 8 inches.

This test was not completely rigorous, particularly in that the effects of "Z-Z" axis acceleration and vibratory loads were not included. However, the magnitude of the test loads (10 G) in comparison with booster phase "X-X" axis flight loads (.4 G) demonstrated the improbability of interference with the hydraulic system even assuming four failures in the bottle support structure.

5.3.7 Conclusions and Recommendations

It was concluded that sufficient restraint on the bottles is afforded by the associated plumbing, etc., to render interference by the bottles with the sustainer highly improbable even after a failure of the bottle structure.

GD/A recommends that no further testing be done in this area.


HELIUM BOTTLE INTERFERENCE TEST
STRUTS DISCONNECTED AT THE 1206.19 BULKHEAD BRACKET ONLY.
INTERFERENCE WITH LO2 TOPPING LINE
STRUTS DISCONNECTED AT THE 1206.19 & 1237.08 BULKHEAD BRACKETS.
SHROUDS INTERCONNECTING BELLOWS BROKE LOOSE.
LN2 VENT LINE TO BOTTLE STRUT CLIP BROKE LOOSE.
PERMANENT DEFLECTION FROM FIRST LOADING
LOAD - POUNDS
0
500
1000
1500
2000
2500
DEFLECTION - INCHES
0
1
2
3
4
5
6
7
8

5.4.0 JETTISON TRACK VIBRATION TEST

5.4.1 Test Objective

Due to the close proximity of the Solo LOX Bottle Vent Control Valve to the hydraulic reservoir lines, it appeared feasible that certain modes of vibration in the LOX bottle and/or reservoir could cause impact between the two. The primary objective of this test was to determine the possibility of interference between the LOX bottle valve and the hydraulic lines at the reservoir.

5.4.2 Test Set-up

An electrodynamic vibration exciter was mounted on a vertical test stand at an angle of 30° from the Y-Y axis to provide a radial input. The exciter was rotated 90° for the tangential input. The exciter was attached to the Quad IV jettison rail opposite the "A" frame attach point with a stinger and an impedence head. The impedence head consisted of an accelerometer and a force transducer and served to determine the input to the rail.

The mock-up fuel tank was pressurized to 8 psig throughout the test. The hydraulic reservoir and the LOX bottle were unpressurized though the bottle was filled with water to simulate the weight of LOX.

5.4.3 Instrumentation

Accelerometers were mounted on the LOX bottle. The LOX bottle vent control valve, the hydraulic reservoir, the Quad IV jettison rail and the fuel tank apex to measure accelerations radially (30° from the Y-Y axis), tangential (90° from the radial) and along the Z-Z axis. Strain gages were installed on the struts at the tank end of the jettison rail. An instrumentation trailer provided means of recording data and control of vibration input.

Pulse cameras were used to record the relative motion between the LOX bottle and the reservoir (Film No. Engineering Test -391 MP). Visual observations were made of the other components.

5.4.4 Test Method

To prevent damage to the staging mock-up, strain gages on the jettison rail struts at the tank end were monitored and the input level adjusted to maintain the strut loads below a specified level.

Two series of sweep frequency vibration runs were made; the first was tangential input & the second radial input. The following table illustrates the input variables in the runs.

5.4.4 Test Method (con't)

Run No.	Input - g_{rms}	Axis	Frequency Range - CPS	Sweep Rate Min/Octane
1A	.25	Tangential	10-200	1
1B	.50 *	"	"	2
1	.25/.50	"	10-50/50-200	2
2	.35/1.0	"	" "	2
3	.25	Radial	15-200	1
4	.25	"	15-100	2
5	.25/.35	"	15-30/30-100	2
6	.25/.50	"	" "	2

* Could not hold this input near resonant frequencies. Input lowered to .25 g_{rms} between 25 & 30 cps.

The tangential series had a frequency range starting at 10 cps. Strain gage readings on the rail struts indicated strut loads of greater magnitude than specified. The radial series inputs were therefore started at a frequency of 15 cps. Also, little excitation was found above 100 cps. and the last three sweeps were not carried beyond this frequency.

The significant runs were the last of each series, i.e., runs number 2 & 6. The previous runs in each series were preliminary to determine effects with lower input levels.

5.4.5 Test Results

Little activity was seen in the tank apex during the runs and the response of the hydraulic reservoir was negligible.

The LOX bottle and the jettison rail showed response, however, with the LOX bottle showing an apparent resonance point between 30 & 33 cps (the bottle resonance point appeared to be approximately 33 cps with the bottle filled with water & approximately 29 cps when filled with LOX) for both the tangential and radial inputs and the rail responding between 55 & 65 cps during the tangential inputs and at 44 & at 80 cps for the radial inputs. The LOX bottle responded to the rail inputs at the 55-65 cps tangential and at the 44 cps radial.

The transmissibility factor for the LOX bottle accelerations reached a maximum of 3.5 during the tangential runs and 4.0 during the radial runs.

No appreciable closure between the LOX bottle and the hydraulic reservoir was observed during the test.

5.4.6 Discussion

No attempt was made to approach flight level accelerations during this test. Also, a compromise was made in the fuel tank pressure and in the method and location of input. Therefore, no direct correlation between the test results and flight performance is possible. However, later tests in the "CLASP" program were made with the reservoir and rail mounted on a rigid plate and a different mode of input. The results of these tests were compatible with those on the staging mock-up (i.e., the LOX bottle resonance points remained essentially the same and the transmissibility factor for the LOX bottle accelerations was a maximum of 4 for a tangential input of 3g.).

5.4.6 Discussion (con't)

The relative motion between the LOX bottle and the reservoir was calculated from the accelerations and found to be a maximum of .030 inches. While an accurate prediction of relative motion during staging is not possible from the results of this test (due in part to the method and location of input), it was apparent that the resulting motion of the LOX bottle and the transmissibility factor of rail input to LOX bottle response was not of sufficient magnitude to indicate a marginal condition for vibration input to the rail.

The test does serve as a preliminary survey of the response of the entire rail - bottle system.

No previous knowledge was available of the responses of the various components when the system was subjected to vibration. As stated previously, the fuel tank apex did not vibrate. However, the sustainer engine visibly responded at the lower frequencies.

5.4.7 Conclusions

Test results indicate there is no interference between the LOX bottle vent control valve and the hydraulic reservoir lines with the mode of input used for the test.

5.5.0 JETTISON RAIL DEFECTION TEST

5.5.1 Test Objectives

Rail deflection vs. load data was not available in the region between the "A" frame and tank. This type of data was important in performing an analytical study of clearance in the area of the Lox bottle and associated equipment.

A secondary objective of the rail deflection test was to determine the effect of tank pressure on the rail deflections and reactions. The effect of tank pressure became an important variable when problems with shoe load distribution occurred during the Sustainer/Booster Deflection Tests.

5.5.2 Test Set-Up

This test was conducted on the horizontal mock-up tank. The booster package was retracted and a loading device was mounted on the rails supporting the test specimen. The hydraulic and pneumatic systems on the test specimen were not pressurized. The tank was cantilevered from its battleship bulkhead at missile station 1049.

The track loads were produced by hydraulic jacks mounted in series with a load cell. The loads were introduced at the center line of the track radial to the missile center line, and parallel to the face of the track at the center of the shoe slot.

Deflections of the track were measured by dial gages mounted on an instrumentation rail. This instrumentation rail was mounted to the tank in such a manner that the bending of the tank centerline was taken into account.

During the initial phase of the test program the deflections were read out with jig transits and optic targets. This method of measurement proved unwieldy and required a good deal of operator skill.

5.5.3 Instrumentation

Load input was measured with a standard weighing kit. The accuracy of this kit is .1%. The loads introduced into the jettison rail attach struts were measured by strain gages read out on a wheatstone bridge. These struts were not physically calibrated and there is some error introduced in the calculation of strain vs. load and in the gage factor of the bridge.

Two dial gages were mounted along the top of the rail at each of the four positions. These gages were used to measure twist and tangential deflection. The two gages were eight inches apart with one gage mounted one inch from the slide face of the tank. The third gage at each position was placed at the radial centroid of the truck cross-section and measured the radial track deflection.

The dial gages were reset to zero at start of the test. They were readable to ± .0005 inch.. The optics method was readable within ± .001 inch.

The dial gage locations are shown in Figure 6.1.

5.5.4 Test Method

The hydraulic jack load was applied at four positions along the Quad IV rail. The positions loaded were M. S. 1259, M. S. 1229 ("A" frame attach points), M. S. 1204 (lox bottle attach point) and M.S. 1181. A 1500 lb load was applied radially inboard and tangentially upward at each position and at tank pressures of 12, 8 and 4 psig.

Dial gage readings were recorded in the unloaded condition, in the loaded condition and again in the unloaded condition. An additional data point was obtained when an outboard radial load was applied to the rail at M. S. 1259.

During the initial phase of testing with optics deflection measurements, the Quad II rail was also loaded radially and tangentially. These loadings were consecutive and not concurrent. The applied load in this initial phase of the test was varied as well as the tank pressure. 500,1000 and 1500 lb loads were applied.

5.5.5 Test Results and Discussion

The test conducted with optic measurements indicated that the track deflections were linear with increasing load and that little load was transmitted through the tank structure from the loaded to the unloaded track. Based on the linearity of the deflections obtained, it was decided to eliminate the requirement of varying the load input.

The deflections measured did not vary significantly with changes in tank pressure. The deflections measured at the forward attach point were small. Figure 5.5.1 compares the data obtained by the optic method with data obtained by dial gages. Comparison of test data and calculated deflections demonstrated a close correlation. This comparison was made after correcting for the test deflections of the forward and "A" frame attach points. Some rotation was noted at the "A" frame due to tangential loads applied to the rail.

A comparison of these deflections with the track deflections obtained in 1961 (Report No. AE60-0633) at a tank pressure equal to flight pressure reveals a close approximation with loads applied at the end of the rail. The degree of "A" frame rotation due to a tangential load was equal in the two tests. The radial deflection of the "A" frame attach was 3 times geater with the 12 psi tank than with the 60 psi tank. The magnitude of deflection was still relatively small (.094 inch).

The strain gage readings on the jettison track support struts give track reaction loads equivalent to the calculated values for applied loads at the "A" frame and forward. The test loads were smaller than the calculated loads. This variance has been substantiated during recent tests on the jettison track subassembly.

5.5.6 Conclusions

The rail deflections obtained at 12 psi may be considered representative of the deflections obtained with the tank at flight pressure. The load vs. deflection data may be used for spring constant determination and for clearance studies. Maxwell's theorem may be used to determine the deflection of the lox bottle attach point when jettison shoe loads are applied to the track. Tables 5.5.1 and 5.5.2 give the deflections of rail end and the lox bottle attach point when the calculated shoe loads are applied to the rail. The reactions as determined from the strain gage readings on the forward attach struts may be used to assist in the determination of the booster shoe loads. These readings will be monitored at Point Loma during the drop tests.

5.5.7 Recommendations

No further testing is necessary in this area. The test data obtained in this test should be applied to the Point Loma program.

TABLE 5.5.1

Deflections at AFT end of track in trangential direction due to calculated shoe loads.

-S Downward

Booster Separation	Track Deflection (in.)
6"	+.07
12"	+.02
30"	-.34
48"	-1.16
56"	-1.14

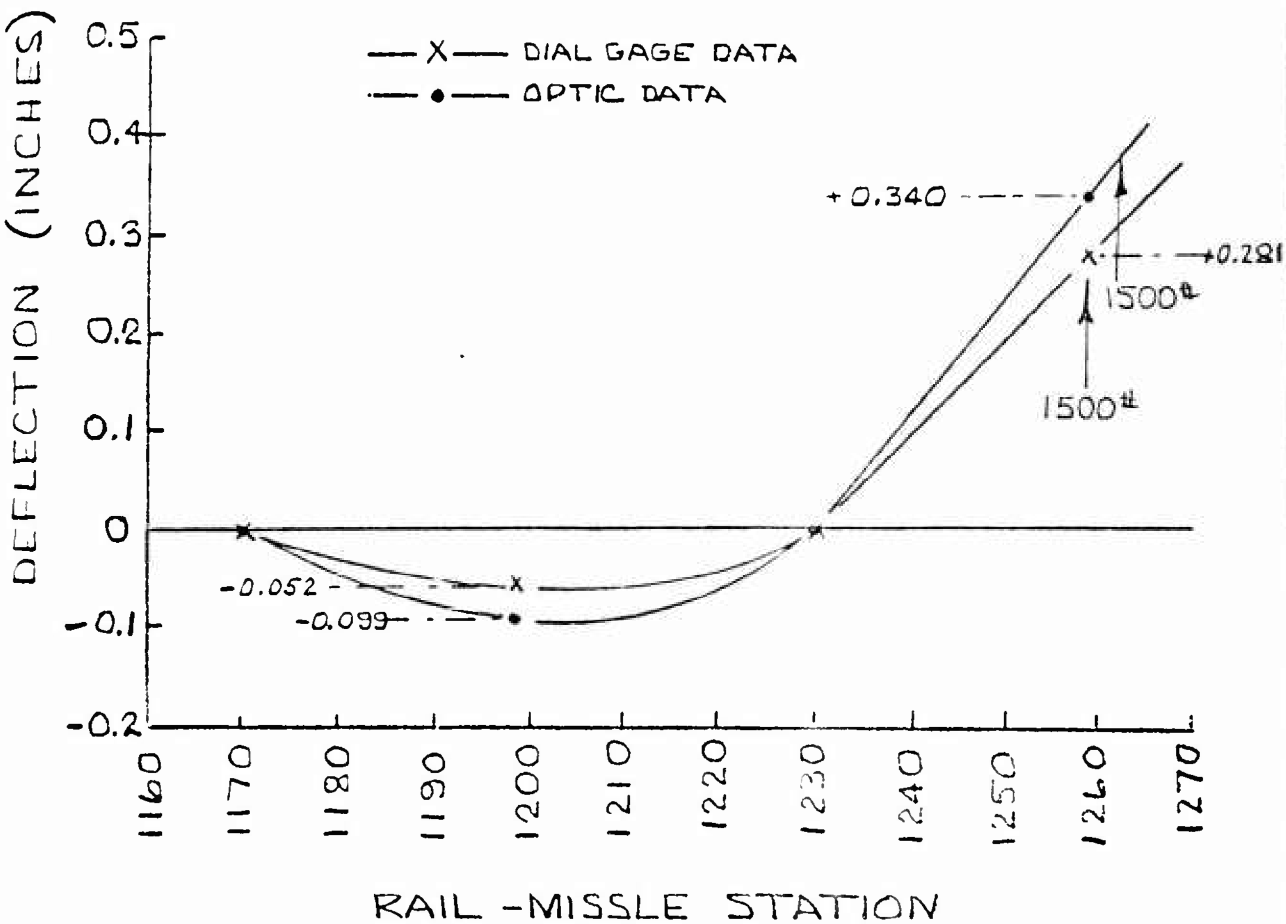
Table 5.5.2

Deflection LOX Bottle attach point in tangential direction due to calculated shoe loads.

Booster Separation	Track Deflection (in.)
6"	-.08
12"	+.01
30"	+.26
48"	+.48
56"	+.39

COMPARISON OF OPTIC DATA AND DIAL GAGE DATA

FIG. 5.5.1



RADIAL DEFLECTION
QUAD IV RAIL
TANK PRESSURE - 12 PSI

PREPARED BY	DATE	CHECKED BY	DATE	REVISED BY	DATE
P. BANDOW	5-6-64	W A Kan	5-6-64		

A706-1 (1-62)

5.6.0 LOX BOTTLE AREA DEFLECTION TEST

5.6.1 Test Objectives

The object of this test was to determine the magnitude of the rail and "A" frame deflections relative to the lox bottle. These deflections were then to be compared to other test values to determine if a failure load could be introduced into the lox bottle support brackets.

5.6.2 Test Set-up & Instrumentation

This test was conducted concurrently with the jettison rail deflection test. Five dial gages were placed on the "A" frame to measure its motion under the various conditions of rail loading. These dial gages were mounted to the same instrumentation rail as the dial gages measuring rail deflection. The dial gage locations and load locations are shown in Systems Test Report No. 27B3388-1.

5.6.3 Test Method

The test method was described in the report on the Jettison Rail Deflection Test. The "A" frame deflections were not measured in the first phase of that test where the applied loads were varied.

5.6.4 Test Results and Discussion

The maximum rotation of the "A" frame in the vicinity of the lox bottle attach points occurred with a tangential load applied near the end of the jettison rail. This rotation was 1/5 the maximum rotation obtained in the lox bottle bracket test.

5.6.5 Conclusions

The "A" frame deflections are very low when compared to the values obtained in the lox bottle tests. The lox bottle attach point deflection tests may be considered a conservative test.

5.6.6 Recommendations

In view of the above conclusions and the conclusions of Test 5.7, no further Testing in this area is necessary unless data from Flight Tests and Point Loma Testing, indicate considerably higher Jettison Rail Loads.

5.7.0 LOX BOTTLE DEFLECTION TESTS

5.7.1 Test Objectives

To obtain spring constants of the Lox Bottle support brackets for significant loading conditions. Loads induced in these supports by structural deflections can then be obtained by comparing these spring constants with the deflection characteristics of the jettison rail and "A" frame.

5.7.2 Test Set-up

The tests were conducted with the bottle installed on the staging mock-up. Loads were applied by screw jack via load cells for the following conditions:

Test 5.7A - The bottle was removed and a radial outward load was applied to the inbd support fitting at the bottle attach point, as shown in Figure 5.7.1.

Test 5.7B - The inboard support fitting was removed and a tangential load was applied to the bottle at the inboard attach point as shown in Figure 5.7.2.

Test 5.7C - The outboard support fitting was removed and a tangential load was applied to the bottle at the outboard attach point as shown in Figure 5.7.3.

Test 5.7D - The outboard support fitting was removed and a pure torque was applied to the bottle at the outboard attach point as shown in Figure 5.7.4.

5.7.3 Instrumentation

A load cell was interposed between the loading jack and the specimen. Deflections were obtained from dial gages.

5.7.4 Test Method

Test 5.7A - The load was applied gradually and read from the load cell at .05 inch increments of deflection from 0 inches to .80 inches. Deflection was read from a dial gage. (Normal to the plane of the inbd support bracket.)

Test 5.7B - The load was applied in 10 lb increments to a maximum of 130 lbs. Deflections were read from dial gages at each increment for the following:

(a) Translation at the load point in the direction of the load.

(b) Torsion of the "A" frame at the attach fitting.

(c) Torsion and radial translation of the jettison track at the attach point.

(d) Radial translation of the pilot valve.

Test 5.7C - The load was applied in 10 lb increments to a maximum of 50 lbs. Deflections were read from dial gages at each increment for the following:

(a) Translation at the load point in the direction of the load.

(b) Radial, tangential, and "normal" to "A" frame translation of the inbd. attach point.

Test 5.7D - The torque was applied in 400 in/lbs increments, to a maximum of 4,000 in/lbs. The test was run with and without the plumbing attached to the pilot valve. Deflection was read from dial gages at each increment to obtain the following:

(a) Rotation at the load point in the plane of the torque.

(b) Rotation of the "A" frame at the inbd attach point.

5.7.5 Test Results

Test 5.7D - Torque applied with attaching tubes removed increased the deflection rate of bottle attachment points.

The upper inboard support arm between "A" frame and bottle attach point deflected approximately .25 at center of column near the 4000 in/lb loading. The spring constant obtained is given in Figure 5.7.4.

Test 5.7A - Spring constants are given in Figure 5.7.1. The stiffer spring constant found on Missile 77E may be due paint build-up and higher bolt torques.

Test 5.7B - Spring constants given in Figure 5.7.2.

Test 5.7C - Spring constant given in Figure 5.7.3. Maximum deflection of the attach fitting was greater than that necessary to take the deflections due to the calculated shoe loads. See Table 5.6.2.

5.7.6 Discussion

The vernier solo LOX bottle and its support bracket provide a rigid link between the pin connected jettison rail and its pin connected ("A" frame) support. Therefore, the relative displacements between the rail and the "A" frame in conjunction with the relative stiffness of the rail, "A" frame and link determine the secondary loads imposed in the lox bottle and its support. Excessive secondary loads in the lox bottle link could cause bracket failures which in turn could cause damage to the hydraulic system.

The three tests conducted on the lox bottle and its supporting structure were devised to provide relative stiffnesses and/or

5.7.6 Discussion (contd)

allowable displacements in the respective directions. The lox bottle is a pin connected link but can transmit side load and moment, torque and vertical displacement. The results of this testing can be used for analytical evaluation, or compared with unit rail loading test to show this areas vulnerability.

The results show the top of the lox bottle could move vertically 0.8 inches, laterally 0.7 inches and rotate 7.0 degrees without fracturing any of its supports. This is also representative permissable track to "A" frame relative movements, which are of the order of 6 to 8 times the relative movements expected from any possible track loading condition.

5.7.7 Conclusions

The lox bottle support structure is sufficiently flexible to ensure that failure will not occur due to loads induced by deflections of the jettison track and "A" frame under any known loading conditions.

LOX BOTTLE BRACKET
(VERTICAL DISPLACEMENT)

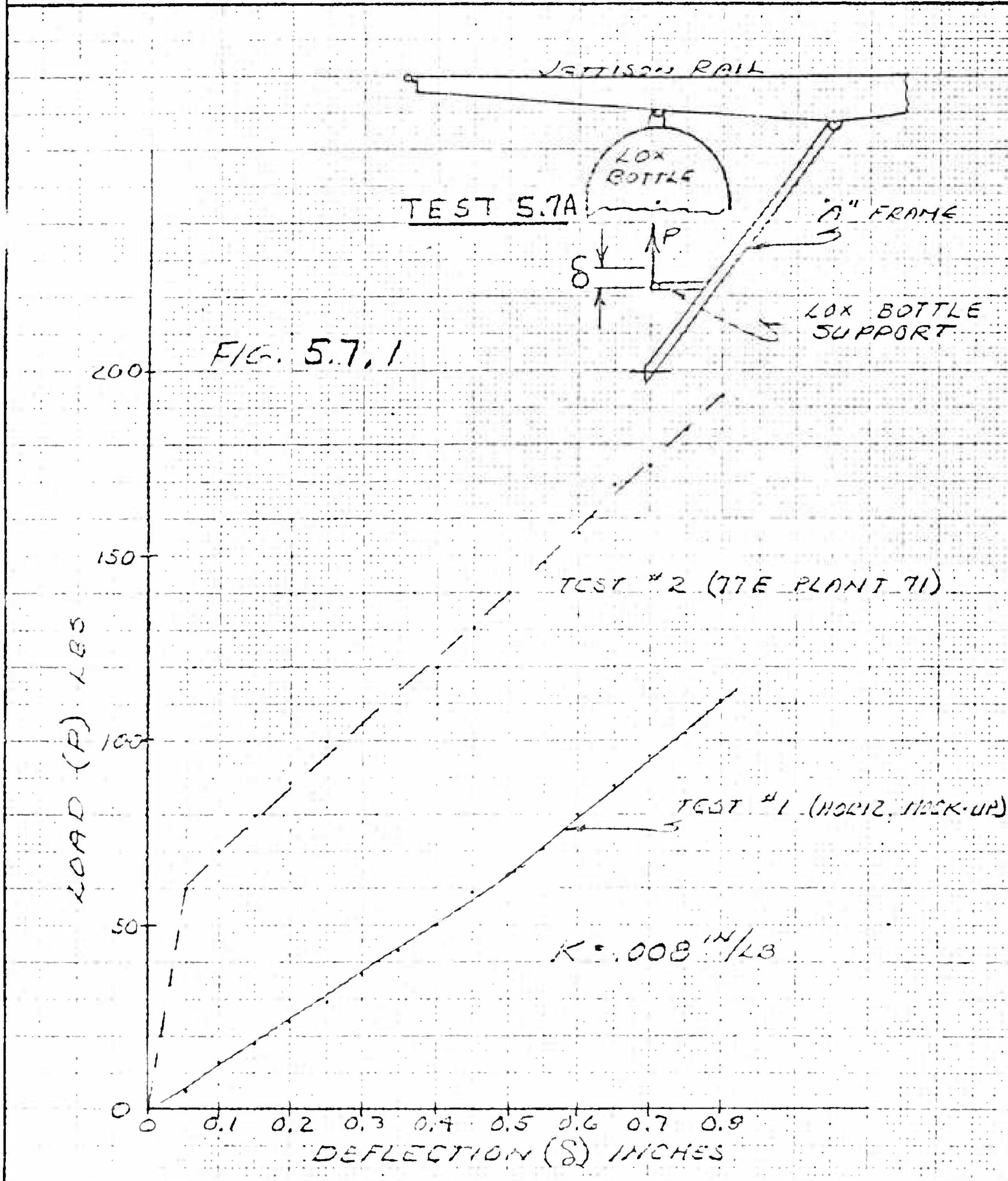


FIG. 5.7.1

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LOX BOTTLE
(SIDE EXCURSION)

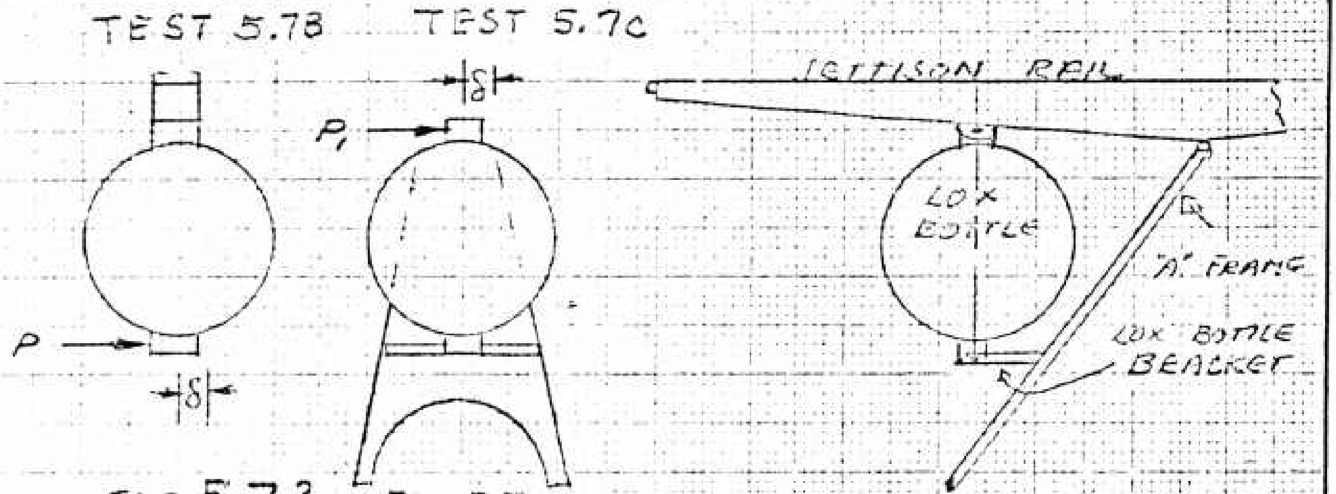
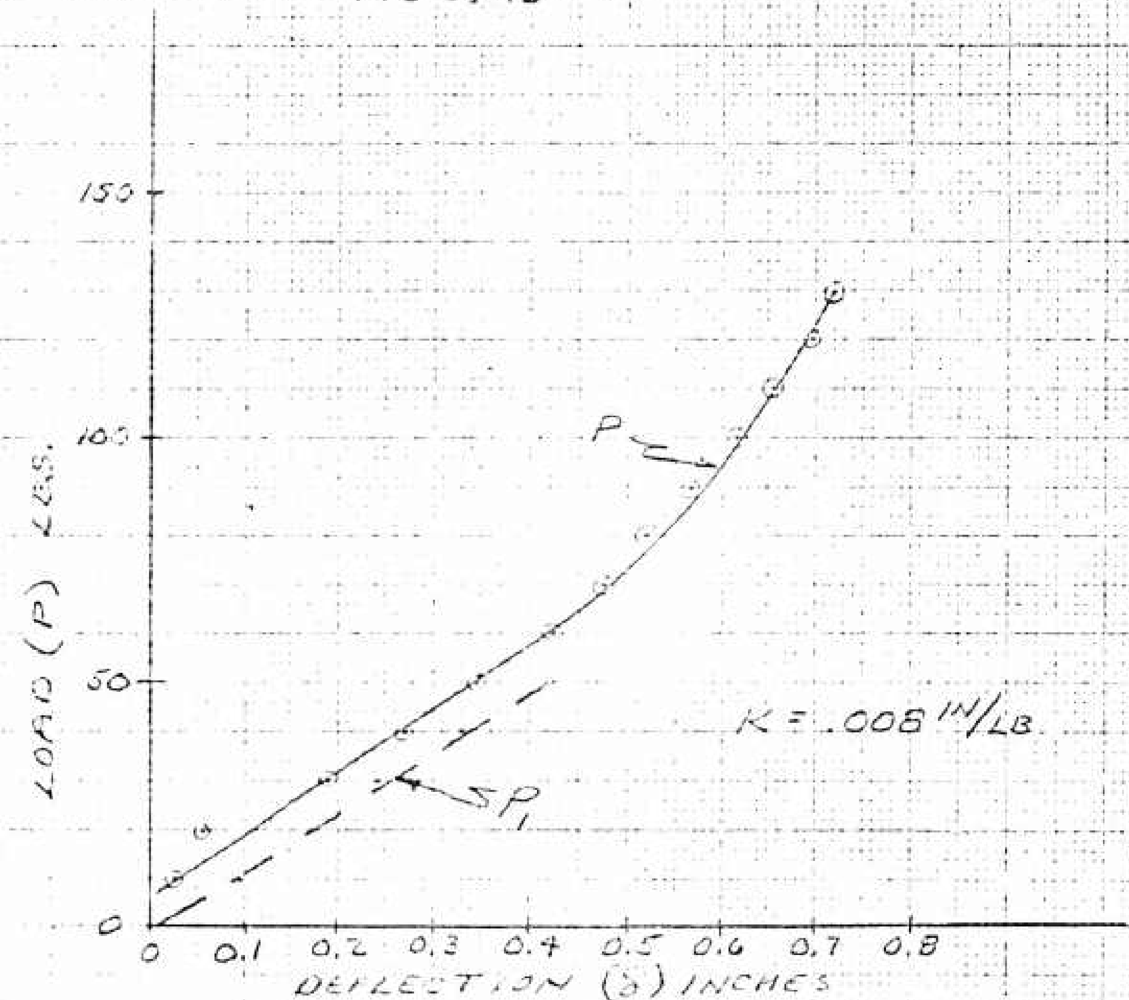


FIG 5.7.2 FIG 5.7.3



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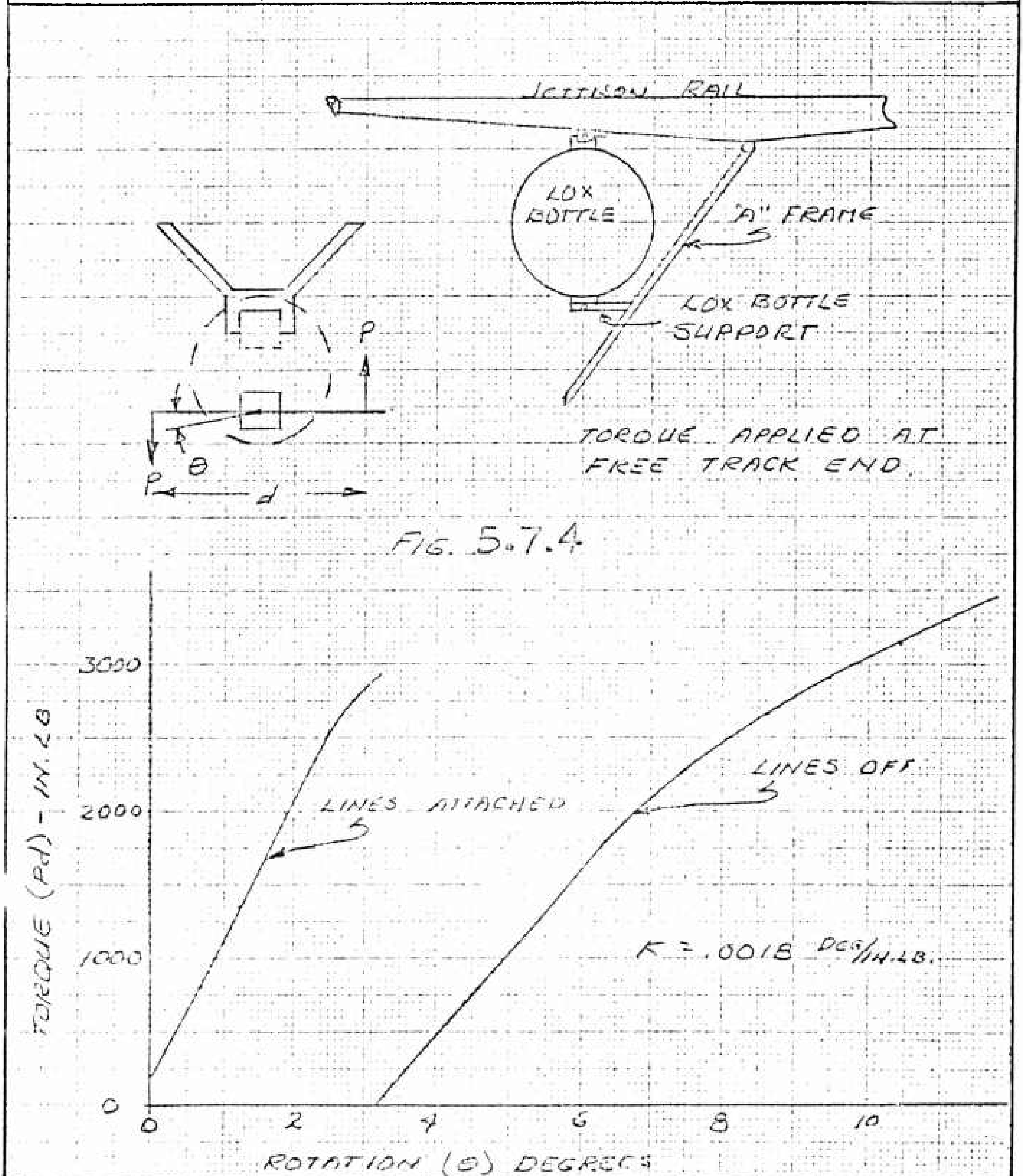
LOX BOTTLE TORQUE
(ROTATIONAL DISPLACEMENT)



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5.8.0 JETTISON SHOE PEDESTAL TESTS

During the staging mock-up tests, the quad four forward guide shoe pedestal failed. Reference (paragraph 5.2.0 Sustainer/ Thrust Section Deflection Tests). Readings on the guide shoes indicated a much higher load than was being applied, it was necessary to verify the actual loading as well as the failure mode of the pedestal.

This failure had been experienced in previous drop tests during E & F investigation at Point Loma. Reference: Dynamics Report number AD1558 - 28 May 1962.

5.8.1 TEST OBJECTIVES

Determine the Load versus deflection of the pedestal in its primary load axis, the vertical plane parallel to the X-X axis. Verify the load at which the pedestal fails and correlate with shoe strain gauge readings. Perform load/deflection tests on the quad four forward pedestal and the quad two pedestal to establish their relative performance.

Determine the effect on load/deflection characteristics and ultimate strength of stiffening the upper edge of the pedestal.

5.8.2 TEST SET UP

The Booster section with forward pedestal and guide shoe assembly installed was used as the specimen. A fixture to contain a loading device and instrumentation was fabricated and attached to the booster bulkheads.

A Vee block fitted to the guide shoe edge vertically and mounted upon a screw jack/load cell arrangement was installed in the fixture to apply and record loads.

Three dial indicators were mounted to read vertical motion and rotation of the guide shoe during test.

5.8.3 INSTRUMENTATION

0-5000 lb. capacity load cells and visual readout kit.

0-.500 dial indicators.

0-5000 lb. SR4 strain gauge.

5.8.4 TEST METHOD

Test 8.1 - To determine load and deflection of Pedestal at the failure point, the fixture and loading device were positioned to apply downward Vertical load to the QIV forward guide shoe.

5.8.4 (continued)

Load was manually applied through a "V" Block with a screw jack and load cell in the following increments. Data was recorded at each level.

LOAD	DEFLECTION	LOAD	DEFLECTION
400	.025	2000	.201
800	.063	2050	.207
1200	.100	2100	----
1600	.145	2200	.216
1800	.171	2230	.226
1900	.185		

The pedestal failed upon reaching 2300 lbs. with .226 ins. vertical deflection and .050 rotation of the slide. Strain gage readings followed the loading until 2100 pounds. At this applied load the strain gage read 1420 lbs. and after that it read a gross error which indicated excessive load.

Test 8.2 - To determine the load/deflection characteristics and ultimate strength of the QII pedestal. Load was applied manually through a "V" block, with a screw jack and a load cell in the following increments. Data was recorded at each level.

LOAD	DEFLECTION	LOAD	DEFLECTION
400	.017	2800	.235
800	.058	3000	.267
1200	.087	3100	.289
1600	.088	3200	.314
2000	.154	3300	.338
2400	.19	3340	.372 FAILURE

The pedestal failed approaching 3340 lb. load .372 ins. vertical deflection and strain gage readout of approximately 3250 lbs.

Test 8.3 - To determine deflection rate versus load below failure point the fixture and loading device were positioned to apply an upward vertical load to the QII forward guide shoe.

5.8.4 (continued)

Load was manually applied through a "V" block with a screw jack and a load cell in the following increments. Data was recorded at each level.

LOAD	DEFLECTION	LOAD	DEFLECTION
0-200	.017	1200	.124
400	.035	1400	.151
800	.077	1500	MAX .166
1000	.104		

Load relieved in the following increments and data recorded at each level to determine what permanent set would result.

LOAD	DEFLECTION
1500-500	.089
500-100	.046
100-0	.033

Test 8.4

To determine deflection rate versus load below the failure point the fixture and loading device were positioned to apply a downward Vertical load to the QII forward guide shoe.

Load was manually applied through a "V" Block with a screw Jack and a load cell in the following increments. Data was recorded at each level.

LOAD	DEFLECTION	LOAD	DEFLECTION
200	.017	1600	.087
400	.031	1800	.103
600	.044	2000	.118
800	.050	2200	.137
1000	INVALID	2300	.148
1200	.059	2400	.158
1400	.074		

Test 8.5

A pedestal with added stiffener was tested to determine its load and deflection characteristics. The fixture and loading device were positoned to apply a downward vertical load to the QIV forward guide shoe.

Load was manually applied through a Jack and load cell in the following increments.

A. 0- to 3000 in 200 lb. increments. Maximum deflection at 3000 lb. was .113. Pedestal started to yield and load was relieved.

B. 0 to 3800 in 400 lb. increments. Repeated run (a) results.

C. 2800 lb. to failure in 200 lb. increments. Maximum deflection at 3600 lbs. .147 inches (Guide shoe attach bolts pulled out when loading to 3800). Figure 5.8.2 illustrates stiffened pedestal and test data.

5.8.5 TEST RESULTS

The loading of quad four pedestal demonstrated that it failed at 2300 lbs. load. The crack occurred at the same location and shape as happened in the Sustainer/Thrust Section Deflection Test. Strain gauge error at loads applied verified that loading recorded when pedestal failed during system test were not correct.

The loading of the QII pedestal in the same direction showed that since it is mounted opposite to the QIV installation the structure stiffness was different. The loading required to fail this pedestal was 3300 lbs. vs. 2300 lbs. for the QIV pedestal.

The stiffened pedestal failed at 3800 lbs. by tear out through the pedestal skin of the bolts attaching the shoe to the pedestal. The stiffness was increased by 150%.

5.8.6 DISCUSSION

The requirement for component testing of jettison shoe pedestal was generated by the failure of the QIV forward shoe pedestal in the Sustainer/Thrust Section Deflection Test described in paragraph 5.2.0.

In that test the intended loading condition would have applied 3060 lbs. to the forward shoe, parallel to the "X" axis vertically down. It was felt that failure may have been caused by overload, due to:

5.8.6 DISCUSSION (continued)

A. Inadvertant overload due to the method of manipulation of the loading fixture.

B. Due to uneven distribution of load between the forward shoes.

The strain gage reading for the QIV forward shoe prior to failure (7200 #) seemed to substantiate an overload.

Test No. 8.1 was performed on two specimens to determine the ultimate stength of the pedestal. The test specimens failed at 2150 lbs. and 2300 lbs. respectively, and in the same mode as the sample in the Sustainer/Thrust Section Deflection Test. This demonstrated that the QIV forward shoe was not overloaded in that test with respect to the intended test loads, but that the shoe strain gage instrumentation was inadequate. The applied test load was higher than pedestal failure point. Figure 5.8.1 illustrates loading.

To aid in the determination of a sequence of failure following a QIV shoe pedestal failure, an ultimate load test was performed on the QII forward shoe pedestal. Due to the geometrical difference illustrated in Figure 5.8.1, the QII pedestal was expected to be 110% stronger than the QIV pedestal with the same direction of load. This was not verified by the test result, - failure at 3300 lbs. The mode of failure was unchanged.

At the time of these tests, the failure load for the QIV pedestal was thought to be below flight loads. Test 8.5 was accomplished to check a method of stiffening and stengthening the QIV pedestal to give a basis for a possible design fix. The method tested consisted of bolting the upper flange of the pedestal to an added intercostal beam to reduce the load and deflection a the two corner attachments. This arrangement is illustrated in Figure 5.8.2.

Test 8.5 showed an increase in ultimate load to 3800 lbs. The mode of failure was different, in this case the bolts attaching the shoe to the crown of the pedestal pulled through the pedestal skin.

A second reason for these tests was the determination of the flexibility of the pedestals.

The results of Test 8.1 indicate that the QIV pedestal is somewhat flexible. The deflection at 2000 lbs. being .20 inches. This was reduced to .08 inches in Test 8.5.

5.8.6 (Continued)

Summarizing the results we have:

	FAILURE LOAD	DEFLECTION AT 2000 LBS.
QIV Production Pedestal	2150-2300 Lbs.	..20 in.
QIV Stiffened Pedestal	3800 lbs.	.08 in.
QII Production Pedestal	3300 lbs.	.16 in.

5.8.7 CONCLUSION

Flight loading applied in the opposite direction would reverse relative strength and stiffness of pedestals as tested.

The strength of the QIV forward pedestal is less than the load anticipated in the Point Loma Tests (2150 lbs. vs. 2835 lbs.).

The QII forward shoe pedestal is probably adequate for 2835 lbs..

2835 lbs. can easily be accommodated by stiffening the QIV pedestals to the equivalent of the test 8.5 specimen.

A requirement to increase the strength of the Quad IV pedestal above 3,800 lbs. would involve strengthening the attachment of the shoe to the pedestal in addition to strengthening the attachment to the bulkheads.

Deflection of the forward shoe pedestal makes a significant contribution to the deflection of the sustainer relative to the thrust section.

5.8.8 RECOMMENDATION

Pedestals should be instrumented during further tests. It would be desirable to instrument a flight article.

JETTISON SLIDE PEDESTAL TEST

FIG. 5.8.1

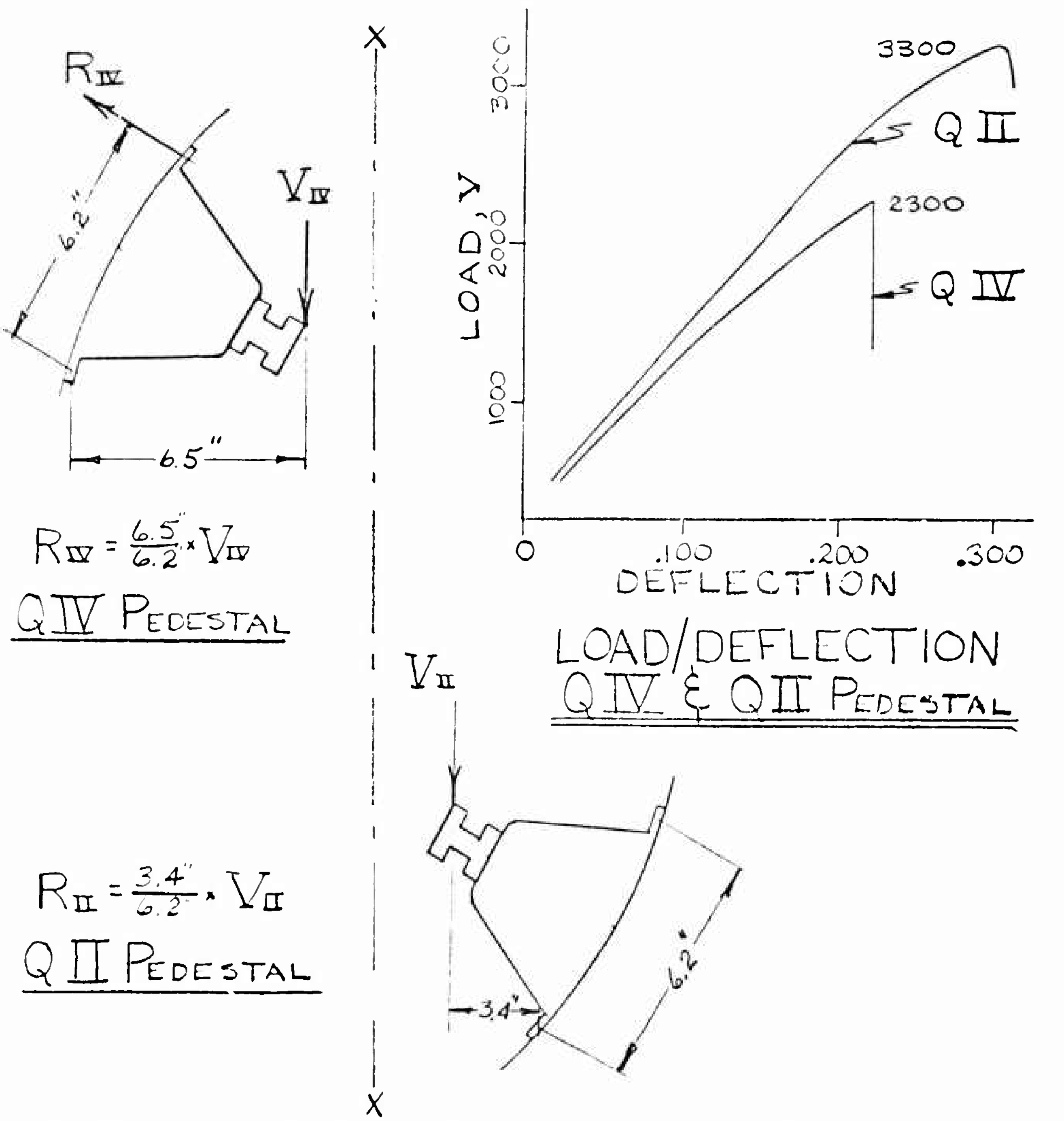

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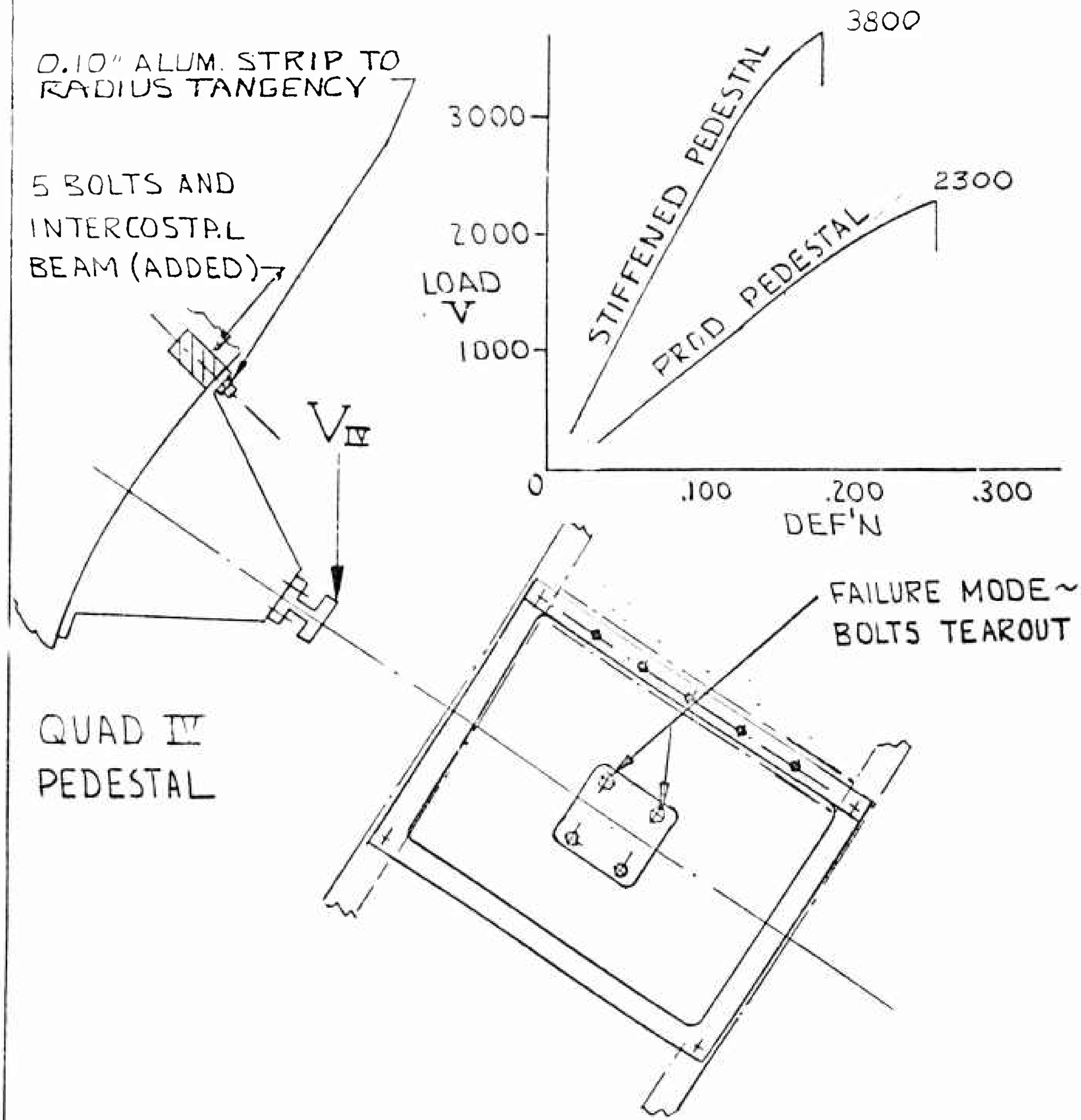
FIG 5.8.2.

JETTISON SLIDE PEDESTAL DESIGN FIX TEST



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5.9.0 SUSTAINER ENGINE DROOP TEST

5.9.1 TEST OBJECTIVE

The objective was to determine the effect on clearances of low fuel tank pressures (8 to 12 PSI) used in the Staging Mock-Up. This was to be obtained by measuring the motion of the sustainer engine relative to the booster due to varying tank pressures.

5.9.2 TEST SET UP

The Staging Mockup test stand with Stub tank and sustainer engine was used. A linear motion device was located on the X-X axis in two places on the engine. One device at the aft end of engine thrust chamber and one at the tank ring connection point.

The devices were mounted from the test fixture to reference Z-Z centerline of tank.

5.9.3 INSTRUMENTATION

(2) 0-1" Extensiometers
Sanborn recorder
Test stand tank pressurization gauges.

5.9.4 TEST METHOD

Recorder and Linear Motion devices are zero with tank pressure at 4 PSIG. Using test stand pressurization system the tank was pressurized to 8 PSIG. Data was recorded, the tank was then pressurized to 12 PSIG and data was recorded.

NOTE: The tank was not pressurized above 12 PSIG in the Bldg 1 test location to avoid hazard to personnel and the test specimen.

5.9.5 TEST RESULTS

It was found that the Vertical movement of sustainer engine thrust chamber was .004 when pressure was raised from 4 to 12 PSIG. Displacement was linear.

5.9.6 DISCUSSION

The test results indicate that movement of sustainer engine is not sufficient to cause additional clearance problems.

5.9.7 RECOMMENDATION

No further study in this area is warranted.

6.0 DISCUSSION OF PROBLEMS ENCOUNTERED

6.1 Jettison Shoe Strain Gage Instrumentation

Strain Gages mounted to the production jettison shoe configuration proved to be inadequate for the accuracy required. The strain gage installation is shown in Figure 6.1.1. The strain gaged shoes were calibrated in the Materials Test Lab to ± 3000 # axial and ± 3000 # shear. These loads were applied consecutively and not concurrently.

During the calibration process it was noted that a shear load caused a large effect on the axial bridge and vice versa. This "cross-talk" complicated the reduction of data. Difficulty was experienced in maintaining a zero setting. The "zero drift" was caused by the shifting of the shoe legs during loading and the retention of this strain due to friction when the shoe was unloaded.

A new shoe configuration was machined with a single leg. This new design eliminated the problem of differential displacement between two legs. (Figure 6.1.2)

The forward shoe single leg configuration was nearly insensitive to "cross-talk" between shear and axial loads. The single leg aft shoe configuration proved difficult to strain gage because of the radius on the short side. The single leg aft shoe was never installed.

During the sustainer/thrust section deflection tests the two aft shoes consistently indicated an axial load in the opposite sense to that which was predicted. This sign difference may be attributed to the miswiring of axial bridge or the effect of a twisting moment applied to the shoe face. This sign reversal was not observed in the forward shoes during this series of tests.
During the shoe pedestal tests the shear bridge followed the applied load very closely when the load was applied to the stiffer pedestal (Quad II). When the weak pedestal (Quad IV) was loaded the sign of the shear load reversed when the deflection became large. (see Tables 6.1.1 and 6.1.2).

TABLE 6.1.1

SHEAR BRIDGE OUTPUT
VS APPLIED LOAD (QUAD II)

APPLIED LOAD (LB.)	CALCULATED SHEAR COMPONENT (LB.)	TEST SHEAR (LB.)
0	0	0
405	350	340
815	706	660
1200	1040	990
1600	1385	1460
2000	1735	1675
2400	2080	2010
2800	2425	2325
3200	2770	2725

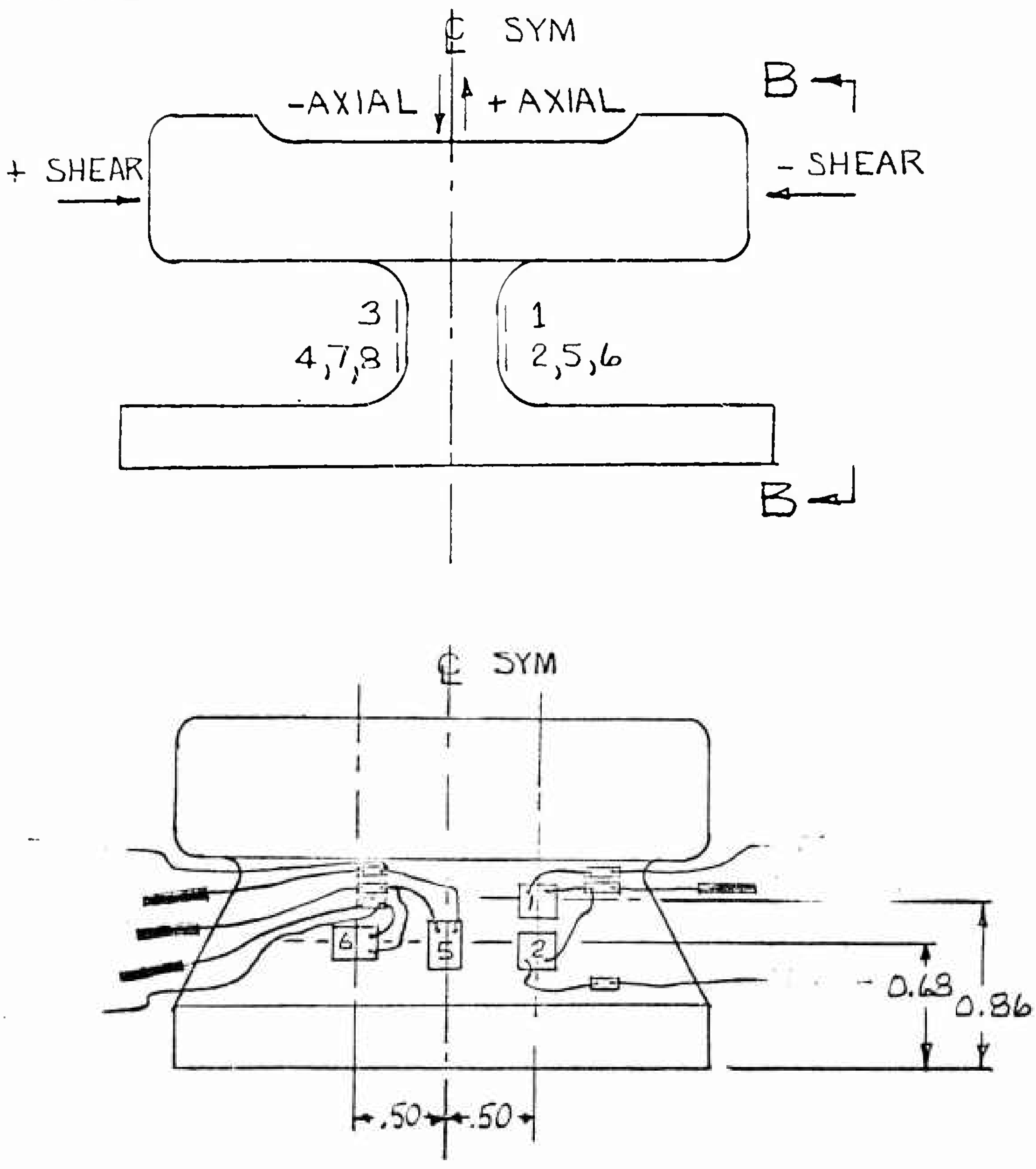
TABLE 6.1.2

SHEAR BRIDGE OUTPUT
VS APPLIED LOAD (QUAD IV)

APPLIED LOAD (LB.)	CALCULATED SHEAR COMPONENT (LB)	TEST SHEAR (LB.)
400	346	150
800	693	420
1200	1040	680
1600	1385	940
2000	1730	1170
2100	1820	1250
2150	1860	-530
2200	1905	-1030

INSTRUMENTATION - FWD JETTISON SLIDE QUADS II

FIG. 6.1.2



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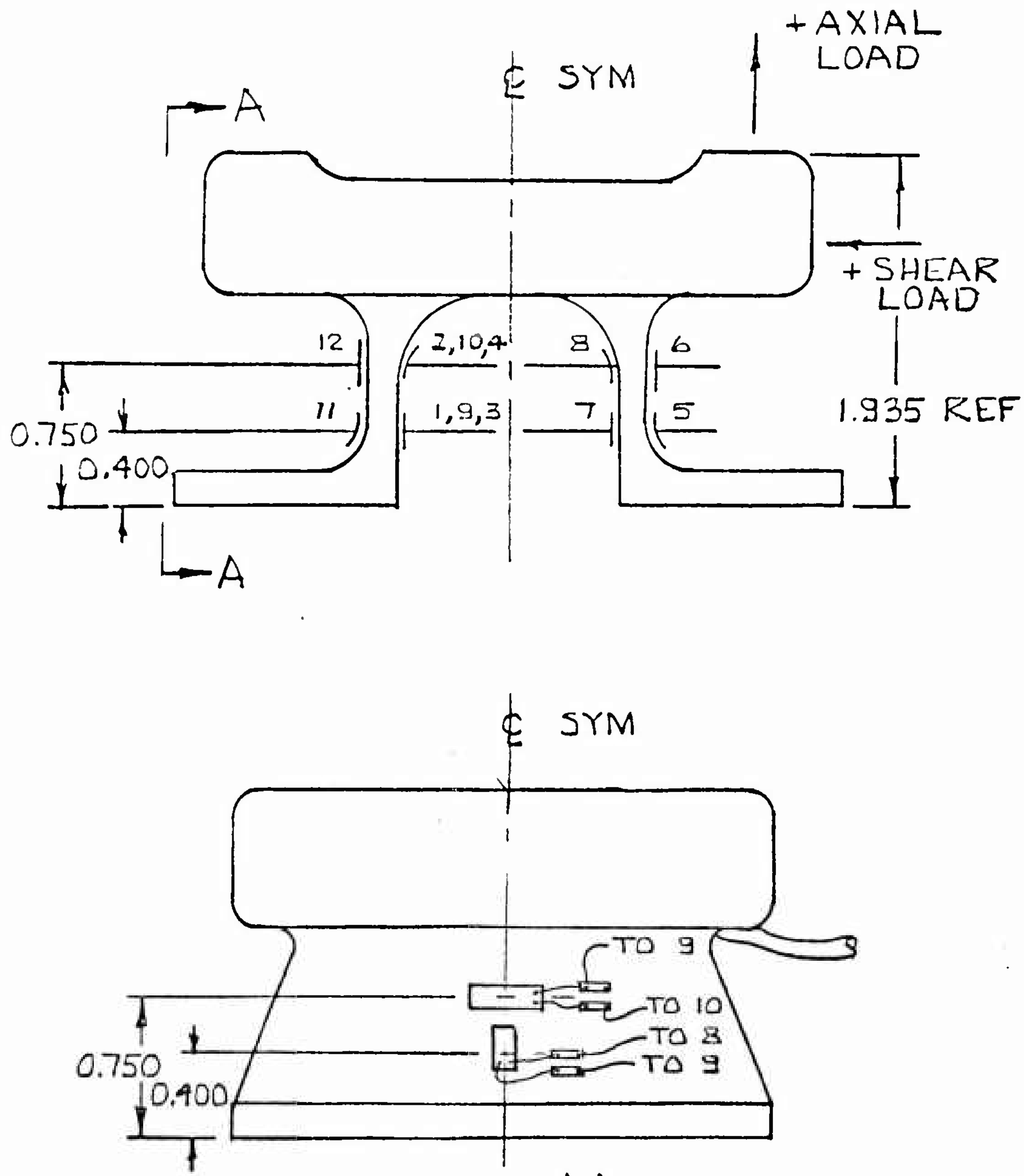
INSTRUMENTATION - FWD JETTISON SLIDE QUADS II

FIG 6.1.1



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6.2 Forward Jettison Pedestal Failure

The flight loads simulated on the horizontal mock-up were complied from booster loads described in Report AA-E-315 dated 4-24-63. These loads had been previously applied to the booster during a series of drop tests at Pt. Loma. No pedestal failure occured when these loads were applied. In the same series of tests; however, several drops were conducted with higher loads applied. In one of these drops a pedestal failure did occur. This fact would indicate that there is a reduction in the load carried by the forward jettison shoes when the load is applied dynamically.

The booster loads proposed for the current Pt. Loma tests have been modified to conform to the latest calculations and flight information. The major change in this revised loads analysis is the movement of the point of application of the LOX Expulsion force forward from MS 1215 to MS 1150. This change in load application point has changed the sense of the moment acting on the jettison shoes from clockwise about the positive Y-Y axis to counter clockwise. This revision has changed the direction of the shoe reaction load. Because the jettison shoe installation is assymettric about the Y-Y axis, the weakest pedestal installation is now located in Quad II rather than Quad IV. The failure load experienced during component level testing was 2300# parallel to the X-X axis. The equivalent calculated load on the horizontal mock-up is 3060# statically. The equivalent calculated load for the current Pt. Loma test program is 2830# statically. From the previous dynamic tests conducted at Pt. Loma it may be expected that the dynamic load will be lower. The pedestals for the Pt. Loma testing have been instrumented and the magnitude of the load carried by these pedestals will be monitored. In addition a strain gaged pedestal is being planned as part of flight instrumentation. This instrumentation will provide a basis for determining whether a redesign of this pedestal is required.

6.3 Hydraulic Reservoir Failure

At the start of the test program on the staging mock-up an initial hydraulic fill and bleed was completed successfully by following the operating procedure 27B3331. An outline of this procedure and a hydraulic system schematic are contained in Appendix A.

Prior to the initiation of the sustainer gimballing tests it was necessary to rerun the hydraulic fill and bleed procedure. During the procedure, while pressurizing the system to 3000 psig (see Appendix A, Step 10. Note that a hand valve is required to throttle the return line pressure to 100 psig), the reservoir end cap failed and oil flow was expended into the booster area.

The test conductor and the technicians monitoring the hydraulic return line pressure gages stated that the maximum hydraulic return pressure at the time of the reservoir failure was 105 psig. However, the failure mode indicated that the return system pressure was sufficient to fail the reservoir seals.

A check was then made to determine if the operating procedure would allow the system to be overpressurized. The hydraulic pressure & return lines were disconnected from the mock-up & connected together through a throttling valve. Pressure transducers were installed and the portion of the procedure where failure occurred was checked out. However, no unusual pressure spikes were discovered and the system functioned properly.

The reservoir history revealed it had serial No. 49. It was estimated to be approximately 4 years old and had been through many tests. The possibility exists that the reservoir could have been overpressurized in the past.

As the system was originally installed, with the hand valve as the only means of controlling the return system pressure, the possibility of overpressurization of the return system was quite high. To prevent such an event occurring, a relief valve was installed bypassing the return system hand valve. The hydraulic fill & bleed procedure (27B3331) was then considered adequate for any further operations.

7.0 DISCUSSION OF UNCOMPLETED PORTION OF THE PROGRAM

Phase Two of the Staging Mock-up test program was in the planning stage when the specimen was relinquished to start refurbishment in support of Pt. Loma Test Program.

The Separation Latch test has been carried on as a separate investigation. A test plan has been formulated and procedures written.

The Sustainer/Thrust Section Deflection tests planned for phase two would have been accomplished at the three additional separation distances defined for this program as 30 - 48 - 56 inches.

Sustainer gimbal positions were planned to be additive to Missile Deflections to obtain minimum staging clearances.

Dynamic separation tests would have the objective of determining staging clearances and function for the first eight inches of travel including latch separation. Fixtures had been partially fabricated to supply necessary sustainer thrust load and separation loads.

The Phase two effort would have demonstrated the ability to stage within the limits of the horizontal test stand. It would also define minimum clearances and the affect of deflections on the sequence.

The test area was secured and all fixtures were stored in Bldg. 1 Plant 19 for period of time. The fixture and supporting equipment have since been dismantled.

Point Loma dynamic drop tests will include dynamic loading and engine gimbal positions during staging. These tests will demonstrate what clearances are critical and also the affect of structural deflections on the sequence. The Point Loma tests and the intent of the Phase two tests are similiar. The Pt. Loma test installation has the advantage of giving the test specimen less artificial restraint than the horizontal installation.

136F Mock-Up Hydraulic Bleed Procedure (Mated)

1. Pressurize the VSA accumulator to 1000 PSIG and the sustainer accumulator to 2000/2550 PSIG with GN_2.

2. Pressurize the pneumatic fuel tank pressurization duct to 60 PSIG with GN_2 to provide a pressure source for the gas side of the hydraulic reservoir.

3. Open the hand valve between the sustainer hydraulic pressure and return rise-off disconnects and between the vernier engine hydraulic pressure and return lines. The hydraulic-ground system is not connected through the rise-off disconnects on the mock-up and the vernier actuator lines are capped (V-2 engine is removed from the mockup). These hand valves prevent the lines from being dead-ended and allow flow through the system.

4. Pressurize the hydraulic pressure line to 60 PSIG maximum and flow for 5 minutes to fill the system with fluid.

5. Close the hand valves between the rise-off disconnects and between the pressure and return lines on the vernier engines to separate the pressure and return systems at these points.

6. Increase hydraulic pressure until the airborne relief valve opens (3850 PSIG max.) and maintain for 1 minute to bleed air from the pressure line to the missile. Reduce pressure to 60 PSIG.

7. Actuate the pump reverse flow valve (27-08568) and hold. Increase pressure until pump rotation is established (2250 to 2850 PSIG) and hold for 1 minute to bleed air from the pump and associated lines. Reduce pressure to 100 PSIG and release pump reverse flow valve.

8. Pressurize the return and pressure lines to 100 PSIG and bleed at the reservoir and accumulator to remove air from these two components.

9. Return Line hand valve to open. Reduce return and pressure lines to zero.

10. Pressurize the return and pressure lines to 100 and 3000 PSIG by increasing the pressure to 3000 PSIG in the pressure lines and slowly closing the hand valve in the return system until the return pressure is 100 PSIG. Hold for 30 minutes to allow air to bleed from the sustainer servo cylinders and from the sustainer hydraulic control manifold.

11. Perform a reservoir drop check to determine the amount of air in the system.

    A. Reduce pressure line pressure to 100 PSIG and shut off flow.

    B. Reduce return line pressure to 60 PSIG and shut off flow.

    C. Observe red pin protruding from the pneumatic end of the reservoir.

    D. Verify 60 PSIG is being maintained in the fuel tank pressurization duct.

    E. Drain oil from the reservoir bleed port into a large beaker until the pin protrudes from the oil end of the reservoir.

    F. Close bleed port as soon as the pin is observed.

    G. If the volume of oil drained is less than 135 cubic inches, the system contains too much air and the entire procedure must be repeated.

Pneumatic Pressurization Requirements:

Line Nomenclature	Pressure (PSIG)	Preferred Pressurization Point
LOX tank pressurization	27	27-81002 ECN 166214
LOX tank sensing	27	27-81023 ECN AY
Fuel tank sensing	60	27-81023 ECN AY
Fuel tank pressurization	60	27-81003 ECN 166210
Helium supply line	3000	27-81025 ECN 196953 (disconnect side of sphere only)

Hydraulic Pressurization Requirements:

Sustainer hyd. pres.	3000	Tee for H191P
Sustainer hyd. return	60-100	Tee between reservoir and relief valve (replace tee with a cross)

A flow capacity of 10 gpm at 3750 PSIG will be required for system bleeding. All bleeds will conform to normal practices except the sustainer engine will not be gimballed. A reservoir level drop test will be required to verify bleed adequacy. Provision must be made to bleed the pressure and return hydraulic lines between the rise-off and staging disconnects.

See Figure 4.1 for schematic of system.

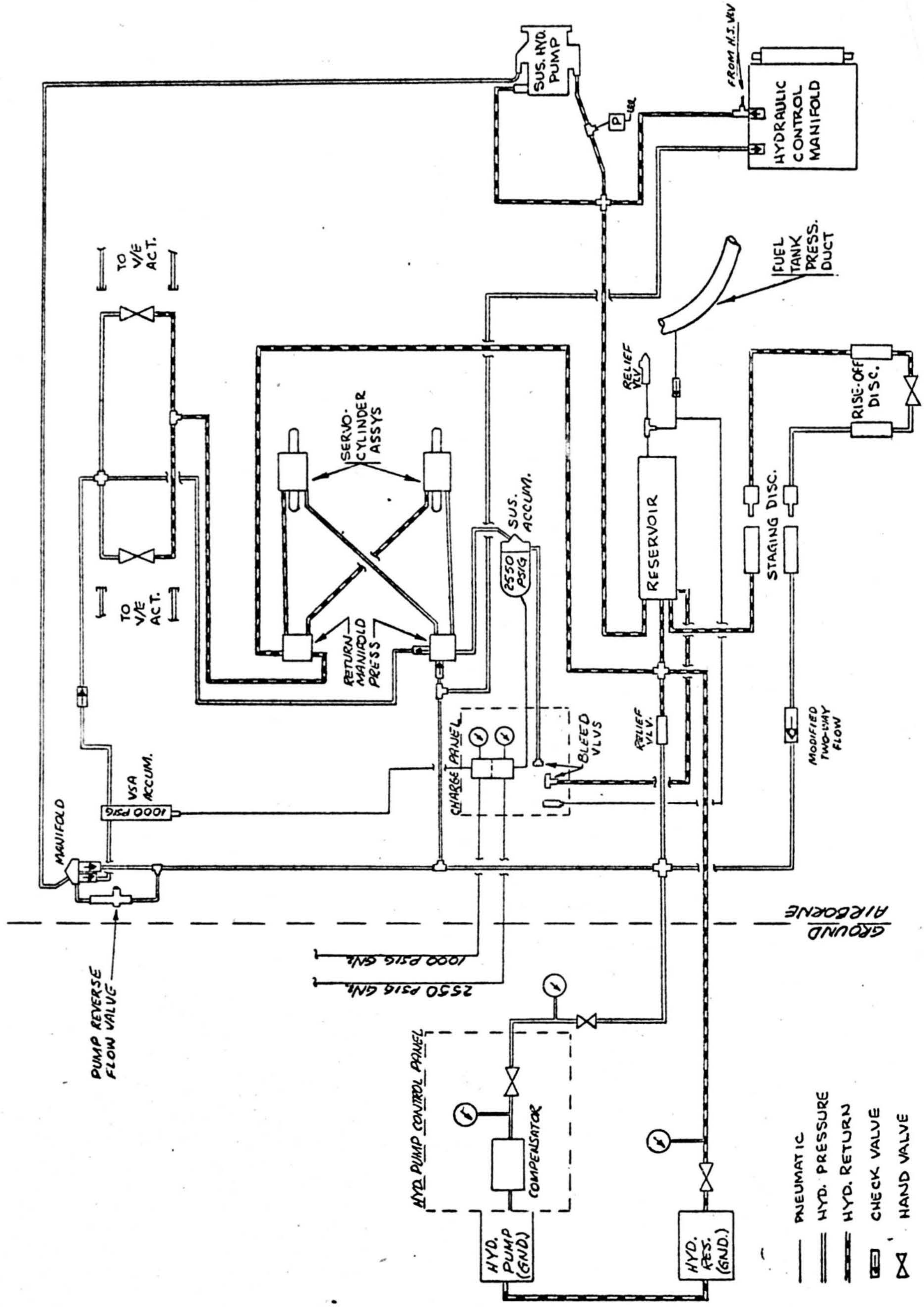
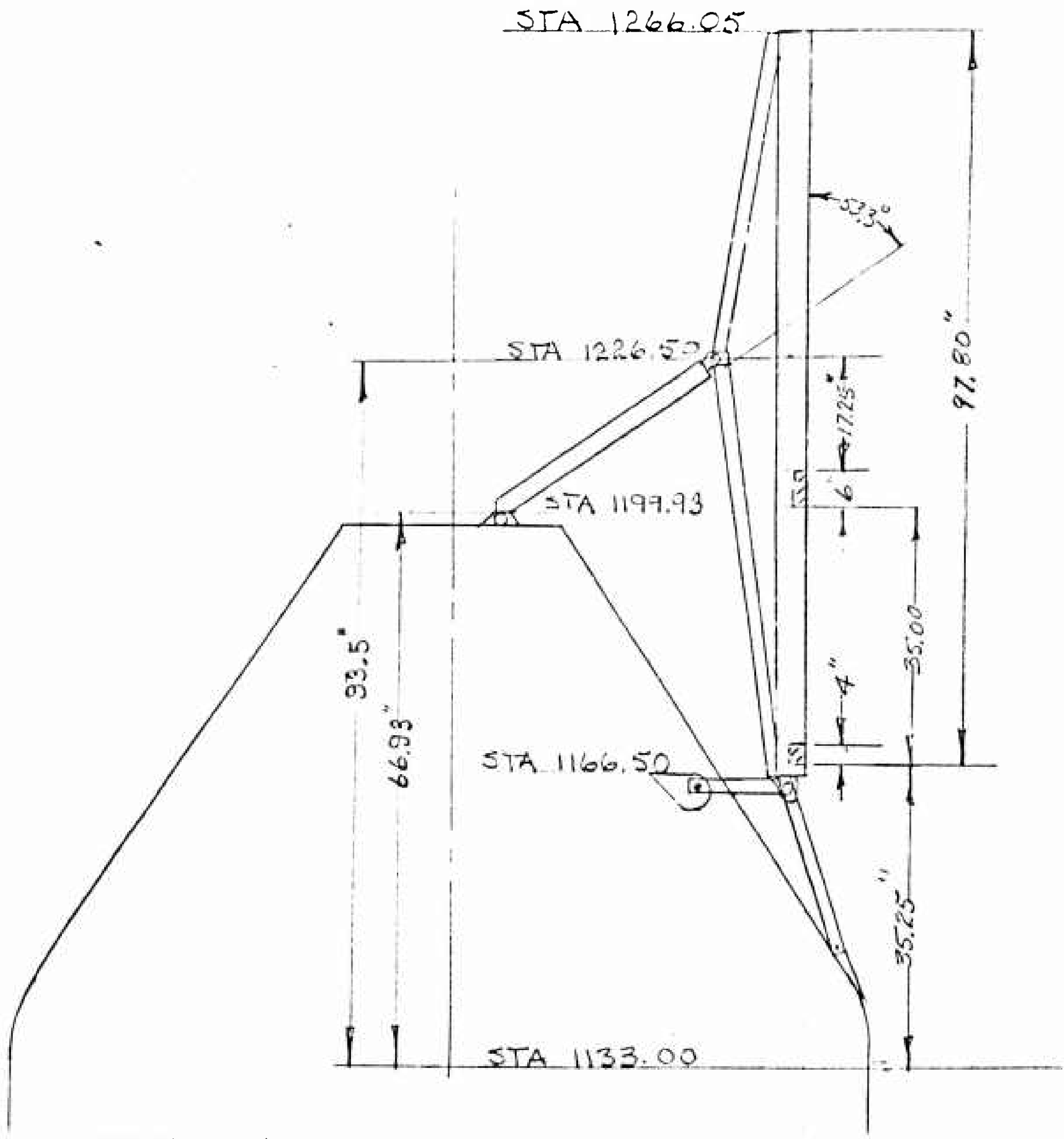


FIG. 4.1 - SUSTAINER HYDRAULIC SYSTEM - "F" SERIES MOCK-UP

APPENDIX B
SHEET 1



JETTISON SHOE LOCATION
AT MATED POSITION

PREPARED BY	DATE	CHECKED BY	DATE	REVISED BY	DATE
P. C. BANDOW	4-13-64	[illegible]	5-8-4		

APPENDIX B
SHEET 2

JETTISON SLIDE CLEARANCES