Avco CORPORATION
AEROSPACE STRUCTURES DIVISION
NASHVILLE, TENNESSEE 37202

MODEL M.A. 5503 REPORT R-1051

CONTRACT NO. NAS 8-11870 DATE 18 October 1965

FINAL REPORT

OPTIMIZATION OF SATURN IB AND V MOUNTING AND THERMAL CONDITIONING PANELS

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FINAL REPORT

OPTIMIZATION OF SATURN IB AND V

MOUNTING AND THERMAL CONDITIONING PANELS

I. INTRODUCTION

This Final Report is submitted in response to the requirements of NASA Contract NAS 8-11870. It contains a description of the tasks and major milestones encountered in the program.

The Appendices of this report contain the results of both static and dynamic testing, along with stress analyses which utilize the test results. A drawing, 2-10086, defining the various panel configurations, has been made and is to be considered as part of this report, but will be transmitted under separate cover.

II. OBJECTIVE

The primary objective of this program was to investigate various weight reduction techniques for weight optimization of the Mounting and Thermal Conditioning Panel without a degradation in structural integrity. Following the investigation and study, hardware was to be fabricated and tested in order that a final optimized design could be formulated.

III. TASK

A. Investigate various methods of reducing the weight of the Saturn 1B and V Mounting and Thermal Conditioning Panel while maintaining its structural adequacy and integrity.

B. Statically load a mounting and thermal conditioning panel of existing design, furnished by MSFC, with simulated equipment loads and measure deflections and strains. Combining the results of the static load test and dynamic tests previously conducted at MSFC, perform a comprehensive stress analysis to verify the proposed changes.

C. Perform static pull tests on small specimens and analyze results to determine optimum insert design.

D. Fabricate three full size, heat treated panels. Two panels to represent the two most feasible configurations as determined by the studies and preliminary tests; the configuration of the third panel based on the results of the tests performed on the first two panels.

E. Perform vibration and shock tests on the three panels (Ref. C above). Following the vibration and shock tests, the panels shall be subjected to the proof pressure test outlined in SCD 20M42000.

F. After completion of all tests, panels are to be delivered to MSFC.

IV. TASK EVENTS

Two panels reflecting the existing design were received from MSFC and one

was sent to Inland Testing Laboratories for shock testing. The other panel was retained at AVCO for use in static tests.

An investigation of possible insert designs resulted in a selection of six configurations to which test specimens were fabricated. The test specimen configurations are as follows:

A. Existing design

B. Existing design with only broken cells filled with potting compound

C. Optimized design of existing aluminum insert (See Fig. 4, Appendix A)

D. Inverted optimized insert design placing KNL insert at top of mounting assembly (See Fig. 5, Appendix A)

E. Replace entire insert assembly with Shur-Lok insert (See Fig. 6, Appendix A)

F. KNL insert installed in brazement.

The test specimens of the various insert designs were tested by means of static pull tests. These test results are included in Appendix A. From the data gathered by static pull tests and margin of safety calculations, two insert designs were recommended for use in the full size panels to undergo shock and vibration testing. The two insert designs selected were the inverted optimized design and the Shur-Lok, as described in D. and E. above.

It was determined that panel weight could be reduced considerably by holding material thickness of panel components to a minimum and adding lightening holes in the spacer bars. From calculations based upon results of

static and dynamic testing of panels which conform to existing design, it was determined that the following changes are feasible:

A. Reduce top skin thickness of braze assembly from .065-inch to .030-inch.

B. Reduce width of braze assembly frame to .10-inch where possible.

C. Place .375-inch dia. holes in braze assembly spacer bars on .50-inch centers.

D. Reduce bottom skin thickness of braze assembly from .025-inch to .020-inch.

E. Eliminate 7075-T6 .020-inch top doubler skin from mounting panel assembly.

Calculations of expected stress levels in the thinner members are included in Appendix B.

According to original direction, three panels of optimized design configurations were to be fabricated simultaneously. One panel was to be built to each of two chosen designs and an additional panel to the design estimated to be the most feasible. However, at the program review, 4/1/65, the NASA representative requested that fabrication of the third panel be postponed until completion of dynamic testing of the first two panels. This eliminated a possible wrong choice and permitted a panel of a third, more conservative, design to be fabricated in the event that both panel designs failed dynamic testing.

At the 4/1/65 program review, it was agreed that the designs for the first two test panels should incorporate the inverted optimized insert and the

Shur-Lok insert per AVCO's recommendations. In addition, it was agreed that both panels should be fabricated with the thinner face sheets and lightening holes as described previously. (See Dwg. 2-10086-1 & -3 for panel configurations.)

The two test panels also incorporated a new coolant fitting design which provides a method of adjusting pressure drop. The new coolant fitting design, however, is considered an improvement change and does not contribute to either structural integrity or weight reduction.

Dynamic testing of the panels was performed by Inland Testing Laboratories according to the procedures described in their Report No. 551177-B, which is included in this report as Appendix C. Panel 2-10086-1 with inverted optimized inserts successfully passed all phases of dynamic testing. Panel 2-10086-3 with Shur-Lok inserts passed shock testing, but experienced failure during vibration along the "Z" axis and testing was discontinued. The failure appeared as a crack in the brazement outer skin about 1/2-inch from an insert.

Both optimized panels exhibited a lower transmissibility during these tests than the previously tested, existing design. This resulted in maximum peak loads of approximately 50% less for the optimized panels.

During fabrication of the test panels, some difficulty was experienced in maintaining acceptable flatness on the brazement skin which mates to the mounting panel assembly. The problem was noted after heat treatment of the braze assembly and appeared as bulges in the skin opposite spacer bar

lightening holes. This condition resulted from expansion of entrapped gas during heat treat. The deformation occurred in the common skin, since the top skin is considerably thicker.

It was jointly agreed that the third panel configuration should be identical to panel 2-10086-1 (inverted optimized inserts) with the exception of deleting lightening holes in the spacer bars. Deletion of the lightening holes solved the flatness problem.

The third panel (2-10086-5) was fabricated and shipped to Inland Testing Laboratories for dynamic testing. The panel was tested according to the procedures set forth in Inland's Test Report No. 551218 which is included in this report as Appendix D. The panel successfully passed all phases of dynamic testing. It was then returned to AVCO and subjected to proof pressure test per Specification Control Drawing 20M42000. No leakage or deformation resulted from the pressure test.

V. CONCLUSIONS

With the completion of testing of the final optimized panel design, the objective of this program has been successfully met. Without sacrificing structural adequacy of the Mounting and Thermal Conditioning Panel, the weight has been reduced approximately 24.5 per cent. This weight is believed to be the minimum attainable, consistent with structural requirements.

The inverted optimized insert design which was used in the final panel configuration represents a total weight reduction per panel of 1.176 pounds. An additional weight reduction of 5.564 pounds was accomplished by reducing material thickness of various panel components. This provides a total weight savings of 6.74 pounds per panel.

APPENDIX A

STATIC TEST DATA AND MARGIN OF SAFETY CALCULATIONS

FOR VARIOUS INSERT DESIGNS

STRESS ANALYSIS

PROBLEM:

This analysis calculates the margins of safety (M.S.) for each of the equipment mounting insert designs.

MATERIALS:

6061-T4 to T6

F_{ty} = 33,000 psi

F_{tu} = 40,000 psi

Endurance Limit = 12,000 psi

F_{bru} = 88,000 psi

APPLIED INSERT LOADS:

Orientation of axes may be obtained from Figure 3.

X-Axis

Assume R_2 reacts in the middle of a section 0.1 in. wide at the edge of the block.

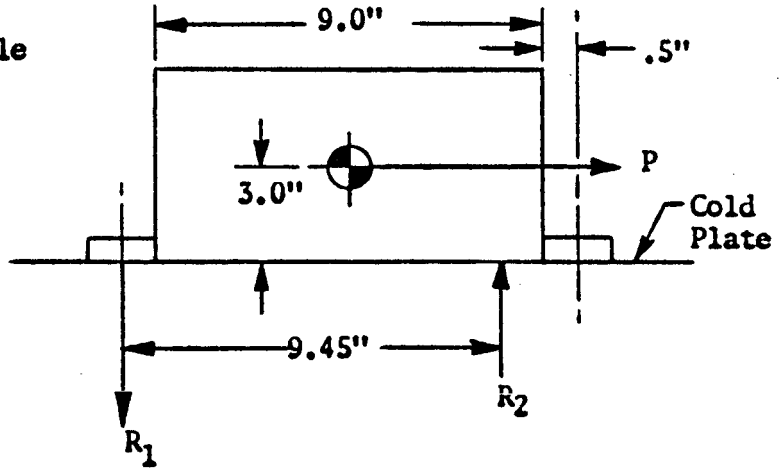


Figure 1

Based on one g in the x and y directions:

$P = 1g \cdot 50 \text{ lbs.} = 50 \text{ lbs.}$

$\sum M_{R_2} = R_1 \cdot 9.45" = 50 \text{ lbs.} \cdot 3"$

$\therefore R_1 = R_2 = 150/9.45 = 15.9 \text{ lbs.}$

Since there are two inserts on each side of the equipment,

$\text{Load/Insert} = R_1/2 = 15.9/2 = 7.95 \text{ lbs.}$

Y-Axis

Assume R_4 reacts in the same way as R_2.

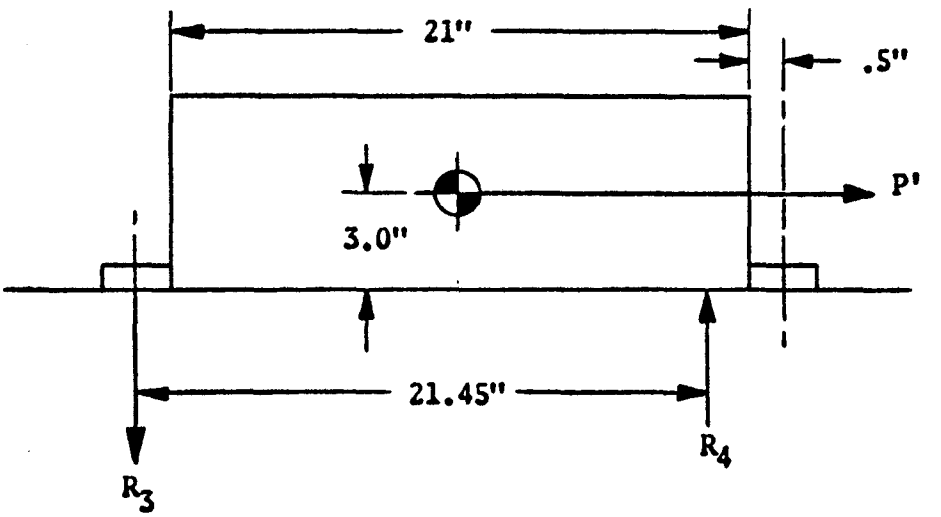


Figure 2.

Balancing out the loads for the 1g output:

$P' = 1g \cdot 50 \text{ lbs.} = 50 \text{ lbs.}$

$\sum M_{R_4} = R_3 \cdot 21.45" = 50 \text{ lbs.} \cdot 3"$

$R_3 = R_4 = 150/21.45 = 6.99 \text{ lbs.}$

$\therefore \text{Load/Insert} = 6.99/2 = 3.495 \text{ lbs.}$

	One g LOAD	ULTIMATE LOAD *	LIMIT LOAD**	MAXIMUM LOAD***
X-Direction Load/Insert	7.95 lbs.	179.5 lbs.	141.0 lbs.	801.0 lbs.
Y-Direction Load/Insert	3.495 lbs.	78.9 lbs.	62.0 lbs.	489.0 lbs.

* Ultimate Load = Applied Insert Load x 1.40 x g Level

** Limit Load = Applied Insert Load x 1.10 x g Level

The g Level is obtained from the preliminary vibration test results in the X & Y directions.

g Level = 16.129 g

This g level is the root-mean-square of accelerometer #3.

*** This load is based on the maximum g level obtained during the vibration tests; however, these loads are usually for only a very short period.

Maximum Load = Applied Insert Load x 1.40 x Maximum g Level

Max g; X = 72 & Y = 100

STATIC YIELD LOADS APPLIED TO INSERT TEST SPECIMENS

CONFIGURATION	TENSILE (LBS)	SHEAR (LBS)
(1) Existing Design	4400	4900
	4330	5730
	3910	5730
	3890	5810
	4270	5840
AVERAGE	4160	5802
(2) Existing Design with only broken cells filled with potting compound	3740	5850
	2900	5950
	3390	5860
	4020	5820
	3540	5820
AVERAGE	3518	5860
(3) Optimized Design of existing insert	3830	5800
	4290	5830
	4370	5920
	4410	5880
	4005	5880
AVERAGE	4181	5862
(4) Inverted Optimized Insert Design	4350	5640
	4280	5670
	4200	5630
	4370	5680
	4245	----
AVERAGE	4289	4657
(5) Shut-Lok Insert	2825	3920
	2955	3760
	2645	3220
	2690	3950
	2750	----
AVERAGE	2773	3713
(6) Entire insert assembly removed with KNL insert installed in brazement	1715	4840
	1920	5260
	1620	4570
	1660	4270
	1545	4100
AVERAGE	1692	4608

	ULTIMATE TENSION TEST LOAD	TYPE OF FAILURE	ALLOWABLE LOAD*	M.S.**	M.S.***
(1) Existing Design	4160 lbs.	Core Shear	1248 lbs.	Large	.558
(2) Potting Compound in Broken Cells Only	3518 lbs.	Bond Failure	1055 lbs.	Large	.317
(3) Optimization of Existing Insert	4181 lbs.	Core Shear	1254 lbs.	Large	.565
(4) Inverting Optimized Insert	4289 lbs.	Core Shear	1286 lbs.	Large	.605
(5) Shur-Lok Insert	2773 lbs.	Local Core Crushing	832 lbs.	Large	.039
(6) Insert Assembly Removed	1692 lbs.	Bond Failure	507 lbs.	1.82	-.367

* Allowable Load is based on the endurance limit of 12,000 psi and is calculated from the following:

$$\text{Allowable Load} = \text{Ult. Tension Test Load} \times \frac{12{,}000 \text{ psi}}{40{,}000 \text{ psi}}$$

** $\text{M.S.} = \frac{\text{Allowable Load}}{\text{Ultimate Load}} - 1.0$

*** $\text{M.S.} = \frac{\text{Allowable Load}}{\text{Maximum Load}} - 1.0$

The Margin of Safety calculations indicate that designs (1) through (5) are structurally adequate, while design (6) is insufficient.

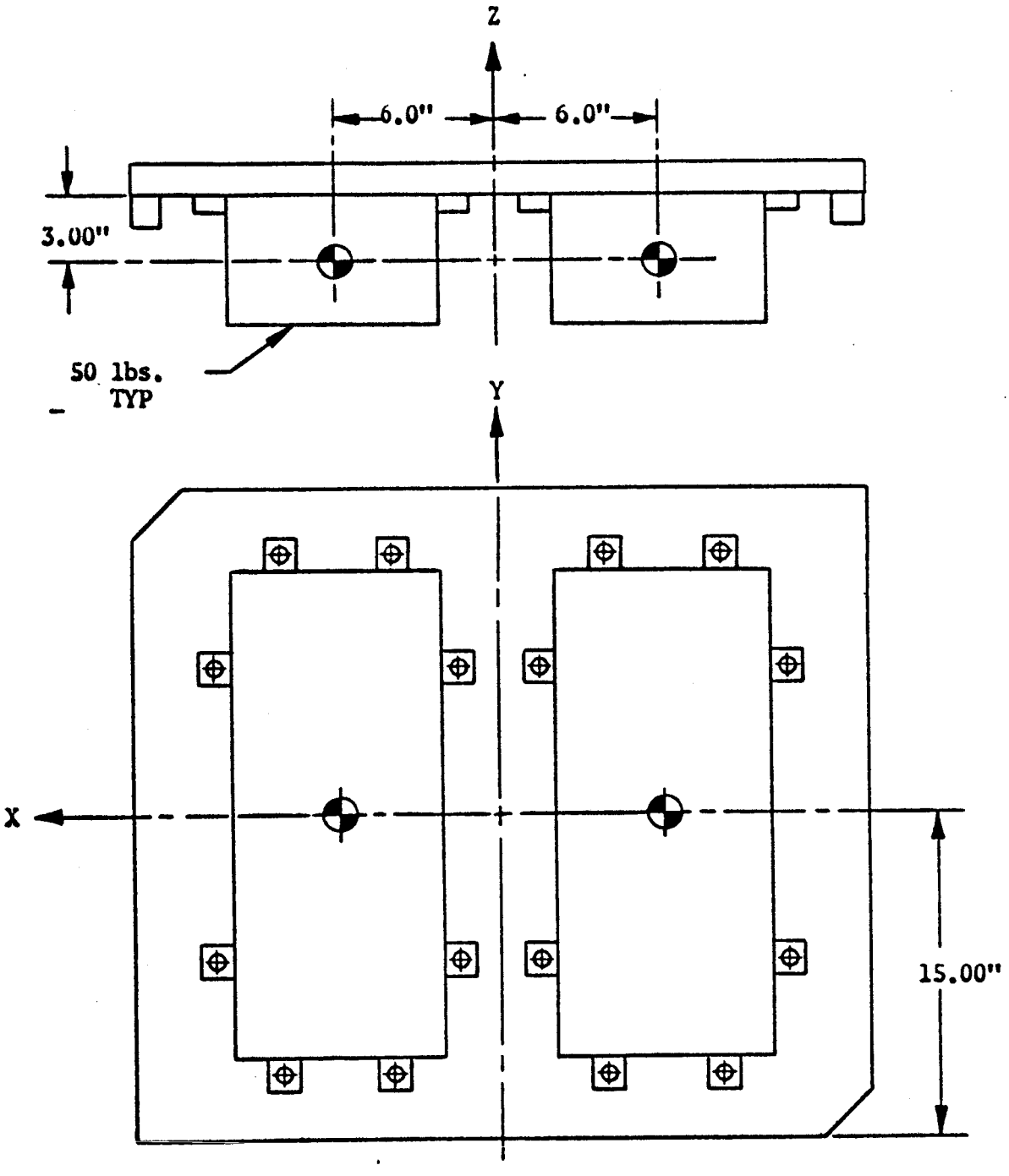
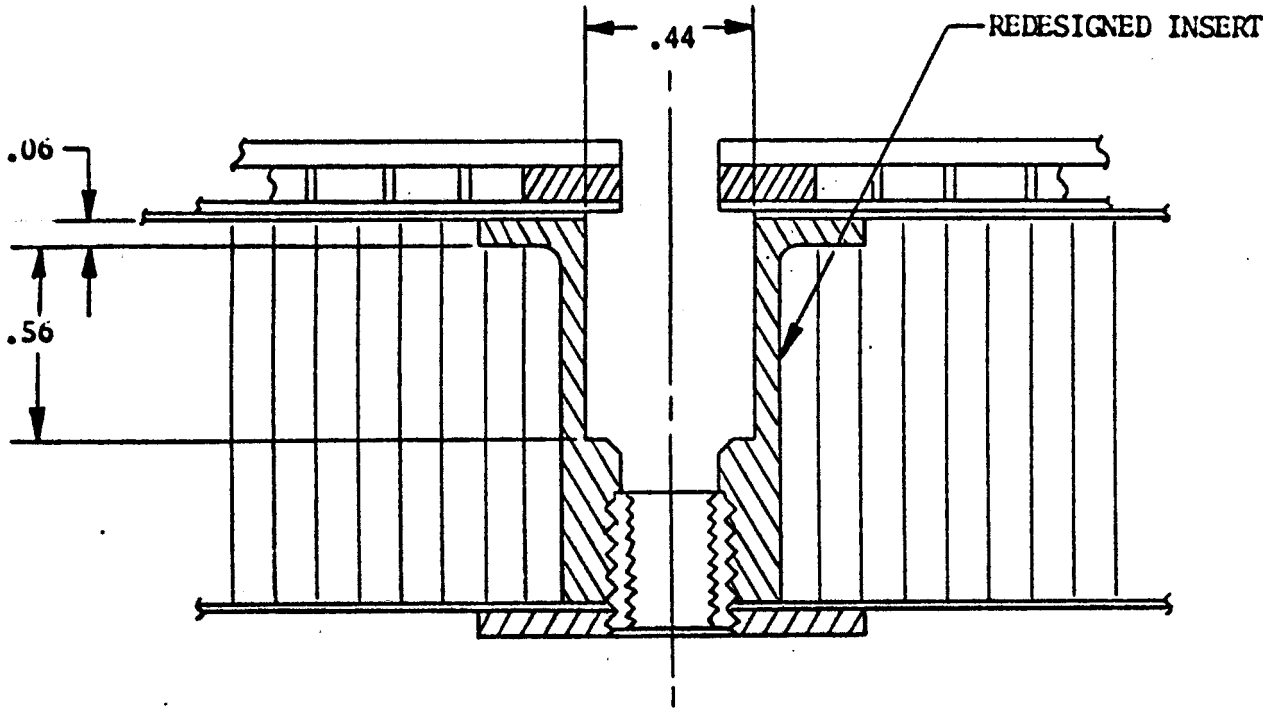


Figure 3.

TYPICAL SECTION - OPTIMIZED DESIGN

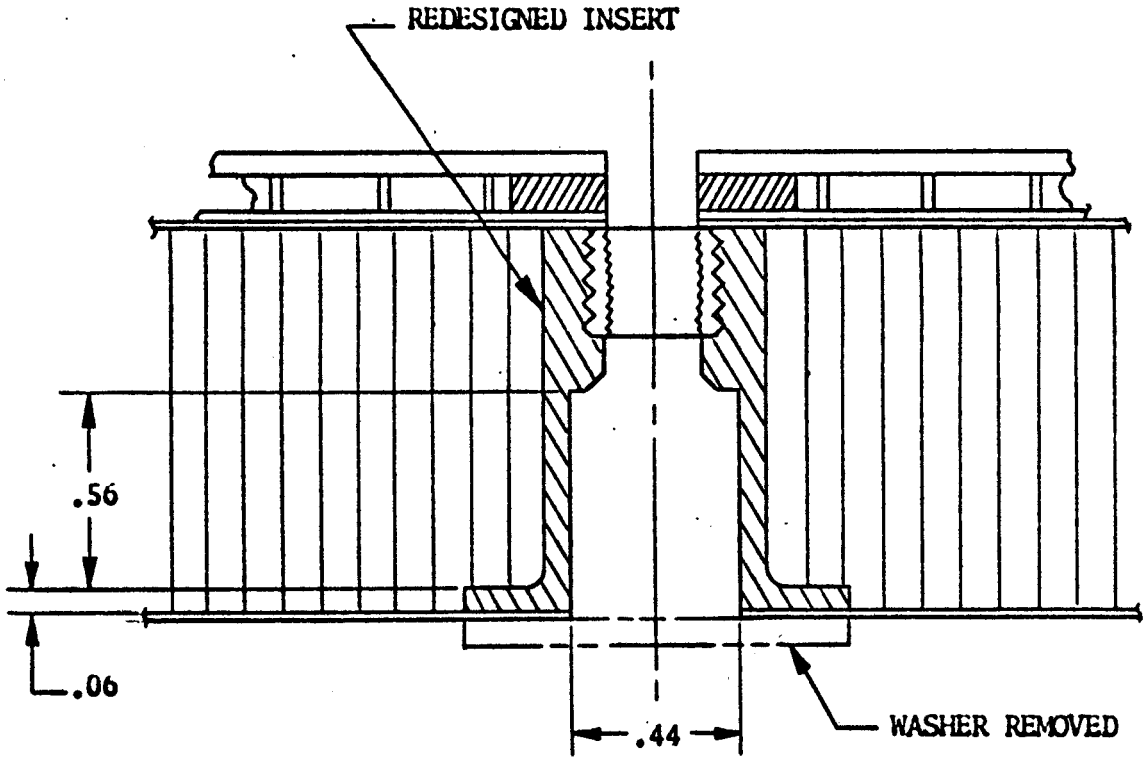


NOTE:

ALL CHANGES INDICATED BY DIMENSION.

Figure 4.

TYPICAL SECTION - INVERTED OPTIMIZED DESIGN

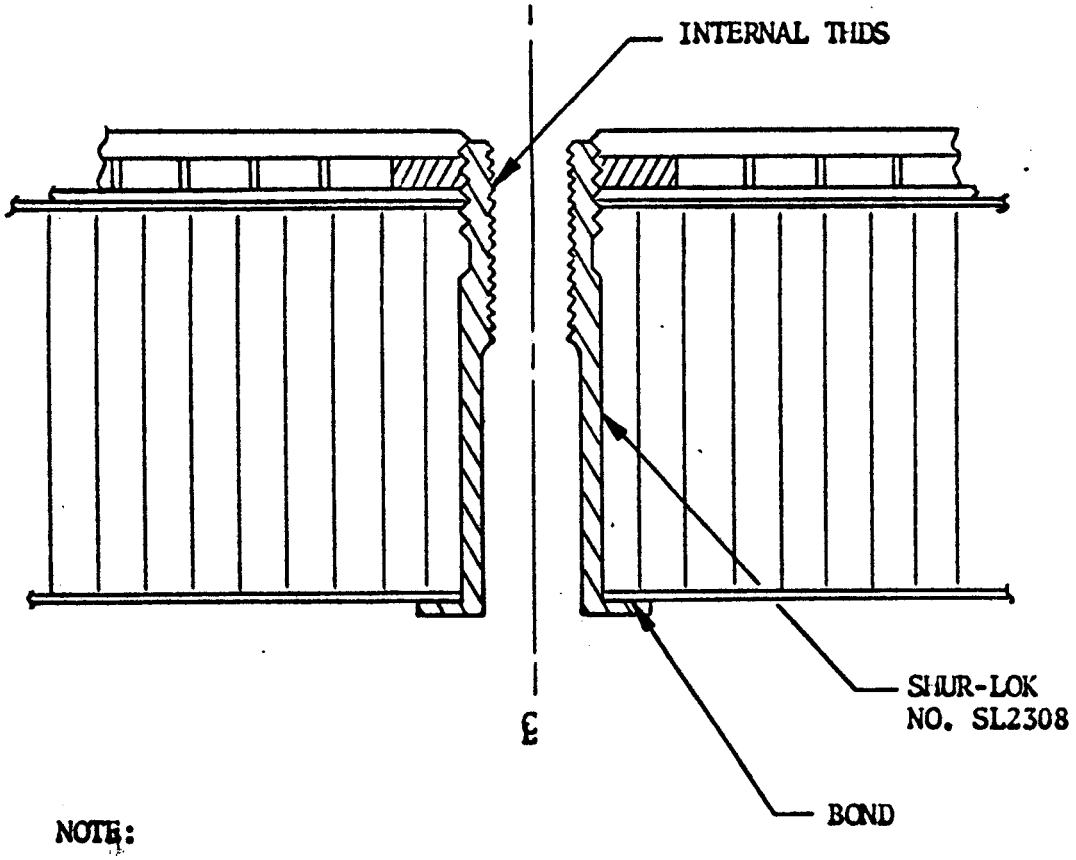


NOTE:

1. CHANGES
   - A. AS INDICATED BY DIM.
   - B. WASHER REMOVED
   - C. ALUMINUM INSERT INVERTED

Figure 5.

TYPICAL SECTION - SHUR-LOK INSERT

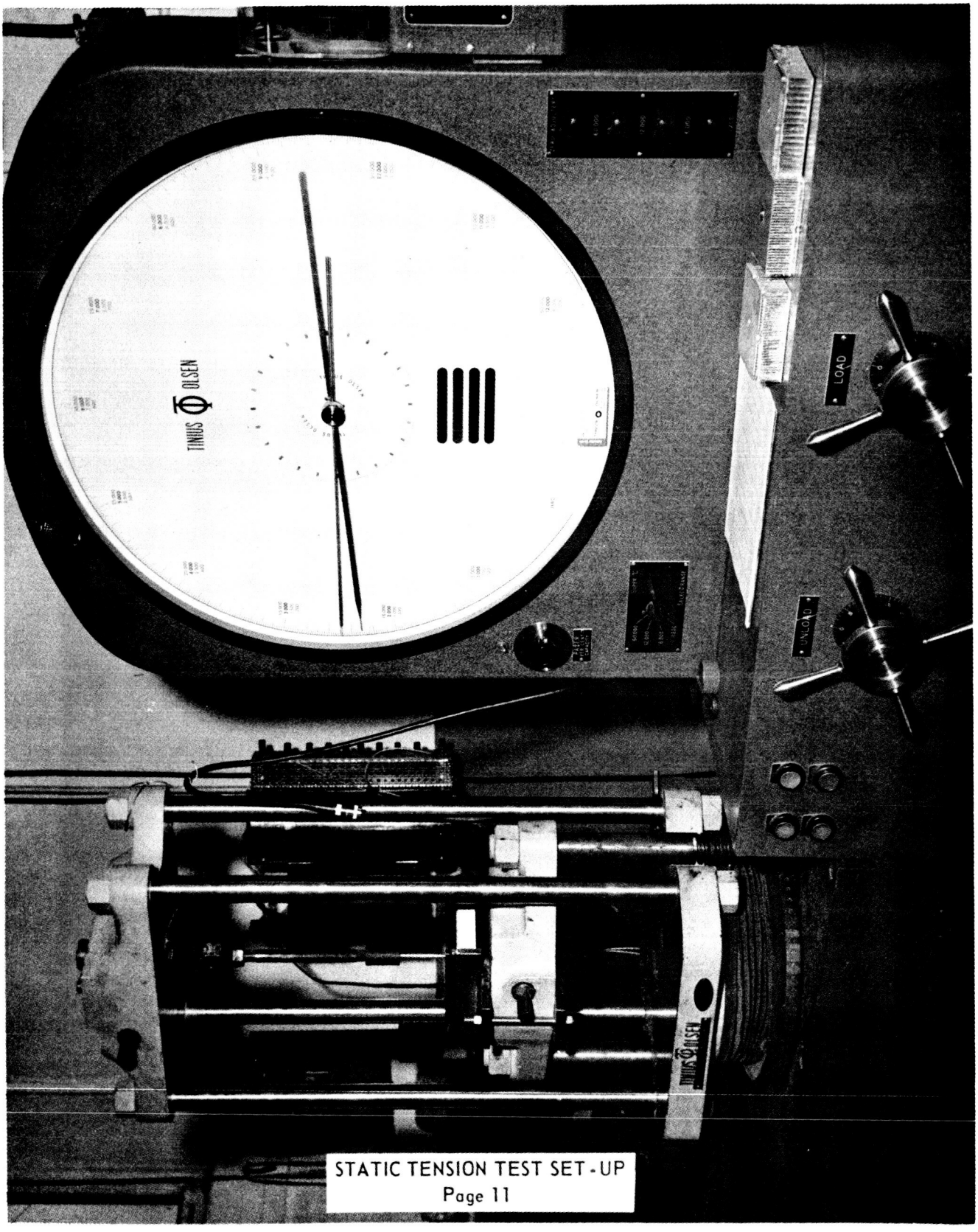


NOTE:

1. ITEMS REPLACED BY SL2308:

   A. ALUMINUM INSERT
   B. ALL POTTING
   C. WASHER
   D. KNL INSERT

Figure 6.



STATIC TENSION TEST SET-UP
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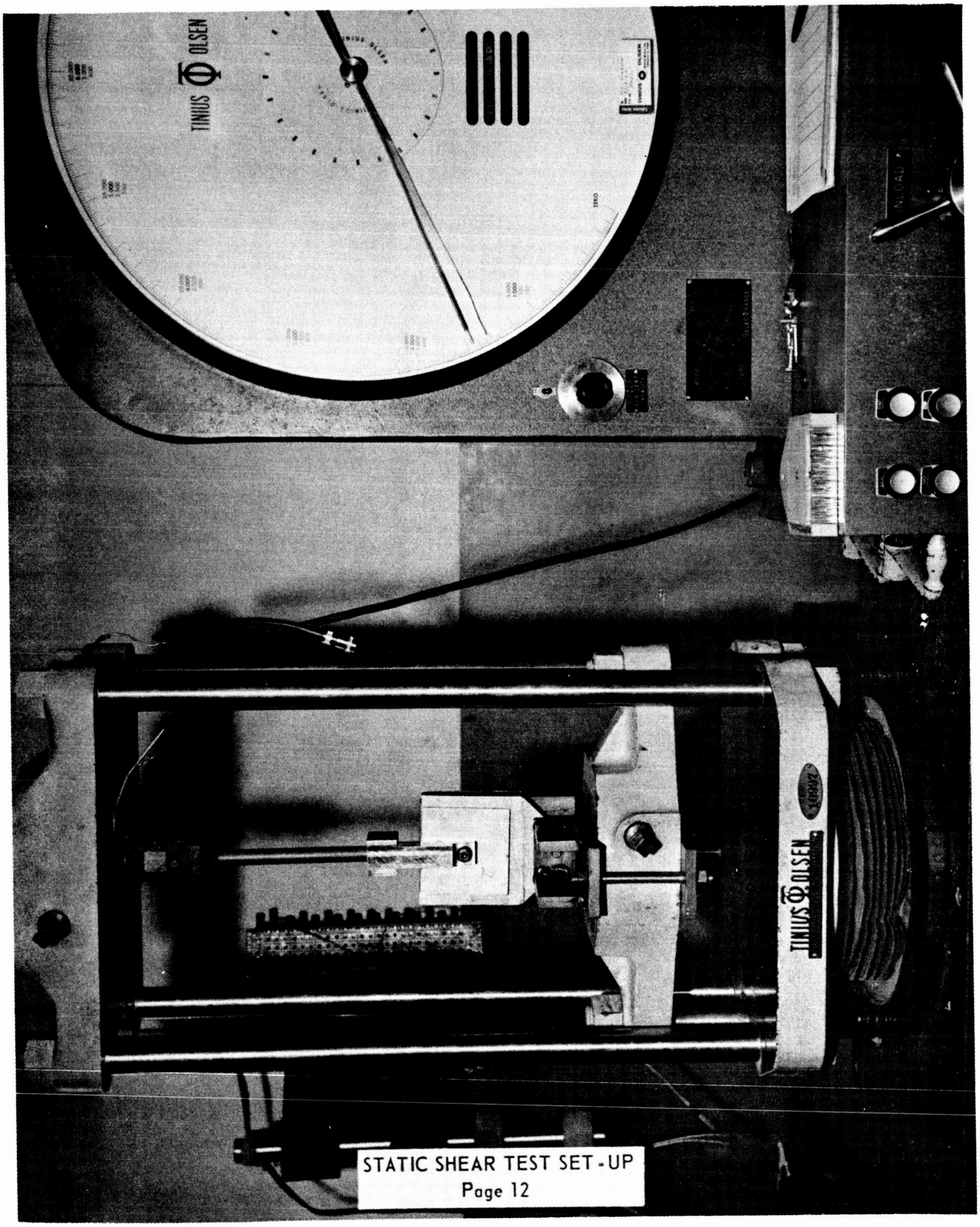


STATIC SHEAR TEST SET-UP

APPENDIX B

STRESS LEVEL CALCULATIONS

FOR PANELS WITH PROPOSED DESIGN CHANGES

STRESS ANALYSIS

Stress levels in face plates based on static test data and dynamic test accelerations. For Static Test data, see page 8.

MATERIAL:

Upper Face - 6061-T4 to T6

F_{tu} = 44,000 psi

F_{ty} = 33,000 psi

Endurance Limit = 12,000 to 15,000 psi

Lower Face - 7075-T6

F_{tu} = 76,000 psi

F_{ty} = 66,000 psi

Endurance Limit = 17,000 psi

Stress Level for Existing Configuration

$$\sigma_{face} = \frac{\sigma_{test}}{p_{test}} \times \text{Box Wt.} \times g \text{ Level}$$

The g level was obtained from preliminary vibration test data involving a broad range of input frequencies. Two g levels were used from these test results, one being a peak output g and the other being an endurance limit g. The endurance limit g was the root-mean-square value of all the g levels.

∴ 30g is the endurance g limit

and 90g is the peak g limit felt for a short period.

For 90g:

$\sigma_{\text{upper face}}$ = 327/394 x 100# x 90 = 7496 psi

For 30g:

$\sigma_{\text{upper face}}$ = 327/394 x 100# x 30 = 2490 psi

For 90g:

$\sigma_{\text{lower face}}$ = -726/394 x 100# x 90 = 16,583 psi

For 30g:

$\sigma_{\text{lower face}}$ = -726/394 x 100# x 30 = 5528 psi

For 30g(tension):

$\sigma_{\text{lower face}}$ = 414/394 x 100# x 30 = 3152 psi

Stress Level for New Configuration

Proposed Changes:

1. Reduce top skin of the brazement from .065 to .030".
2. Reduce bottom skin of the brazement from .025 to .020".
3. Remove top skin of the mounting assembly.

Existing Configuration (See page 5)

I = .02225 in^4/in

C_1 = .2381 in.

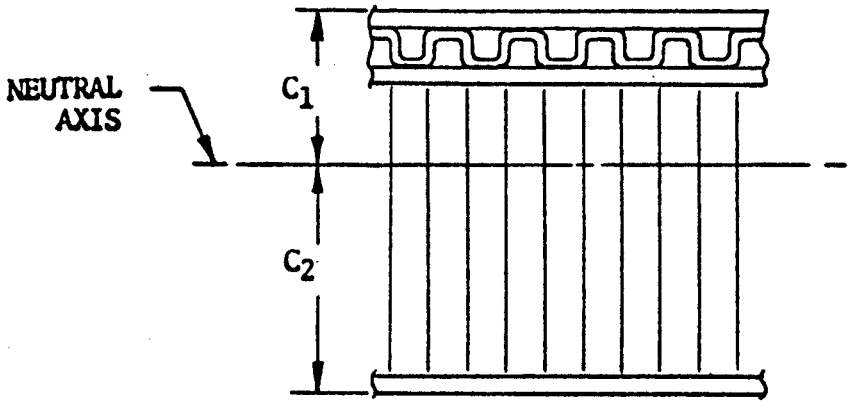
C_2 = .9819 in.

New Configuration (See page 6)

I = .0171 in^4/in

C_1 = .3715 in.

C_2 = .7885 in.



$$\sigma = \sigma_{existing} \times \frac{C_{new}}{C_{existing}} \times \frac{I_{existing}}{I_{new}}$$

$\sigma_{upper} = \sigma_{existing} \times .3715/.2381 \times .02225/.0171 = \sigma_{existing} \times 2.03$

$\sigma_{lower} = \sigma_{existing} \times .7885/.9819 \times .02225/.0171 = \sigma_{existing} \times 1.045$

For 90g:

$\sigma_{upper\ face}$ = 7496 psi x 2.03 = 15,217 psi

M.S. = 44,000/15,217 - 1 = 1.89 M.S.

For 30g:

$\sigma_{upper\ face}$ = 2490 psi x 2.03 = 5055 psi

M.S. = 12,000/5055 - 1 = 1.37 M.S.

For 90g:

$\sigma_{lower\ face}$ = 16,583 psi x 1.045 = 17,329 psi

M.S. = 76,000/17,329 -1 = 3.39 M.S.

For 30g:

$\sigma_{lower\ face}$ = 5528 psi x 1.045 = 5777 psi

M.S. = 17,000/5777 -1 = 1.94 M.S.

For 30g(tension):

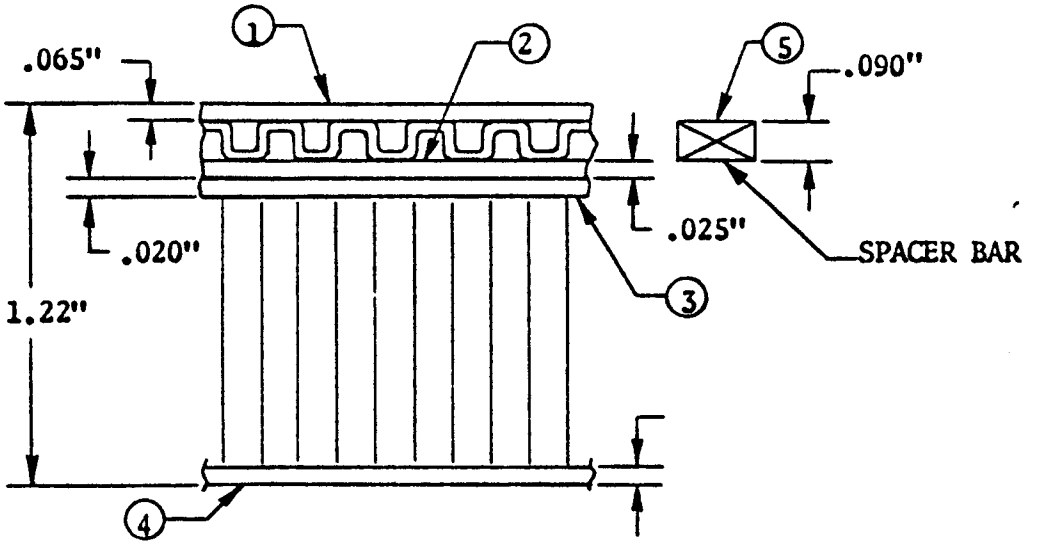
= 3152 psi x 1.045 = 3294 psi

M.S. = 17,000/3294 -1 = Hi M.S.

The above analysis indicates that the proposed changes to the panel design are feasible and will not adversely affect its structural integrity.

Existing Design:

Determination of Neutral Axis & Moment of Inertia



Element	A/in.	Y	M = AY	AY^2
1	.065	1.1875	.07719	.09166
2	.025	1.0525	.02631	.02769
3	.020	1.03	.0206	.02122
4	.020	.01	.0002	.000002
5	.02619	1.11	.02907	.03227

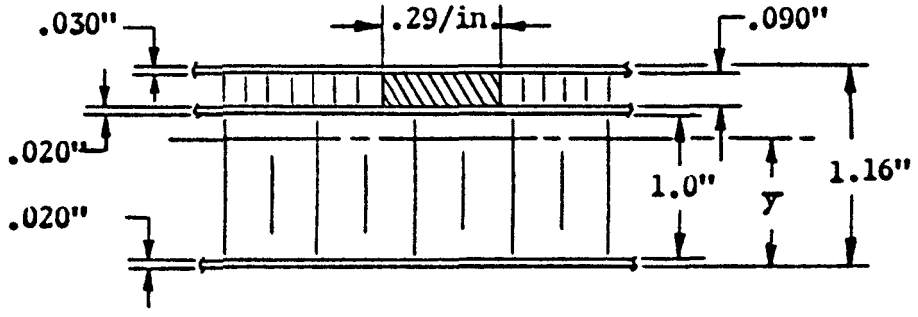
$\sum A$ = .15619 $\sum M$ = .15337 .17284 = $\sum AY^2$

$\bar{Y} = \frac{\sum M}{\sum A} = \frac{.15337}{.15619} = \underline{.9819}$ in. $\quad C = 1.22 - .9819 = \underline{.2381}$ in.

$I = \sum(AY^2) + I_o - \sum A(\bar{Y})^2$ $\quad$ Neglect (I_o) Term

$= .17284 - .15059 = .02225$ in^4/in.

MOMENT OF INERTIA OPTIMIZED DESIGN (Spacer Bar Included)



	A/in	y	Ay	Ay^2
TOP SKIN	.030	1.145	.0344	.0394
INTERMEDIATE SKIN	.020	1.03	.0206	.0212
LOWER SKIN	.020	0.01	.0002	-
SPACER	.0262	1.085	.0284	.0308
$\sum$	.0962	-	.0836	.0914

$I = \sum Ay^2 + I_o - A\bar{y}^2$

$I = .0914 - -- - .0962 \times (.87)^2$

$I = .0914 - .0726$

$\underline{I = .0188 \text{ in}^4/\text{in}}$

$\bar{y} = \sum Ay / \sum A$

$\bar{y} = .0836/.0962$

$\underline{\bar{y} = .87 \text{ inch}}$

$C = 1.16 - .87$

$\underline{C = .29 \text{ inch}}$

MOMENT OF INERTIA OPTIMIZED DESIGN (Spacer Bar Not Included)

	A/in.	y	Ay	Ay^2
TOP SKIN	.030	1.145	.0344	.0394
INTERMEDIATE SKIN	.020	1.03	.0206	.0212
LOWER SKIN	.020	0.01	.0002	.000002
$\sum$	.070	-	.0552	.0606

$I = \sum Ay^2 + I_o - \sum A(\bar{y})^2$

$I = .0606 - .0435$

$\underline{I = .0171 \text{ in}^4/\text{in.}}$

$\bar{y} = \sum M / \sum A$

$\bar{y} = .0552/.070$

$\underline{\bar{y} = .7885 \text{ in.}}$

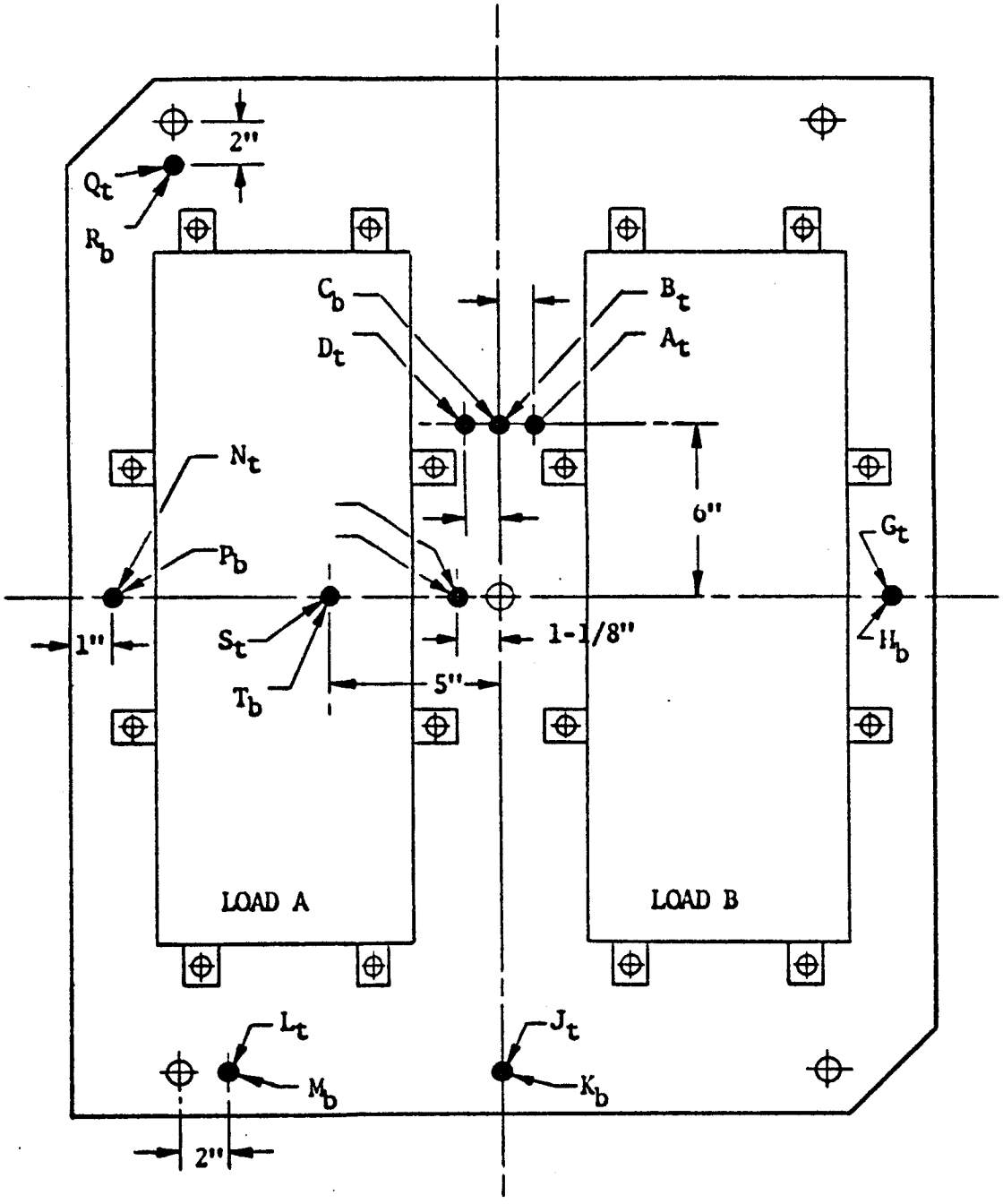
$C = 1.16 - .7885$

$C = .3715 \text{ in.}$

STRESSES BASED ON STATIC TEST

Applied Load = 394 lbs. For load and strain gage location, See Figure 1.

	STRESSES				AXIAL LOAD	
	σ_{max} PSI		max PSI		LBS/IN.	
GAGE	UPPER	LOWER	UPPER	LOWER	UPPER	LOWER
A	45.8	-	1.5	-	2.9	-
B-C	64.0	309	8.7	103	4.0	6.2
D	72.2	-	42	-	4.6	-
E-F	327	-726	73	97	20.6	-14.5
G-H	-144	375	75	167	-9.1	7.5
J-K	64	370	28	156	4.0	7.4
L-M	176	-87	64	77	11.1	-1.7
N-P	-60	349	21	189	-3.8	7.0
Q-R	-251	414	160	261	-15.9	8.3



NOTE: Subscript designates either top or bottom.

STRAIN GAUGE LOCATIONS

APPENDIX C

TEST REPORT - VIBRATION AND SHOCK TEST

OF OPTIMIZED MOUNTING AND THERMAL CONDITIONING PANELS

INLAND
TESTING
LABORATORIES

REPORT

TEST REPORT NO. 551177-B

on

Two (2) Mounting & Thermal Conditioning
Panels, Dwg. No. 20M42088
Mod. 1, Serial No's. 1 & 3

for

Aerospace Structures Div.

TECH-CENTER DIVISION
COOK ELECTRIC COMPANY
6401 Oakton St. Morton Grove, Illinois 60053
1482 Stanley Ave. Dayton, Ohio 45404

COOK ELECTRIC

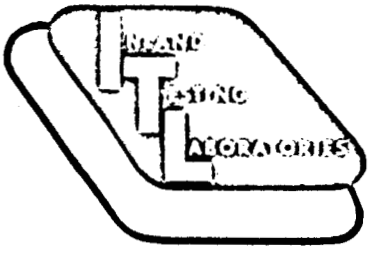
TEST REPORT NO. 551177-B

on

Two (2) Mounting & Thermal Conditioning Panels, Dwg. No. 20M42088 Mod. 1, Serial No's. 1 & 3

for

Aerospace Structures Div.
AVCO CORPORATION



INLAND TESTING LABORATORIES

COOK ELECTRIC COMPANY
TECH-CENTER DIVISION

6401 OAKTON STREET • MORTON GROVE, ILLINOIS
1482 STANLEY AVENUE • DAYTON, OHIO

TEST REPORT

6401 OAKTON STREET • MORTON GROVE, ILLINOIS

Report No. 551177-B

ADMINISTRATIVE DATA

AVCO Corporation
Purchase Order No. 42856
Dated: February 16, 1965

I. NAME & QUANTITY OF ITEMS TESTED:
Two (2) Mounting & Thermal Conditioning Panels, Dwg. No. 20M42088, Mod. 1, S/N's 1 and 3

II. PURPOSE OF TEST:
The purpose of this test was to determine the ability of the panel, when loaded, to withstand Vibration and Shock, applied as described in this report.

III. MANUFACTURER:
AVCO Corporation, Aero Structures Div., Nashville, Tenn.

IV. SPECIFICATION:
AVCO Corp. "Statement of Work"

V. DATE TEST COMPLETED:
May 28, 1965

VI. TEST CONDUCTED BY:
Inland Testing Labs., Tech-Center Division

VII. DISPOSITION OF TEST ITEMS:
Returned to AVCO Corporation

VIII. SIGNATURE:

Report prepared by:

Irving F. Hazard, Chief Engineer

STATE OF ILLINOIS } SS
COUNTY OF COOK }

T. J. Burns, being duly sworn, deposes and says: That the information contained in this report is the result of complete and carefully conducted tests and is to the best of his knowledge true and correct in all respects.

T. J. Burns Mgr.

SUBSCRIBED and sworn to before me this 8th day of June 1965.

My commission expires February 20, 1969

Notary Public in and for the County of Cook, State of Illinois

INLAND TESTING LABORATORIES

TEST REPORT

6401 OAKTON STREET • MORTON GROVE, ILLINOIS

Report No. 551177-B

DESCRIPTION OF TEST:

VIBRATION

Requirements:

Each panel shall be subjected to a Vibration Test in accordance with AVCO Corporation "Statement of Work", Par. 1.

Test Procedure:

Two (2) Mounting and Thermal Conditioning Panels, Drawing No. 20M42088, Mod. 1, Serial No's. 1 and 3, were submitted by the Aerospace Structures Division of AVCO Corporation, for a Vibration Test in accordance with AVCO Corporation "Statement of Work", Par. 1. Each panel was individually subjected to a Vibration Test in the following manner.

The Mounting and Thermal Conditioning Panel was loaded with two (2) 50-pound ballast weights, distributed as shown in Figure I. The panel and load assembly were then attached to the test fixture, which in turn, was attached to the vibration machine. With the exhaust port of the panel capped, 50 psig distilled water pressure was applied for the duration of the test. During each axis of the vibration test, the panel was instrumented with accelerometers, as illustrated in Figure II. The accelerometers were maintained in an atitude such that the sensitive axis of each accelerometer was perpendicular to the surface of the panel throughout all vibration testing. The applied vibration was measured by means of an accelerometer located on the test fixture, adjacent to the unit mounting.

Sinusoidal vibration was then applied over the frequency range of 5 to 2000 to 5 cps, at a scanning rate of one (1) octave per minute along each of the three major axes. The applied vibration was at the following levels:

Frequency Range (cps)	Double Amplitude (inch D.A.)	Acceleration (g's)
5-28	0.075	--
28-155	-----	3
155-240	0.0024	--
240-2000	-----	7

DESCRIPTION OF TEST:

VIBRATION (Cont'd.)

Test Procedure: (Cont'd.)

Throughout the vibration test frequency range, the output from each accelerometer was measured and the frequency and magnitude of each resonant point was noted and recorded.

Next, with the panel still pressurized and with the ballast weights still attached, the panel was subjected to five (5) minutes of random vibration applied consecutively along each of the three principal axes. The power spectral frequency distribution was as follows:

Frequency Range (Cps)	Spectral Density (g^2/Cps)
20-200	9 db. per octave increase
200-700	0.22
700-900	18 db. per octave roll off
900-2000	0.05

Envelope Composite 6.9 g rms

Random equalization and spectrum analysis were performed with 80-channel, 25 cps bandwidth filters. All equalization was within 1 db. of Specification requirements.

Following each axis of vibration, the unit was visually examined for evidence of water leakage or damage.

Description of Test Apparatus:

Vibration Machine, M.B. Mfg. Co., Model C-50E, S/N 127
Random Vibration Console, M.B. Mfg. Co., Model T288, S/N 123644
Pressure Gage, Heise, 0-500 psig, 0.1%, Model H41214, S/N MIN100
Dynamonitor, Endevco, Model 2704, S/N HA42
Accelerometer, Endevco, Model 2213, S/N R-2344
Accelerometer, Endevco, Model 2213, S/N R-6284
Accelerometer, Endevco, Model 2213, S/N 5302
Accelerometer, Endevco, Model 2213, S/N 6613
Accelerometer, Endevco, Model 2213, S/N 2388

DESCRIPTION OF TEST:

VIBRATION (Cont'd.)

Test Results:

After completion of both sinusoidal and random vibration along the "Z" axis, Panel S/N 3 exhibited evidence of leakage at a location approximately one-half inch from an insert, at the upper right hand corner of the plate, 4 inches from the top and 2 inches from the right edge. Leakage appeared only when vibration was applied. Volume of water accumulated was only sufficient to form one drop. Further testing of this unit was discontinued, in accordance with the instructions of the witnessing AVCO representative. A tabulation of the resonant frequencies existing in the "Z" axis appears as follows:

Resonant Frequency (Cps)	Input Acceleration Measured on Panel (g's) Accelerometer Position			
	1*	2	3	4
77	3	6	6	6
110	3	18	13	30
140	3	19	27	50
800	7	11	13	24
1100	7	3	19	3
1250	7	6.5	11	19

* Accelerometer No. 1 was measuring applied acceleration at unit mounting point.

After completion of both sinusoidal and random vibration along the "Z" axis, Panel S/N 1 was examined and a bulging condition was noted around one insert, on the back-side of the unit. The panel skin had pulled slightly away from the insert hole. No evidence of leakage was noted. Under the direction of the witnessing AVCO representative, vibration was continued along the remaining two axes. No further evidence of leakage or physical damage was noted. A tabulation of the resonant frequencies and accelerations existing on the panel appears as follows:

DESCRIPTION OF TEST:

VIBRATION (Cont'd.)

Test Results: (Cont'd.)

S/N 1 Panel:

"Z" Axis

Resonant Frequency (Cps)	Input Acceleration Measured on Panel (g's) Accelerometer Position 1*	2	3	4
90	3	2.5	5	6
135	3	3	12	21
140	3	5	11	27
170	3.8	30	18	65
850	7	3	5	85
1200	7	1.5	60	40

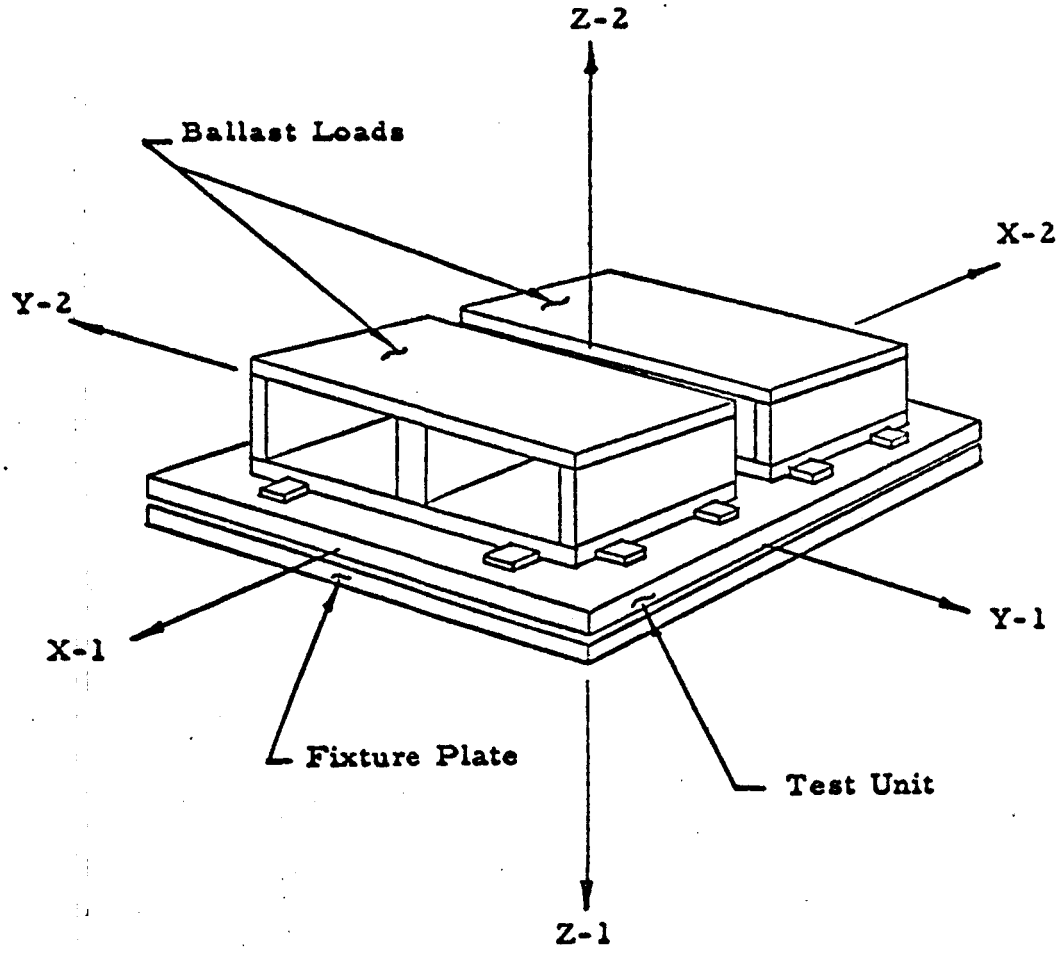
"X" Axis

295	7	15	15	25
490	4	18	50	100
840	7	9	2.5	70
875	7	28	9.5	50
1200	7	15	35	70

"Y" Axis

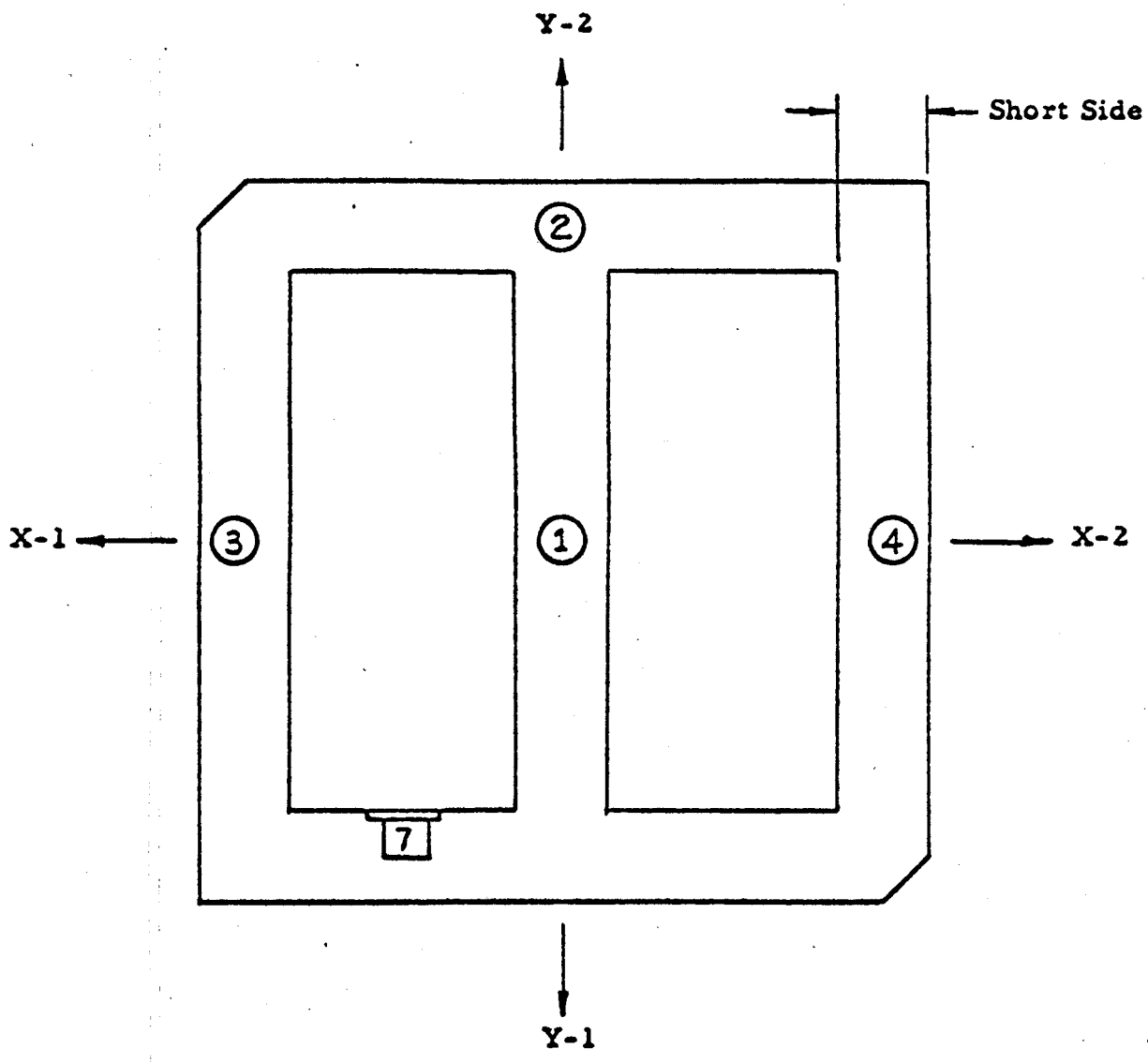
82	3	5	4	5
95	3	17	3	3
300	7	17	87	14
325	7	17	85	35
355	7	14	6.5	23
900	7	55	5	5

*Accelerometer No. 1 was measuring applied acceleration at the unit mounting point.



VIBRATION AND SHOCK
AXES

Figure L



ACCELEROMETER LOCATIONS

Figure II.

DESCRIPTION OF TEST:

SHOCK

Requirements:

Each panel shall be subjected to a Shock Test in accordance with AVCO Corporation, "Statement of Work", Par. 2.

Test Procedure:

Two (2) Mounting and Thermal Conditioning Panels, Drawing No. 20M42088, Mod. 1, Serial No's. 1 and 3, were submitted by the Aerospace Structures Division of AVCO Corporation, for a Shock Test in accordance with AVCO Corporation "Statement of Work", Par. 2. Each panel was individually subjected to a Shock Test in the following manner.

The Mounting and Thermal Conditioning Panel was loaded with two (2) 50-pound ballast weights, distributed as shown in Figure I. The panel and load assembly were then attached to a test fixture, which was in turn, attached to the carriage of a shock test machine. With the exhaust port of the panel capped, 50 psig distilled water pressure was applied for the duration of the test. During each shock, the panel was instrumented with accelerometers as illustrated in Figure II.

The panel was then subjected to a Shock Test consisting of three (3) shocks, in each direction, along each of the three (3) major axes, for a total of 18 shocks. The shock intensity was 20 (±15%) g max., the pulse shape was half-sine wave with a duration of 10 ± 2 milliseconds.

Description of Test Apparatus:

Shock Machine, ITL, Model SI-1027, S/N 123, designed and fabricated to Specification MIL-S-4456.
Pressure Gage, Heise, 0-500 psi, 0.1%, Model H41214, S/N M1N100
DynaMonitor, Endevco, Model 2704, S/N HA42
Accelerometer, Endevco, Model 2213, S/N R-2344
Accelerometer, Endevco, Model 2213, S/N R-6284
Accelerometer, Endevco, Model 2213, S/N 5302
Accelerometer, Endevco, Model 2213, S/N 6613
Oscillograph, CEC, Model 5-119, S/N 15125

DESCRIPTION OF TEST:

SHOCK (Cont'd.)

Test Results:

A visual examination of each panel after completion of the Shock Test revealed no evidence of damage. No loss of water pressure was noted.

A tabulation of the accelerations measured by each accelerometer appears on Pages 9 and 10.

GENERAL DATA SHEET

TEST	SPEC:	PAR:	TEST NO:
Shock	AVCO	2	551177-B

CONDITIONING: Apply 20 g's, 1/2 Sine, 10 ± 2 Ms.

DATE: 5/24/65

MATERIAL: Mounting & Thermal Conditioning Panel S/N 3, Dwg. 20M42088

TEMP: 26°C RH: 51%

MANUFACTURER: AVCO Corporation, Aerospace Structures Div.

M. NO:

INSTRUMENTS:

TESTED BY: Schwab

LAB SUP CHECK: Loveless

ENGRG CHECK: Hazard

Accelerometer Position	Drop No.	Measured Acceleration (g's) Axis						
		X_1	X_2	Y_1	Y_2	Z_1	Z_2	
1	1	12.5	12.5	12.5	10	15	12.5	
2	1	16.5	15	15	15	40*	22.5	
3	1	18	16.5	15	15	40*	20	
4	1	17.5	17.5	17.5	17.5	40*	27.5	
1	2	12.5	12.5	12.5	10	15	12.5	
2	2	15	15	15	15	25	22.5	
3	2	17.5	16.5	15	15	27.5	22.5	
4	2	20	17.5	17.5	17.5	30	27.5	
1	3	12.5	12.5	12.5	10	20	12.5	
2	3	17.5	15	15	15	30	22.5	
3	3	17.5	15	15	15	25	22.5	
4	3	20	17.5	17.5	17.5	27.5	30	

* Measured on 200 g/in. scale. All other measurements were on a 50 g/in. scale.

GENERAL DATA SHEET

TEST	SPEC:	PAR:	TEST NO:
Shock	AVCO	2	551177

CONDITIONING:	DATE:
Apply 20 g's, 1/2 Sine, 10 ± 2 Ms.	5/25/65

MATERIAL:	TEMP:	RH:
Mounting & Thermal Conditioning Panel, S/N 1, Dwg. 20M42088	26°C	49%

MANUFACTURER:	M. NO:
AVCO Corporation, Aerospace Structures Div.	

INSTRUMENTS:	TESTED BY:
	Schwab
	LAB SUP CHECK: Loveless
	ENGRG CHECK: Hazard

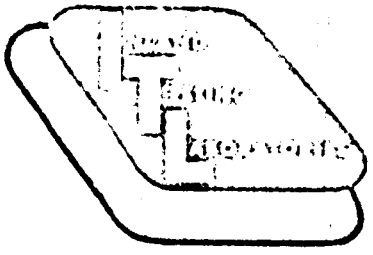
Accelerometer Position	Drop No.	Measured Acceleration (g's) Axis						
		X_1	X_2	Y_1	Y_2	Z_1	Z_2	
1	1	12	10	10	10	12.5	10	
2	1	15	15	15	15	20	30	
3	1	16	15	15	15	25	22.5	
4	1	17.5	15	15	17.5	25	20	
1	2	12.5	10	10	10	12.5	10	
2	2	15	15	15	15	20	30	
3	2	15	15	15	15	25	30	
4	2	17.5	15	15	17.5	27.5	20	
1	3	12.5	10	12.5	10	12.5	10	
2	3	15	15	15	15	20	25	
3	3	15	15	15	15	25	27.5	
4	3	17.5	15	17.5	20	27.5	22.5	

APPENDIX D

TEST REPORT - VIBRATION AND SHOCK TEST

OF FINAL OPTIMIZED DESIGN MOUNTING AND THERMAL CONDITIONING PANEL

TEST REPORT NO. 551218
on
One (1) Mounting & Thermal Conditioning
Panel, Dwg. No. 20M42088
Serial No. 1
for
Aerospace Structures Div.
AVCO CORPORATION



INLAND TESTING LABORATORIES

COOK ELECTRIC COMPANY
TECH-CENTER DIVISION

6401 OAKTON STREET • MORTON GROVE, ILLINOIS
1482 STANLEY AVENUE • DAYTON, OHIO

TEST REPORT

6401 OAKTON STREET • MORTON GROVE, ILLINOIS

Report No. 551218

ADMINISTRATIVE DATA

AVCO Corporation
Purchase Order No. 42856,
Amendment 02
Dated: August 12, 1965

I. NAME & QUANTITY OF ITEMS TESTED:
One (1) Mounting & Thermal Conditioning Panel, Dwg. No. 20M42088, Serial No.

II. PURPOSE OF TEST:
The purpose of this test was to determine the ability of the panel, when loaded, to withstand Vibration and Shock, applied as described in this report.

III. MANUFACTURER:
AVCO Corporation, Aero Structures Div., Nashville, Tenn.

IV. SPECIFICATION:
AVCO Corp. "Statement of Work", (Attachment "A")

V. DATE TEST COMPLETED:
August 25, 1965

VI. TEST CONDUCTED BY:
Inland Testing Labs., Tech-Center Division

VII. DISPOSITION OF TEST ITEMS:
Returned to AVCO Corporation

VIII. SIGNATURE:

Report prepared by: John A. Schaffner

John A. Schaffner,
Project Engineer

STATE OF ILLINOIS } ss
COUNTY OF COOK }

Irving F. Hazard being duly sworn deposes and says: That the information contained in this report is the result of complete and carefully conducted tests and is to the best of his knowledge true and correct in all respects.

Irving F. Hazard Ch. Engr.

SUBSCRIBED and sworn to before me this 15th day of September 19 65

My commission expires February 20th 19 69

Harvey T. Peterson
Notary Public in and for the County of Cook, State of Illinois

INLAND TESTING LABORATORIES

TEST REPORT

6401 OAKTON STREET • MORTON GROVE, ILLINOIS

Report No. 551218

DESCRIPTION OF TEST:

VIBRATION

Requirements:

Each panel shall be subjected to a Vibration Test in accordance with AVCO Corporation "Statement of Work", Par. 1.

Test Procedure:

One (1) Mounting and Thermal Conditioning Panel, Drawing No. 20M42088, Serial No. 1, was submitted by the Aerospace Structures Division of AVCO Corporation, for a Vibration Test in accordance with AVCO Corporation "Statement of Work", Par. 1. The panel was subjected to a Vibration Test in the following manner.

The Mounting and Thermal Conditioning Panel was loaded with two (2) 50-pound ballast weights, distributed as shown in Figure I. The panel and load assembly were then attached to the test fixture, which in turn, was attached to the vibration machine. With the exhaust port of the panel capped, 50 psig distilled water pressure was applied for the duration of the test. During each axis of the vibration test, the panel was instrumented with accelerometers, as illustrated in Figure II. The accelerometers were maintained in an atitude such that the sensitive axis of each accelerometer was perpendicular to the surface of the panel throughout all vibration testing. The applied vibration was measured by means of an accelerometer located on the test fixture, adjacent to the unit mounting.

Sinusoidal vibration was then applied over the frequency range of 5 to 2000 to 5 cps, at a scanning rate of one (1) octave per minute along each of the three major axes. The applied vibration was at the following levels:

Frequency Range (cps)	Double Amplitude (inch D. A.)	Acceleration (g's)
5-28	0.075	--
28-155	-----	3
155-240	0.0024	--
240-2000	-----	7

DESCRIPTION OF TEST:

VIBRATION (Cont'd.)

Test Procedure: (Cont'd.)

Throughout the vibration test frequency range, the output from each accelerometer was measured and the frequency and magnitude of each resonant point was noted and recorded.

Next, with the panel still pressurized and with the ballast weights still attached, the panel was subjected to five (5) minutes of random vibration applied consecutively along each of the three principal axes. The power spectral frequency distribution was as follows:

Frequency Range (Cps)	Spectral Density (g^2/Cps)
20-200	9 db. per octave increase
200-700	0.22
700-900	18 db. per octave roll off
900-2000	0.05

Random equalization and spectrum analysis were performed with 80-channel, 25 cps bandwidth filters. All equalization was within 1 db. of Specification requirements.

Following each axis of vibration, the unit was visually examined for evidence of water leakage or damage.

Description of Test Apparatus:

Vibration Machine, M.B. Mfg. Co., Model C-50E, S/N 127
Random Vibration Console, M.B. Mfg. Co., Model T288, S/N 123644
Pressure Gage, Heise, 0-500 psig, 0.1%, Model H29098, S/N MIN701
Dynamonitor, Endevco, Model 2704, S/N HA42
Accelerometer, Endevco, Model 2213, S/N R-2344
Accelerometer, Endevco, Model 2213, S/N R-6284
Accelerometer, Endevco, Model 2213, S/N 5302
Accelerometer, Endevco, Model 2213, S/N 1605
Accelerometer, Endevco, Model 2213, S/N 1691

DESCRIPTION OF TEST:

VIBRATION (Cont'd.)

Test Results:

Visual examination of the panel after each axis of vibration and after completion of the entire Vibration Test, revealed no evidence of visual damage or evidence of water leakage.

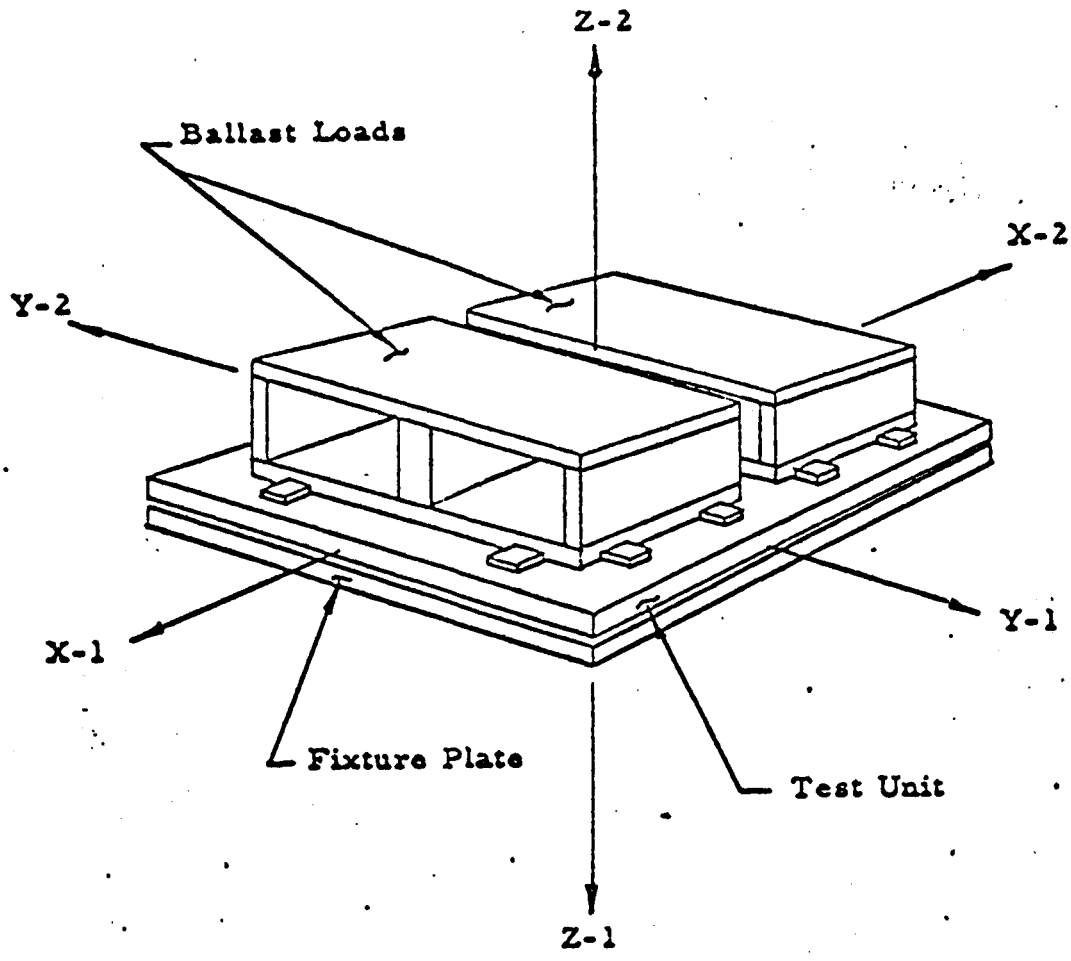
The resonant frequencies and accelerations recorded during the Vibration Test were as follows:

S/N 1 Panel:

"Z" Axis

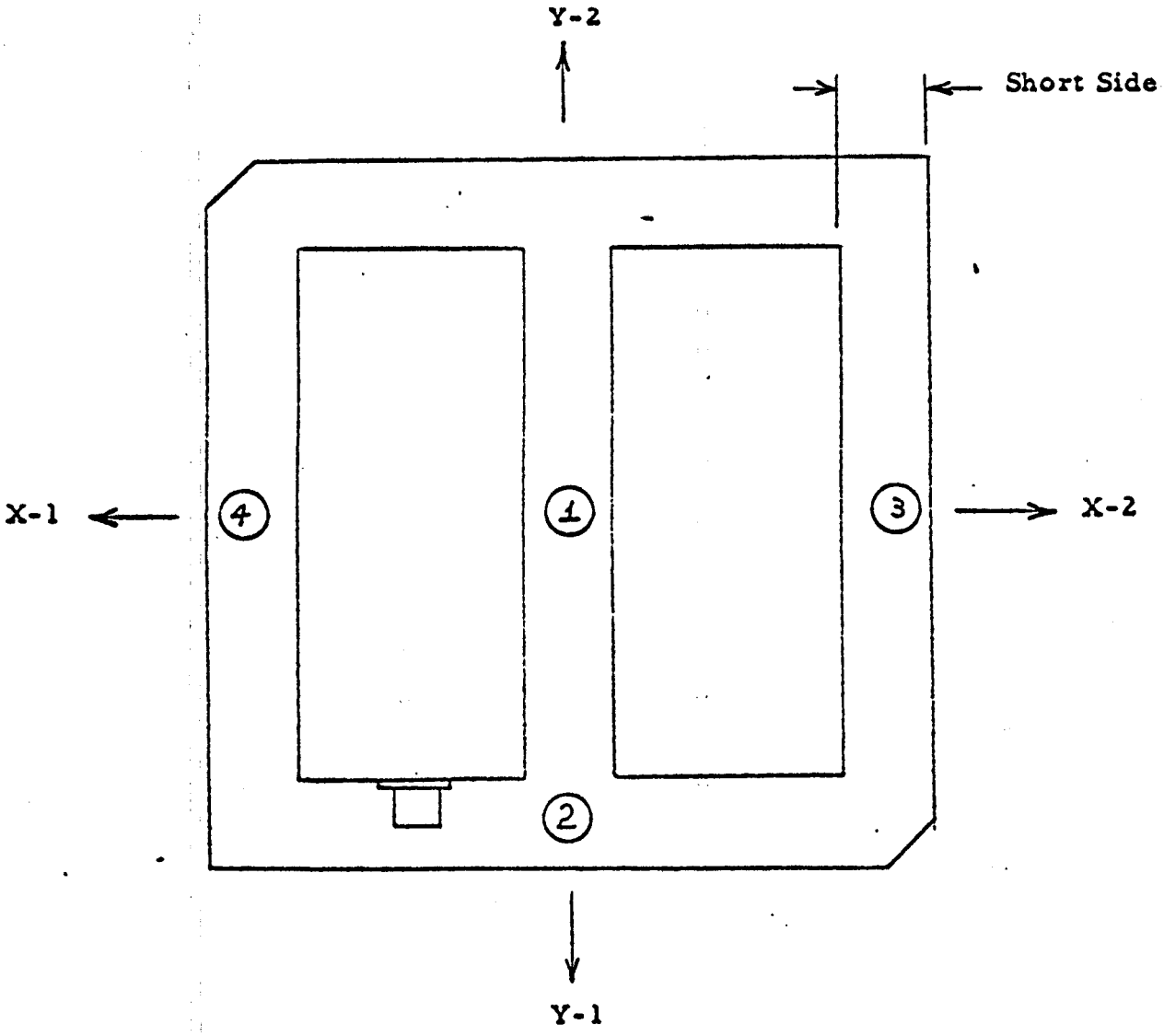
Resonant Frequency (Cps)	Input Acceleration Measured on Panel (g's) Accelerometer Position 1*	2	3	4
110	3	2.5	2.8	5
205	5.5	5.5	8.5	5.2
930	7	11	13	11.5
1025	7	20	25	18
1100	7	18	20	15
1400	7	18	25	16
"X" Axis				
350	7	21	20	26
"Y" Axis				
300	7	29	25	30
500	7	30	28	32
900	7	26	20	27
1200	7	20	22	22
1500	7	21	25	22

*Accelerometer No. 1 was used to measure applied acceleration at the unit mounting point.



VIBRATION AND SHOCK
AXES

Figure 1



ACCELEROMETER LOCATIONS

Figure II.

DESCRIPTION OF TEST:

SHOCK

Requirements:

Each panel shall be subjected to a Shock Test in accordance with AVCO Corporation, "Statement of Work", Par. 2.

Test Procedure:

One (1) Mounting and Thermal Conditioning Panel, Drawing No. 20M42088, Mod. 1, Serial No. 1, was submitted by the Aerospace Structures Division of AVCO Corporation, for a Shock Test in accordance with AVCO Corporation "Statement of Work", Par. 2. The panel was subjected to a Shock Test in the following manner.

The Mounting and Thermal Conditioning Panel was loaded with two (2) 50-pound ballast weights, distributed as shown in Figure I. The panel and load assembly were then attached to a test fixture, which was in turn, attached to the carriage of a shock test machine. With the exhaust port of the panel capped, 50 psig distilled water pressure was applied for the duration of the test. During each shock, the panel was instrumented with accelerometers as illustrated in Figure II.

The panel was then subjected to a Shock Test consisting of three (3) shocks, in each direction, along each of the three (3) major axes, for a total of 18 shocks. The shock intensity was 20 (±15%) g max., the pulse shape was half-sine wave with a duration of 10 ± 2 milliseconds.

Description of Test Apparatus:

Shock Machine, ITL, Model SI-1027, S/N 123, designed and fabricated to Specification MIL-S-4456.
Pressure Gage, Heise, 0-500 psi, 0.1%, Model H29098, S/N MIN701
Dynamonitor, Endevco, Model 2704, S/N HA42
Accelerometer, Endevco, Model 2213, S/N R-2344
Accelerometer, Endevco, Model 2213, S/N R-6284
Accelerometer, Endevco, Model 2213, S/N 5302
Accelerometer, Endevco, Model 2213, S/N 1605
Oscillograph, CEC, Model 5-119, S/N 15125

DESCRIPTION OF TEST:

SHOCK (Cont'd.)

Test Results:

A visual examination of each panel after completion of the Shock Test revealed no evidence of damage. No loss of water pressure was noted.

A tabulation of the accelerations measured by each accelerometer appears on Page 8.

GENERAL DATA SHEET

TEST	SPEC:	PAR:	TEST NO:
Shock	AVCO	2	551218

CONDITIONING: Apply 20 g's, 1/2 Sine, 10 ± 2 Ms.

DATE: 8/23/65

MATERIAL: Mounting & Thermal Conditioning Panel, S/N 1, Dwg. 20M42088

TEMP: 26°C RH: 49%

MANUFACTURER: AVCO Corporation, Aerospace Structures Div.

M. NO:

INSTRUMENTS:

TESTED BY: F. Hall

LAB SUP CHECK: Loveless

ENGRG CHECK: JAS

Accelero-meter Position	Drop No.	Measured Acceleration (g's) Axis					
		X_1	X_2	Y_1	Y_2	Z_1	Z_2
1	1	23.7	20	23.3	22	22	22
2	1	17	24	23.3	20.7	22.3	24
3	1	23	20.7	22.3	17.7	22.3	19
4	1	21.4	14.7	22.3	14.3	15	16.7
1	2	23.4	21.3	21.7	20	20	23.4
2	2	18.3	24.6	22	18	20	18.7
3	2	21.7	21.0	21.3	18	25	18.7
4	2	19.4	14.7	18.4	12	15.7	15.3
1	3	21.6	21	22	20	21.6	21.7
2	3	20	22	22	18.7	17.3	23.4
3	3	20.7	20	23.3	18.7	26	18.3
4	3	21.4	14.7	22	17.7	36.6	18

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