Aerospace Systems Division

LUNAR SEISMIC PROFILING EXPERIMENT HOUSING AND CHARGE ASSEMBLY FOAM TEST REPORT

ATM-1094

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DATE

This ATM presents the test results and recommendations as to the type of foam to be used in the LSPE Housing and Charge Assembly.

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1.0 INTRODUCTION

1.1 PURPOSE

The purpose of this ATM is to evaluate foam materials for use in the Housing and Charge Assemblies (Drawing Numbers 2348558 and 2348559) on the LSPE Experiment Explosive Package.

1.2 BACKGROUND

During prototype model thermal cycling tests at NOL/NWL, one 1/8 lb charge moved slightly (tilted 3 to 5 degrees) within the housing. Examination of X-rays showed that foam had collapsed slightly along one side of the charge allowing the charge to drop slightly. NOL estimated that the tilting of the high explosive charge was not detrimental to the detonation of the explosive package.

Bendix also noted partial similar collapse of foamed material during oven bond cure operations on two of the 16 Bendix in-house prototype Housing and Charge Assemblies.

Thus, as a result of these anomalies and discussions with MSC, Bendix undertook this investigation to determine the availability of a more stable foam material over temperature requirements.

1.3 FOAM REQUIREMENTS

The foam used in H&CA must comply with the following requirements:

1. Must be stable in vacuum.
2. Must be stable over a temperature range of -100°F to +250°F.
3. Must not peel, flake, crack over temperature range and dynamic environments. (Loose material could bind up safe/arm slide.)
4. Must be available in form with density about 2 pounds per cubic foot to minimize Explosive Package weight.

2.0 FOAM MATERIAL TESTED

Tests were conducted on three foam materials; Eccofoam FP, Eccofoam FPH, and Eccofoam SH. Eccofoam FP was used on the 32 prototype H&CA's and was the material on which the anomaly was noted during NOL/NWL testing. The properties of these foam materials are given below.

Eccofoam FP is a polyurethane foam formulated specially for foam-in-place applications. The foam expands and cures to a semi-rigid thermal setting unicellular foam in density range of 2 to 14 pounds per cubic foot. The density variations are obtained by varying the quantities of resin and the type of catalyst used. The continuous service temperature for FP is 225°F with specification of short time maximum of 275°F. Foamed and cured FP material is somewhat pliable and has a resilience similar to hard foam rubbers.

Eccofoam FPH is similar to FP except it forms a very rigid structure and is not pliable. It is rated to continuous service at 275°F and short time maximums of 325°F.

Eccofoam SH is only available from the supplier in rigid sheet form and is not a foam in place material. Foam is very rigid and not pliable like FP foam. The continuous service temperature for SH is 275°F with short time capability of 325°F.

4.0 TEST SAMPLES AND FOAMING PROCESS

The FP and FPH test samples were made in residual or scrap H&CA fiberglass housings using the same molds, manufacturing processes, and manufacturing personnel that were employed to build prototype, Qual, and Flight H&CA's.

The foaming procedure provided in the manufacturer's literature called for curing the foam for one hour at 150°F and allowing foam to cool to ambient. First attempts with FPH were discouraging in that the foam dished on cooling, was discolored, and did not appear to have as good a stability as FP foam. Further contacts with manufacturer indicated that in order to obtain the best high and low temperature stability characteristics, a more elaborate preparation and cure cycle was required than indicated in their standard literature. The cycle consists of:

1. Heating the liquid catalyst to 225°F and stirring until clear to drive off any dissolved gasses.

2. Cool catalyst to ambient.

3. Foam material in mold at 150°F for one hour.

4. Allow foam and mold to cool to ambient.

5. Remain at ambient for 12 hours.

6. Heat to 200°F for 2 hours.

7. Heat to 250°F for 2 hours.

8. Heat to 300°F for 2 hours.

9. Cool to ambient and remove mold.

FPH material foamed by the above technique produced a uniformly pink colored rigid foam which showed no noticeable dishing upon removal from the mold.

The Eccofoam SH sample was made by bonding the sheet foam material into a housing. A hole sized for a 1/4 pound charge was then machined in the solid foam material. Figures 1 through 3 show photographs of the foam samples used in these tests.

5.0 TEST MEASUREMENTS

The samples were marked in two grid patterns as shown in Figures 4 and 5. The pattern used in tests 1 through 5 consisted of 12 points on the top surface of the foam and 9 points in the hole sized for 1/4 pound charge (Figure 4). The 9 points in the hole included one point in the center of the bottom and 4 points at 90° intervals one-third the way up the wall of the hole and another 4 points at two-thirds the way up the wall of the hole. The H&CA used in tests 6 and 7 was the same as those used in previous tests except that inert charges were placed in the hole in the foam and four grid points (13, 14, 15, and 16) where added on the top of the inert charge (see Figure 5).

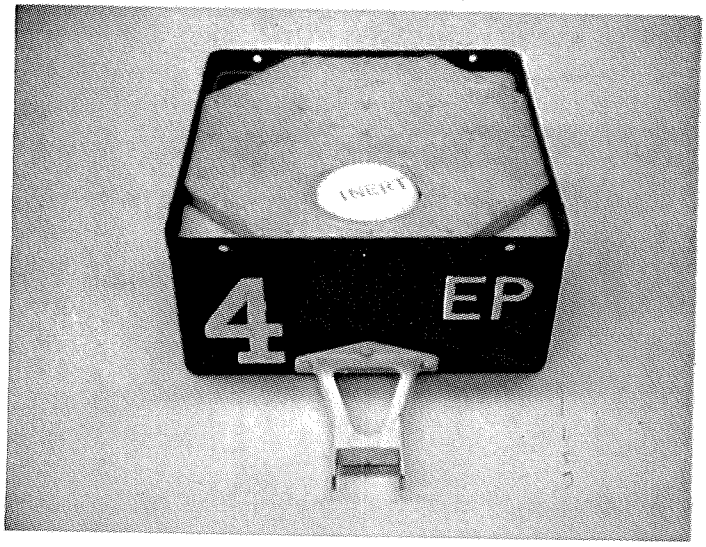

Figure 1. H&CA Typical of FP Foam Sample Used in Test

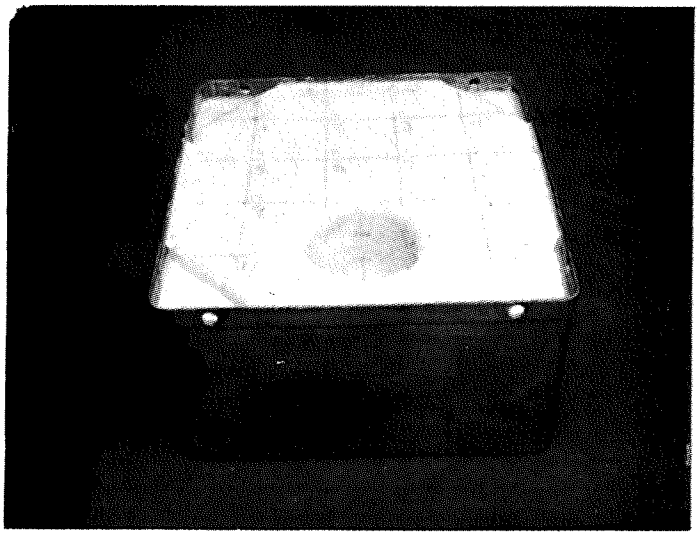

Figure 2. Eccofoam FPH Sample Used in Test

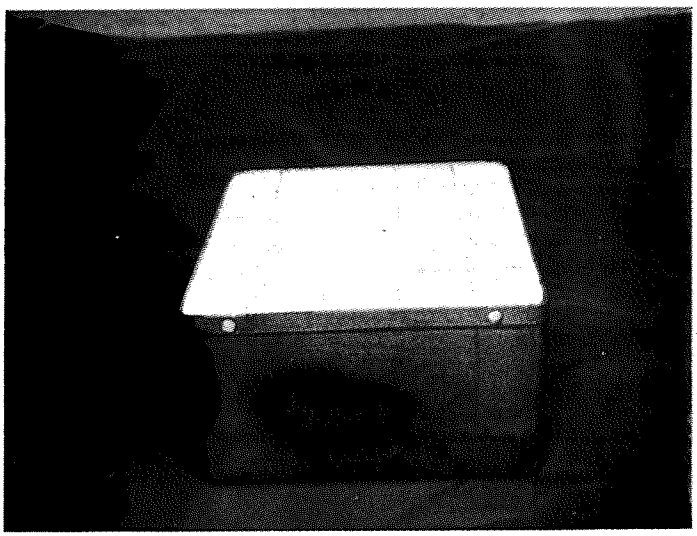

Figure 3. Eccofoam SH Sample Used in Test

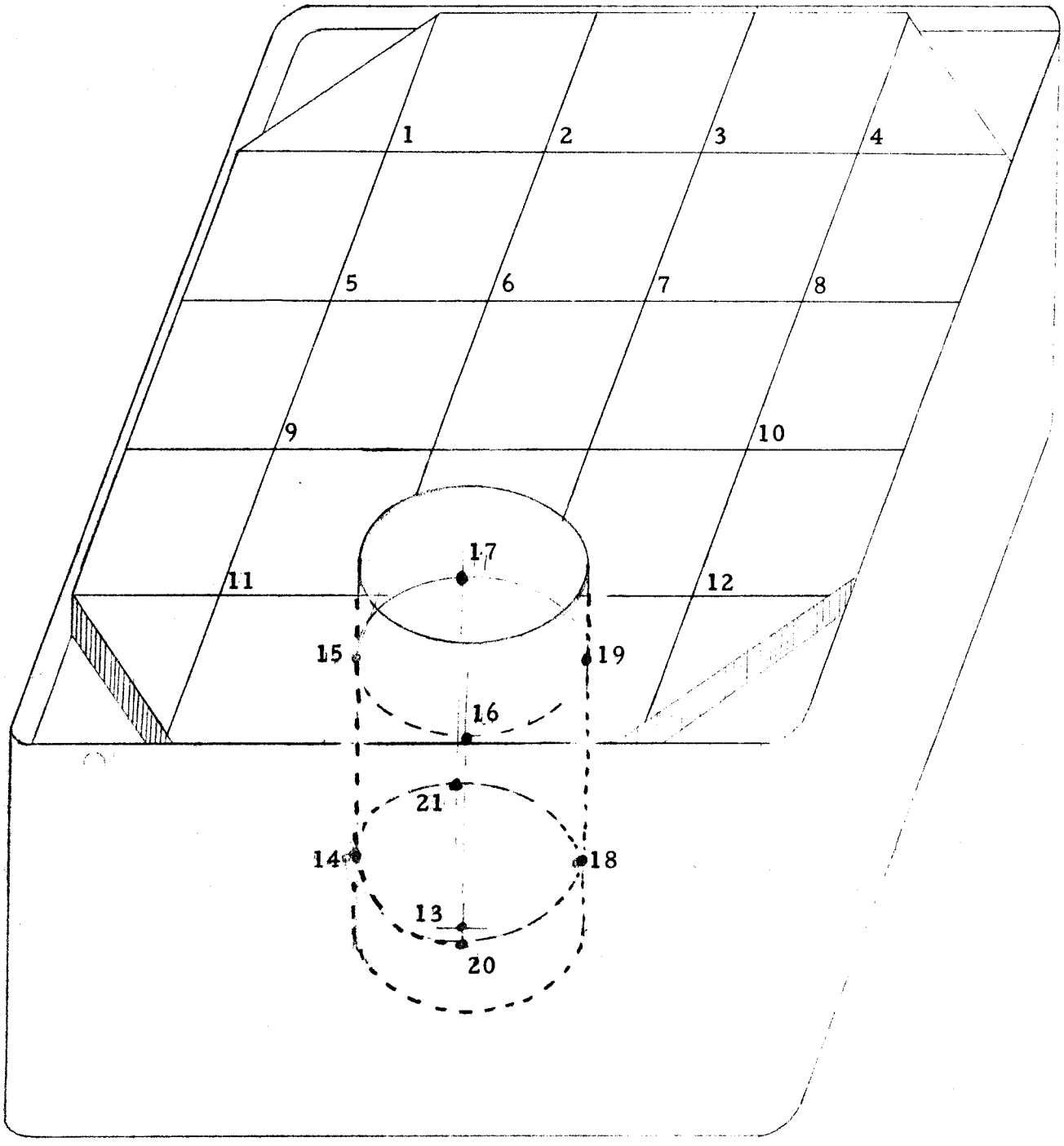

Figure 4. Configuration for Test Samples 1 to 5

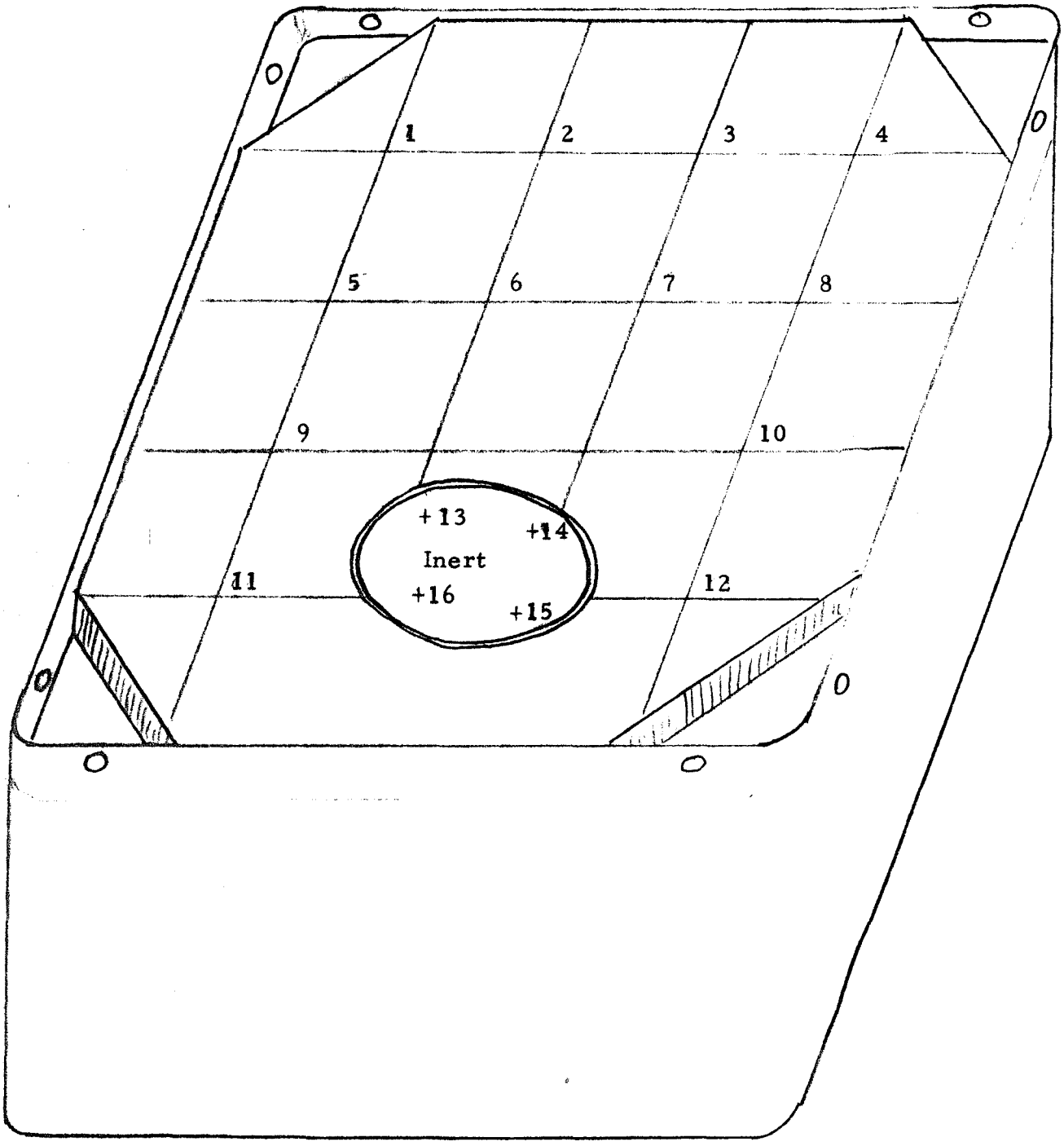

Figure 5 - Configuration for Test Samples 6 and 7

At each temperature the height of each of the 12 grid points on top of package were measured relative to a height block with a plunger type dial indicator height gage. The grid points on the hole were measured relative to a fixed block with a ball type indicator gage. An estimate of reading error is ±.005 while measurement accuracy is estimated to be ±.010 for top surface points and ±.020 for points on the side of hole. The reading error accounts for uncertainty of knowing exactly when the top surface is contacted with the soft material while such factors as warping of fiberglass H&CA cases with temperature enter into accuracy estimate.

6.0 TEST RESULTS

Foam evaluation tests were performed under the conditions shown in Table 1.

The results of the two Eccofoam FP tests substantiated the observations at NOL/NWL during temperature cycling and at BxA during oven bond cure operations. That is, at temperatures of 210°F and 250°F the FP foam became very soft having a consistency similar to a soft foam rubber. As shown in Table 2, the foam expanded at elevated temperatures and then collapsed slightly (~.020) on return to ambient.

The first FPH tests (Table 3) showed that the foam was dished and collapsed at both high and low temperatures. The foam manufacturer attributed this collapse to excess gasses dissolved in catalyst. The foam procedure was changed to heat the catalyst prior to use to drive off dissolved gasses. Subsequent FPH samples (Tables 4, 6, and 7) were very rigid and showed little or no dishing. The change in dimensions was acceptable, particularly test samples 6 and 7 where changes were typically less than .020 inch. The samples were rigid at both high and low temperatures. Samples 6 and 7 are also better in that measurements 13-16 are representative of the movement of the change, while it is difficult to relate the differences in the earlier tables to change movement. These tests indicate that the stability of FPH over temperature is superior to FP foam.

One test was performed with Eccofoam SH material. The test results (Table 5) showed that the SH material had about the same dimensional stability as FPH. The eccofoam SH had one bad feature in that its surfaces tended to crumble and flake. This flaking is undesirable in that the small pieces could get into the E&SA and hang-up moving parts such as timers, slides, switches, etc.

7.0 CONCLUSIONS

Based on the above data Bendix changed the foam material in H&CA's from Eccofoam FP to Eccofoam FPH. Based on data obtained from NOL the magnitude of the shift in foam and charge position does not adversely affect the explosive train. Under worst case lunar detonation conditions (baseplate and small charge temperatures of about +185°F) the change would be moved slightly towards the baseplate, thus reducing the separation between charge and lead and increasing detonation efficiency.

Table 1. Foam Test Conditions

Material	Foam Cure Conditions	Test Cycle	Test Date	Summary of Test Results
1. Eccofoam FP	1 hour at 150°F	Ambient 150°F - 2 hrs* 180°F - 1 hr 210°F - 1 hr Ambient	9/22/71	Foam discolored and slight dishing of foam occurred. Foam was soft when hot.
2. Eccofoam FP	1 hour at 150°F	Ambient -100°F - 1 hr +250°F - 1 hr	9/30/71	Same as 1.
3. Eccofoam FPH	1 hour at 150°F	Ambient -100°F - 1 hr +180°F - 1 hr +210°F - 1 hr +250°F - 1 hr	9/30/71	Dishing later attributed to lack of proper catalyst preparation by foam manufacturer. Slight discoloration of foam.
4. Eccofoam FPH	Special catalysts preparation 12 hrs at ambient 200°F - 2 hrs 250°F - 2 hrs 300°F - 2 hrs	Same as 3.	11/8 & 11/9/71	Very slight dishing, foam rigid at high temperature.
5. Eccofoam SH	None required.	Same as 3.	11/8 & 9/71 11/9/71	No dishing, foam rigid at high temperatures, material surface flaked badly.
6. Eccofoam FPH	Same as 4.	Ambient +180°F - 1 hr +210°F - 1 hr +250°F - 1 hr	5/22/72	No dishing, foam rigid at high temperature, dimensionally more stable than FPH and similar to SH.
7. Eccofoam FPH	Same as 4.	Same as 6.	5/22/72	Same as 6.

*F change was approximately three degrees per minute, time listed indicates soak period prior to taking measurement

TABLE 2. Test No. 1 - Eccofoam FP

Test Date: 9/22/71
Estimated Accuracy Points 1-12 - ±0.10
Estimated Accuracy Points 13-21 - ±.015
Estimated Measurement Error Points 1-21 - ±.005

Points 1 to 13, + direction is upward.
Points 14 to 21, + direction is toward the center of the hole.

Test Point	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Ambient																					
150°F	+ .010	+ .015	+ .014	+ .010	+ .011	+ .020	+ .019	+ .014	+ .009	+ .014	+ .003	+ .010	+ .014	0	+ .010	+ .005	+ .025	+ .010	+ .015	+ .015	0
180°F	+ .008	+ .019	+ .018	+ .009	+ .014	+ .030	+ .029	+ .020	+ .014	+ .017	+ .005	+ .011	+ .025	0	+ .010	+ .025	+ 0	+ .015	+ .010	+ .010	+ .010
210°F	- .005	+ .008	+ .013	+ .004	+ .013	+ .030	+ .026	+ .016	+ .021	+ .020	+ .013	+ .010	+ .018	- .050	- .015	0	0	+ .015	+ .015	- .010	+ .010
Ambient	- .033	- .025	- .022	- .026	- .024	- .026	- .025	- .022	- .015	- .017	- .018	- .015	+ .003	- .025	- .015	+ .005	+ .005	- .020	0	- .010	+ .020

TABLE 3 - TEST NO. 3 Eccofoam FPH

Test Date: 9/30/71

Catalyst not properly prepared.

Test Point	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Ambient																					
-100°F	- .022	- .036	- .031	- .023	+ .004	- .016	- .024	- .042	- .042	- .059	- .023	- .018	+ .005	0	0	0	0	0	0	+ .015	+ .015
+180°F	- .033	- .027	- .037	- .025	- .036	- .023	- .031	- .006	- .019	- .009	+ .015	- .016	- .025	+ .025	+ .025	0	+ .025	+ .015	+ .015	0	0
+210°F	- .053	- .057	- .057	- .040	- .046	- .070	- .048	- .041	- .010	- .019	- .001	- .020	- .021	- 0	- 0	+ .025	- .025	+ .040	+ .015	0	0
+250°F	- .093	- .087	- .087	- .070	- .091	- .086	- .073	- .071	- .050	- .049	- .016	- .050	- .021	0	0	0	0	+ .015	+ .015	0	0
Ambient	- .083	- .098	- .080	- .079	- .106	- .120	- .108	- .089	- .066	- .071	- .046	- .065	- .036	0	0	+ .025	0	- .010	- .010	0	0

TABLE 4 - TEST NO. 4 Eccofoam FPH

Test Date: 10/8/71 and 11/9/71

Test Point	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Ambient																					
-100°F	- .017	- .023	- .024	- .020	- .021	- .025	- .024	- .019	- .018	- .016	- .016	- .014	+ .002	+ .025	+ .025	0	- .015	- .010	0	0	0
180°F	- .015	+ .016	+ .018	+ .017	+ .019	+ .021	+ .022	+ .018	+ .020	+ .018	+ .018	+ .018	+ .010	+ 0	+ 0	- .005	+ .010	0	0	0	- .015
210°F	+ .022	+ .023	+ .025	+ .029	+ .024	+ .024	+ .026	+ .024	+ .026	+ .025	+ .029	+ .031	+ .006	0	+ .010	+ .025	+ .010	0	0	0	0
250°F	+ .047	+ .039	+ .044	+ .054	+ .050	+ .044	+ .044	+ .048	+ .064	+ .054	+ .072	+ .072	+ .028	+ .025	+ ,050	+ .040	+ .035	0	0	+ .025	+ .025
Ambient	+ .024	+ .014	+ .020	+ .036	+ .024	+ .013	+ .014	+ .025	+ .036	+ .034	+ .050	+ .056	+ .016	+ .025	+ .040	+ .005	+ .010	0	0	0	0

TABLE 5 - TEST NO. 5 - Eccofoam SH

Test Date: 11/8/71 and 11/9/71

Test Point	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Ambient																					
-100°F	- .012	- .007	- .014	- .013	- .013	- .013	- .011	- .016	- .012	- .015	- .009	- .017	- .003	- .025	- .015	0	0	- .015	- .015	0	0
+180°F	- .007	- .010	- .013	- .009	- .008	- .003	- .007	- .006	- .003	- .002	- .006	- .002	- .002	0	0	0	0	0	0	0	0
+210°F	+ .006	+ .006	+ .006	+ .006	0	- .001	0	- .004	0	- .010	+ .003	- .008	- .002	0	0	0	0	0	0	0	0
+250°F	+ .004	+ .001	- .006	- .007	- .010	- .014	- .026	- .043	- .009	- .054	- .003	- .040	- .020	+ .025	+ .025	0	0	- .050	- .025	+ .025	0
Ambient	+ .003	- .020	- .023	- .026	- .023	- .031	- .046	- .062	- .024	- .071	- .013	- .052	- .024	+ .025	+ .025	0	0	- .050	- .045	0	0

TABLE 6 - TEST NO. 6 - Eccofoam FPH

Test Date: 5/22/72
Measurement Error - .005
Accuracy - .010

													Top of Inert Charge			
Test Point	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Ambient	2.370	2.370	2.365	2.379	2.368	2.365	2.364	2.372	2.367	2.370	2.357	2.361	2.359	2.357	2.358	2.357
+180°	+.001	+.006	+.004	+.001	+.003	+.006	+.007	+.004	+.003	+.003	+.002	.000	+.007	+.019	+.008	+.008
+210°	+.004	+.009	+.007	+.003	+.006	+.009	+.010	+.006	+.004	+.003	+.003	.000	+.010	+.012	+.011	+.011
+250°	+.014	+.022	+.014	+.014	+.014	+.021	+.022	+.021	+.009	+.015	+.010	+.011	+.024	+.026	+.021	+.020
Ambient	-.005	.000	.000	.000	-.001	+.002	+.002	+.003	-.001	+.001	-.003	-.003	-.001	+.001	-.003	-.003

Test Date: 5/22/72

TABLE 7 - TEST NO. 7 - Eccofoam FPH

Test Points	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Ambient	2.903	2.914	2.917	2.906	2.906	2.911	2.916	2.912	2.905	2.907	2.886	2.913	2.904	2.905	2.902	2.903
+180°	+.007	+.003	+.002	+.005	+.010	.000	+.001	+.006	+.003	+.006	+.007	+.004	+.010	+.010	+.008	+.009
+210°	+.007	+.006	+.008	+.008	+.009	+.005	+.005	+.004	+.004	+.005	+.009	+.005	+.012	+.013	+.010	+.010
+250°	+.010	+.009	+.009	+.011	+.006	+.012	+.013	+.011	+.008	+.006	+.010	+.007	+.019	+.019	+.013	+.012
Ambient	-.010	-.004	-.009	+.002	-.003	-.006	-.007	+.001	-.008	+.001	-.010	-.013	+.014	+.013	+.009	+.009