

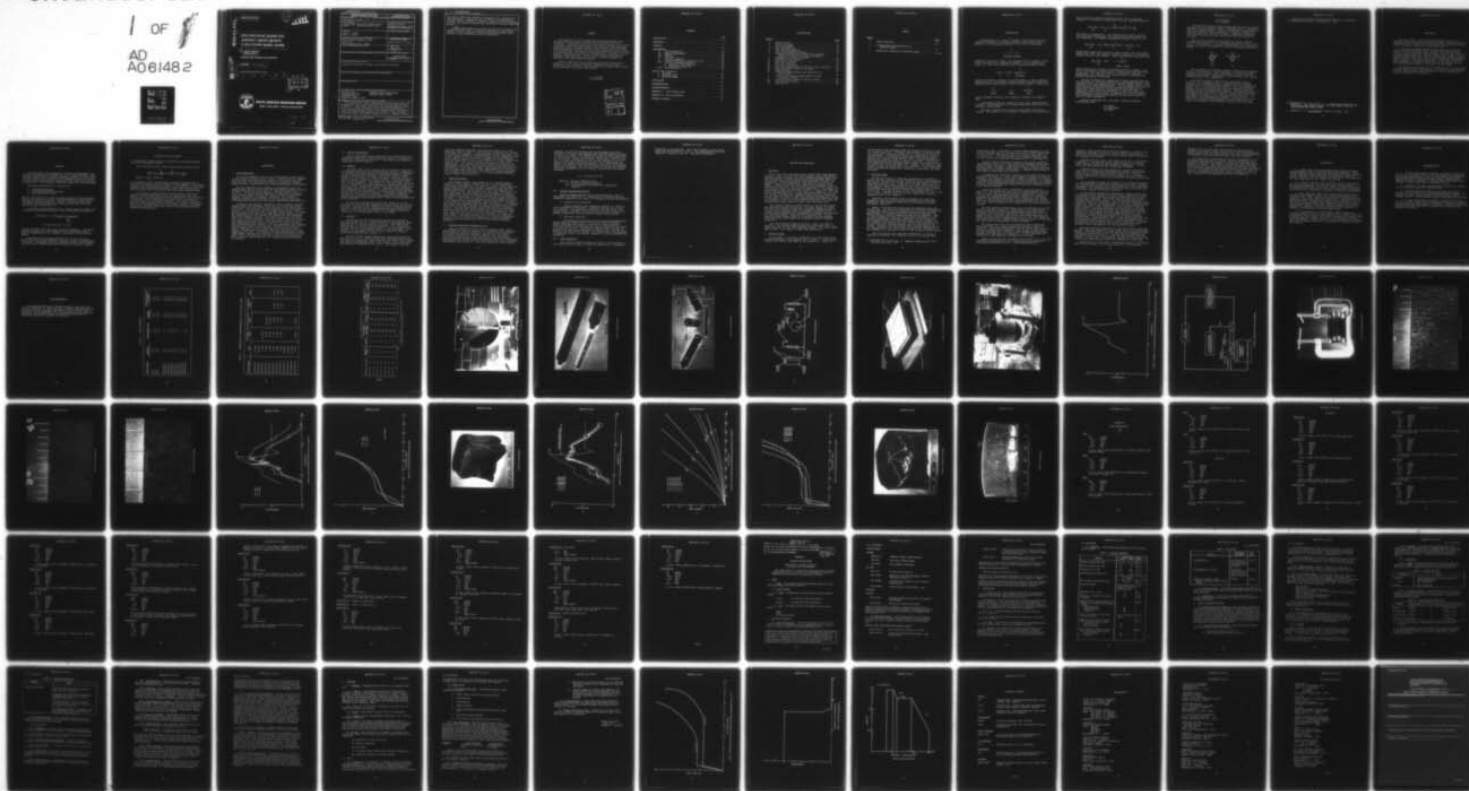
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POLYURETHANE FOAMS FOR  
AIRCRAFT SHOCK MOUNTS.  
I. POLYETHER BASED FOAMS.

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BY HUBERT J. BOOTH  
JAMES V. DUFFY

RESEARCH AND TECHNOLOGY DEPARTMENT

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tert-amine ratios were studied to determine their influence on foam properties. Properties such as density, compressibility, rebound, tensile strength, elongation, hydraulic fluid resistance, porosity and vibration damping were obtained on the most promising systems.

Several foams based on the above polyols were optimized with respect to polyol ratio, surfactant concentration and catalyst composition, and sufficient foam was prepared to enable these systems to be evaluated on aircraft shock mounts.

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## SUMMARY

The objective of this program was to develop flexible foam systems which would meet the specifications outlined in MIL-F-81334B(AS). This report deals with the results obtained from a series of one-shot polyether foams derived from mixtures of poly(oxytetramethylene) glycol, poly(oxypropylene) and ethylene oxide terminated poly(oxypropylene) polyols. Polyol ratios, surfactant type, surfactant concentration and stannous octoate/tert-amine ratios were studied to determine their influence on foam properties. Properties such as density, compressibility, rebound, tensile strength, elongation, hydraulic fluid resistance, porosity and vibration damping were obtained on the most promising systems.

Several foams based on the above polyols were optimized with respect to polyol ratio, surfactant concentration and catalyst composition, and sufficient foam was prepared to enable these systems to be evaluated on aircraft shock mounts.

J. R. DIXON  
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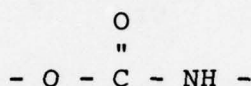
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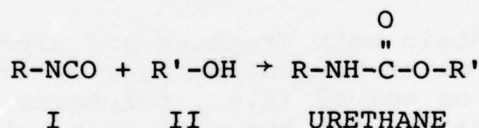
## INTRODUCTION

Polyurethanes, as a class of polymers, have become important commercial materials. The basic urethane linkage shown below is common to all polyurethanes whether in the form of elastomers,

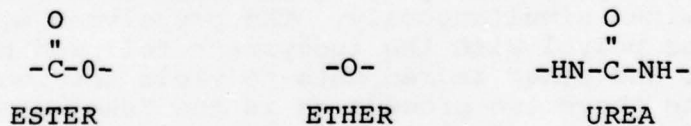


## URETHANE LINKAGE

adhesives, coatings or foams. The urethane bond is commonly formed by the reaction of an isocyanate compound, I, and a hydroxy compound, II. While the presence of the repeating urethane linkage



usually classifies a material as a polyurethane, in most commercial applications the polyurethane polymers contain other distinguishing repeating units such as ester, ether and urea linkages. Hence, the

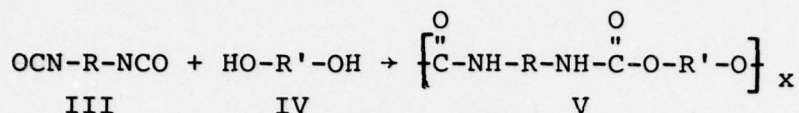


terms "polyester urethane" and "polyether urethane" are commonly used.

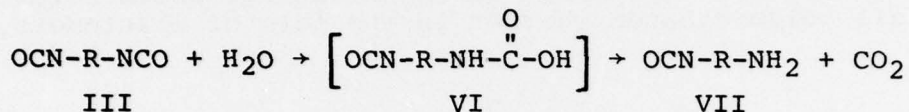
Polyurethane foams are classed as being rigid, semirigid and flexible. This report and the following discussion deal mainly with flexible urethane foams.

The basic reactions which yield a polyurethane foam are as follows. The reaction of an isocyanate, typically a diisocyanate III

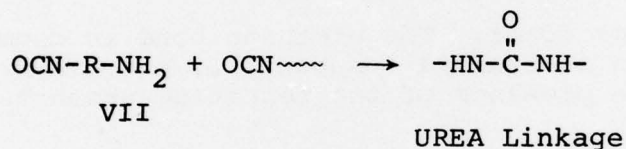
with a polyol IV (hydroxy-terminated resin) gives a urethane polymer V. The degree of functionality of the components determine



the amount of crosslinking. The foaming action usually results from the carbon dioxide gas (CO<sub>2</sub>) released when water reacts with the isocyanate. An unstable intermediate carbamic acid, VI, is



formed which breaks down quickly to give an amine, VII, and carbon dioxide gas. Now, this amine VII readily reacts with an isocyanate moiety to yield a urea linkage. Thus, a polyurethane foam blown with



carbon dioxide will contain both urethane and urea linkages. The ratio of isocyanate to water content largely determines the density of the foam. The type of polyol (i.e., polyester, polyether, hydrocarbon, etc.) dictates, for the most part, the chemical and physical properties of the foam.

Two main procedures for preparing a flexible urethane foam are the "one-step" or "one-shot" method and the prepolymer method. Most commercial foams are prepared by the "one-shot" method where all the ingredients are mixed simultaneously. The prepolymer method involves first reacting the polyol with the isocyanate followed by the addition of water and other ingredients to yield the foam. A combination of the above two procedures is the "semi-prepolymer" method where part of the polyol is reacted with a large excess of the isocyanate followed by the remainder of the resin along with water and other ingredients.

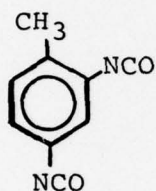
Typical ingredients for a "one-shot" flexible polyether urethane foam are:

- (a) Polyol
- (b) Isocyanate
- (c) Water

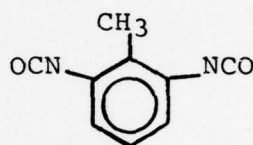
- (d) Surfactant
- (e) Catalysts

The polyether polyols (hydroxy-terminated resins) are normally prepared from 1,2-propylene oxide or combinations of 1,2-propylene oxide with ethylene oxide. Various low molecular weight hydroxy and amine compounds such as glycerine, trimethylol propane and ethylene diamine are used as initiators. Therefore, polyethers with various molecular weights and hydroxy functionalities are available.

While several different isocyanates are used in flexible urethane foam production, the isocyanate most widely used is a mixture of eighty percent 2,4-toluene diisocyanate, VIII, and twenty percent 2,6-toluene diisocyanate, IX--this combination referred to as TDI.



VIII



IX

The preparation of flexible polyether foams normally requires the use of a surfactant. This surfactant is usually a silicone-polyether block copolymer which stabilizes the rising foam and regulates cell growth. Additionally, some surfactants may improve the miscibility of the components.

"One-shot" polyether foams usually require two types of catalyst. A tin compound, such as stannous octoate, strongly catalyzes the isocyanate-hydroxyl reaction which is necessary for polymer growth. A tertiary amine material, such as triethylene-diamine, is a strong catalyst for both the isocyanate-hydroxyl reaction and the isocyanate-water reaction. The ratio and level of catalysts greatly influence the success of the foaming operation. For example, too much or too little tin catalyst may give a foam with splits and tears or give a closed-cell foam (usually undesirable) with accompanying shrinkage. Too much or too little amine may not catalyze the formation of carbon dioxide at the proper time leading to foam collapse, splits or poor foam rise.

Detailed discussions concerning foam chemistry, preparation and application are given in references 1 and 2.

1. Saunders, J. H., and Frisch, K. C., Polyurethane Chemistry and Technology, High Polymer Series, Vol. XVI, Parts I and II, Interscience (New York), 1962.
2. Dombrow, B. A., Polyurethanes, Reinhold (London), 1965.



## BACKGROUND

One of the Navy's uses of flexible urethane foam is as a damping material for aircraft shock mount bases. Delicate electronic equipment must be protected from shock and vibration during an aircraft's departure, flight and landing operations.

In the past, polyester-based urethane foams have been used rather than polyether-based foams, because they generally have better strength properties, more resistance to fuels and fluids, and a higher energy absorption (high hysteresis loss). Some of these polyester-based foams have, however, experienced hydrolytic degradation or reversion with resulting potential damage to the equipment being protected. Polyether-based foams, on the other hand, have good resistance to hydrolytic damage but do not compare favorably with polyester-based foams in the areas mentioned above.

The purpose of this work was to develop and test a polyurethane foam for use in avionic shock mounts. In addition to the required military specifications (MIL-F-81334B-AS), the foam should have improved resistance to hydrolysis.



## APPROACH

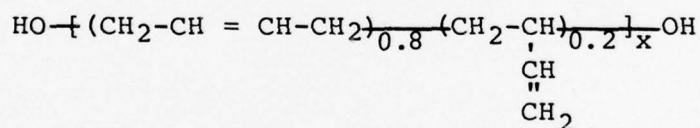
Previous work in this Laboratory involved the development and testing of polyurethane elastomers for use in Naval hardware. Some of these elastomers had excellent hydrolytic stability. We believed that the polyols used to prepare the elastomers could also be used to make flexible polyurethane foams which would have good resistance to hydrolysis. Other required properties would have to be evaluated.

The three basic polyols of interest are:

1. polybutadiene polyol
2. poly(oxytetramethylene) glycol
3. polycaprolactone polyol

None of these polyols are used to prepare commercial foams probably because of factors such as cost and processibility (when compared to the popular polyether polyols). However, the polyols above may contribute improved properties to foams prepared from them which, therefore, may justify their use.

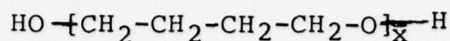
For example, polybutadiene polyol, general structure below, has a completely hydrocarbon backbone. Thus, the hydrolytic stability



OH functionality  $\approx 2.4-2.6$

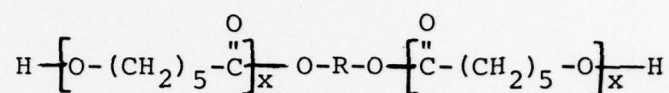
of foams prepared from this polyol should be excellent. One should, however, be aware that foams prepared from polybutadiene polyol might be susceptible to air oxidation and possibly fluid and fuel damage.

Foams made from poly(oxytetramethylene) glycol, structure below, should have good hydrolytic stability as shown by polyethers in general. Furthermore, based on elastomer results, foams prepared from this polyol should have improved strength properties compared



to those foams prepared from the conventional poly(oxypropylene) and poly(oxyethylene) polyols.

While polycaprolactone polyol, generalized structure below,



where R = some initiator

is a polyester polyol, polyurethane elastomers prepared from it usually have better hydrolytic stability when compared to elastomers prepared from conventional polyesters. The assumption is that foams prepared from polycaprolactone polyol would offer improved hydrolytic stability over conventional polyester-based urethane foams.

In addition to preparing foams from the above three basic polyols as the exclusive polyol in the formulation, there are a number of polyols that might be used in combination with the polyols of interest. These combinations of polyols will give foams of varying chemical and physical properties. This report will deal only with flexible polyurethane foams based on poly(oxytetramethylene) glycol and combinations of it with other polyols. Following reports will examine those foams prepared from polybutadiene and polycaprolactone polyols.

## EXPERIMENTAL

I. Foam Preparation

All of the components used in this foam study have been listed in the Chemical Glossary of this report. Identification of chemical structure has been made whenever possible, and sources have also been included. The manufacturer's data with regard to hydroxyl number and water content were used without experimental verification.

The foam components were weighed in polyethylene-lined, disposable paper cups on a Sartorius 3704 top-loading balance featuring automatic taring and digital readout. Weighing accuracy was  $\pm 0.03$  g. It was also found convenient to add certain components such as water, DABCO 33LV and TDI, which appeared in most formulations, by means of L/I Repipet dispensers. This addition technique provided rapid transfer of the gas-forming components which maximized mixing times and reduced undesirable side reactions.

In general, the polyols, surfactant, water, colorant and amine catalyst were mixed together, before the tin catalyst was added. After briefly stirring, the mix was completed by the rapid addition of the TDI. This procedure minimized hydrolysis of the stannous octoate. TDI content was 105% of required stoichiometry. All foams were prepared by the hand mixing technique unless otherwise noted. The foam mixture was then poured into appropriate sized cardboard boxes when creaming occurred. The bottom of each box was fitted with a 1 mil film of polyvinyl flouride (Tedlar) which facilitated the removal of the cured foam. Some foams were allowed to rise at room temperature before placing in the oven for final cure while other formulations were placed in the oven immediately after pouring. The foams were cured in a forced air circulating oven which had a preset temperature of  $110^{\circ}\text{C}$ , depending on the particular foam system. The foams were allowed to cure until the top surface was completely tack free. The Polymeg [poly(oxytetramethylene) glycol] foams usually reached this condition in less than one hour at  $125^{\circ}\text{C}$ . After curing, the foams were allowed to cool to room temperature before cutting, with a band saw, into appropriate sized specimens for testing.



## II. Density Measurement

Density measurements were made according to ASTM D1564-71 on specimens prepared for vibration damping (5x5x1") or mechanical properties' measurements (5x5x0.5"). The results are reported in pounds/cubic feet in Table 1.

## III. Rebound

The ASTM D1564-71 ball rebound test for resilient foams was investigated and found to give inconsistent results. Consequently, an alternate method was devised to reproducibly measure rebound. It was recognized that the basic Tinius Olsen (#37110) impact machine used to measure the impact strength of plastics could be modified in such a way as to suit our needs. With this purpose in mind, we simply replaced the impact head with a spherical steel ball (0.625" diameter). (See Figure 1.) The foam sample (minimum of 2" in thickness) was firmly attached by double stick tape to a massive (25 lb.) steel block which in turn was solidly anchored to the tester base by means of a brace. Unbonded, plied specimens were acceptable as test samples. A linear rebound scale was added to the face of the tester such that the zero point coincided with the striker arm in the rest position. An arbitrary starting position was attached at a point which would give reproducible rebound distances (approximately 10-15") which could be easily read by the operator.

The test was conducted by raising the striker arm to the starting position and then releasing it and recording the rebound distance. A series of five impacts were made on each sample, and the last three were used to determine the average rebound value (Table 1). The results were converted to an energy dissipation value which will be discussed later in this report.

## IV. Gas Flow

Cylindrical gas flow measurement samples were prepared by pouring a portion (15 g.) of the foam mix into polyethylene resin cartridges which had been sealed at one end. Cartridges which measured 12"L x 1-19/32"ID (Pyles Industries, Inc., #950-C-12X) were suitable for this purpose (Figure 2). The foam samples were allowed to rise, set and finally cure in these cartridges. On cooling, the cartridges were cut in such a way as to obtain a three-inch center section (Figure 3).

One end of these foamed sections was then inserted into the open end of a 4"L x 1-19/32"ID Pyles resin cartridge (#950-C-2½x). The insertion process was facilitated by first heating the receptor cartridge to approximately 90°C. Upon cooling, a gas tight seal was obtained at pressures below 5 psig. The receptor cartridge

which was threaded internally could then be placed in the flow apparatus shown in Figure 4. The apparatus consisted of a cylinder of nitrogen (oil pumped), a pressure gauge and two flowmeters. The pressure gauge (Wallace & Tiernan Model No. FA145) measured pressure up to a maximum 5 psig in 0.01 psi increments. The flowmeters (Fisher-Porter CD#2F-1/4-20-5/36 and SA#2F-1/8-12-5/36) covered the gas flow range from 0 to 950 cc/min and from 0 to 9500 cc/min, respectively. Each sample cartridge was pressure tested for gas leakage around the seal before it was placed in the apparatus for measurement. Initially, the sample foam was measured using the low range flowmeter and, when warranted, measurements were also made with the high range flowmeter. The results of these measurements are recorded as gas flow (cc/min.) at a given internal pressure (psig), (Table 2 and Figure 17).

#### V. Vibration Damping

Foam samples (5x5x1") were bonded to 1/4" aluminum plates (Figure 5) using EA9309.2 (Hysol Division - Dexter Corporation) epoxy resin as an adhesive. The ratio of resin to curing agent was 100/22 parts by weight, and the resin system was fully cured at ambient temperature. After bonding, a load which measured 5"x5" and weighed 7.5 lbs. was secured to the top plate. The base of the foam test sample was then mounted on an electrodynamic vibrator (Ling Model 246, Figure 6) which was used to control and maintain the input vibration over the levels and frequency ranges specified in Figure 7. The vibration response of the test sample was derived from a piezoelectric accelerometer (Endevco Model 2313E) attached at the center of the test weight as shown in Figure 8. The response and control accelerometers were fed into charge amplifiers (Kistler Model 504A) which were adjusted to produce an output voltage of 10 mv/g. The amplified output voltage from the control accelerometer was then fed into an electronic servo (Unholtz-Dickie Model SP-7) which was used to drive a Ling 40 Kw power amplifier. The power amplifier was used to drive the vibrator to the required input levels. The amplified output of the response accelerometer was fed into an x-y plotter for comparison of the test samples' vibration characteristics with that of the response standard (Figure 7).

#### VI. Constant Deflection Compression Set

After the completion of the vibration damping tests, these same samples were used to determine the compression set properties of the foams at constant deflection according to ASTM D1564-71. The sample thickness was carefully measured with a caliper to  $\pm 0.01$  mm at two points on opposite sides of the foam sample. These points were marked so that measurements made after temperature exposure would be at the same two locations as the initial thickness measurements (see Figure 5). Four foam samples were then stacked



together, and two 3/4" spacers were placed between each mount (Figure 9), and the entire assembly was fastened together by means of 7-inch "C" clamps. The samples which had thus been compressed to 50% of their initial condition were placed in a forced air oven at  $70 \pm 5^{\circ}\text{C}$  for a period of 22 hours. Upon removal from the oven, the "C" clamps were removed, and the samples allowed to cool at ambient for a period of thirty minutes. Final measurements were made on the samples within ten additional minutes at the premarked points on the plates. The data was used to calculate the constant deflection compression set as a percent function of the original thickness.

$$C_t = [(t_o - t_f) / t_o] \times 100$$

where  $C_t$  = percent compression set  
 $t_o$  = original specimen thickness  
 $t_f$  = final specimen thickness after temperature exposure

## VII. Tensile Strength/Elongation

Tensile strength and elongation measurements were made in accordance with ASTM D1564-71. Resistance to hydraulic fluid and hydrolytic degradation was tested in accordance with MIL-F-81334B(AS).

### A. Hydraulic Fluid Exposure

Tensile specimens were completely immersed in hydraulic fluid conforming to MIL-H-5606. Immersion time was one (1) hour  $\pm 5$ , -0 minutes. The specimens were removed, and the excess fluid drained prior to testing. The results are reported in Table 3 as percent change from original tensile strength and elongation.

### B. Hydrolytic Stability

The hydrolytic stability of these poly(oxytetramethylene) glycol foams was determined at  $85^{\circ}\text{C}$  and 95% relative humidity. Tensile specimens were placed in dessicators that contained a saturated potassium sulfate solution, and the dessicator was placed in an oven at  $85 \pm 3^{\circ}\text{C}$ . Samples were removed after 125 hours of exposure and allowed to equilibrate at ambient ( $23^{\circ}\text{C}$ ; 55% RH) for a period of one hour before testing. The tensile data after exposure is reported in Table 3 as percent retention of initial strength and elongation.

## VIII. Load Deflection

The vibration damping specimens (Figure 5) were exposed to a load range from zero load to a load that resulted in a 70 percent

deflection of the specimen. The loading applied by the Instron Tester was continuous at 5 cm/min. The stress/strain curves are reported in Figures 14 and 18. [See MIL-F-81334B(AS).]

## RESULTS AND DISCUSSION

1. PM Foams

PM-1 to PM-5 were formulated using Polymeg 2000 [poly(oxytetramethylene) glycol] as the only polyol present in the foam mixture. Stannous octoate (Catalyst T-9) and triethylenediamine (DABCO 33LV) were cocatalysts in these systems while DC198 and B3136 were the surfactants. The foams prepared using DC198 (PM-1 to PM-3) all tended to have large closed cells, and they had a stiff boardy texture. However, when B3136 was used as the surfactant in this system (PM-4 and PM-5), the resulting foams had a soft texture, and the cells were finer and more open (Figures 10-12). The density of these foams ranged from 4.0 to 4.6 lbs/cu. ft. (Table 1). PM-1 had a lower rebound value (14.0 inches) than did either PM-4 (17.5 and 15.9 inches, respectively), suggesting that both cell count/inch and the degree of open or closed cell content influence the results of this test. Also PM-1, which contained heavily-ribbed cells, had less compression set (2.5%) than either PM-4 or PM-5 (8.1 and 9.8%, respectively), which contained finer, less rigid cell ribs.

The vibration damping characteristics of the PM foam systems were measured between 5 and 500 Hz. The data (Figure 13) shows that PM-1, PM-4 and PM-5 foams have acceptable damping properties in the 5-40 Hz frequency range, but between 40 and 140 Hz the recorded sample accelerations are beyond the standard foam envelope for vibration damping. PM-4 and PM-5 outperform PM-1 in this frequency region showing less of a deviation from the envelope. Above 150 Hz all three foams have acceptable vibration damping properties.

The load deflection behavior of PM-1, 4 and 5 is given in Figure 14. The coarse, heavily-ribbed cell structure of PM-1 is demonstrated by its high load deflection values. The finer, softer cells of PM-4 and 5 result in lower load deflections.

2. PM-PL355 Foams

In an attempt to introduce crosslinking into the linear poly-(oxytetramethylene) glycol systems (PM-1 to PM-5), a second polyol, Pluracol 355 (PL355), was added to the formulation. PL355 is a



tetrol derived from propylene oxide and an amine from which it gets its catalytic activity. PM-PL355-1 and PM-PL355-2 were both based on a 90/10 weight ratio of Polymeg 2000 to PL355 and used B3136 as the surfactant. The PM-PL355-1 which was cocatalyzed by stannous octoate (T-9) and triethylenediamine (DABCO 33LV) was extremely reactive and produced, after an oven cure, a closed cell foam which experienced severe shrinkage on cooling (Figure 15). PM-PL355-2 was formulated without the DABCO 33LV in order to increase the time to cream as well as the gelation time. However, the resulting foam showed the same shrinkage behavior as PM-PL355-1. This foam system was not pursued any further, and, therefore, no additional data was collected.

### 3. PM-PL718 Foams

The PM-PL718 series of foams were formulated in an effort to improve the cell structure of the PM foam by using a poly(oxypropylene) polyol, Pluracol 718 (PL718), which had been shown to yield an excellent, open cell foam. PM-PL718-1 to 4 were foams based on a 70/30 weight blend of Polymeg 2000 to PL718 using 0.5 phr of B3136 as surfactant. While the surfactant/resin ratio was held constant, the T-9/33LV ratio was varied to obtain the optimum ratio of 0.2/0.3 phr. The density range for this foam system was 3.6-3.9 lbs/cu. ft. with a rebound value of 16.3-16.5 inches and a percent compression set of 3.9 (Table 1).

PM-PL718-2 had excellent tensile strength (51.8 psi) and elongation (421%) but experienced severe mechanical properties' degradation when exposed to hydraulic fluid according to MIL-F-81334B(AS), (Table 3).

Table 1 also shows the energy each foam absorbed during the rebound test. The values were obtained by calculating the difference in potential energies of the pendulum before and after rebound.<sup>3</sup> Unfortunately, no correlation between the energy absorbed in the rebound test and vibration damping properties was observed. That is, those formulations that had a high energy absorption or low rebound (considered a desirable indication) did not necessarily fall completely within the reference damping curve envelope. On the contrary, some formulations with a high rebound performed just as well during the vibration damping tests as those having low rebound. Possibly, the rebound test and vibration damping test do not correlate well with one another because of the differences in the frequencies of the tests as well as the different energy inputs.

Once the T-9/33LV ratio had been established, it was then important to determine the surfactant limits for this particular

3. Holliday, D., and Resnick, R., Physics - Parts I & II, Wiley and Sons (New York), 1967.

70/30 resin ratio. PM-PL718-5 to 10 were foams formulated so that the only variable was the surfactant/resin ratio which ranged from 0.25 to 2.0 phr. The density range for these six foams was 3.2-3.4 lbs/cu. ft., while the rebound values reached a maximum value of 15.3 inches at a surfactant concentration of 1.0 phr (Table 1).

Tensile strength decreased slightly at the higher surfactant concentrations (42.3 to 38.9 psi) while the elongation values were quite constant (389-406%). Samples subjected to hydraulic fluid suffered serious strength losses (Table 3) which is consistent with the behavior of polyether polyurethanes. Compressibility losses at 70°C after 22 hours were only 1.8-2.2%.

As expected, the hydrolytic stability of the PM-PL718 foams is excellent (see Table 3). Their small change in tensile strength and elongation upon exposure to moisture compares favorably to a number of commercial polyester foams tested in this Laboratory. For example, under the same temperature/humidity conditions, the tensile strengths of those polyester foams were reduced by more than 90 percent after 60-80 hours of exposure.

Vibration damping curves of PM-PL718-5 to 10 are given in Figure 16. The curves are, for practical considerations, the same. Thus, the fact that the surfactant level changed from 0.25 phr to 2.0 phr, with a corresponding increase in closed cell content as evidenced by decreasing gas flow values (Figure 17), had little effect on the vibration properties in the frequencies of interest. While the rebound values for these foams ranged from 12.5 (#10) to 15.3 (#8), this difference was not revealed in the vibration damping results.

The load deflection measurements for the PM-PL718-5 to 10 foam series are shown in Figure 18. While there is no clear pattern observed that demonstrates the relationship of load deflection to surfactant level, the lower surfactant level foams (#'s 5, 6, 7) appear to have generally lower initial load deflections than the higher surfactant level formulations ('s 8, 9, 10). The shapes of the curves also differ somewhat between the two groups. In any case, the foams meet the requirements of MIL-81334B(AS).

The results show that the 70/30 PM-PL718 resin system with B3136 surfactant is a stable formulation yielding an open cell structure. Surfactant concentration did not appear to be critical and can be safely varied between 0.5 and 1.5 phr in small mixes. At lower concentrations (0.25 phr), some collapse was experienced together with less open cell structure. At high surfactant concentrations, some mechanical strength loss can occur.

Based on these results, the B3136 level was set at 0.5 phr while additional modifications of the T-9/33LV ratio were observed in formulations PM-PL718-11 and 12. Both formulations gave



excellent, open celled foams which again appeared to indicate that sufficient latitude in the T-9, 33LV and B3136 concentrations existed so that these formulations were stable enough to be scaled up to larger foam batches.

PM-PL718-13 was a 1200 g. mix based on the 100 g. PM-PL718-12 formulation. The foam was stirrer mixed and after a 45-second cream time was allowed to rise at ambient temperature. At peak rise, the foam experienced gas release and collapsed.

PM-PL718-14 was a stirrer mixed 400 g. batch of PM-PL718-12 which did not collapse but experienced gas release at peak rise which led to a large internal fissure (Figure 19). This gas release indicated that gelation was too slow, but an increase in the T-9 level from 0.2 to 0.3 phr (PM-PL718-15) failed to solve this problem.

In an attempt to reduce the exotherm of the foaming reactions, the PM-PL718 polyol mixture was prereacted with the TDI at ambient for a period of 45 minutes prior to the addition of the other foam components. The resulting foam (PM-PL718-16) had a top split and an internal fissure and shrank on cooling.

It then became necessary to reestablish a stable formulation which could then be scaled up to obtain larger quantities of foam. In addition, a grey colored foam had to be produced for military identification purposes. This color additive introduced a new variable that had to be studied. For this purpose, PM-PL718-1 was selected as the base formulation since it had given excellent initial properties. When it was established that this same formulation no longer gave stable foams (PM-PL718-17), the surfactant activity became suspect. When the surfactant concentration was increased from 0.5 to 1.0 phr (PM-PL718-18 and 19), excellent, open celled foams with a soft texture could once again be obtained. Even the addition of a polyurethane colorant (CONAP BLACK) to the new formulation did not cause any instability or fissure formation (PM-PL718-20). Three successful 400 g. foams were poured from this new formulation (PM-PL718-21 to 23). It has subsequently been learned that B3136 surfactant has a limited shelf life ( $\leq 6$  months) and apparently loses some of its activity by hydrolysis when exposed to moist environments for long periods of time.

With the successful completion of the 70/30 PM-PL718 foam work, we then turned our attention to other resin ratios using these same polyols. The 50/50 ratio of polyols (PM-PL718) was studied in foam formulations PM-PL718-24 to 26. A stable foam was obtained when the B3136 level was raised to 1.0 phr, and the T-9/33LV ratio was reduced to 0.3/0.2 phr. The resulting foam had fine open cells, and colorant was added without causing any instability in the foam.

PM-PL718-27 to 31 were 400 g. formulations based on PM-PL718-26. After initial success in this size foam (#27), the foams that

followed (#28, 29) developed closed cells and severe legging (Figure 20) problems. Again, the activity of the B3136 surfactant became suspect, and when fresh material was used in PM-PL718-30 and 31, excellent foams resulted with good, open cell structure.

The final resin ratio which was briefly investigated in this PM-PL718 series was the 30/70 ratio. The use of DC198 as the surfactant (PM-PL718-32) produced a closed cell foam which shrank severely on cooling. When B3136 surfactant was substituted for DC198 at the 0.5 phr level with a varying T-9/33LV ratio, closed cell foams with shrinkage and legging problems resulted (PM-PL718-33 and 34). The density of PM-PL718-33 was 2.9 lbs/cu. ft. and, in spite of its closed cell structure, gave a rebound value of only 10.9 inches while the compression set was 3.9% (Table 1).

## CONCLUSIONS

1. Stable, open cell polyurethane foams based on poly(oxytetramethylene) glycol as the sole polyol were prepared. These foams, compared to many commercial polyether-based foams, appeared to have improved tensile strengths and elongation properties. However, because of the low degree of crosslinking, the compression set was borderline for the intended application.
2. A tetrol (Pluracol 355) containing tertiary amine groups was found too reactive to be used as a crosslinking agent for poly(oxytetramethylene) glycol based foams. Urethane foams based on combinations of these two polyols had severe shrinkage problems that could not be alleviated by changes in catalyst or surfactant.
3. Fine, open cell foams were prepared from combinations of poly(oxytetramethylene) glycol with a poly(oxypropylene) polyol (Pluracol 718). These foams had improved physical properties when compared to commercial polyether-based foams. Compression set was also acceptable. Resistance to hydraulic fluid was poor, which is typical of polyether-based foams. Hydrolytic stability is good. The vibration damping properties depended somewhat on formulation changes but, generally, vibration properties were comparable to presently used commercial polyester-based foams.
4. No correlation was found between rebound values and vibration damping results in the frequencies of interest (5-500 Hz). Furthermore, within a given formulation, changes in surfactant level or open/closed cell content had little or no practical effect on vibration damping. However, within a given formulation, indications were that increasing surfactant corresponded to increasing closed cell content.

## RECOMMENDATIONS

1. In those areas where resistance to hydraulic fluids and fuels is not of primary concern, the foams based on a combination of poly(oxytetramethylene) glycol and poly(oxypropylene) polyol should serve well as vibration damping foams. Significantly improved hydrolytic stability is also available from these foams compared to those foams based on polyester polyols.
2. Additional work optimizing existing formulations, particularly for scale-up purposes, should be done.
3. Improved vibration properties may result from foams prepared from combinations of poly(oxytetramethylene) glycol with a relatively new class of modified polyether polyols termed "polymer polyols". These systems should be developed and evaluated.
4. In those areas where resistance to hydraulic fluids and fuels is of prime concern, work to improve the hydrolytic stability of polyester-based foams should be performed. Polyester-based foams typically have good resistance to hydraulic and fuels but poor hydrolytic stability.



ACKNOWLEDGEMENTS

The authors would like to recognize Robert T. Williams and Robert N. Peterson for determining the vibration damping properties of these foams and for their assistance in evaluating the data. Arthur Harris was responsible for the preparation of the vibration specimens, and Richard Prosise and George Green measured the mechanical properties reported in this work.

Table 1. FOAM PROPERTIES

FOAM NUMBER	DENSITY (lbs./cu. ft.)	COMPRESSION SET %	REBOUND (Inches)	REBOUND-ENERGY ABSORBED %
PM-1	4.0	2.5	14.0	58.7
PM-4	4.4	8.1	17.5	39.7
PM-5	4.6	9.8	15.9	47.9
PM-PL718-1	3.9	3.9	16.3	45.5
PM-PL718-2	3.6	-	16.5	44.6
PM-PL718-5	3.2	2.2	13.5	61.2
PM-PL718-6	3.2	1.8	13.5	61.2
PM-PL718-7	3.2	1.8	13.5	61.2
PM-PL718-8	3.4	-	15.3	51.2
PM-PL718-9	3.3	-	14.0	58.7
PM-PL718-10	3.3	-	12.5	66.1
PM-PL718-33	2.9	3.9	10.9	73.6

Table 2. PRESSURE/FLOW CHARACTERISTICS OF PM-PL718 FOAMS

FOAM NUMBER	NITROGEN FLOW RATE (CC/MIN) AT PRESSURE			
	10MM	20MM	30MM	40MM
PM-PL718-1	>10,000	-	-	-
PM-PL718-2	>10,000	-	-	-
PM-PL718-5	7,400	>10,000	-	-
PM-PL718-6	6,000	8,850	>10,000	-
PM-PL718-7	5,400	8,300	>10,000	-
PM-PL718-8	3,400	5,350	6,850	8,200
PM-PL718-9	2,600	4,100	5,500	6,750
PM-PL718-10	1,800	2,850	3,750	4,550
PM-PL718-17	>10,000	-	-	-
PM-PL718-18	>10,000	-	-	-
PM-PL718-24	>10,000	-	-	-
PM-PL718-34	4,650	8,700	>10,000	-
				9,500
				7,950
				5,300

Table 3. MECHANICAL PROPERTIES OF PM-PL718 FOAMS

FOAM NUMBER	PM/PL718 RATIO	SURFACTANT CONCENTRATION (phr)	TENSILE STRENGTH (psi)		ELONGATION (%)	
			ORIGINAL STRENGTH (psi)	AFTER HYDRAULIC FLUID EXPOSURE <sup>1</sup> (% Str. Change)	ORIGINAL ELONGATION (%)	AFTER HYDRAULIC FLUID EXPOSURE (% Elong. Change)
PM-PL718-5	70/30	0.25	42.3	17.3 (-59.1)	406	144 (-64.5)
PM-PL718-2	70/30	0.50	51.8	27.1 (-47.7)	421	202 (-52.0)
PM-PL718-6	70/30	0.50	51.4	25.8 (-49.8)	401	150 (-62.6)
PM-PL718-7	70/30	0.75	41.3	22.0 (-46.7)	396	182 (-54.0)
PM-PL718-8	70/30	1.00	40.7	15.9 (-60.9)	405	101 (-75.1)
PM-PL718-9	70/30	1.50	38.9	18.6 (-52.2)	389	141 (-63.8)
PM-PL718-10	70/30	2.00	38.9	15.7 (-59.6)	392	108 (-72.5)
						569 (+40.2)
						496 (+17.8)
						546 (+36.2)
						549 (+38.6)
						536 (+32.4)
						522 (+34.2)
						489 (+24.7)

## NOTES:

1. Hydraulic Fuel Exposure: One (1) hour in MIL-H-5606 Hydraulic Fluid
2. Hydrolytic Exposure: 85°C/95% RH for 125 hours.



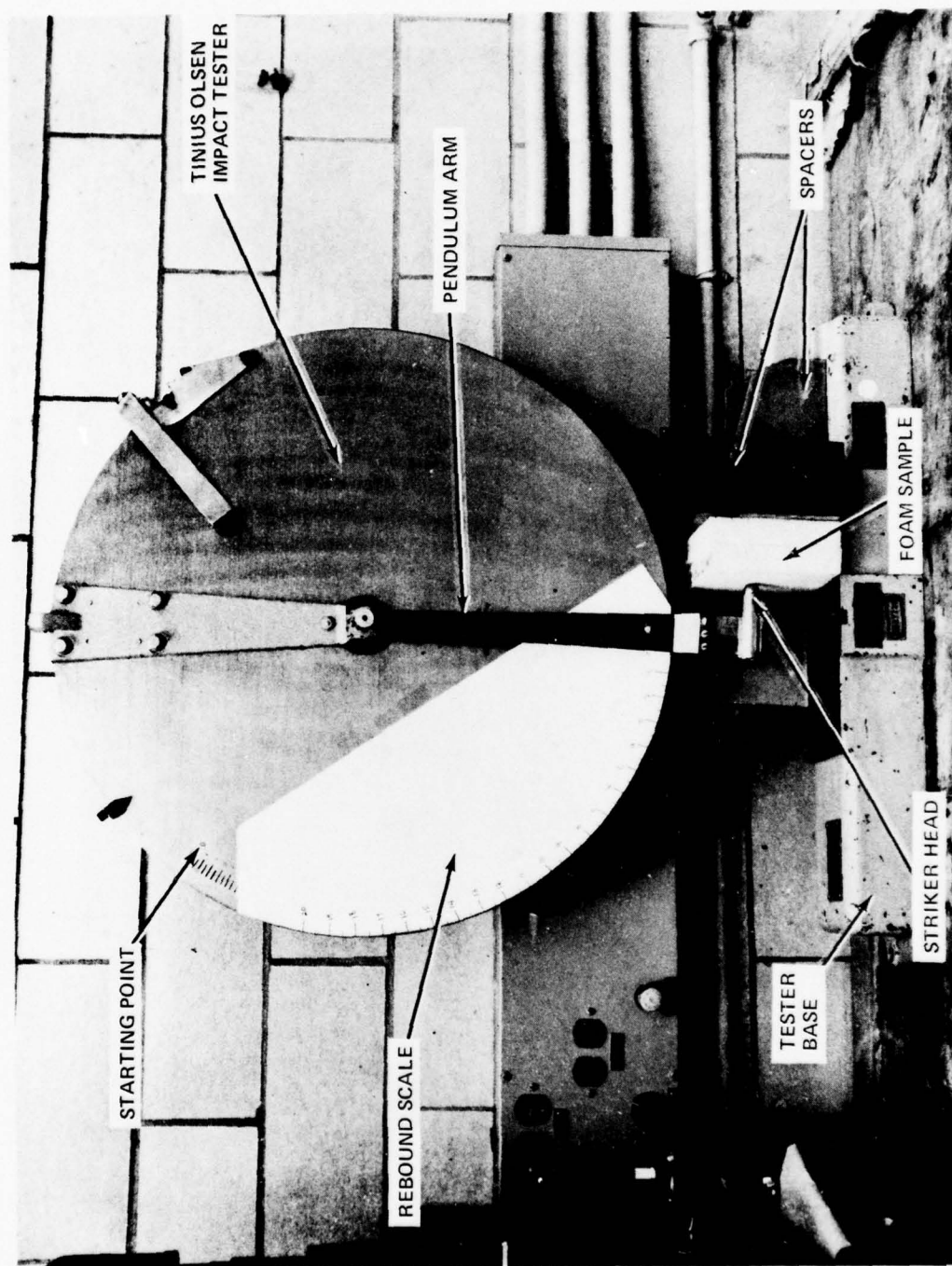


FIGURE 1. REBOUND TESTER

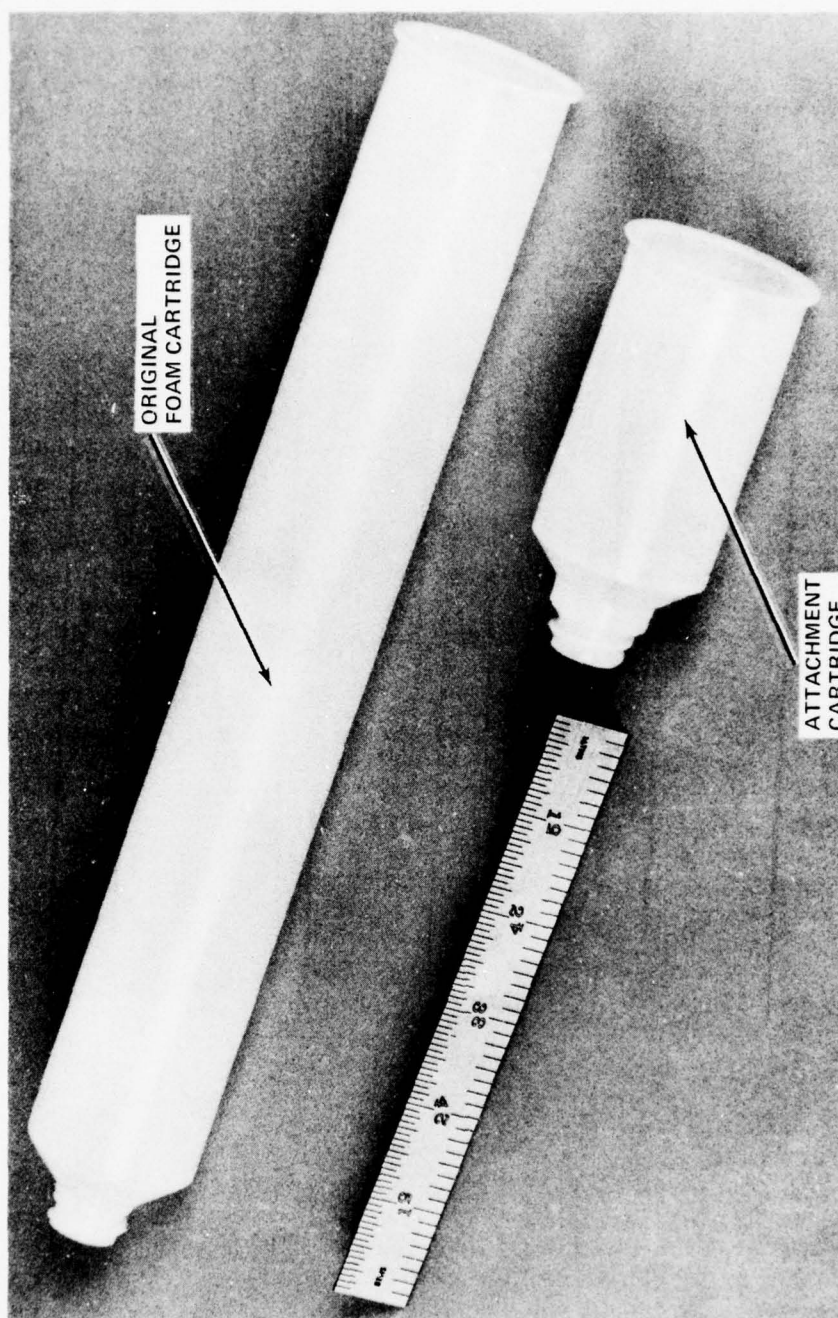


FIGURE 2. RESIN CARTRIDGES

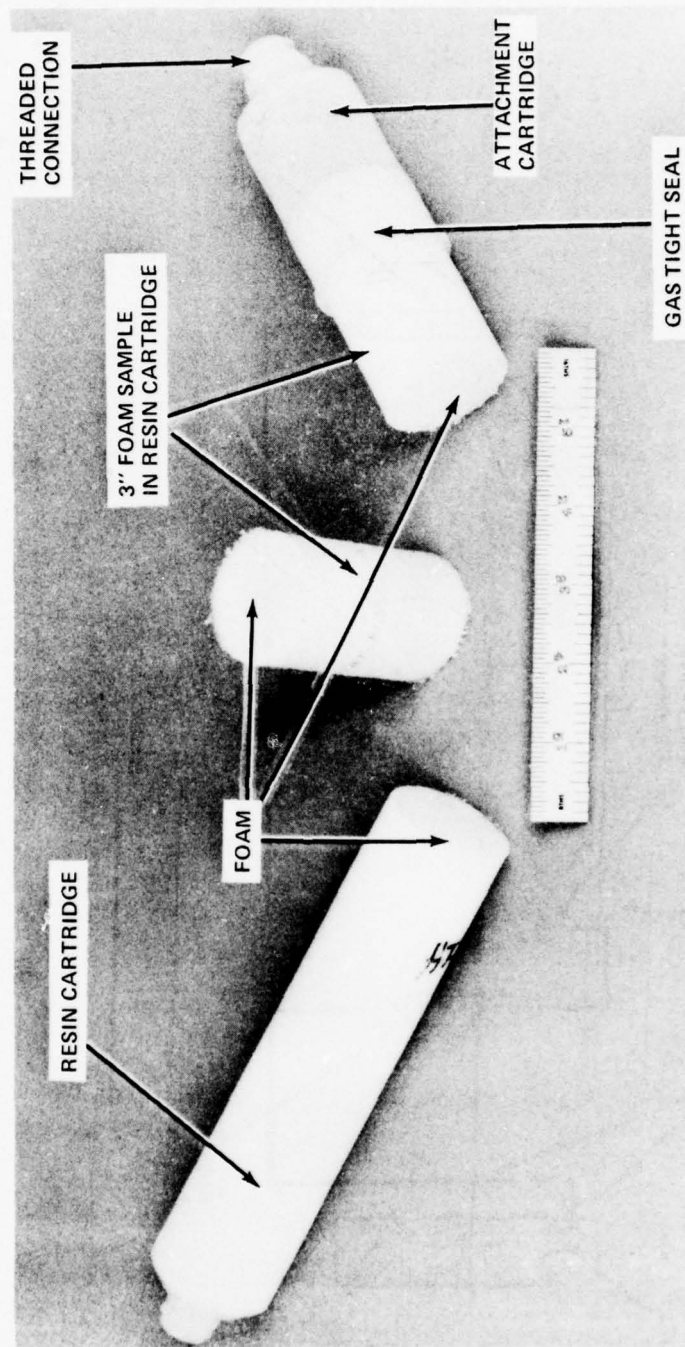


FIGURE 3. GAS FLOW SAMPLES

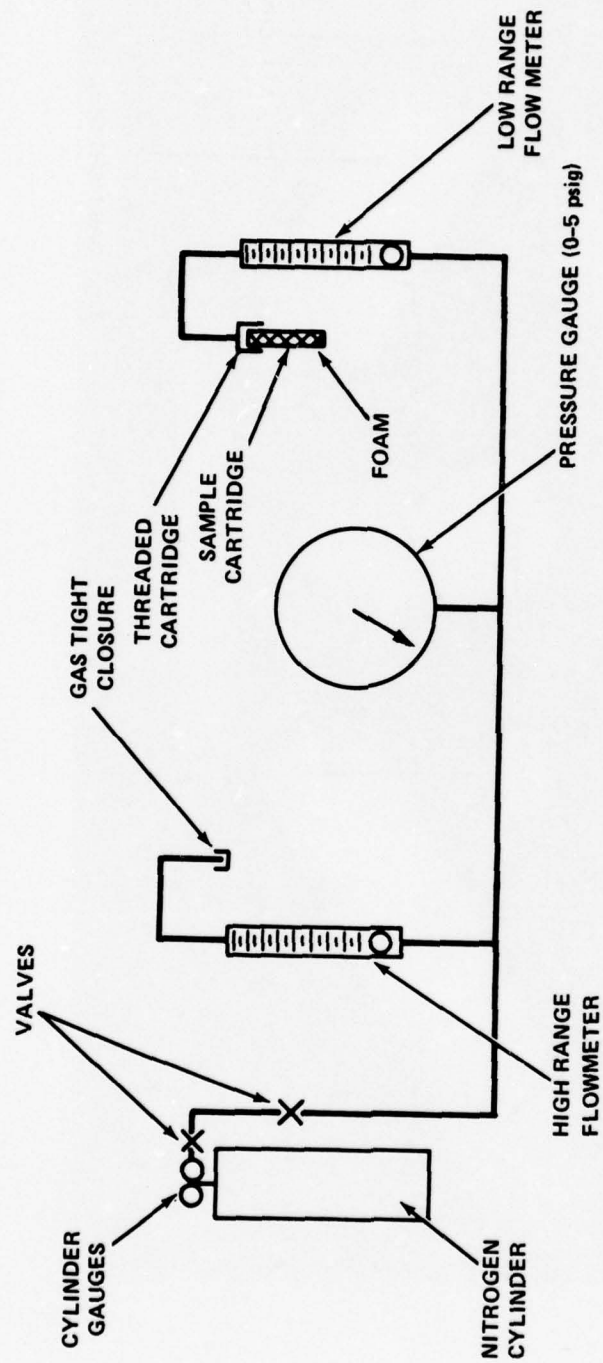


FIGURE 4. GAS FLOW APPARATUS



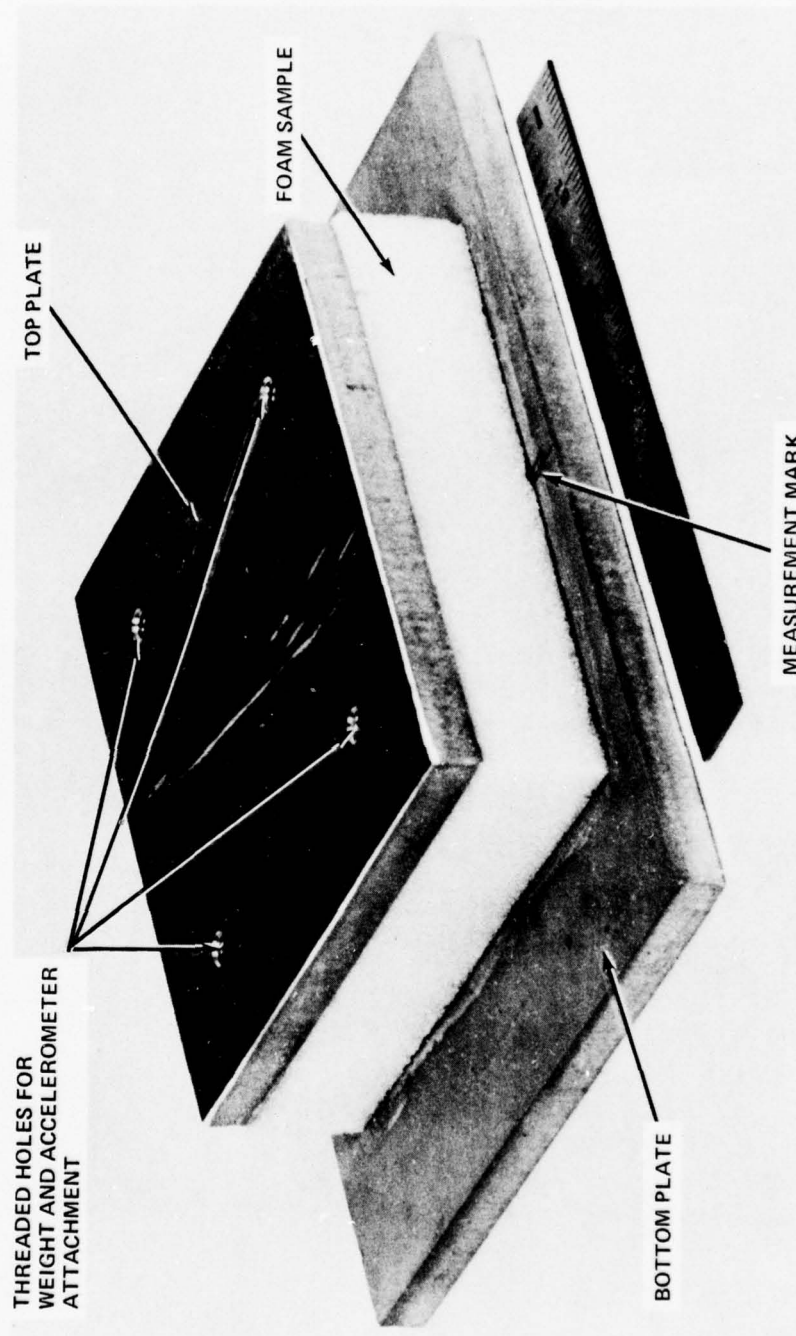


FIGURE 5. FOAM VIBRATION SAMPLES

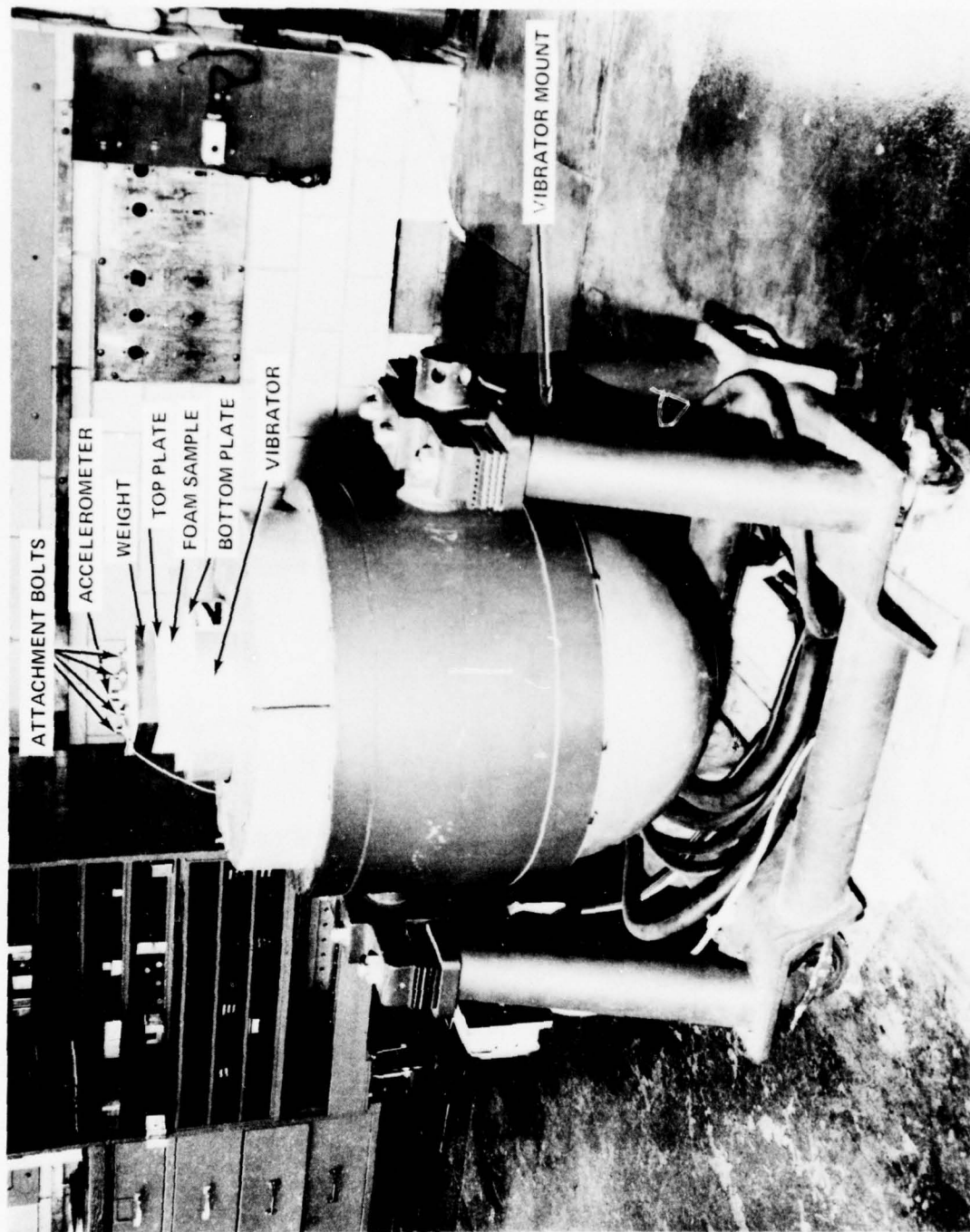


FIGURE 6. LING ELECTRODYNAMIC VIBRATOR

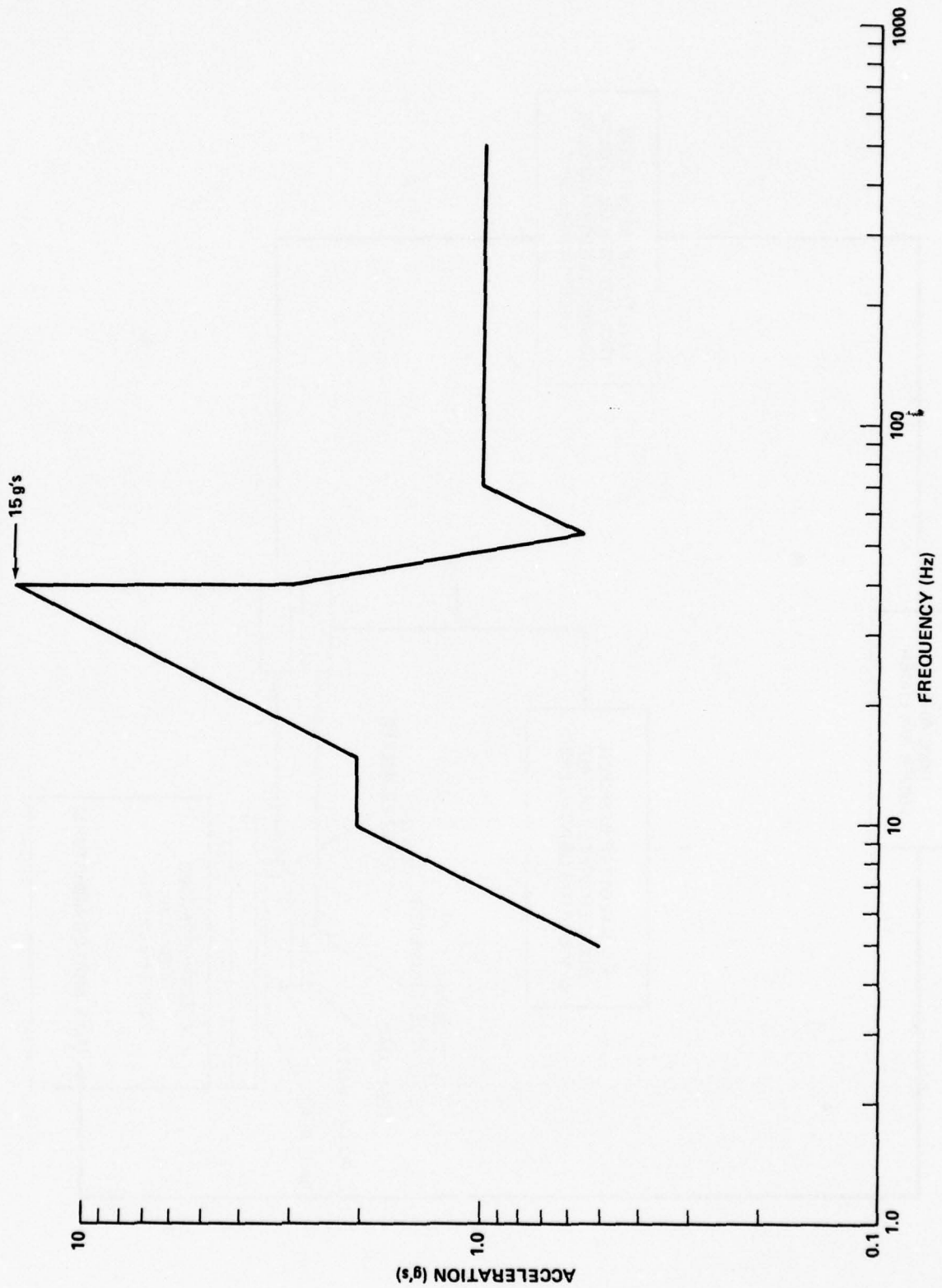


FIGURE 7. FREQUENCY -- ACCELERATION ENVELOPE FOR VIBRATION DAMPING AS SPECIFIED IN MIL-F-81334B (AS)

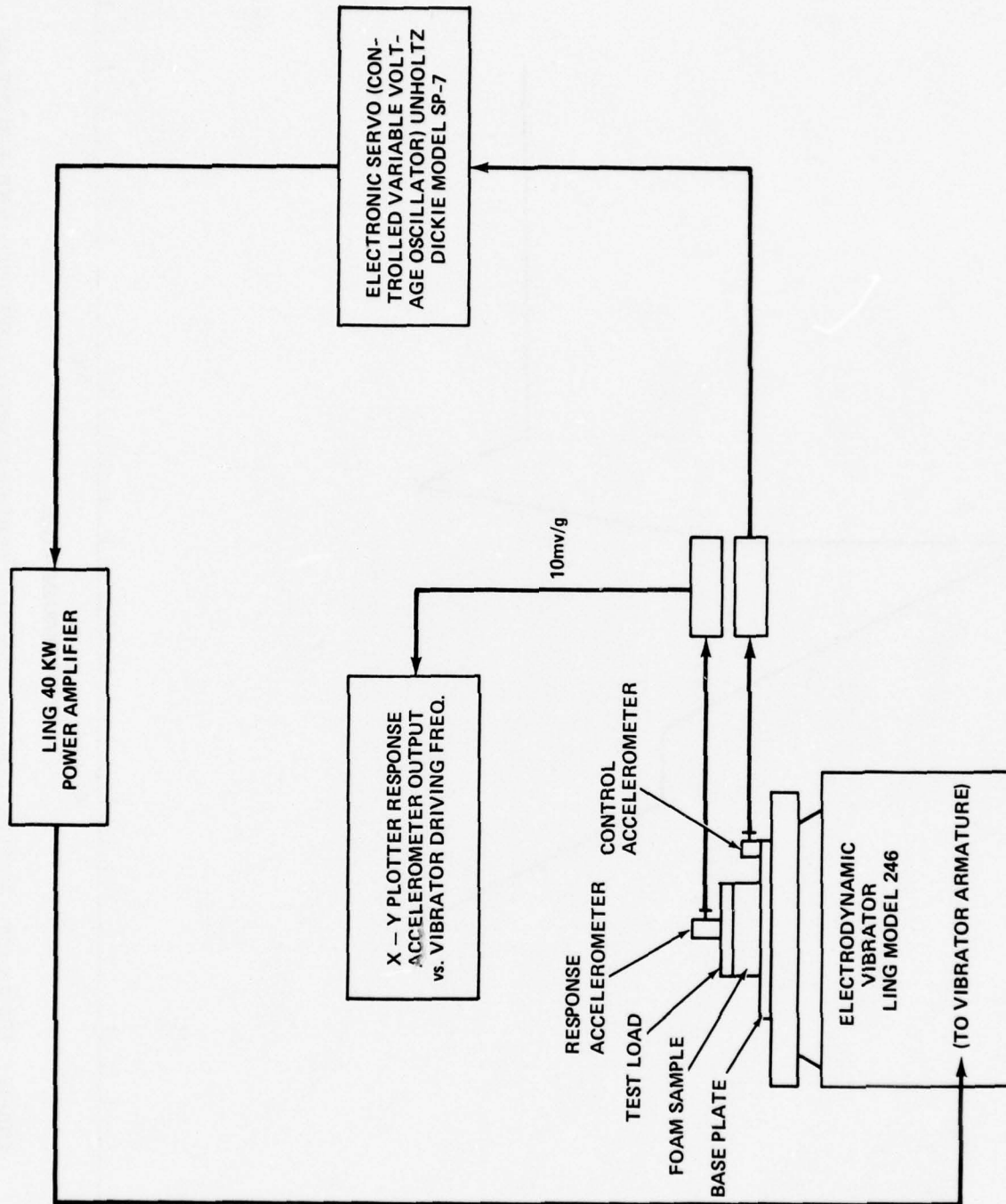


FIGURE 8. SCHEMATIC OF VIBRATOR EQUIPMENT



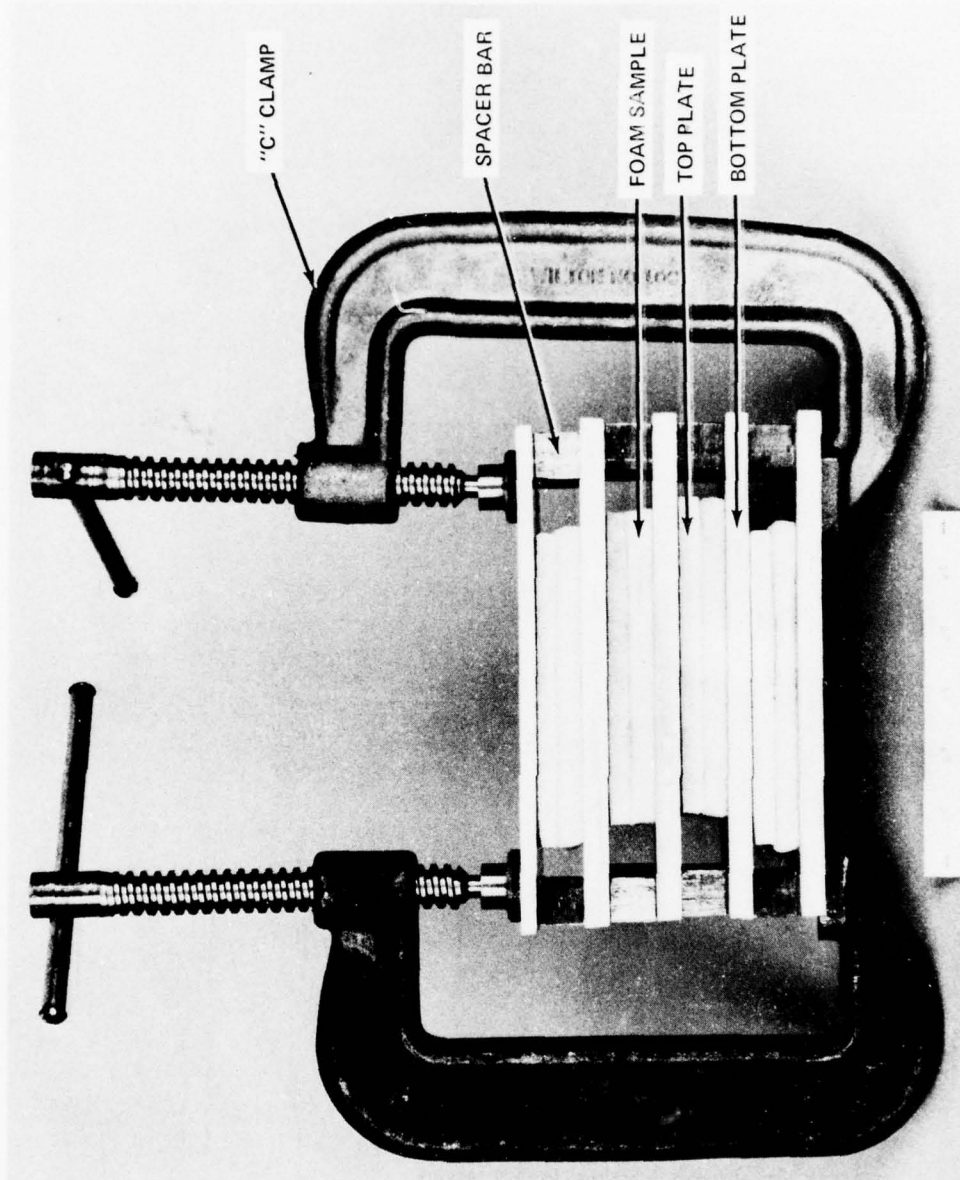


FIGURE 9. COMPRESSION SET ASSEMBLY

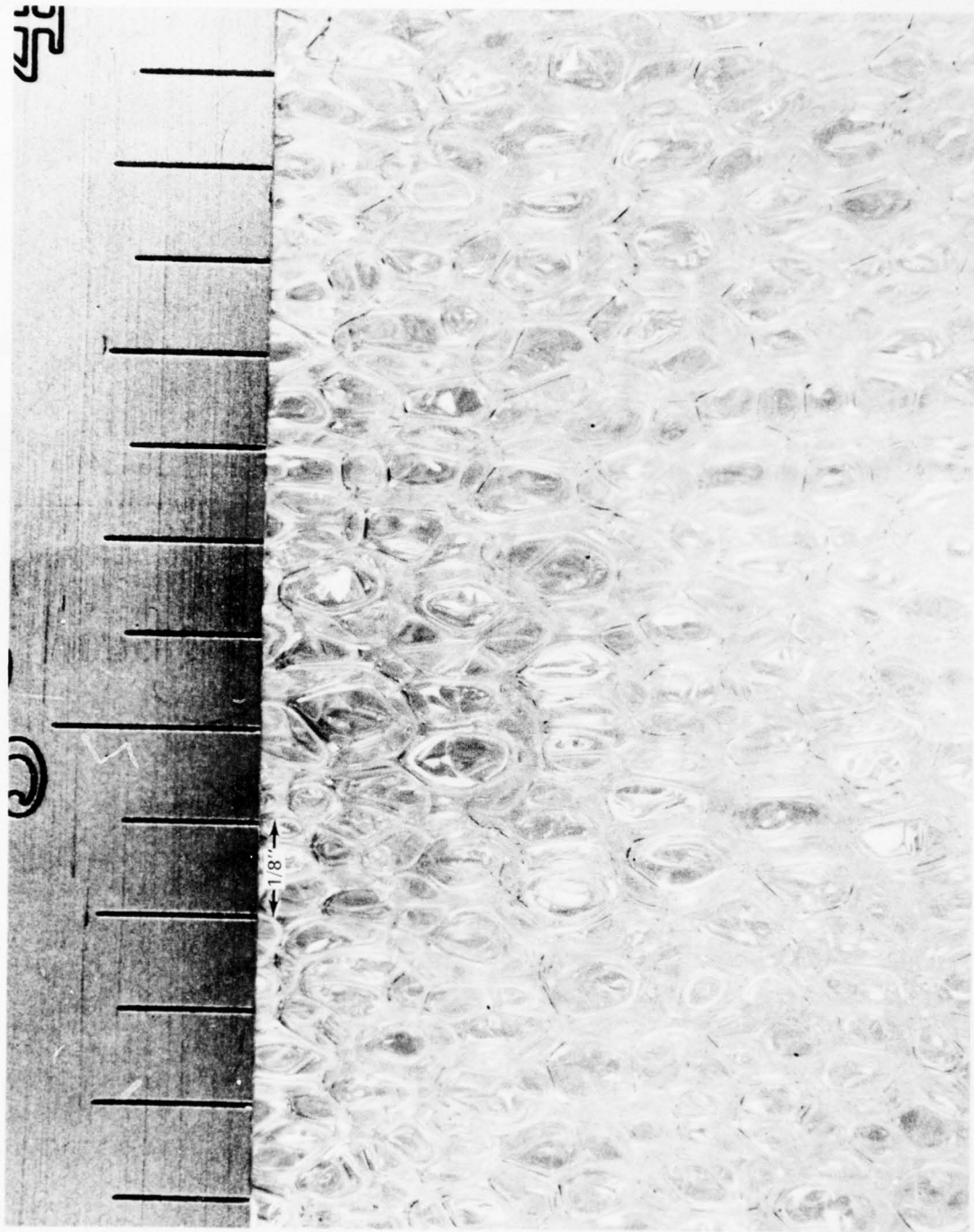


FIGURE 10. PM-1 CELL STRUCTURE



FIGURE 11. PM-3 CELL STRUCTURE

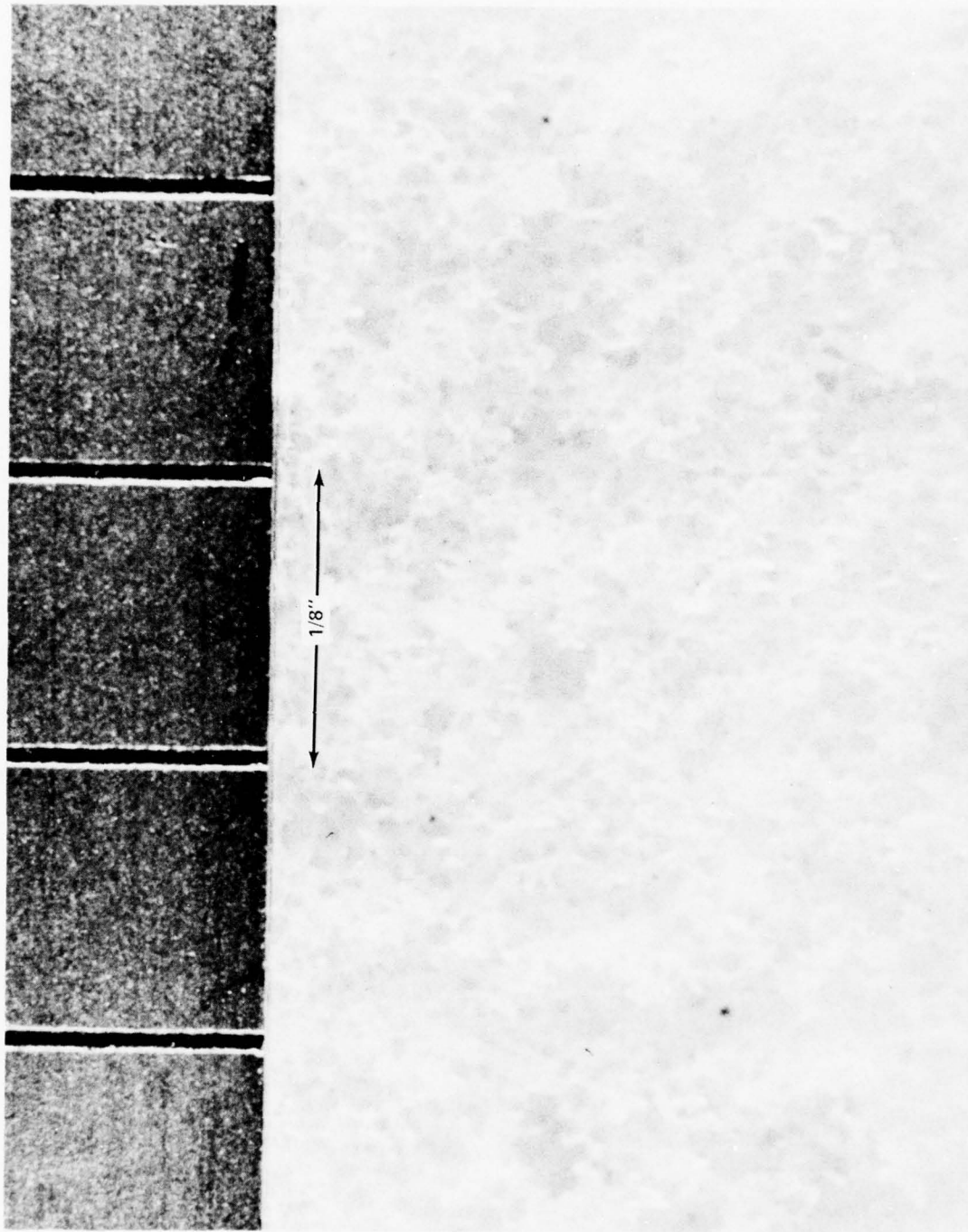


FIGURE 12. PM-5 CELL STRUCTURE



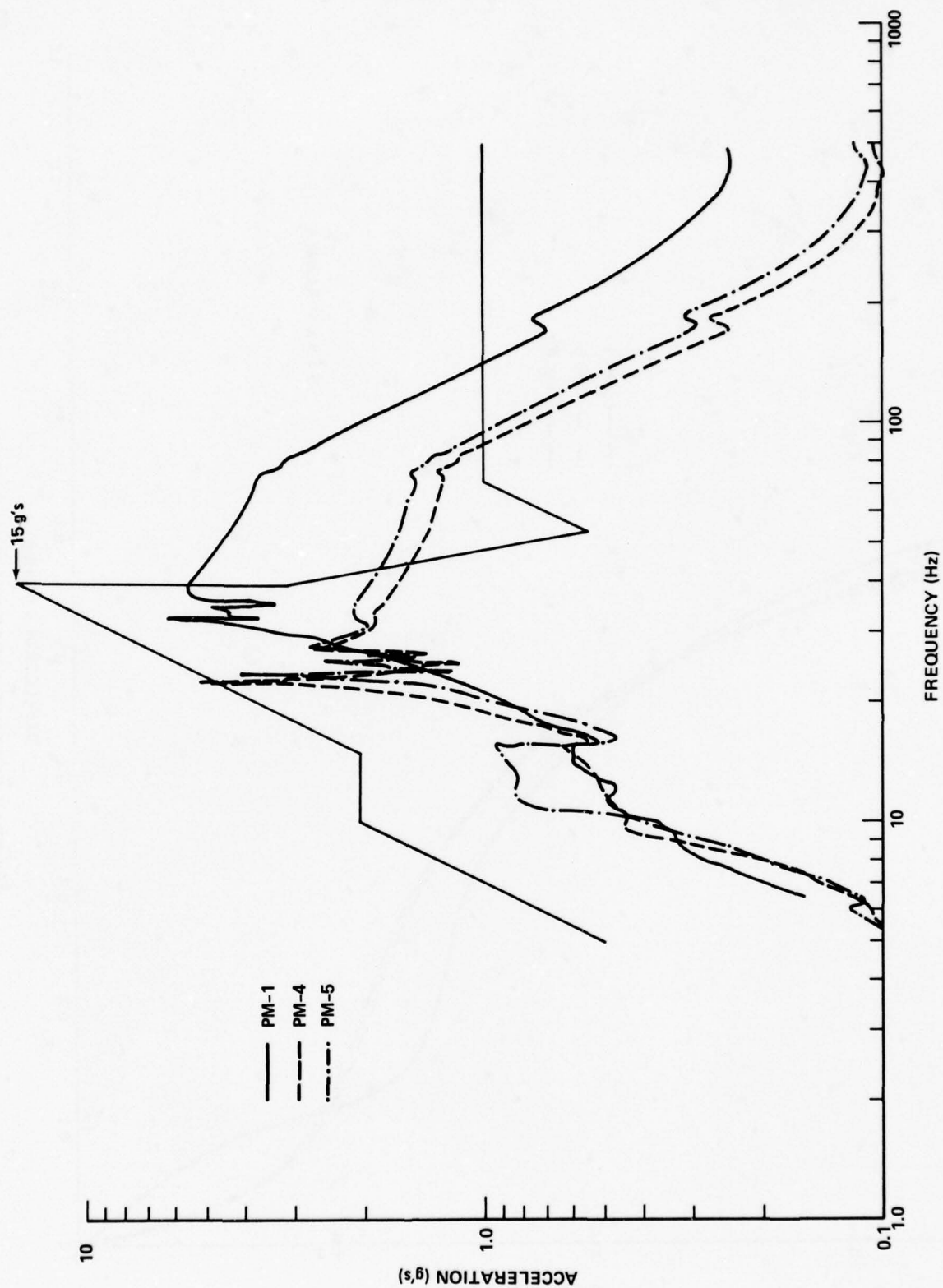


FIGURE 13. VIBRATION DAMPING SPECTRA FOR PM-1, PM-4 AND PM-5

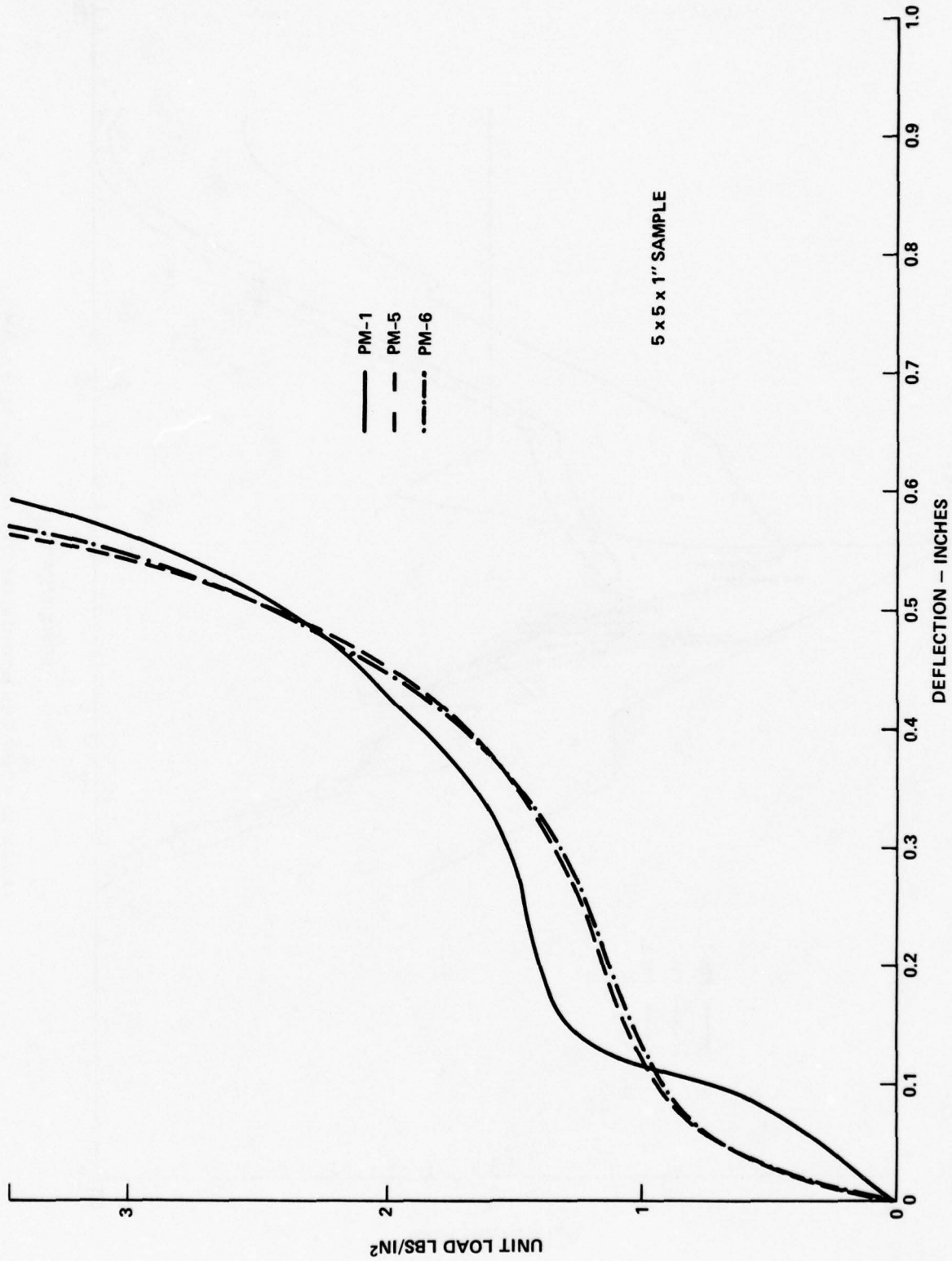


FIGURE 14. LOAD DEFLECTION CURVES FOR PM FOAMS

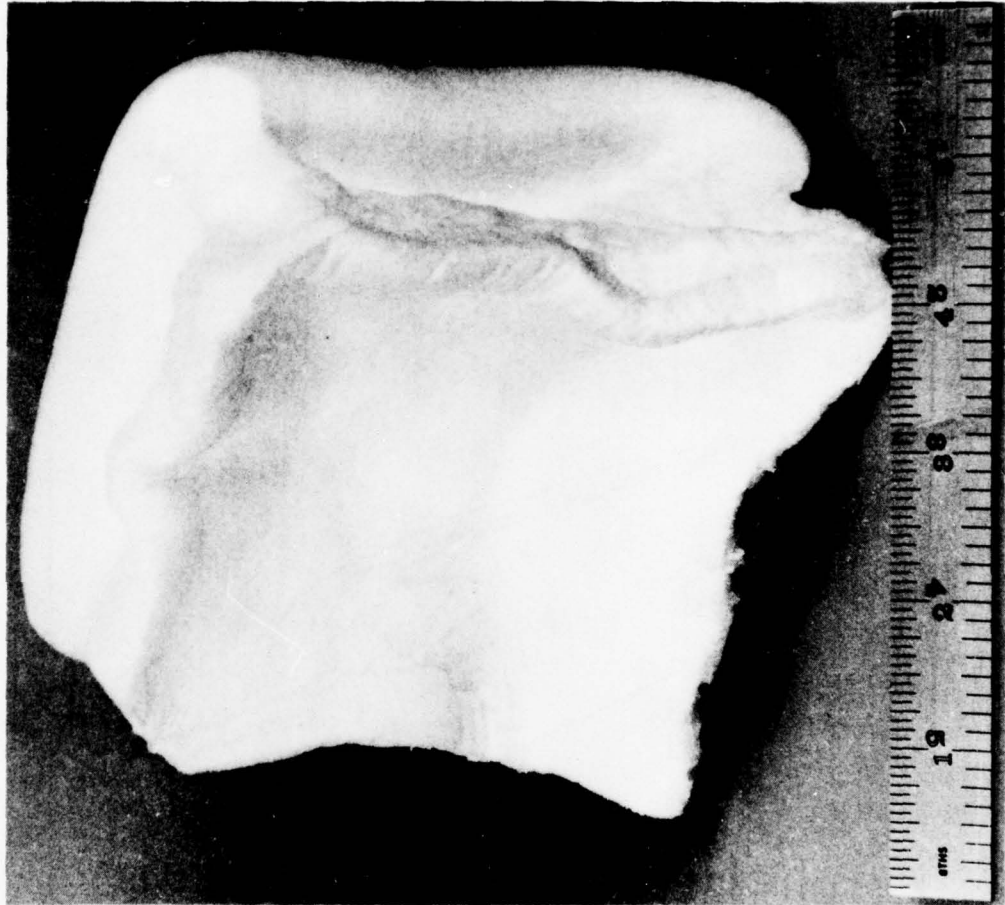


FIGURE 15. FOAM SHRINKAGE

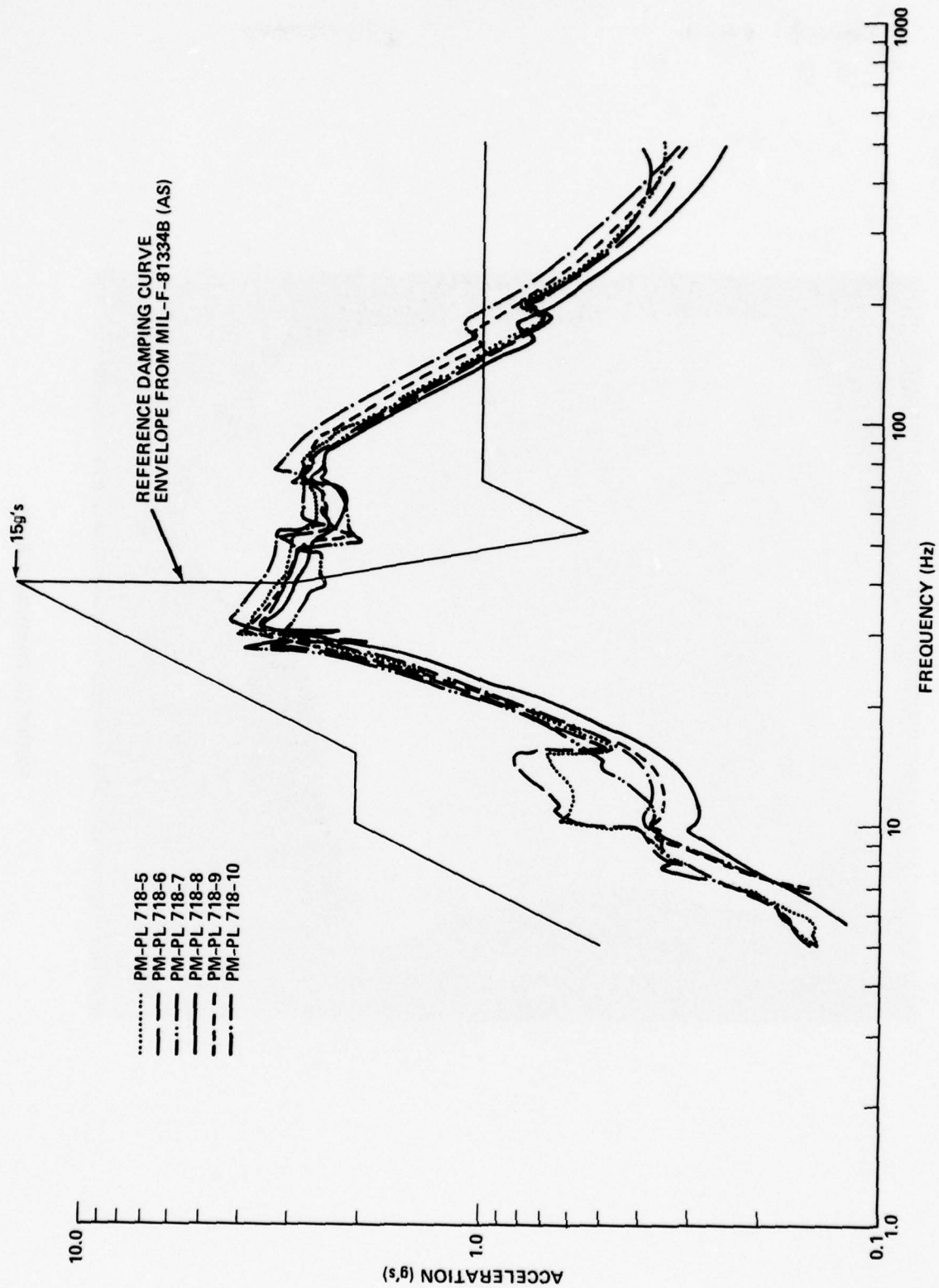


FIGURE 16. VIBRATION DAMPING SPECTRA FOR PM-PL 718-5 TO PM-PL 718-10



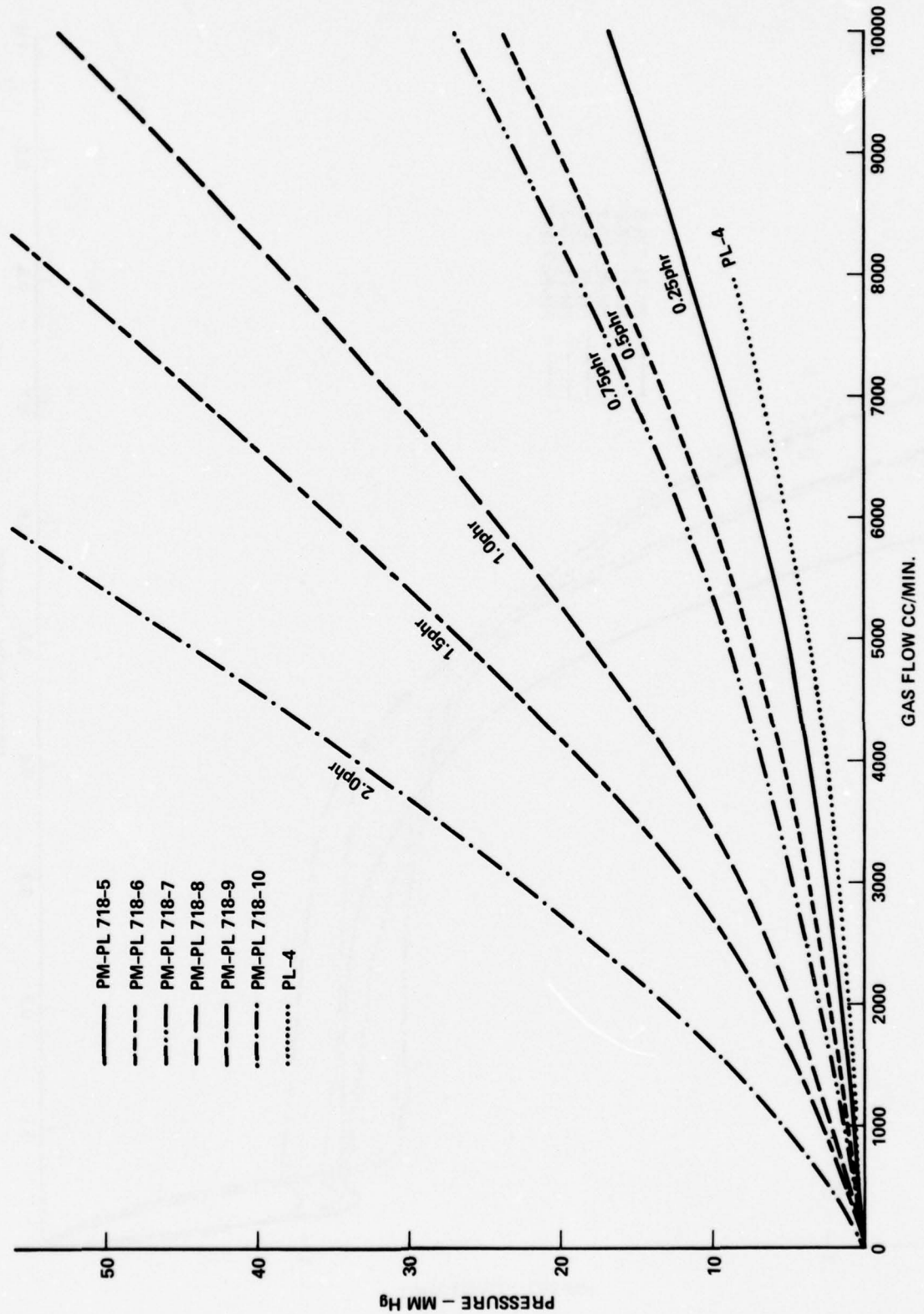


FIGURE 17. EFFECT OF SURFACTANT CONCENTRATION ON FOAM (PM-PL 718) POROSITY



FIGURE 18. LOAD DEFLECTION CURVES FOR PM-PL 718 FOAMS

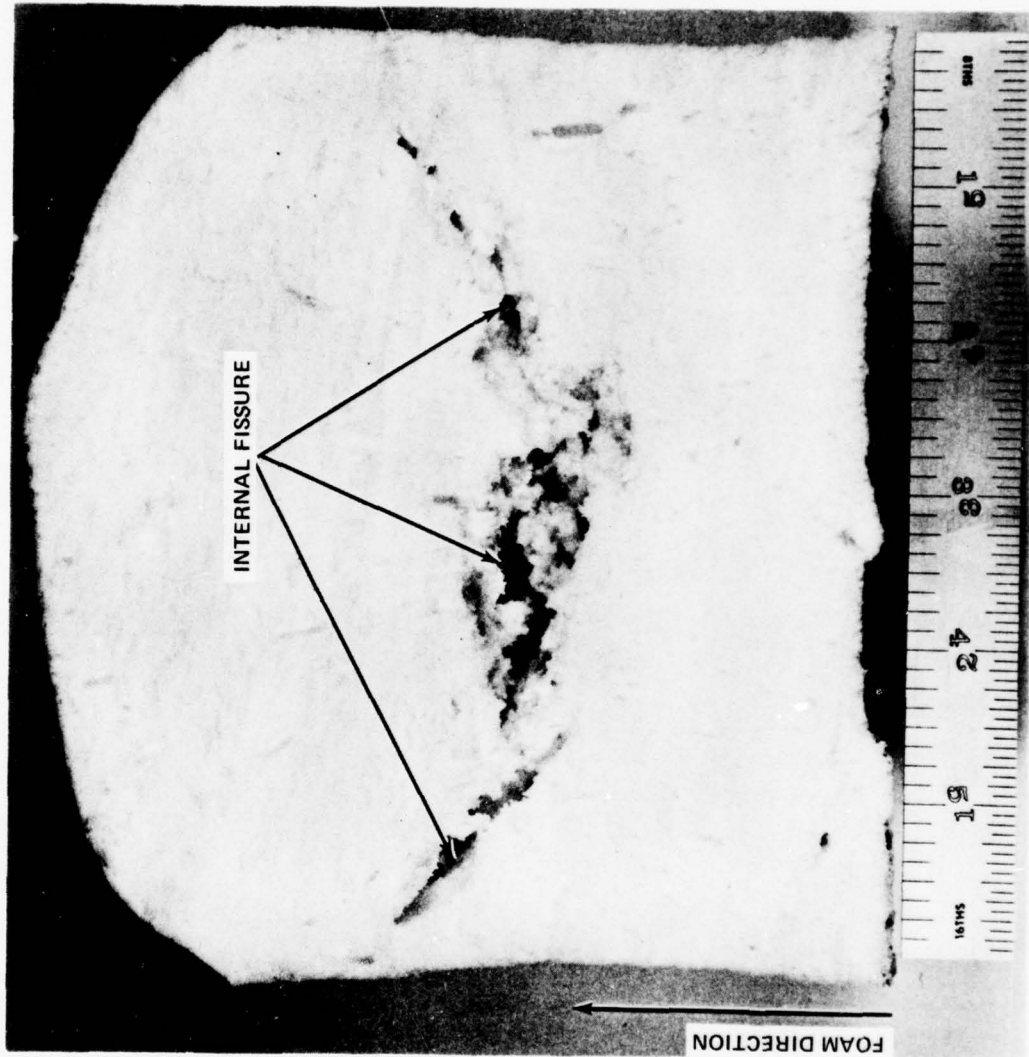


FIGURE 19. INTERNAL FOAM FISSURE

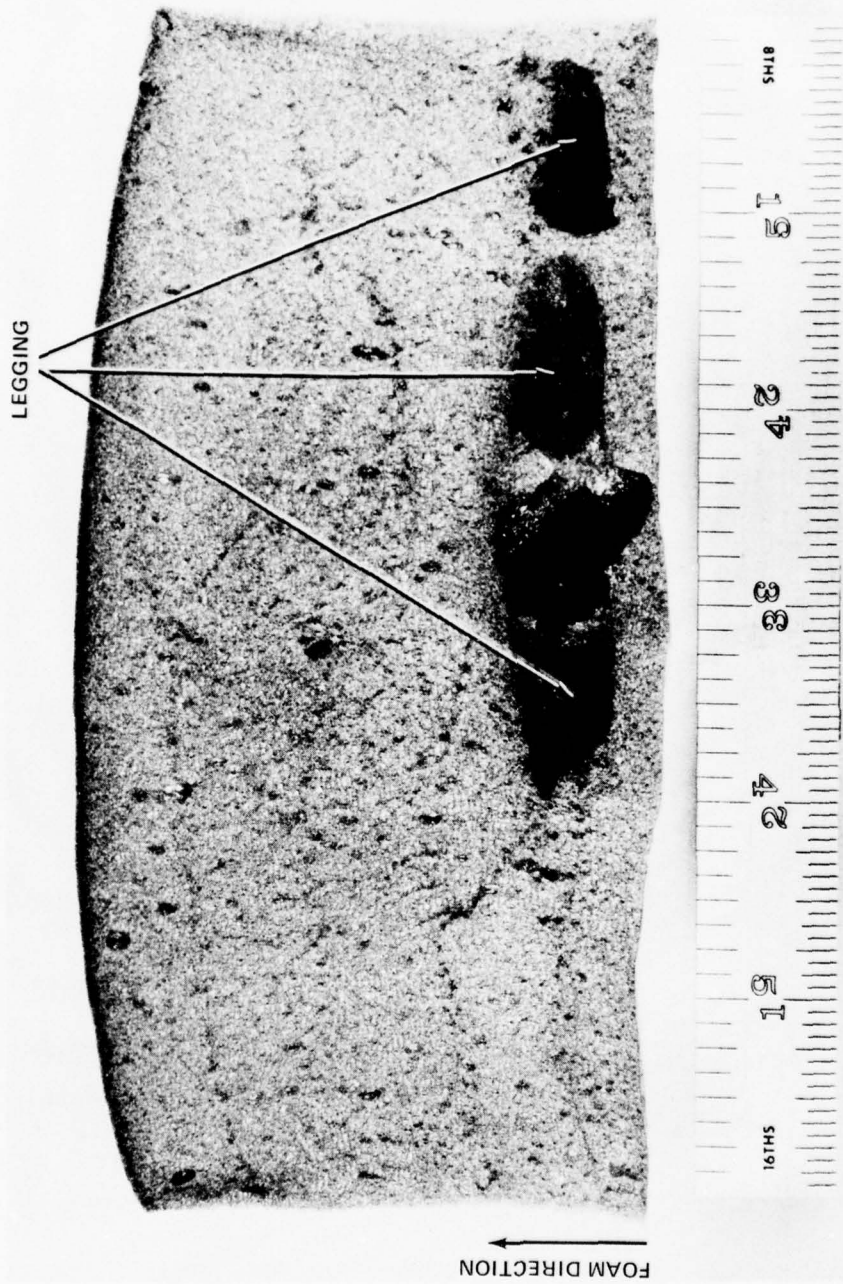


FIGURE 20. FOAM LEGGING



## APPENDIX A

## FOAM FORMULATIONS

PMPM-1

100	PM2000
1.2	DC198
0.3	T-9
0.6	33LV
2.0	H <sub>2</sub> O
29.0	TDI

15 sec. cream; cure 125°C/30 min; top tacky; coarse cells closed; boardy

PM-2

100	PM2000
2.5	DC198
0.3	T-9
0.6	33LV
2.0	H <sub>2</sub> O
29.0	TDI

15 sec. cream; cure 125°C/30 min; shrinkage and legging fine cells; closed cell

PM-3

100	PM2000
0.5	DC198
0.15	T-9
0.5	33LV
2.0	H <sub>2</sub> O
29.0	TDI

15 sec. cream; cure 125°C/30 min; very coarse cells; closed cell; boardy

PM-4

100	PM2000
0.25	B3136
0.3	T-9
0.2	33LV
2.0	H <sub>2</sub> O
29.0	TDI

20 sec. cream; cure 125°C/30 min; good foam; finer, open cells

PM-5

100	PM2000
0.5	B3136
0.3	T-9
0.2	33LV
2.0	H <sub>2</sub> O
29.0	TDI

20 sec. cream; cure 125°C/30 min; some gas release; fine, open cells

## PM-PL355

PM-PL355-1

90	PM2000
10	PL355
0.5	B3136
0.3	T-9
0.1	33LV
2.0	H <sub>2</sub> O
35.6	TDI

15 sec. cream; cure 125°C/30 min; closed cell; severe shrinkage on cooling

PM-PL355-2

90	PM2000
10	PL355
0.5	B3136
0.1	T-9
2.0	H <sub>2</sub> O
35.6	TDI

20 sec. cream; cure 125°C/30 min; severe shrinkage on cooling

## PM-PL718

PM-PL718-1

70	PM2000
30	PL718
0.5	B3136
0.3	T-9
0.2	33LV
2.0	H <sub>2</sub> O
29.2	TDI

20 sec. cream; cure 125°C/30 min; mostly open cell

PM-PL718-2

70	PM2000
30	PL718
0.5	B3136
0.2	T-9
0.2	33LV
2.0	H <sub>2</sub> O
29.2	TDI

20 sec. cream; cure 125°C/30 min; mostly open cell

PM-PL718-3

70	PM2000
30	PL718
0.5	B3136
0.1	T-9
0.3	33LV
2.0	H <sub>2</sub> O
29.2	TDI

20 sec. cream; foamed at ambient; cure 110°C/45 min;  
some top collapse; top tacky; mostly open cell

PM-PL 718-4

70	PM2000
30	PL718
0.5	B3136
0.4	T-9
0.3	33LV
2.0	H <sub>2</sub> O
29.2	TDI

15 sec. cream; foamed at ambient; cure 110°C/30 min; closed  
cell

PM-PL718-5

70	PM2000
30	PL718
0.25	B3136
0.2	T-9
0.3	33LV
2.0	H <sub>2</sub> O
29.8	TDI

15 sec. cream; rise at ambient; 110°C/30 min; top collapse;  
partially open cell

PM-PL718-6

70	PM2000
30	PL718
0.5	B3136
0.2	T-9
0.3	33LV
2.0	H <sub>2</sub> O
29.8	TDI

15 sec. cream; rise at ambient; 110°C/30 min; no fissures  
or collapse

PM-PL718-7

70	PM2000
30	PL718
0.75	B3136
0.2	T-9
0.3	33LV
2.0	H <sub>2</sub> O
29.8	TDI

15 sec. cream; rise at ambient; 110°C/30 min; no fissures  
or collapse

PM-PL718-8

70	PM2000
30	PL718
1.0	B3136
0.2	T-9
0.3	33LV
2.0	H <sub>2</sub> O
29.8	TDI

15 sec. cream; rise at ambient; 110°C/30 min; no fissures  
or collapse



PM-PL718-9

70	PM2000
30	PL718
1.5	B3136
0.2	T-9
0.3	33LV
2.0	H <sub>2</sub> O
29.8	TDI

15 sec. cream; rise at ambient; 110°C/30 min; no fissures or collapse

PM-PL718-10

70	PM2000
30	PL718
2.0	B3136
0.2	T-9
0.3	33LV
2.0	H <sub>2</sub> O
29.8	TDI

15 sec. cream; rise at ambient; 110°C/30 min; no fissures or collapse

PM-PL718-11

70	PM2000
30	PL718
0.5	B3136
0.2	T-9
0.2	33LV
2.0	H <sub>2</sub> O
29.7	TDI

20 sec. cream; rise at ambient; 125°C/30 min; good foam

PM-PL718-12

70	PM2000
30	PL718
0.5	B3136
0.2	T-9
0.1	33LV
2.0	H <sub>2</sub> O
29.7	TDI

20 sec. cream; rise at ambient; 125°C/30 min; good foam

PM-PL718-13

840	PM2000
360	PL718
6	B3136
2.4	T-9
1.2	33LV
24	H <sub>2</sub> O
356.4	TDI

12x formulation of PM-PL718-12; stirrer mixed; 45 sec. cream;  
rise at ambient but collapses at peak rise

PM-PL718-14

280	PM2000
120	PL718
2	B3136
0.8	T-9
0.4	33LV
8	H <sub>2</sub> O
118.8	TDI

4x formulation of PM-PL718-12; stirrer mixed; 17 sec. cream;  
rise at ambient; gas release through fissure but no collapse;  
125°C/30 min; large internal fissure

PM-PL718-15

280	PM2000
120	PL718
2	B3136
1.2	T-9
0.4	33LV
8	H <sub>2</sub> O
118.8	TDI

4x formulation PM-PL718-12 with increased T-9; stirrer mixed;  
15 sec. cream; rise at ambient; gas release through fissure;  
no collapse; 125°C/30 min; internal fissure

PM-PL718-16

280	PM2000
120	PL718
2	B3136
1.2	T-9
0.4	33LV
8	H <sub>2</sub> O
118.8	TDI

repeat of PM-PL718-15 with polyol-isocyanate prereactive at ambient for 45 min; stirrer mixed; 125°C/60 min; top split; internal fissure; closed cell; shrinkage on cooling

PM-PL718-17

70	PM2000
30	PL718
0.5	B3136
0.3	T-9
0.2	33LV
2.0	H <sub>2</sub> O
29.7	TDI
0.3	CONAP BLACK

repeat of PM-PL718-1 with colorant; 15 sec. cream; 125°C/10 min; open cell; soft texture; large internal fissure

PM-PL718-18

70	PM2000
30	PL718
0.75	B3136
0.3	T-9
0.2	33LV
2.0	H <sub>2</sub> O
29.7	TDI
	no colorant

repeat of PM-PL718-1 without colorant; 15 sec. cream; 125°C/10 min; open cell; soft; large internal fissure

PM-PL718-19

70	PM2000
30	PL718
1.0	B3136
0.4	T-9
0.2	33LV
2.0	H <sub>2</sub> O
29.7	TDI
	no colorant

17 sec. cream; rise at ambient; 125°C/10 min; excellent foam; open cell; soft texture

PM-PL718-20

70	PM2000
30	PL718
1.0	B3136
0.4	T-9
0.2	33LV
2.0	H <sub>2</sub> O
29.7	TDI
0.5	CONAP BLACK

repeat of PM-PL718-19 with colorant; 15 sec. cream; rise at ambient; 125°C/10 minutes; excellent foam; open cell; soft texture

PM-PL718-21

280	PM2000
120	PL718
4	B3136
1.6	T-9
0.8	33LV
8	H <sub>2</sub> O
118.8	TDI
2	CONAP BLACK

4x formulation PM-PL718-20; 15 sec. cream; rise at ambient; 125°C/30 min; open cell; soft texture

PM-PL718-22 Repeat of PM-PL718-21

PM-PL718-23 Repeat of PM-PL718-21

PM-PL718-24

50	PM2000
50	PL718
0.5	B3136
0.3	T-9
0.1	33LV
2.0	H <sub>2</sub> O
29.7	TDI

20 sec. cream; rise in oven; 125°C/10 min; slight side shrinkage; excellent foam; open cell; soft



PM-PL718-25

50	PM2000
50	PL718
1.0	B3136
0.4	T-9
0.2	33LV
2	H <sub>2</sub> O
29.7	TDI
0.5	CONAP BLACK

20 sec. cream; rise at ambient; 125°C/10 min; closed cell; legging

PM-PL718-26

50	PM2000
50	PL718
1.0	B3136
0.3	T-9
0.2	33LV
2	H <sub>2</sub> O
29.7	TDI
0.5	CONAP BLACK

20 sec. cream; rise at ambient; excellent foam; no shrinkage or legging; open cell

PM-PL718-27

200	PM2000
200	PL718
4	B3136
1.2	T-9
0.8	33LV
8	H <sub>2</sub> O
118.8	TDI
2	CONAP BLACK

17 sec. cream; rise at ambient; 125°C/30 min; excellent open cell foam

PM-PL718-28

200	PM2000
200	PL718
4	B3136
1.2	T-9
0.8	33LV

PM-PL718-28 (Continued)

8	H <sub>2</sub> O
118.8	TDI
2	CONAP BLACK

17 sec. cream; rise at ambient; 125°C/30 min; severe legging;  
partially closed cell

PM-PL718-29

200	PM2000
200	PL718
4	B3136
1	T-9
0.8	33LV
8	H <sub>2</sub> O
118.8	TDI
2	CONAP BLACK

15 sec. cream; rise at ambient; 125°C/10 min; severe legging

PM-PL718-30

200	PM2000
200	PL718
4	B3136
0.8	T-9
0.8	33LV
8	H <sub>2</sub> O
118.8	TDI
2	CONAP BLACK

fresh B3136; 15 sec. cream; rise at ambient; 125°C/10 min;  
excellent foam; open cell; soft texture

PM-PL718-31 Repeat of PM-PL718-30PM-PL718-32

30	PM2000
70	PL718
0.8	DC198
0.3	T-9
0.2	33LV
2	H <sub>2</sub> O
29.5	TDI

20 sec. cream; 125°C/30 min; closed cell; shrinkage on  
cooling

PM-PL718-33

30	PM2000
70	PL718
0.5	B3136
0.3	T-9
0.2	33LV
2	H <sub>2</sub> O
29.5	TDI

20 sec. cream; 125°C/30 min; no fissures; closed cell

PM-PL718-34

30	PM2000
70	PL718
0.5	B3136
0.15	T-9
0.3	33LV
2	H <sub>2</sub> O
29.7	TDI

15 sec. cream; 100°C/30 min; top shrinkage; legging

NOTE: This draft, dated MAY 1977  
prepared by Engineering Specifications & Standards Department  
has not been approved and is subject to modification. DO NOT  
USE FOR PROCUREMENT PURPOSES.

MIL-F-81334B(AS)  
Superseding  
MIL-F-81334A(AS)  
1 May 1969

## APPENDIX B

## MILITARY SPECIFICATION

FOAM, PLASTIC, FLEXIBLE, OPEN CELL  
POLYESTER TYPE, POLYURETHANE

This specification is approved for use by the Naval Air Systems Command, Department of the Navy, and is available for use by all Departments and Agencies of the Department of Defense.

## 1. SCOPE

1.1 Scope. This specification covers flexible, open cell, polyester type, polyurethane foam. (See 6.1)

1.2 Classification.

1.2.1 Grade. The materials furnished shall be of the following grades:

Grade I            Four pound per cubic foot density

Grade II           Six pound per cubic foot density

1.2.2 Form. The material shall be furnished in the following forms:

Sheet  
Strip  
As ordered (shapes).

## 2. APPLICABLE DOCUMENTS

2.1 Issues of documents. The following documents of the issue in effect on date of invitation for bids or request for proposal, form a part of this specification to the extent specified herein.

Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to: Engineering Specifications and Standards Department (Code 93), Naval Air Engineering Center, Lakehurst, NJ 08733, by using the self-addressed Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document or by letter.



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## SPECIFICATIONS

## FEDERAL

MMM-A-1617	Adhesive, Rubber, General Purpose
PPP-B-601	Box, Wood, Cleated Plywood
PPP-B-636	Box, Shipping, Fiberboard

## MILITARY

MIL-P-116	Preservation; Methods of
MIL-H-5606	Hydraulic Fluid, Petroleum Base, Aircraft, Missile and Ordnance
MIL-L-23699	Lubricating Oil, Aircraft Turbine Engines, Synthetic Base
MIL-M-81288	Mounting Bases, Flexible Plastic Foam

## STANDARDS

## MILITARY

MIL-STD-105	Sampling Procedures and Tables for Inspection by Attributes
MIL-STD-129	Marking for Shipment and Storage

(Copies of specifications, standards, drawings, and publications required by contractors in connection with specific procurement functions should be obtained from the procuring activity or as directed by the contracting officer.)

2.2 Other Publications - The following documents form a part of this specification to the extent specified herein. Unless otherwise indicated, the issue in effect on date of invitation for bids shall apply.

## AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)

ASTM D 412-75	Tests for Rubber Properties in Tension
ASTM D 1564-71	Testing Flexible Cellular Materials - Slab Urethane Foam

ASTM D 1692-74      Test for Rate of Burning or Extent of Burning  
of Cellular Plastics Using a Supported Specimen  
by a Horizontal Screen

ASTM F 74-73      Determining Hydrolytic Stability of Plastic  
Encapsulants for Electronic Devices

(Application for copies should be addressed to the American Society For  
Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.)

#### UNIFORM CLASSIFICATION COMMITTEE

##### Uniform Freight Classification Rules

(Application for copies should be addressed to the Uniform Classification  
Committee, Room 1106, 222 South Riverside Plaza, Chicago, IL 60606.)

(Technical society and technical association specifications and standards  
are generally available for reference from libraries. They are also  
distributed among technical groups and using Federal Agencies.)

### 3. REQUIREMENTS

3.1 First article. Unless otherwise specified, the polyurethane  
foam furnished under this specification shall be a product which has  
passed the first article inspection specified herein.

3.2 Material. The flexible, open cell polyester polyurethane foam  
shall be formed by the addition polymerization of diisocyanate and  
polyhydroxy compounds. Polyesters shall be used as hydroxyl terminating  
groups. The finished material shall consist of a network of predominantly  
open and interconnecting cells of uniform size and character.

3.2.1 Color - Unless otherwise specified (see 6.2), the color  
shall be as supplied.

3.2.2 Finish - Unless otherwise specified (see 6.2), all surfaces  
shall be cut-finished.

3.2.3 Form - The material furnished under this specification shall  
be in the form of sheets, strips, or as ordered (see 6.2).

3.3 Toxicity. The material shall have no adverse effect on the  
health of personnel when used for its intended purpose. Questions  
pertinent to this effect shall be referred by the procuring activity to  
the appropriate departmental medical service who will act as an advisor  
to the procuring activity.

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3.4 Properties. The finished foam properties shall be as specified in Table I.

TABLE I. PHYSICAL PROPERTIES

PROPERTY	REQUIREMENT		TEST PARA.
	GRADE 1	GRADE 2	
Density, pounds/cubic feet	4 $\pm$ 0.3	6 $\pm$ 0.3	4.6.2
Tensile strength, psi, min	30	25	4.6.3
Elongation, %, $\pm$ 100%	450	400	4.6.3
Tear resistance, pounds, min	4.5	4.0	4.6.4
	ALL GRADES		
Pore openings, pores/linear inch	60 $\pm$ 10		4.6.5
Flame resistance	Self extinguishing within 10 sec. No burning on foil		4.6.6
Compression set, %, max	10		4.6.7
Resilience, % recovery of original thickness	95		4.6.8
Properties after high temperature exposure, max % change from original values			4.6.9
Compression set	25		
Tensile strength	25		
Elongation	25		
Die cut resistance, % recovery of initial thickness	95 - No fusion of pores		4.6.10
Steam autoclave, properties after, max % change from orig. value			4.6.11
Compression set	15		
Tensile strength	15		
Fluid resistance, properties after, max % change from orig. values			4.6.12
Tensile strength	10		
Elongation	10		

TABLE I (Continued)

PROPERTY	REQUIREMENT ALL GRADES	TEST PARA.
Load deflection	All portions of curve within 15% of nominal Curve of Figure 1	4.6.13
Low temperature vibration	No tearing. Transmissability shall not exceed that of Figure 2	4.6.14
Hydrolytic stability, extrapolated lifetime at 23°C (73.4°F), minimum	7 years	4.6.15

3.5 Age restrictions. The flexible polyurethane foam shall not be older than 6 months from the date of manufacture when shipped for delivery to the Government.

3.6 Workmanship. The flexible polyurethane foam shall be a product manufactured by such processes as to meet all the requirements of this specification.

#### 4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for inspection. Unless otherwise specified in the contract, the contractor is responsible for the performance of all inspection requirements as specified herein. Except as otherwise specified in the contract, the contractor may use his own or any other facilities suitable for the performance of the inspection requirements specified herein unless disapproved by the Government. The Government reserves the right to perform any of the inspections set forth in the specification where such inspections are deemed necessary to assure supplies and services conform to prescribed requirements.

4.2 Classification of inspections. The inspection requirements specified herein are classified as follows:

1. First article inspection (see 4.3)
2. Quality conformance inspection (see 4.4)



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4.3 First article inspection. When specified (see 4.3.1 and 6.2), first article inspection shall consist of all the tests, examinations and inspections of this specification. Instructions as to testing and approving the first article shall be as specified in 6.3.

4.3.1 Prior approval. First article inspection or any part thereof, may be waived, at the discretion of the procuring activity when it has been determined that the polyurethane foam is from a previously approved batch.

4.3.2 Product changes. Changes in formulation, composition or production techniques shall be cause to reinspect the polyurethane foam product to all the requirements of this specification.

4.3.3 First article sample. First article sample shall consist of 3 sheets of foam 1 foot by 2 foot by 1 inch thick. The sample shall have been produced in the same facility intended for the contract production run. The first article sample shall be identified by labels or tags attached in a manner which will not affect the sample. The label or tag shall contain the following information:

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Sample for first article inspection

Foam, Plastic, Flexible, Open Cell, Polyester Type, Polyurethane

Name of manufacturer

Name of distributor (when applicable)

Manufacturer's product designation

Date of manufacture

4.3.4 Manufacturer's data. The manufacturer shall submit test reports which show the product furnished complies with all the requirements contained herein.

#### 4.4 Quality conformance.

4.4.1 Lot formation. Unless otherwise specified, a lot shall consist of all the polyurethane foam produced under essentially the same manufacturing conditions, at one plant designated a batch, and offered for inspection at one time. Unless otherwise specified, the lot size shall be expressed as the total number of yards supplied.

#### 4.4.2 Sampling.

4.4.2.1 Visual. Sample size shall be determined in accordance with Inspection Level I of MIL-STD-105. The unit of product shall be two feet. The samples shall be randomly selected from the material supplied. Inspection shall be as specified in 4.4.3.1.

4.4.2.2 Physical properties. A quantity of foam sufficient to perform tests specified in 4.4.3.2 shall be randomly selected from each lot submitted for inspection.

4.4.2.3 Packaging. A quantity of shipping containers fully packed, just prior to closure, shall be randomly selected from each lot in accordance with Inspection Level II of MIL-STD-105. The unit of product shall be one shipping container and the lot size shall be the number of shipping containers. Inspection shall be as specified in 4.4.3.3.

#### 4.4.3 Inspections.

4.4.3.1 Visual. Units of product selected in 4.4.2.1 shall be examined for defects as specified in Table II. The Acceptable Quality Level (AQL) for this inspection shall be 1.0 defects per 100 units.

TABLE II. VISUAL INSPECTION

Examination	Defect
Appearance	Sample gouged, torn, or otherwise damaged to prevent acceptance.
Finish	
Marking	Not as specified

4.4.3.2 Physical properties. Samples selected in 4.4.2.2 shall be examined to the properties in Table III. Failure of any test specimen to meet the requirements specified herein shall be cause to reject the lot represented by the specimen.

TABLE III. PHYSICAL PROPERTY INSPECTION

Property	Requirement	No. of test specimens	Results reported as
Density	Table I	2	pass or fail
Pore openings	Table I	5	pass or fail
Load deflection	Table I	3	pass or fail
Compression set	Table I	3	Average 1/

1/ All test values shall be reported and be within the requirements of Table I

4.4.3.3 Packaging. Samples selected in 4.4.2.3 shall be examined to the requirements of Table IV and all other requirements in Section 5. The Acceptable Quality Level (AQL) for this inspection shall be 2.5 defects per 100 units.

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TABLE IV. PACKAGING EXAMINATION

Examine	Defect
Packing (all forms)	<p>Not level specified; not in accordance with contract requirements</p> <p>Container not as specified; closures not accomplished by specified or required methods or materials</p> <p>Any nonconforming component; component missing, damaged, or otherwise defective affecting serviceability</p> <p>Inadequate application of components, such as: incomplete closures of case liners, container flaps, loose ends</p>

4.5 Standard conditions. Unless otherwise specified, all test samples shall be conditioned at  $23 \pm 1.1^{\circ}\text{C}$  ( $73.5 \pm 2^{\circ}\text{F}$ ) and  $50 \pm 4$  percent relative humidity prior to testing.

4.6 Test methods.

4.6.1 Appearance. The color, finish, and form of the foam shall be visually examined to the requirements of 3.2 and related subparagraphs.

4.6.2 Density. The density shall be determined in accordance with ASTM D 1564-71 using a 0.5 cubic foot specimen.

4.6.3 Tensile strength and elongation. Tensile strength and elongation determinations shall be made in accordance with ASTM D 1564-71.

4.6.4 Tear resistance. The material shall be tested in accordance with ASTM Method 1564-71.

4.6.5 Pore openings. The number of pore openings shall be visually determined at 10 power magnification. Photographs taken with a superimposed grid may be used to facilitate the measurement of the number of openings.

4.6.6 Flame resistance. Flammability characteristics shall be determined in accordance with ASTM D 1692-74. Time shall be counted at instant of flame removal.

4.6.7 Compression set. The compression set of the polyurethane foam shall be determined in accordance with ASTM D 1564-71. Specimens shall be deflected 50 percent.

4.6.8 Resilience. The resilience (immediate recovery after compression) of the foam shall be determined as specified in Suffix D of ASTM D 1564 except that the compression shall be maintained only one (1) minute at standard conditions. The specimen shall be re-measured immediately upon removal from the compression apparatus. Percent recovery of original thickness shall be in accordance with the requirement in Table I.

4.6.9 High temperature resistance. Tensile strength and compression set specimens shall be prepared and exposed in an air circulating oven at  $140 \pm 1^{\circ}\text{C}$  ( $284 \pm 2^{\circ}\text{F}$ ) for 22 hours. The specimens shall be cooled to standard conditions, then tested for tensile strength, elongation and compression set as specified in 4.6.3 and 4.6.7 respectively. Percent change from original values shall be reported.

4.6.10 Die cut resistance. Three specimen shall be die-cut at ambient conditions as specified in ASTM D 412 using die "C". Each specimen shall be measured to determine percent recovery of original thickness and then visually examined for evidence of fusion.

4.6.11 Steam autoclave. Three compression set specimens (4.6.7) shall be placed in an autoclave and exposed as follows:

Grade I specimens - 15 pounds per square inch for 2 hours  
Grade II specimens - 15 pounds per square inch for 3 hours

Test specimens shall be removed from the autoclave and dried in a circulating air oven at  $70 \pm 1^{\circ}\text{C}$  ( $158 \pm 2^{\circ}\text{F}$ ) for 1 hour, then conditioned at standard conditions (4.5) for 24 hours before testing for compression set as specified in 4.6.7. Percent change from original compression set values shall be reported.

4.6.12 Fluid resistance. Three tensile strength specimens shall be completely immersed in hydraulic fluid conforming to MIL-H-5606 and three specimens in lubricating fluid conforming to MIL-L-23699. Immersion time at standard conditions shall be one (1) hour  $\pm 5$ , -0 minutes. The specimens shall be removed from the fluid, the excess fluid removed and tested as specified in 4.6.3. Percent change from original tensile strength and elongation values shall be reported.

4.6.13 Load deflection. Three specimens, 5 by 5 by 1 inch ( $\pm 1/16$  inch all dimensions), shall be prepared. A uniform compressive load shall be applied to three (3) specimens over the range from zero load to that load which results in a specimen deflection of 70 percent.



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Loading may be continuous or incremental, but for every measured load value the specimen deflection shall be measured. A graph of unit load (in pounds per square inch) vs. deflection, in inches of unloaded foam thickness shall be made using the average of three specimens. The plot of compressive load shall be in agreement with the requirement in Table I.

4.6.14 Vibration at low temperature - The test specimen shall consist of a foam pad, 6 by 8 by 1.0 inch thick, cemented, using adhesive conforming to MMM-A-1617, between two aluminum plates. A load of 16 pounds, measuring 6 by 8 inches, of uniform density and thickness, shall be secured to the upper plate. The dimension tolerance shall be  $\pm 1/16$  inch. The lower plate shall be rigidly mounted on a vibration platform in its upright attitude. The temperature of the ambient air in an enclosure surrounding the test specimen shall be reduced to  $-40 \pm 1^\circ\text{C}$  ( $-40 \pm 2^\circ\text{F}$ ) and allowed to stabilize for 1 hour. An input of simple harmonic motion shall be applied along the vertical axis only. The frequency shall be varied uniformly between 5 and 500 cps. The entire range of frequencies from 5 to 500 cps and return to 5 cps shall be transversed. The applied vibration amplitude shall be in accordance with Figure 3. The response shall be measured along the vertical axis only. The test specimen shall be vibrated for two hours along the vertical axis only at the predominant resonant frequency, in accordance with Figure 3.

4.6.15 Hydrolytic stability. Hydrolytic stability of the foam shall be determined in accordance with ASTM F 74-73 and the following:

4.6.15.1 Procedure. Tensile specimens shall be prepared as specified in ASTM D 1564-71. Five specimens shall be tested to determine the initial data point (zero time) for all exposure temperatures. Twenty specimens shall be placed in the hydrolytic chamber and exposed at  $97 \pm 1^\circ\text{C}$  ( $206.6 \pm 2^\circ\text{F}$ ). Five specimens shall be removed at each of four specific time intervals to determine the data points. The specimens shall be conditioned at standard conditions (4.5) for 2 hours before tensile tests in accordance with ASTM D 1564-71. This procedure shall be repeated at additional exposure temperatures of  $85 \pm 1^\circ\text{C}$  ( $185 \pm 2^\circ\text{F}$ ) and  $71 \pm 1^\circ\text{C}$  ( $160 \pm 2^\circ\text{F}$ ).

4.6.15.2 Reporting of results. The average value for each data point shall be plotted against time on rectangular coordinate paper. The exact failure time at each exposure temperature shall be determined by interpolation to 5 psi, the theoretical failure data point. Each failure time (one for each temperature) shall be plotted against its respective exposure temperature as specified in ASTM D 74-73, then extrapolated to  $23^\circ\text{C}$  ( $73.4^\circ\text{F}$ ). The service time in years shall conform to the requirement in Table I.

## 5. PACKAGING.

### 5.1 Packaging. Packaging shall be Level A or C as specified (See 6.2)

5.1.1 Level A. Unless otherwise specified, the foam shall be packaged in accordance with Method III of MIL-P-116. Sheets, strips or as ordered shapes shall be packaged in containers conforming to PPP-B-636, Type CF, Class Weather Resistant, Grade V3c or PPP-B-601, overseas type. Closure and waterproofing shall be in accordance with the applicable specification appendix. Foam sheets shall be separated with paper or other suitable separating sheets.

5.1.2 Level C. The foam shall be packaged in accordance with the manufacturer's commercial practice.

### 5.2 Packing. Packing shall be Level A, B, or C as specified.

5.2.1 Levels A and B. Foam packaged as specified in 5.1.1 requires no further overpacking.

5.2.2 Level C. The material packaged in accordance with 5.1.2 shall be packed to afford protection against damage during direct shipment from the source of supply to the first receiving activity for immediate use. Containers shall comply to the Uniform Freight Classification Rules or other regulations applicable to the mode of transportation.

5.3 Marking. Each container shall be marked in accordance with MIL-STD-129. Marking shall include, but not be limited to, the following information:

- (1) Manufacturer's name and location
- (2) Material trade name
- (3) Net weight
- (4) Lot number, batch identification and date of manufacture
- (5) Number and revision of this specification

## 6. NOTES

6.1 Intended use - This flexible, low density, open cell, polyester type polyurethane foam is intended for use in conjunction with MIL-M-81288 for shock cushioning and vibration absorption. Adhesive bonding of the foam to the mounting base metal parts is essential and the effective bond must be stronger than the foam itself. This material is not recommended

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for applications involving static loading where the static deflection exceeds ten per cent compression from unloaded foam thickness.

## 6.2 Ordering data.

6.2.1 Procurement requirements. Procurement documents should specify the following:

- a. Title, number, and date of this specification.
- b. Grade required.
- c. Form required.
- d. Quantity desired.
- e. Level of packaging and packing required (see 5.1 and 5.2)
- f. Any special marking required.
- g. First article, when required (see 4.3.1 and 6.3).

6.2.2 Data requirements. When this specification is used in a procurement which incorporates a DD Form 1423 and invokes the provisions of 7-104.9(n) of the Armed Services Procurement Regulations, the data requirements identified below will be developed as specified by an approved Data Item Description (DD Form 1664) and delivered in accordance with the approved Contract Data Requirements List (DD Form 1423) incorporated into the contract. When the provisions of ASPR-7-104.9(n) are not invoked, the data specified below will be delivered by the contractor in accordance with the contract requirements. Deliverable data required by this specification is cited in the following paragraphs:

<u>Paragraph</u>	<u>Data Requirement</u>	<u>Applicable DID</u>
4.3	First Article Inspection Reports	DI-T-5239-Inspection Test Reports

(Copies of data item descriptions required by contractors in connection with specific procurement functions should be obtained from the procuring activity or as directed by the contracting officer.)

6.3 Contracts or orders shall specify the following provisions for the first article inspection:

6.3.1 Whether first article inspection is required. When a contractor is in continuous production of the polyurethane foam from contract to contract, consideration should be given to waive the first article inspections. If inspection is required, indicate:

- a. Where the first article inspection is to be conducted (at the contractor's plant, Government or commercial laboratory).
- b. That the approval of first article samples or the waiving of the first article inspection shall not relieve the contractor of his obligation to fulfill all other requirements of the specification and contract.

6.4 Uniform density. In order that users may be assured of uniform density across the foam sheet or pad, they should require the foam manufacturers to cut the foam horizontally with respect to the direction it is foamed.

6.5 Changes from previous issue. Asterisks are not used in this revision to identify changes with respect to the previous issue, due to the extensiveness of the changes.

Preparing activity:  
Navy - AS  
(Project No. 5340-N067)



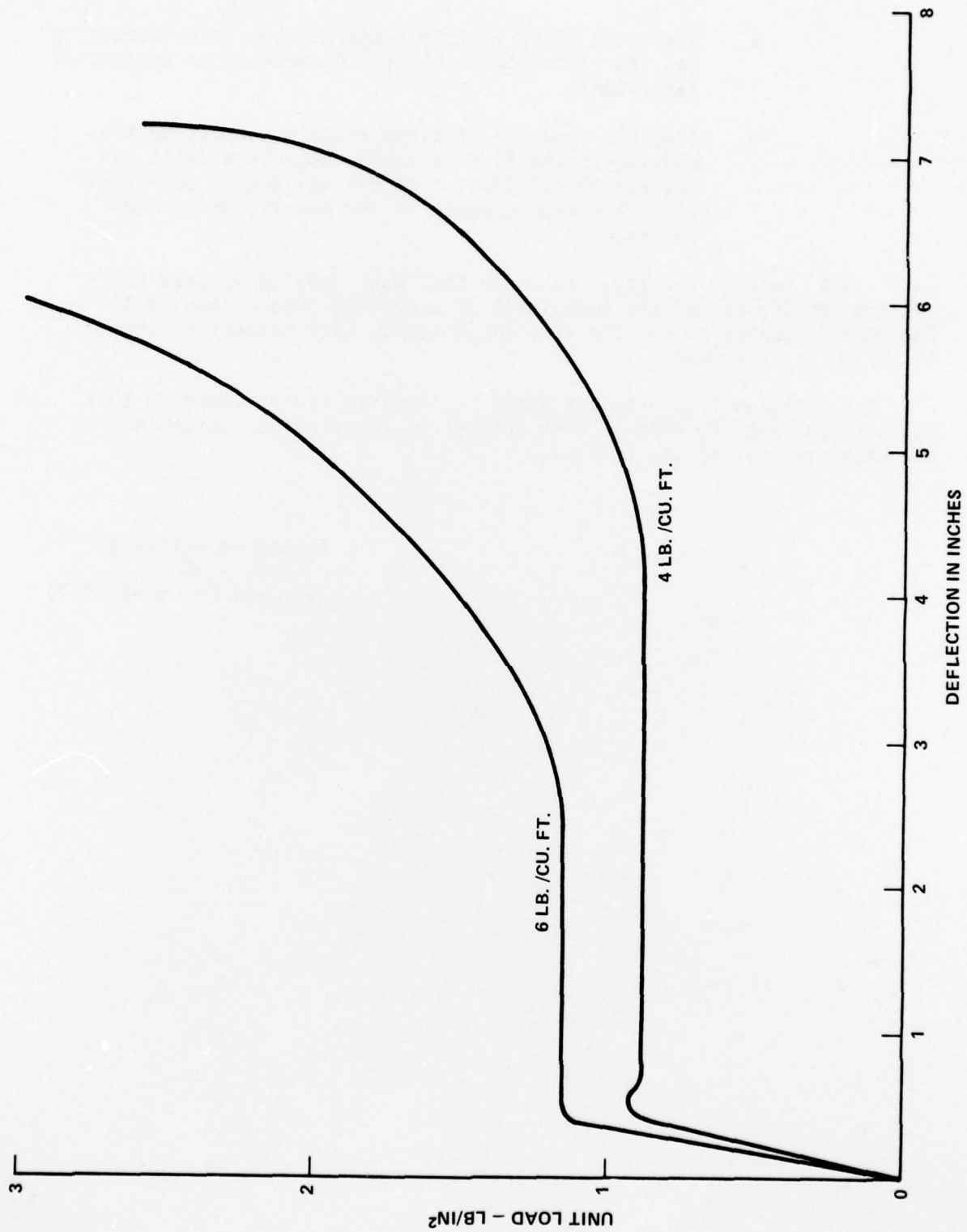


FIGURE 1. LOAD DEFLECTION CURVE FLEXIBLE POLYURETHANE FOAM SAMPLE SIZE 5" X 5" X 1"



FIGURE 2. VIBRATION TRANSMISSIBILITY

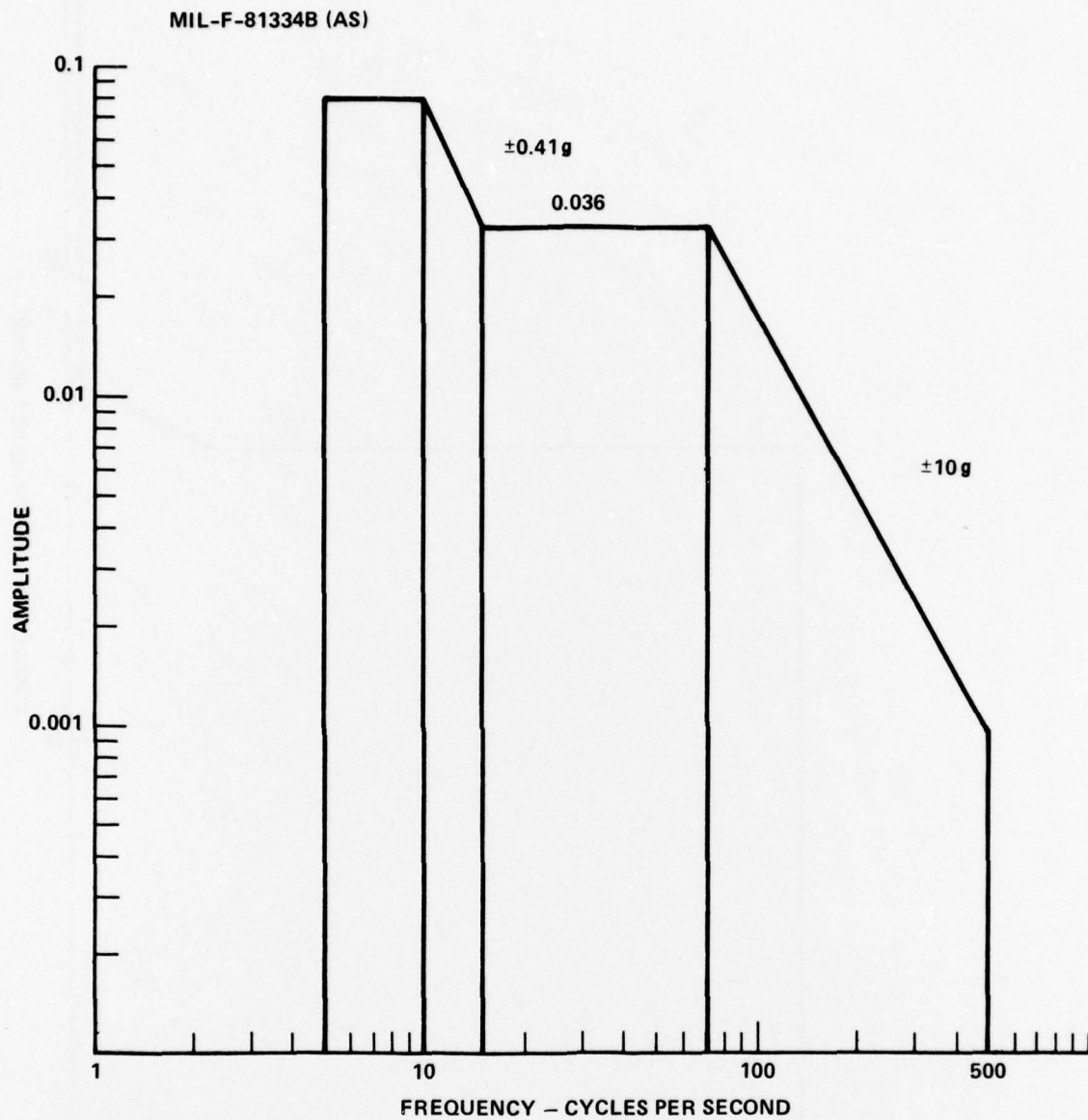


FIGURE 3. APPLIED VIBRATION

CHEMICAL GLOSSARY

Resins

PM	Polymeg 2000 - poly(oxytetramethylene) glycol (Quaker Oaks Company)
PL355	Pluracol 355 - amine based poly(oxypropylene) glycol (BASF Wyandotte Chemical Company)
PL718	Pluracol 718 - poly(oxypropylene) triol (BASF Wyandotte Chemical Company)

Surfactants

DC198	Silicone surfactant (Dow Corning)
B3136	Silicone surfactant (Th. Goldschmidt Products Corporation)

Amine Catalyst

DABCO 33LV	A 33.3% solution of triethylenediamine in dipropylene glycol (Air Products)
------------	---

Tin Catalyst

T-9	Stannous octoate ( M & T Chemicals)
-----	-------------------------------------

Isocyanate

TDI	80/20 mixture of 2,4-toluenediisocyanate to 2,6-toluenediisocyanate (Dow Chemical)
-----	--

Colorant

CONAP BLACK	Inorganic pigment milled in inert liquid medium (CONAP, Inc.)
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