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E-1524

EVALUATION OF URETHANE FOAM FOR POTTING

by

Samuel C. Smith

February 1964

MIT INSTRUMENTATION LABORATORY
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EVALUATION OF URETHANE FOAM FOR POTTING

ABSTRACT

A concentrated amount of effort has been expended to eliminate some deficiencies in urethane foam potting and to improve its reliability. Causes of such problems as blistering, crazing, coarse cell structures, and improper expansion have been found and essentially corrected.

Using percent density and adjusted bulk density as criteria, we found that best results are obtained when Nopco G-506 and Chempol 30-1364 are used for foam potting, with the mixing medium being machine-mix or power-mix. The Chempol does have a slight advantage in that it affords a longer working time.

The use of Nopco G-508 and Chempol 30-1365 is not ruled out when the mixing medium is machine. Handmixing is not recommended; should it be used, however, rapid stirring is necessary.

In the area of using an inorganic pigment dye with the foam, experiments proved conclusively that there is no adverse effect when the pigment is used either at the time it is needed or when it is pre-mixed.

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EVALUATION OF URETHANE FOAM FOR POTTING

I. INTRODUCTION

In order to eliminate some problems in urethane foam potting and be assured of a reliable product, a fairly extensive test was conducted on two types of materials, namely Nopcofoam G-506 and G-508, products of Nopco Chemical Company; and Chempol 30-1322, 30-1364, and 30-1365, products of Freeman Chemical Co.

The test proved categorically that the method of mixing has a significant effect on the foam and that machine mixing and power-mixing are far superior to hand-mixing.

The test also proved that if only such amount as would render a certain rated density is poured in a closed mold, the mold would never be completely filled. Several factors are responsible for this: 1) Metal Molds and other materials which dissipate heat rapidly, will increase the skin density. This is a desirable quality in potting since it acts as a protective coat to help keep moisture out. This desirable skin coating should be properly controlled, however, by preheating mold and proper curing of foam; otherwise crazing may result; 2) The density is affected by the size and configuration of the part to be filled; 3) Thin or shallow sections resist flow, resulting in higher density, i.e., the ratio of surface area to volume will affect density; 4) Forcing air through comparatively small holes due to the constraint of the closed mold will affect density.

These and other factors must be allowed for and our test has produced these allowances.

The figures given may be used within plus or minus 10 percent with good results. Furthermore, when it is difficult to calculate the true volume of a part to be filled as in the case of many electronic modules, a fair estimate will suffice. More or less of the foam will be expelled through the air holes to compensate for the error in the amount of foam poured.

The following is worthy of consideration: provided the heat distortion temperature is sufficiently high, the main determining factor in choosing between a higher and lower density foam material is strength. The higher the density, the higher will be the required increase of the rated density. As shown in the tables, when power is used, the recommended adjusted density with a 6 lb per cu. ft foam is 170%; with an 8 lb per cu. ft foam, 185%; with a 10 lb per cu. ft foam, 195%. Good foam potting requires keeping the increase in density at a minimum. Unless conditions warrant going to a higher density foam, it is better to use a lower one.

Some 75 samples were evaluated. Most of these are included in Tables 1 and 2 of this report.

II. NOPCOFOAM

A. G-508

1. Slow Stirring

   a. An amount of compound equivalent to 130% of its rated density was poured in a 2"x2"x2" chromium-plated steel mold. After curing, it was discovered that the mold was not quite filled. The experiment was repeated with identical results (#1 and #2).

   b. The amount of compound poured in was then increased to 175% of the rated density and allowed to cure as before. This amount proved to be sufficient; however, the lower part of the cube was much more dense than the upper part. The experiment was repeated with identical results (#N3, #N4, and #N9).

   c. We then increased the rated density to 200-225 lb. per cu. in. density with no significant improvement.

2. Rapid Stirring

   The above experiments were made with a slow mixing action. Using the same 200-225% rated density, three additional samples were made, this time with a rapid mixing action. These samples had improved appearances with uniform density and fine cell structures (See #N21, #N22).

3. Machine Stirring

   Several machine-mixed samples were made. Except for some crazing which might have been

due to mold release application, the results were superior even to the rapid-mixed (hand) ones. While our hand-mixed samples exhibited some air bubbles, not one of the machine-mixed ones contained air bubbles. Furthermore, the required adjusted density (150-170%) is lower.

B. G-506

1. Slow Stirring

Using 6 lb. per cu. in. density foam, an amount equivalent to 225% of the rated density was poured in each of 3 steel molds (slow stirring). After curing, the net adjusted density was between 219 and 224, and the appearance was the same as G-508 with slow stirring.

2. Rapid Stirring

a. The experiment was repeated using rapid stirring. Superior results were obtained. All three samples had uniform density and fine cell structure, with a resulting net density of 175-195%.

b. Several more samples were made as in a with identical results.

3. Power Stirring

a. Three mixtures consisting of 225%, 200% and 175%, respectively, of the rated density were poured in the steel molds. After curing, the net rated density of the samples was 163%, 167% and 167% (Nos. 39, 40, 41 of Table 1). The adjusted density was 9.8, 10.0 and 10.0 respectively. Here it was observed that the

more the rated density is increased, the greater the amount of material which is expelled through the air holes, leaving a cured sample with a constant (approximately) adjusted density. This offers better weight control. In addition, the samples had fine appearances with essentially no bubbles.

b. Three other samples were made with the same results and observations.

III. CHEMPOL

A. 30-1365 (8lb density)

1. Slow Stirring

   a. The experiment was as in II-A-1-a (Nopcofoam), the result being essentially the same.

   b. The experiment was as in II-A-1-b. Cell structures were slightly finer, otherwise the results were the same.

   c. The experiment was as in II-A-1-c, the results being essentially the same.

2. Rapid & Power Stirring

   The rapid stirring, and power stirring were processed as in the case of Nopcofoam G-506 with the results being essentially the same.

3. Machine Stirring

   Very good results were obtained, as with Nopcofoam (G-506), but without the crazing effect experienced with Nopcofoam. It should, however, be noted that up to this point the method of mold release application was not controlled. Subsequent power-mix experiments with controlled mold release application indicated no difference in the various samples.

B. 30-1364 (6 lb density)

1. Slow Stirring

   Experiment repeated as in II-B-1. The results were the same except that the adjusting density was lower (164, 174, and 176%). In other words more foam was expelled through the air holes than in the case of the Nopcofoam.

2. Rapid Stirring

Experiment repeated as in II-B-2 (a and b), with same good results as obtained in II-B-2. Again, the adjusting density was somewhat lower (154, 171, and 156%).

3. Machine Stirring

There was no 30-1364 material available for machine testing. Based on other observations, it is expected that 30-1364 would produce results similar to Nopcofoam G-506.

4. Power Stirring

The same experiment was performed as with the Nopco G-506 (II-A-3-a), with very good results as with the Nopcofoam.

C. 30-1322 (10 lb density)

In order to prove that the adjusted density increases proportionately to the rated density, we made three samples with 250, 225, and 200% of the rated density put in the mold (Nos. 36, 37, 38 Table 2). As indicated by the density after curing, not less than 195% should be poured in to fill the mold completely and of course this results in an adjusted density of 19.5, approximately twice as heavy as the 6 lb density material, instead of 1 2/3 times as heavy.

IV. MOLD RELEASE

For best results, Simoniz paste wax or equivalent wax should be used as a mold release. Two coats should be applied and polished. (polishing each coat).

V. BLACK PIGMENT DYE

Experiments were conducted to determine what effect, if any, adding an organic dye, pre-mixed with the catalyst, will have on the foam. Several samples were used, some with the pigment dye, some without. The results were identical.

VI. SUMMARY

A. Tables 1 and 2 summarize the results of some of the samples. If the 6 lb density material is squeezed hard with the fingers, slight indentation will be formed. This indentation is slightly less with the 8 lb density and does not appear on the 10 lb density. However, in going from the 6 lb density to the 8 lb density, the adjusted density increases from 10 to 15 lb/ft^3 (Table 2). The additional firmness is so slight that it does not warrant selecting the more dense one at the expense of the more that 50% increase.

B. Figure 1 shows the result of a slow-mixed sample. Note the coarse cell structures and non-uniform density.

Figure 2 showsthat increasing the density of a 8 lb density foam by only 30 percent is not sufficient to fill the mold.

Figure 3 compares a rapid-mixed and a slow-mixed sample. Note fine cell structure and uniform density of the sample on the right in spite of its lower weight.

Figure 4 shows distinction between slow-mix and rapid-mix even in a flat module.

Figure 5 shows the result of power-mix. Note its smooth, uniform density quality.

C. Not only is the appearance of the power-mix superior to the hand-mix (rapid), but this method of mixing affords a means of measuring the degree of stir. See Table 3 for list of advantages and disadvantages of machine, power and hand mixing.

TABLE I

TRADE NAME	Number	Volume	Rated Density	% Density	% Density after curing	Weight	Adjusted Density (lb/ft^3)	Method of mixing	REMARKS
Nopcofoam G-508	N1	8	8	130	130	22.0	10.4	S	Amount put in was insufficient to fill mold.
Nopcofoam G-508	N2	8	8	130	130	22.0	10.4	S	Amount put in was insufficient to fill mold.
Nopcofoam G-508	N3	8	8	175	175	30.0	14.0	S	Lower portion more dense than upper portion.
Nopcofoam G-508	N4	8	8	175	175	30.0	14.0	S	Lower portion more dense than upper portion.
Nopcofoam G-508	N9	8	8	175	175	30.0	14.0	S	Lower portion more dense than upper portion.
Nopcofoam G-508	N21	8	8	200	200	33.6	16.0	R	Uniform density. Improved appearance. None of foam expelled through air holes.
Nopcofoam G-508	N22	8	8	225	220	37.0	17.6	R	Uniform density. Improved appearance. Some foam expelled through air holes.
Nopcofoam G-508	N19	8	6	225	224	28.2	13.4	S	Lower portion more dense than upper portion.
Nopcofoam G-508	N20	8	6	225	219	27.8	13.1	S	Lower portion more dense than upper portion.
Nopcofoam G-508	N23	8	6	225	180	22.5	10.8	R	Very good appearance. Uniform density.
Nopcofoam G-508	N24	8	6	225	195	24.5	11.7	R	Very good appearance. Uniform density.
Nopcofoam G-508	N25	8	6	225	175	22.0	10.5	R	Very good appearance. Uniform density.
Nopcofoam G-508	A50	5.2	8	175	159	17.3	12.7	M	General appearance good.
Nopcofoam G-508	A70	5.2	8	175	158	17.2	12.6	M	General appearance good.
Nopcofoam G-508	A80	5.2	8	175	171	18.7	13.7	M	General appearance good.
Nopcofoam G-508	B50	5.9	8	175	150	18.7	12.0	M	General appearance good.
Nopcofoam G-508	B70	5.9	8	175	159	19.9	12.7	M	General appearance good.
Nopcofoam G-508	B80	5.9	8	175	173	21.7	13.9	M	General appearance good.
Nopcofoam G-506	39	8	6	225	163	20.5	9.8	P	Very good appearance. No bubbles.
Nopcofoam G-506	40	8	6	200	167	21.0	10.0	P	Very good appearance. No bubbles.
Nopcofoam G-506	41	8	6	175	167	21.1	10.0	P	Very good appearance. No bubbles.

TABLE 2

TRADE NAME	Number	Volume (cu. in.)	Density (Rated) (lb/in^3)	% Density Put in	% Density after curing	Weight in grams	Adjusted Density (lb/ft^3)	Method of mixing	REMARKS
Freeman	27	8	8	199	199	33.5	15.9	S	None of foam escaped through air holes. Considerable bubbles at top.
Freeman	28	8	8	202	202	34.0	16.2	S	None of foam escaped through air holes. Considerable bubbles at top.
Freeman	29	8	8	198	198	33.2	15.8	S	None of foam escaped through air holes. Considerable bubbles at top.
Freeman	30	8	8	198	198	33.5	15.9	R	Except for finer cell structure, none of foam escaped through air holes. Considerable bubbles at top.
Freeman	31	8	8	204	204	34.4	16.3	R	Slightly better than 30.
Freeman	32	8	8	202	202	34.0	16.2	R	Slightly better than 31.
Freeman	36	8	8	200	200	33.6	16.0	P	Appearance - very good. None of foam escaped through air holes.
Freeman	37	8	8	185	184	31.0	14.7	P	Appearance - very good. None of foam Escaped through air holes.
Freeman	38	8	8	160	160	26.9	12.8	P	Not quite enough foam to fill mold.
Freeman	21	8	6	200	174	21.9	10.4	S	Coarse cells similar to slow mixed Nopco but lower adjusted density and some foam expelling.
Freeman	22	8	6	200	164	20.7	9.8	S	Coarse cells similar to slow mixed Nopco but lower adjusted density and some foam expelling.
Freeman	23	8	6	200	176	22.2	10.6	S	Same as 21 but fewer air bubbles.
Freeman	24	8	6	200	154	19.4	9.2	R	Appearance - Good (as in Nopco)
Freeman	25	8	6	200	171	21.6	10.3	R	Appearance - Good (as in Nopco)
Freeman	26	8	6	200	156	19.7	9.4	R	Appearance - Good (as in Nopco)
Freeman	33	8	6	225	161	20.3	9.7	P	Smoother, firmer and less bubbles than rapid mix
Freeman	34	8	6	200	166	20.9	10.0	P	Smoother, firmer and less bubbles than rapid mix
Freeman	35	8	6	175	172	21.7	10.3	P	Smoother, firmer and less bubbles than rapid mix
Freeman	36	8	10	250	205	43.0	20.5	P	Appearance - excellent but too heavy
Freeman	37	8	10	225	210	44.2	21.0	P	
Freeman	38	8	10	200	195	40.8	19.5	P	
Freeman	A50	5.2	8	200	178	10.9	19.4	M	
Freeman	B50	5.9	8	175	168	12.5	21.0	M	
Freeman	C50	6.0	8	200	174	12.7	22.0	M	
Freeman	D50	6.0	8	175	164	12.7	20.8	M	

TABLE 3

Machine-Mix		Power-Mix		Hand-Mix	
Advantage	Disadvantage	Advantage	Disadvantage	Advantage	Disadvantage
Uniform mix	Short working time (due to preheated foam)	Uniform mix	Possible error in mixing ratio	Longer working time	Improper mixing
Lower adjusted density	Completely closed mold required	Lower adjusted density		May remove cover to pour	Higher adjusted density
Repeatability		Repeatability			Possible error in mixing ratio
Correct mixing ratio		Superior quality			Trapped air
Superior quality		May remove cover to pour			Inferior quality

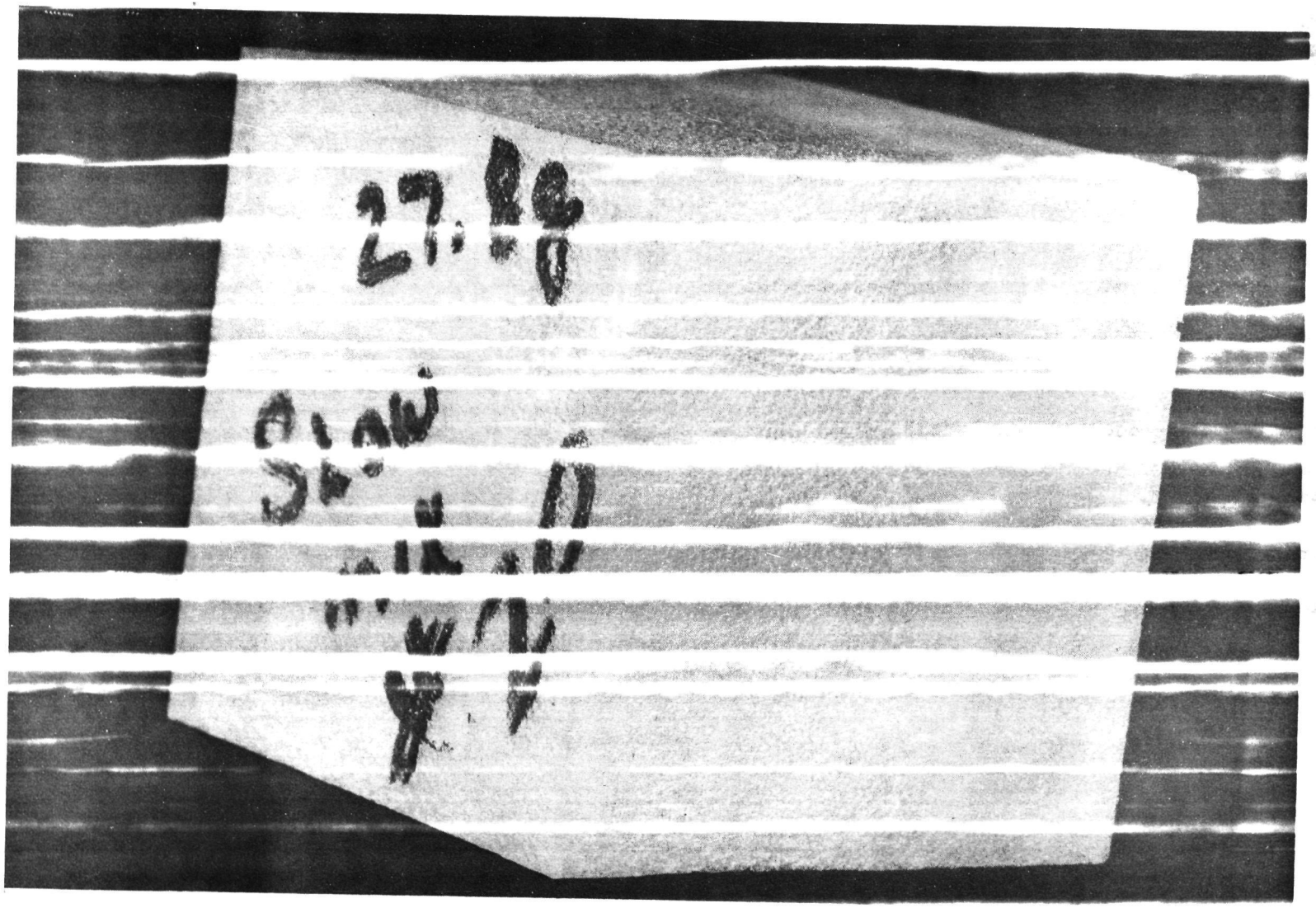


Figure 1

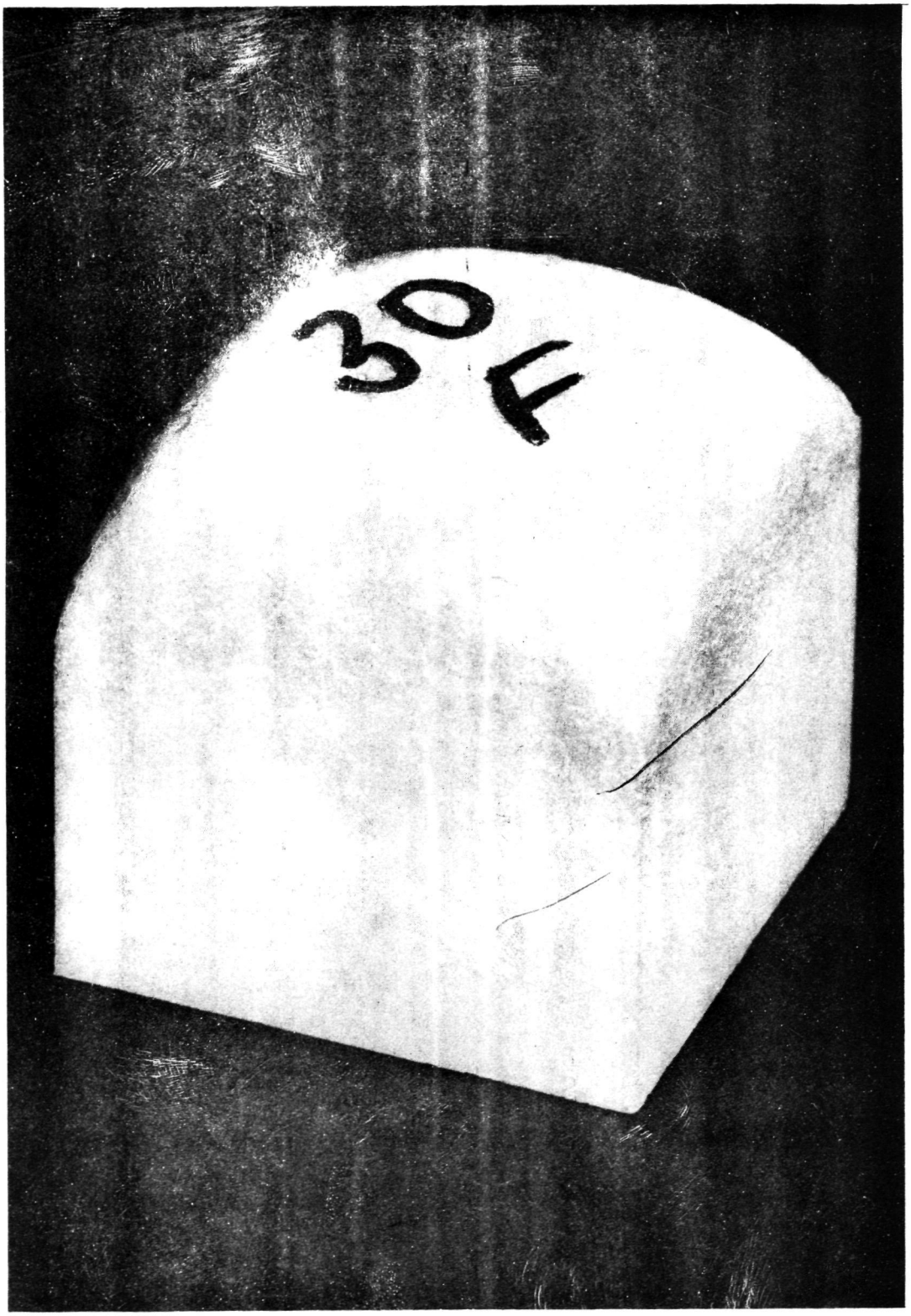


Figure 2

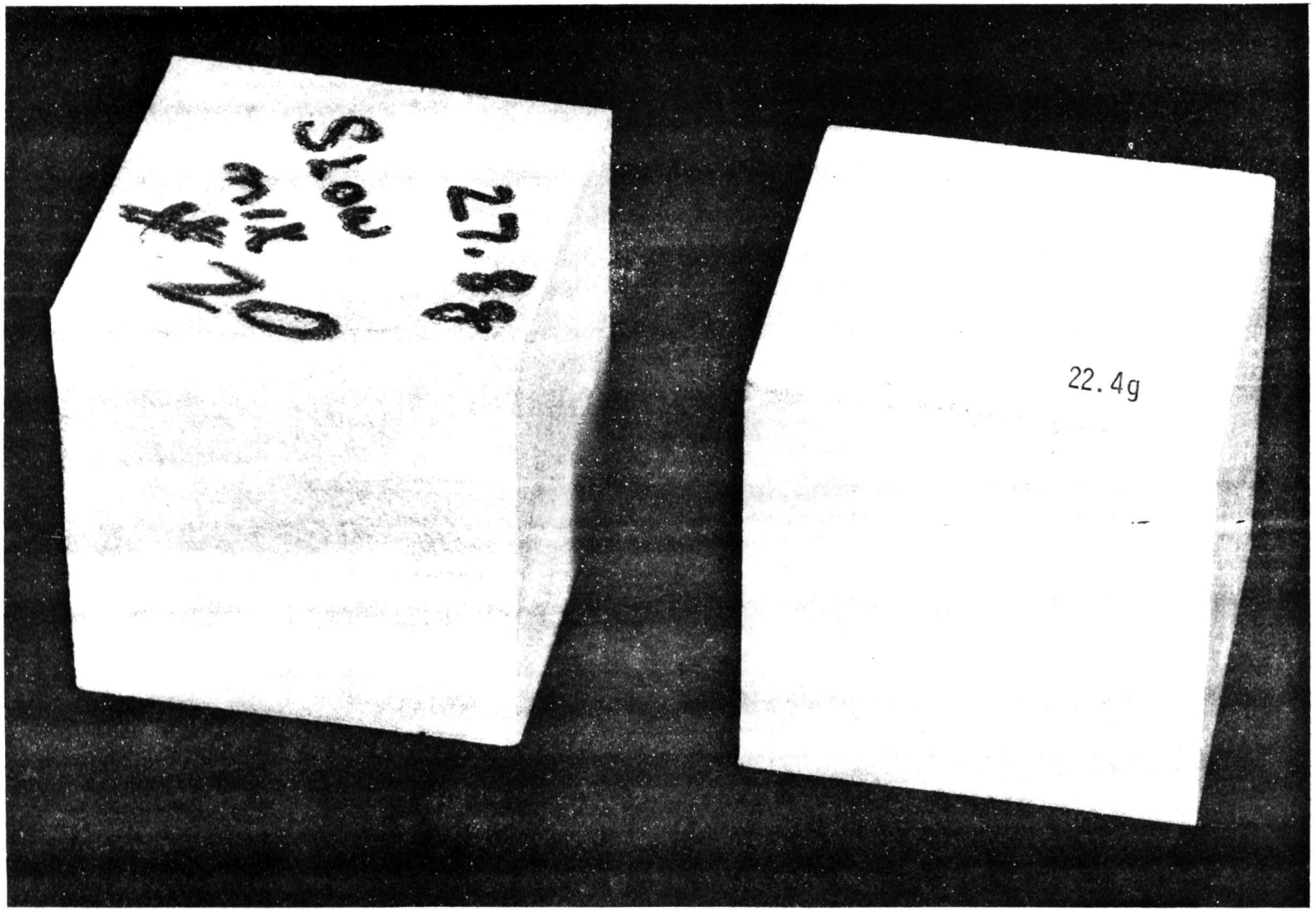
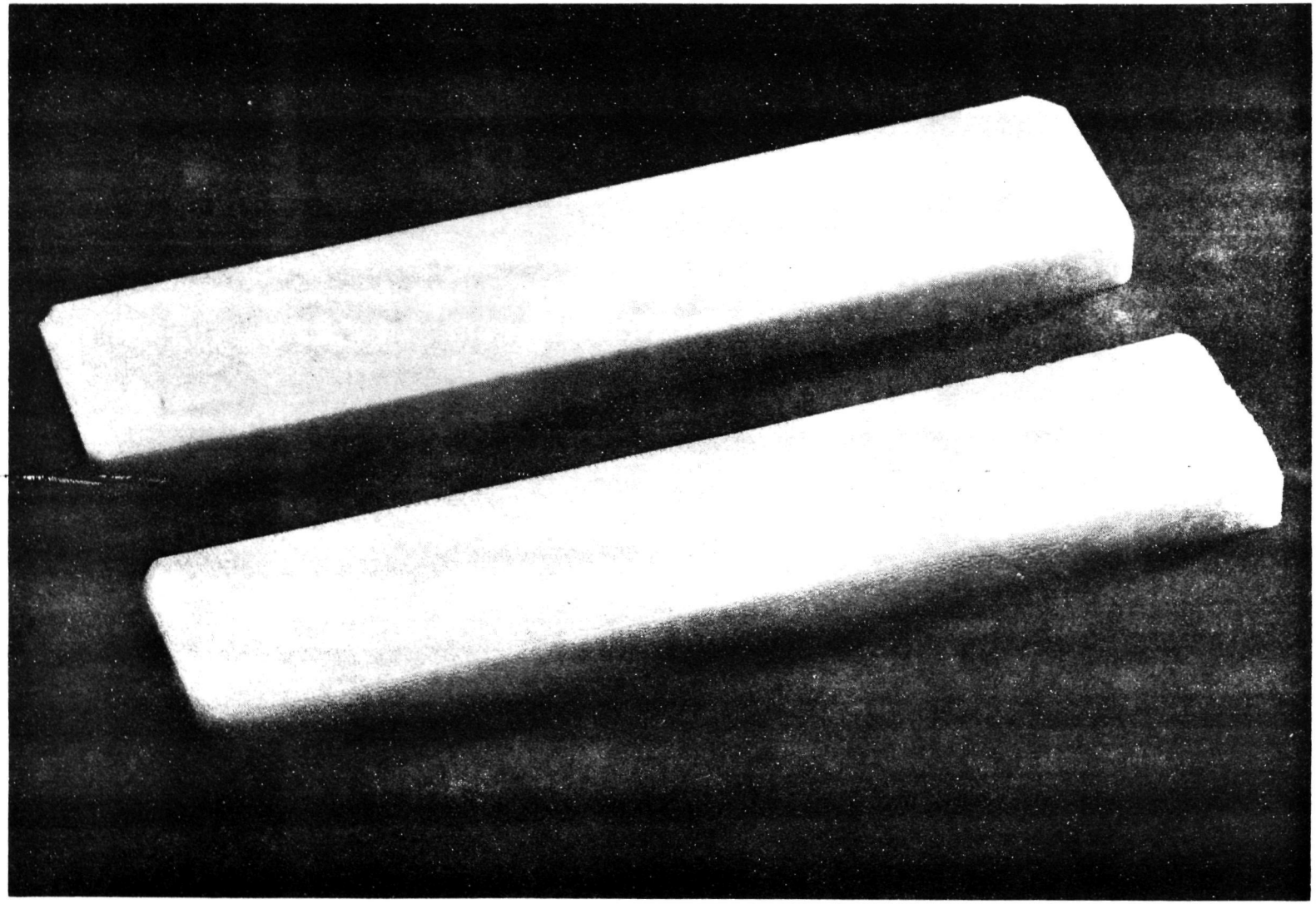


Figure 3



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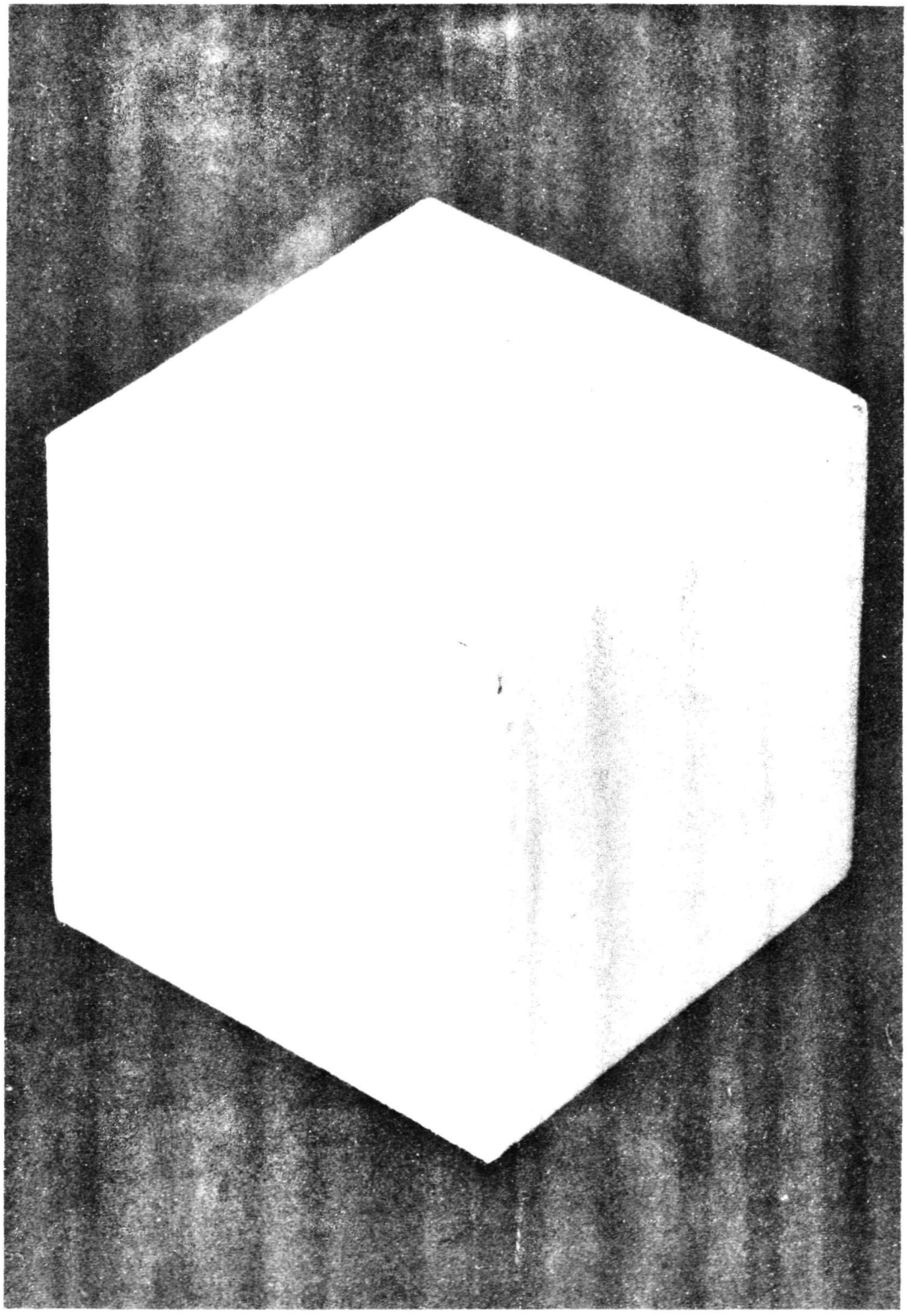

Figure 5

VII. CONCLUSION AND RECOMMENDATION

Nopcofoam and Chempol urethane foam are equally good products. Chempol being a little easier to work with.

As a result of our findings, it is recommended that both of these materials be used in the Space and Polaris programs. It is further recommended that:

a) either machine-mix or power mix be used,

b) the 6 pound density be used in preference to the 8 pound density for optimum result (the 8 pound density may be used, preferably when machine-mixed),

c) the amount poured in mold should be 170% of the rated density,

d) Simoniz paste wax or equivalent paste wax should be used as mold release. It is desirable to apply two coats, polishing after each coat.

e) black pigment dye may be mixed prematurely or when required,

f) molds should be preheated to 150°F,

g) after pouring foam in mold, place in oven for 1 1/2 hrs @ 175°F.

For heat sensitive components such as polystyrene capacitors, allow mold to rest on work bench until foam begins to expel through air holes, then place in oven for a minimum of 3 1/2 hours @ 140°F ± 3°F. In this case, the mold should also be preheated to 140°F.

VIII. NOTES

A. Equipment Used

Blue M oven

2" x 2" x 2" chrome-plated steel mold

6.3" x 1.4" x 0.341" Aluminum mold

Hunter Spring Scale

Stirrer, Electronic Controlled (0-5000 rpm)

1 1/2" Dia. 3-bladed stirrer (45° pitch)

Martin Sweets Mixing and Dispensing Machine

B. Definitions

1.	Machine-mix	- Automatic mixing and dispensing machine.
2.	Power-mix	- Portable motor driven stirrer.
3.	Hand-mix (Fast, slow)	- Using a spatula or other type of stirrer and stirring by hand.
4.	Rated density	- Density as specified by manufacturer.
5.	Net rated density	- Cured density in percent (having lost some material through air holes).
6.	Adjusted density	- Same as net rated density (in lb per cu. ft).

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