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SOME PROPERTIES OF SPONGE RUBBER

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ABSTRACT

This paper gives general information on soft sponge rubber as commercially manufactured and furnishes data on the physical properties of 13 different samples of sheet material. The general appearance of the samples is shown in Figure 1 and the various determinations made are given in a table and in two figures.

CONTENTS

I. INTRODUCTION

Sponge rubber is a name applied to rubber compounds which are porous or spongelike in character. The spongy condition is produced by the inclusion or the formation of gases within the compound during the vulcanizing process. One of the common methods of producing sponge rubber is to mix a leavening agent, such as ammonium carbonate, in the compound. Other methods depend upon gases forced into the stock under high pressure and allowed to expand during vulcanization. Of these methods, the first is the more usual. Sponge rubber is produced with many different degrees of hardness, size of pores, etc., and both as hard and as soft rubber. It may be obtained in molded shapes and in cylindrical or sheet form.

The first use that occurs to one for sponge rubber is as a substitute for natural sponges. In addition to this use, there are many other important applications in particular for the more dense grades or those with small pores. As examples of uses, the following are listed:

Shock-absorbing cushions for use in mounting radio apparatus and other sensitive instruments.

As a backing for rubber stamps.

For padding in athletic goods.

As a substitute for air in tires.

As pads under carpets.

For inner heels in shoes.

For bath mats.

For chair cushions and as an upholstering material.

For window channels in automobiles.

For hospital cushions and pads (usually of special shapes).

For heat and sound insulation, such as in refrigerators, and as a lining for airplane cabins.

As a lining for aviation suits.

For life preservers and floats (limited to certain types).

These different uses call for rubber with different characteristics. The wide range of properties which it is possible to obtain with sponge rubber suggests that if the properties are known it may be adapted to many other uses.

II. SAMPLES STUDIED

This work was undertaken to obtain general information on the properties of soft sponge rubber as commercially manufactured and was confined to a study of the properties of sheet materials. Thirteen samples were used covering a wide range with respect to physical properties and representing the product of five different manufacturers.

Figure 1 shows the appearance of the cross section of these sheets enlarged three times. Sample A was approximately five-eighths inch thick and F approximately three-eighths inch thick. The remainder were all very nearly one-half inch in thickness. F and J differ quite decidedly in character from the others in that the pores are closed. F was decidedly lighter in weight than any of the others. In J the closed pores apparently contained gases under a slight pressure. There was a tendency for these sheets to puff out, and they would not lie flat on a table so that accurate measurements were difficult. J also had a heavy skin of nonspongy material on each surface. In most cases it will be noted that the sheets are inclined to be denser near the surfaces than in the center. In several cases the flow of the rubber during molding is indicated.

III. PROPERTIES INVESTIGATED

Data were obtained concerning the following properties. The results are given in Table 1 and in Figures 2 and 3.

1. Weight per unit volume.
2. Hardness.
3. Porosity.
4. Tensile strength and elongation.
5. Permanent "set."
6. Buoyancy in water.
7. Hysteresis under slow compression.
8. Hysteresis under impact.
9. Thermal conductivity.

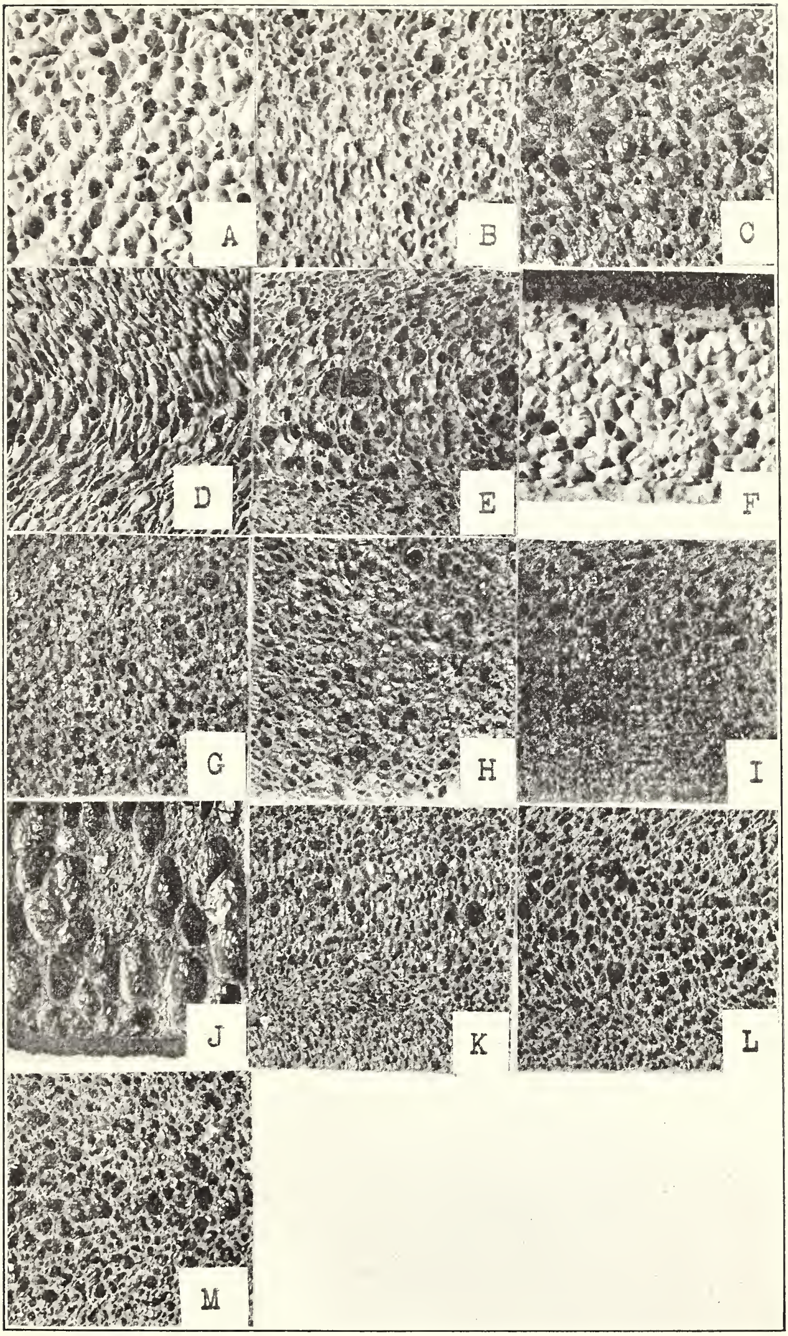

FIGURE 1.—*Appearance of cross section of sponge rubber sheets enlarged three times*

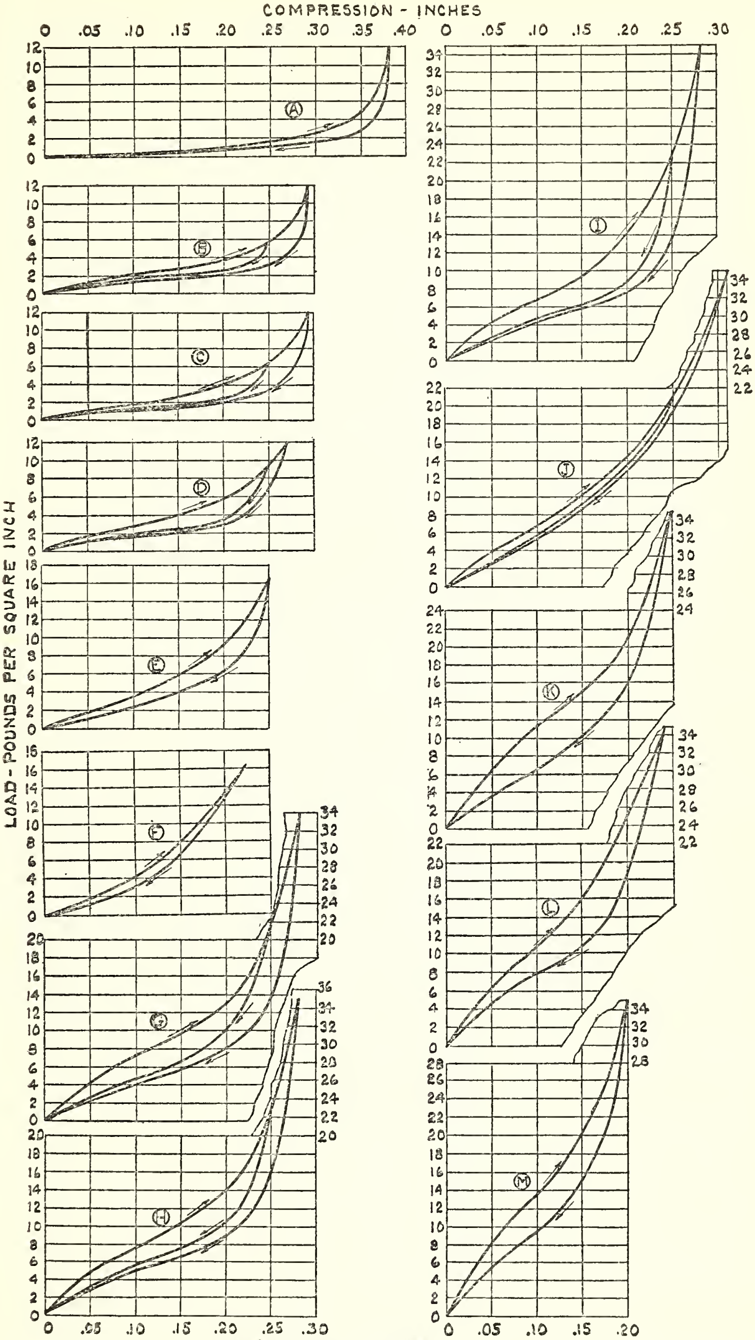

FIGURE 2.—*Hysteresis curves of sponge rubber in compression*

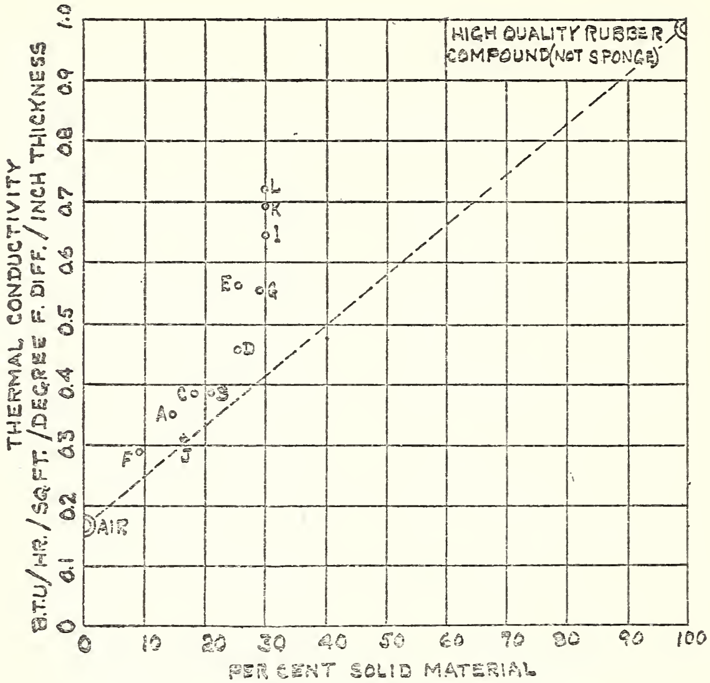

FIGURE 3.—*The thermal conductivity of sponge rubber*

TABLE 1.—*Properties of sponge rubber*

Designation of sample	Color	Weight per square yard, based on one-half inch sheet.	Hardness (load in lbs./in.²) to compress sheets 40 per cent.	Solid material based on compression at 4,000 lbs./in.²	Set compressed 65 per cent with 1 1/16-inch diameter ball.	Set compressed 40 per cent with 1 1/16-inch diameter ball.	Tensile strength	Elongation	Hysteresis loss under impact in per cent of input.	Thermal conductivity in B t u./hr./ft.²/° F. difference/inch thickness. Test made at 90° F.
		Pounds		*Per cent*	*Per cent*	*Per cent*	*Lbs./in.²*	*Per cent*		
A	Natural	4.4	1.0	15	0	0	75	460	43	0.35
B	do	5.7	3.5	21	0	0	85	605	60	.38
C	Red	5.7	3.5	19	0	0	50	370	65	.38
D	Natural	8.0	6.0	26	0	0	70	645	60	.46
E	Red	9.8	9.0	26	0	0	40	245	60	.56
F	Natural	2.0	10.5	9	45	35	35	210	40	.29
G	Red	9.7	13.0	29	0	0	140	435	33	.55
H	do	10.3	13.0	29	0	0	110	415	50	--------
I	Black	10.8	13.5	30	0	0	55	455	58	.64
J	Red	3.3	13.5	[1] 17	45	30	35	295	32	.31
K	Black	11.4	20.5	30	0	0	130	325	33	.69
L	Red	11.6	25.0	30	0	0	85	255	45	.72
M	Black	11.8	40.0	29	0	0	90	275	32	--------
High quality rubber not sponge		22.0	--------	100	--------	--------	3,000	800	28	.99
Cork board		--------	--------	--------	--------	--------	--------	--------	--------	.30

[1] Difficult to make an accurate determination on account of nature of sample. True value probably slightly lower. Since these tests were made, more uniform samples of improved quality have been received.

The methods used in measuring these properties follow:

Hardness.—The usual method of expressing hardness as the indentation of a ball under a definite load was not satisfactory, due to the fact that none of the instruments available were suited to the range of hardness found. Several means of measuring this property were tried and the best way appeared to be to measure the load required for a definite per cent compression. In this work the hardness is expressed as the pounds per square inch required for 40 per cent compression, this figure being chosen as all samples could be compressed at least this amount. The load required can be taken directly from the curves in Figure 2. In Table 1 the samples are listed in order of increasing hardness.

Porosity.—Inasmuch as the specific gravities of the rubber compounds were not known, it was difficult to make an absolute measure of the porosity of the different samples. The method used, which was considered sufficiently accurate for the purpose, consisted in compressing sheets of known dimensions between plates with a load of 4,000 lbs./in.^{2} and again measuring the dimensions. The voids under this high compression were considered negligible.

Tensile Strength and Elongation at Break.—The tensile strength and elongation were measured in the usual way, using specimens one-half inch wide and the full thickness of the sponge sheets, in most cases also one-half inch. Approximate values for a high-quality rubber compound (not sponge) are given for comparison. It is noted that in all cases the tensile strengths are low compared with the nonspongy sample and apparently not in proportion to the solid material present.

Permanent Set.—Samples were compressed in one case to 40 per cent and in another case to 65 per cent of their original thickness by means of steel balls 1$\frac{1}{16}$ inches in diameter. They were allowed to remain in the compressed condition for 48 hours and then removed and measured. As will be noted, only two samples showed any measurable set even under the more severe condition. With the exception of these two, the samples apparently returned to their original dimensions almost immediately.

Buoyancy in Water.—Samples F and J were the only samples with closed pores. They did not take up any appreciable amount of water except on the surface, and are the only ones which would be classed as buoyant. The others trap air to a more or less extent and the buoyancy simply depends upon the amount that happens to be retained. A heavy skin on the surface naturally hinders the escape of air and increases buoyancy.

Hysteresis Under Slow Compression.—Hysteresis curves in compression were made on each sample as follows: Sheets about 8 inches square were placed in a test machine and the central portion compressed between platens 4¾ inches in diameter. The compression under increasing and decreasing loads was recorded graphically. (Fig. 2.) In making tests of sponge rubber in this way the speed of the machine would naturally influence the shape of the curves. For these tests the speed of the jaws was comparatively slow (about 2 inches per minute) so that the effect of air being forced in or out of the sponge pores was not great. A very high speed would naturally show quite different results. In most cases curves are shown when samples were compressed to 50 per cent of their original thickness and released, and also when compressed to a greater extent. The curves for A and F were taken from similar ones made with samples five-eighths and three-eighths inch thick, respectively. Points on the curves were reduced or increased proportionally to approximate sheets one-half inch thick and give a basis of comparison with the remainder of the samples. The curves illustrate the range of properties which are available in sponge rubber with respect to the load capacity for a given compression. They also show quite a variation in hysteresis losses. The closed pore samples F and J show small losses compared with other samples of equivalent hardness.

Hysteresis Under Impact.—Samples were placed against a steel block and struck by a vertical pendulum 36 inches long consisting of a steel ball 1$\frac{1}{16}$ inches in diameter suspended by a silk thread. The pendulum was allowed to strike a sample from various heights of drop, and the loss of height on rebound recorded as a hysteresis loss. The results are shown in Table 1. The per cent loss shown in this table is that for a 1-inch height of fall of the pendulum. The loss was somewhat less for very low heights of fall and slightly more for greater heights of fall. These differences are due largely to the resistance to passage of air in and out of the pores of the rubber during the very rapid compression and recovery. The values given represent average figures suitable for comparison of samples. It will be noted that the figures vary from 32 to 65 per cent. For comparison a high quality rubber sample is shown with a loss of 28 per cent. The per cent loss apparently bears no direct relation to any of the other figures in the table. In mounting instruments a rubber with good damping properties is usually desired, in which case it is obvious that a material such as B, C, D, E, or I should be chosen. It will be noted that the hardness of these five samples as expressed in this table varies from 3.5 to 13.5, while the hysteresis loss under impact of each is very nearly the same. The superior damping properties of these particular samples compared with the others may be plainly shown by simply dropping a small weight on them and observing the number of bounces. If a low loss is desired, G, J, K, or M would be the obvious choice, and it will be noted that although these samples are about equivalent in this respect there is a range of hardness from 13 to 40.

THERMAL CONDUCTIVITY.—The thermal conductivity was determined by the plate method, which consists essentially in the maintenance of a constant temperature difference between two flat metal plates mounted parallel to each other, and the measurement of the rate of heat flow between them through a flat slab of the test material placed between the plates.[1] The conductivity of most of the samples was measured, and the results are shown in the table and also in Figure 3, in which they are plotted against the per cent solid material. The broken line in this figure, which is shown for reference, connects the value for the conductivity of air alone (0 per cent solid) with that for rubber alone (100 per cent solid). If the sponge samples, which were essentially rubber compounds interspersed with air spaces, contained air and rubber only, conductivities would be expected to follow this line.[2] All vulcanized rubber, of course, contains a small percentage of sulphur and more or less of other compounding materials. The reason for higher values than would be indicated by this line are evidently due largely to these other materials. It is probable that most of the ingredients commonly used in rubber compounding would have this same tendency to increase the thermal conductivity, though some, of course, to a greater extent than others. It appears from Figure 3 that for heat insulation a low percentage of solid material (high porosity) is desirable and also that the rubber itself should not be compounded to any great extent.

IV. CONCLUSIONS

An examination of these samples of sponge rubber shows that there are at least three types manufactured. In two of these the cells are closed and in the other they are largely open. The closed-cell types may be used for some purposes for which the ordinary type is not suitable.

The physical properties of sponge rubber are due both to the texture of the material and to the rubber compound of which made.

Sponge rubber can be obtained commercially in various weights from about 5 pounds per cubic foot upward.

The tensile strength and, in most cases, the elongation of sponge rubber are low compared with ordinary soft rubber.

Softness or hardness is apparently no criterion of damping properties.

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[1] M. S. Van Dusen, J. Am. Soc. Heating and Ventilating Engrs., 26, pp. 625–652; October, 1920.

[2] This conclusion is based on tests of insulating materials of similar character.

For heat insulation, a high degree of porosity is desirable. The usual rubber fillers tend to decrease the insulation value.

V. ACKNOWLEDGMENT

Acknowledgment is made to M. S. Van Dusen and J. L. Finck for data on heat conductivity.

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