THE EFFECT OF A NEW TYPE
FIBROUS FLOUR FILLER ON THE PHYSICAL
AND MECHANICAL PROPERTIES OF A
ENOL FORMALDEHYDE PLASTIC

THE EFFECT OF A NEW TYPE FIBROUS FLOUR FILLER ON THE PHYSICAL AND MECHANICAL PROPERTIES OF A PHENOL FORMALDEHYDE PLASTIC

This report is submitted as partial fulfillment for the degree of Master of Wood Technology.

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Ann Arbor, Michigan 1947

ACKNOWLEDGEMENTS

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Introduction

With the advent of Plastics came the knowledge that an extender or filler should be added to them to make them cheaper and also to impart to them desirable properties which they did not themselves possess.

Because of its abundance, purity, low price, and satisfactory physical properties, wood flour soon became the leader in the field of plastic fillers. Within recent years, practically every possible type of vegetable and mineral filler has been used. Some of these are carbon, mica, asbestos, corn stalks, peanut shells, and wheat straw. Usually when some filler material, other than the generally accepted wood flour is used, it is to impart some special property to the molded product. Mica might be added to increase the electrical resistance of the product, asbestos to improve the heat resistance or insulation properties. Where cheapness is of prime importance some material such as corn stalks might be used. All of these fillers, however, impart undesirable properties along with their desirable ones. The mica, for instance, would make its parent product very brittle, and the asbestos introduces special problems of molding and preform technique. Disregarding, however, the specific cases in which special properties are desired, the trend in research has been to find a filler which will exceed standard wood flour filler in its general and average physical properties, taking into account, of course, such factors as cost, purity, uniformity of product, and availability.

It is usually agreed that of all the physical and mechanical properties considered, impact resistance is the most important and needs most improvement. It is the purpose of this report to determine the physical and mechanical properties of a plastic extended with a new type of wood flour filler and to compare these results with those obtained from a plastic filled with the standard commercial type of wood flour filler. Because of its inherent nature, it is hoped that this type of filler will increase the impact strength of the plastic in particular.

Before going into any test procedure it might be well to point out the limitations of any data on strength properties of molded phenolic plastics obtained with standard specimens and standard methods of testing. Specific data of this type, as in this case, is usually obtained in accordance with methods of testing established by the American Society For Testing Materials. (1)*

Manufacturers acknowledge that a "molding material, which on standard test pieces seems superior, may show up in actual production as being inferior to another material which on standard test pieces reveals a lower order of desirable properties". (2)

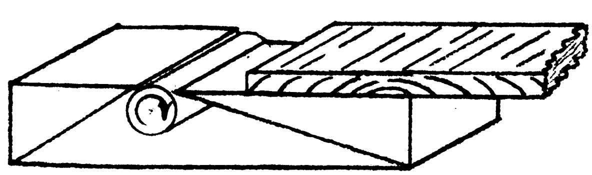
*Numbers in italics refer to literature cited and will be found in bibliography.

These discrepancies encountered in actual production are attributed to peculiarities of design, size, shape, and variations in molding conditions and not to inherent differences in the test materials. It is, of course, the main purpose of any report to make possible a wise and equitable use of the data obtained to the industry concerned. It is with this thought in mind that this note in introduced. If results brought out by this report seem excessively inclined, there is sufficient reason to believe that they will also be so inclined if and when put to practical use. There is, however, no definite assurance that this will be the case.

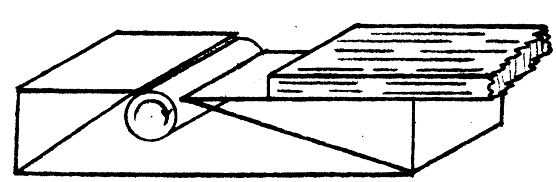
Preliminary Study

Woodflour's greatest inherent weakness is the low impact strength it imparts to its parent plastic. The commercial type of woodflour filler is made on a hammermill grinder and the resultant product lacks a definite fibrous structure. It is because of this lack of fibrous structure that a wood-flour filled plastic has a low impact strength. Mr. Meharg (3) points out that a flour prepared on an altrition mill would have a more fibrous structure and consequently would be better for molded plastic products requiring a high impact strength.

While doing plastics research at this University it occured to Mr. L. A. Patronsky that a fibrous wood-flour could be produced by running a board through a jointer or planer at right angles to the grain. Preliminary experiments showed such a flour actually obtainable. The author was then delegated to carry on a more thorough investigation of this type of flour.



Planing At Right Angle
To Fibers



Standard Planing

PROCEDURE

Preparation of Flour

The jointer used was a six inch bench type jointer. The species of wood was white pine (Pinus lambertiana). The depth of cut was adjusted so that a desirable size of fiber was obtained. By measurements with a machinists micrometer the most desirable depth of cut was found to be between .002 and .005 inches. The size of fiber is also determined by the rate of feed and the speed of the cutter.head. Since the feeding was done manually, the operator maintained what he considered a reasonably fast, safe, and not too tiresome rate of feed. Maintaining this feed speed as much as possible, three cutter head speeds were tried. The highest feed produced a fiber too fine for the purpose. The lowest feed produced a larger fiber in general and a number of very large torn fibers, probably from the ends of the board. For the rate of feed speed used, the medium cutter head speed (7100 r.p.m.) was found most desirable. In actual production, of course, the highest speeds concurrent with good results could be used. The flour was collected in a clean pan and was mixed to account for any variations in cutting.

MIXING

It was decided that three proportions of resin and flour combinations should be tested. The resin used was Durite S-2692, a phenol-formaldehyde molding resin. A medium texture commercial type of wood flour filler was used as a control. The medium texture being defined as all passing through a number 50 sieve and being retained on a number 200 sieve. The control flour also was white pine, but in this case was Pinus strobus. The difference between P. strobus and P. lambertiana can be considered insignificant as far as their effect on the physical and mechanical properties of the plastic is concerned.

The proportions of resin and flour in the mixtures is given below. These mixtures will be referred to, hereinafter, by their numbers.

Type of Flour	Mixture No.	% Resin	% Flour
Commercial	1	30	70
"	2	40	60
"	3	50	50
Fibrous	4	30	70
"	5	40	60
"	6	50	50

Proper proportions of resin and flour were weighed to give a batch weighing two pounds. This mixture was placed in a ball mill and was mixed for 10 minutes $\pm$ 1 minute. After this preliminary dry mixing it is customary to compound the mixture on a Thropp mill. This compounding operation heats the resin to a plastic stage and coats the individual fibers with resin. It also advances the polymerization to some extent, depending on the temperature of the rolls and the compounding time. After the compounding operation, the mixture of resin and flour is in a hard sheet-like form and must, therefore, be ground, on an attrition or hammermill, to proper size for molding operations. Because grinding of this sort would break the long fibers of the flour being tested, an alternative method of coating the fibers with resin had to be adopted. This method was an acetone mix.

A certain amount of acetone was placed ina 500 cc. beaker and a decided upon amount of resin flour mixture was added and stirred completely. Mixing of this type, although it does not advance the polymerization stage of the resin, coats the individual fibers with resin so that uniformity of mixture is insured throughout the preforming and molding operations, and no separation of flour and resin is possible. To decrease the bulk factor of the control mixtures it was found expedient to pass the molding powder through a number 12 sieve after it had dried completely. It was impossible to do this with the new type of filler because of the fiber length.

The ratios of resin & flour mixture and acetone used were as follows:

100	ccs.	of	acetone	per	0.2	pounds	of	mix	number	1
"	"	"	"	"	0.2	"	"	"	"	2
"	"	"	"	"	0.25	"	"	"	"	3
"	"	"	"	"	0.1	"	"	"	"	4
"	"	"	"	"	0.15	"	"	"	"	5
"	"	"	"	"	0.2	"	"	"	"	6

PREFORMING

After the mixing with acetone, and consequent drying, the powder was ready for preforming and molding. Three types of specimens were molded, a bar 3/8" x 1/2" x 5", a bar 1/4" x 1/2" x 5", and a disk 2" in diameter and 1/8" thick.

The bars were first preformed in a specially constructed mold under 8,000 p.s.i. in a Riehle testing machine. (Figure 1). The weight of powder necessary to produce a specimen of a desired size was found by experimentation. This amount varied with each of the three mixes, because of their difference in specific gravity. In most cases, however, this difference was taken care of by the allowed tolerances of dimension. The following weights of powder were found to give the proper dimension.

Mixture Numbers	3/8" Bars	1/4" Bars	2" Disks
1 and 4	21 gms.	13.5 gms.	9.0 gms.
2 and 5	21 gms.	13.5 gms.	8.8 gms.
3 and 6	20.5 gms.	13.0 gms.	8.5 gms.

Except for the fact that the new type flour, because of its high bulk factor, was more difficult to weigh and handle in the preform mold, no difficulties were encountered in the bar preforming operations.

No preforming operation was needed for the disks molded from the control flour. The flour was compact enough so that it fit in the chase of the mold with ease. The fibrous flour, having a higher bulk factor, had to be preformed. A piece of aluminum sheet was shaped to form a shim for the

FIGURE 1

Preforming Bars With A Riehle Testing Machine

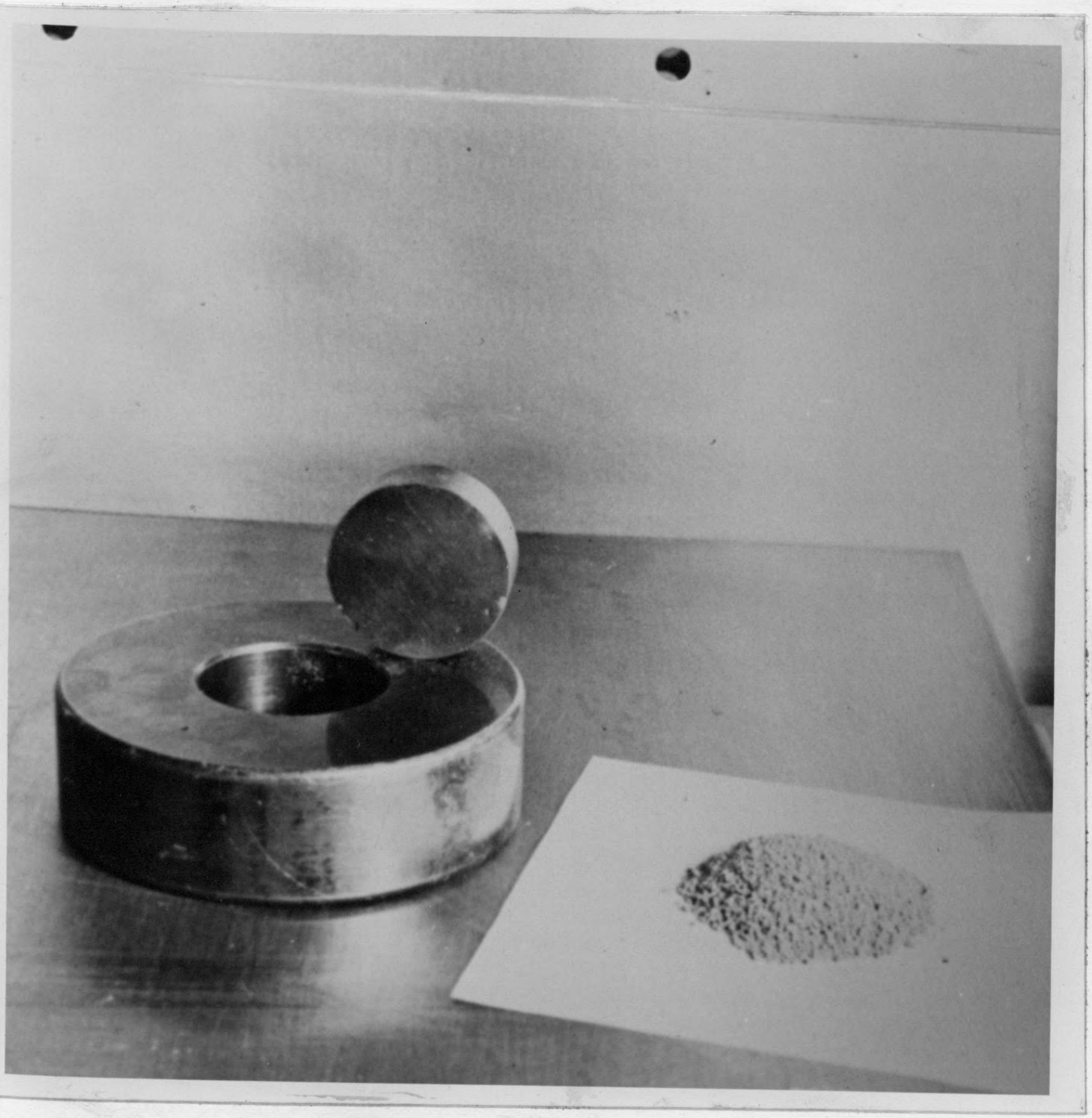
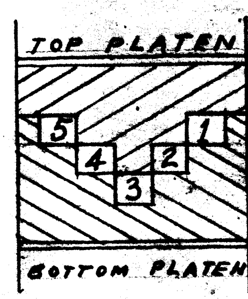


FIGURE 2

Mold For Making Water Absorption Test Specimens chase of the mold (Figure 2). This allowed for the necessary difference in size between the preform and the mold. A wooden plunger was turned to fit this shimmed hole, and the preforming operation was carried on as usual.

MOLDING

The molding was done in an Elmes 20-ton, hand operated, hydraulic press (Figure 3). The mold for the bars was designed so that five bars could be molded at the same time. These bars were numbered from 1 to 5 in the following manner.



Because the press was not designed for holding a mold of this type, uneven temperature distributions were encountered. It was noted that bar No. 3 always turned out better than bars 2 and 4, and that bars 2 and 4 were better than bars 1 and 5. The defective bars appeared not to have enough resin in them, i.e., the ends and centers of the bars were mostly loose wood flour filler. The bars, however, all had the same amount of resin in them. The reason for the defective appearance was that the 1 and 5 cavities apparently did not become hot enough with a resultant slow flow of resin and a defective specimen.

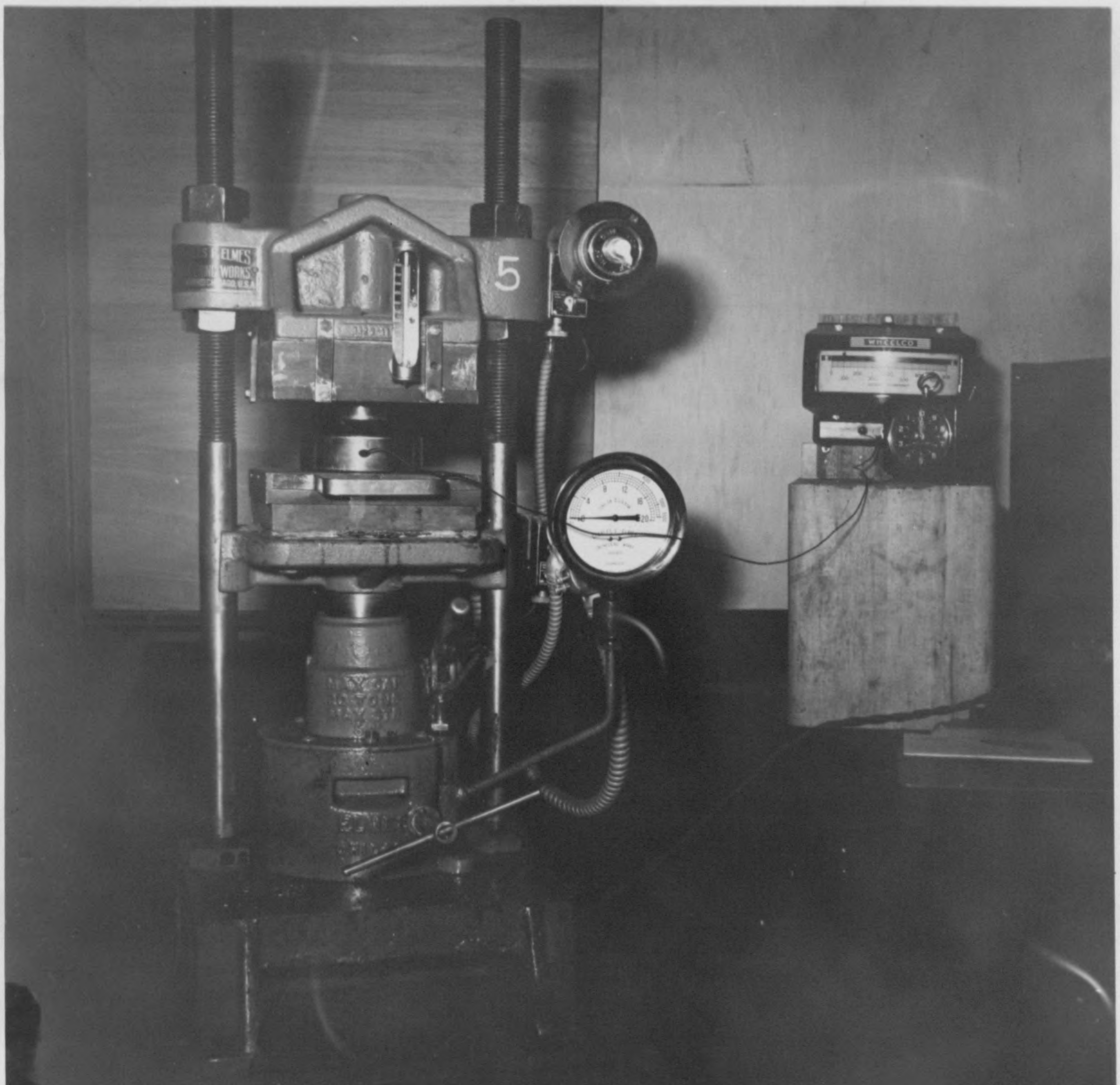


FIGURE 3

Elmes 20 Ton Hot Plate Press And Thermocouple

The specimens were molded at a temperature of 320°F. $\pm$ 5°F., and a pressure of 2500 p.s.i $\pm$ 500 p.s.i. for 10 minutes. These conditions were chosen as a mean to satisfy conditions prescribed by the American Society For Testing Materials and those suggested by the producers of the resin. It may be noted here that those specifications set forth by the American Society For Testing Materials on plastics were followed throughout these tests as much as was possible with the equipment at hand.

Except for the aforementioned incomplete flow of resin in some bars due to uneven temperature distributions, no molding troubles such as blistering or excessive flash formation were encountered. A zinc stearate powder was used to lubricate the molds so that the specimens would not stick excessively.

Molding temperatures were recorded, throughout each 10 minute molding period. Figure 4 is a sample of such a temperature variation chart.

Testing Data

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10-A

Specimen No. 3-3
Diameter 2.00"
Thickness 0.124

% loss in wt. on initial drying

Original Wt. (gr.) 8.6208
Date and time placed in oven 2:20
Date and time removed from over 2:20
Conditioning time 24 hours
Conditioning temp. (F.) 122°
Wt. after conditioning (gr.) 8.6130
% loss in wt.
Remarks:

Form 5876 1-42 1M

Water absorption in 24 hrs.

Conditioned wt. (gr.) 8.6130
Date and time placed in water 2:30
Date and time removed from water 2:30
Wet weight (gr.) 8.6710
% water absorption 0.67
Observations as to warping, cracking, etc.:
smooth- no defects

Specimen No. 3-3

Date molded 12-17-46
Wt. molding powder (gr.) 8.8
Molding conditions 320 ± 5°f.
2500 ± 500 p.s.i.
10 minutes molding time

Remarks:

Molding time (minutes)	Mold temp. (F)
T. B. C.	316
3	318
4	319
5	320
6	321
7	322
8	323
9	325
10	325
11	
12	
13	
14	
Average	321

FIGURE 4

Molding Record Card Showing Temperature Variation

TESTS ON PHYSICAL PROPERTIES

Water Absorption

Scope of test: This test covers the procedure for determining the relative water absorption rate of the molded specimens. Just as the physical and mechanical properties of wood are affected by changes in moisture content, so are those of a molded plastic product. Changes in the moisture content affect the electrical resistance, appearance, specific gravity, and various mechanical properties. The effect on these properties brought about by the changes in moisture content due to water absorption varies with the shape, surface condition (whether molded or machined), type of exposure, and the inherent properties of the plastic and its filler.

Apparatus: (a) An analytical balance, weighing accurately to tenths of milligrams (1/10,000 gms.).

(b) An oven capable of maintaining a temperature of 122°F. ± 5°F.

(c) Circulating water bath capable of maintaining a temperature of 77°F. ± 5°F.

(d) A micrometer measuring to an accuracy of one thousandth of an inch (.001")

Specimens: The specimens of molded plastic were 2" in diameter and 1/8" (.125") thick. Permissable variation in thickness was ± .007". The specimens were molded in accordance with the molding procedure already set forth.

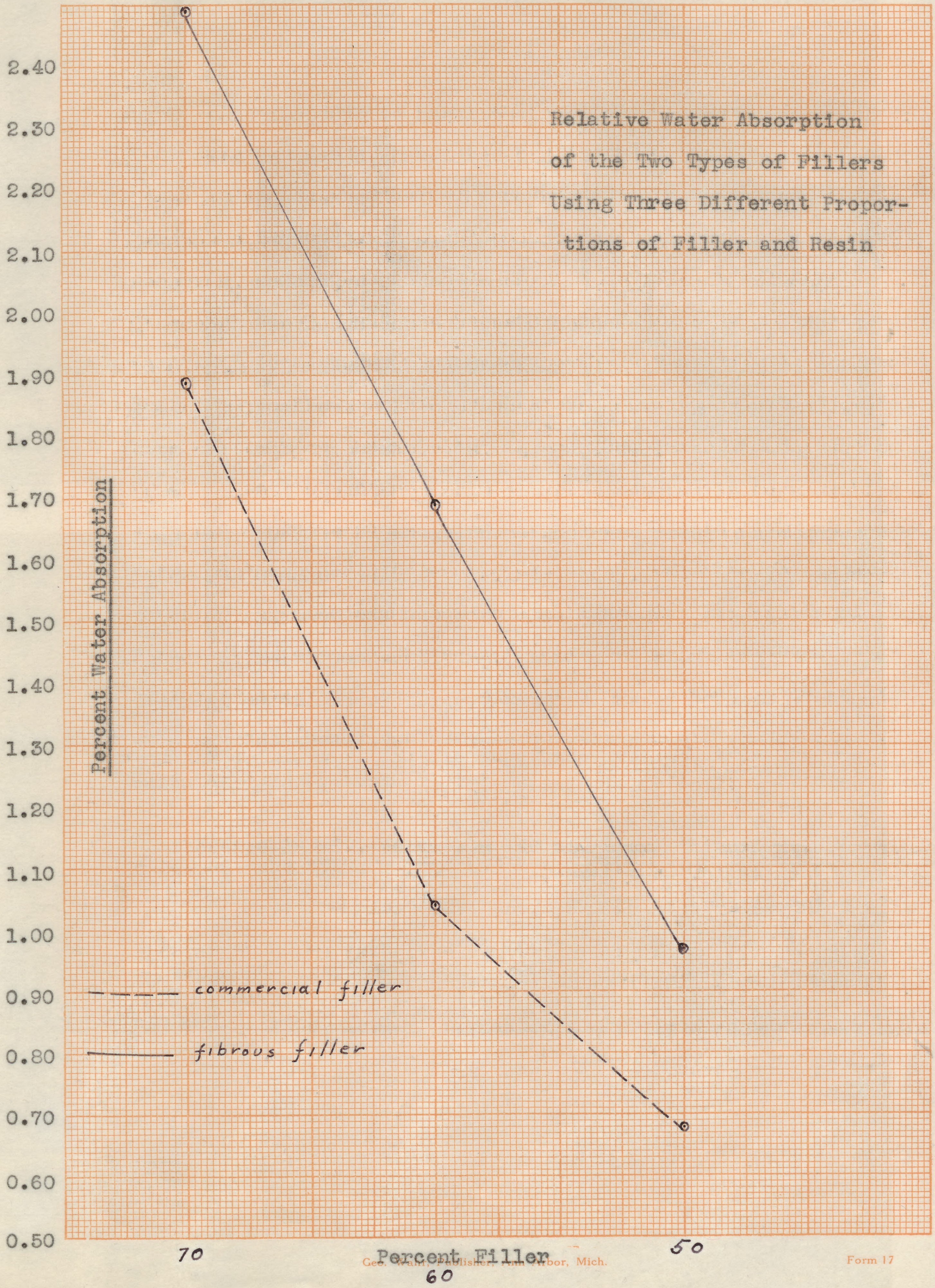
Conditioning: The specimens were washed with white gas to remove any grease that might change their water absorption properties. Each specimen was then weighed and its mean thickness recorded. The specimens were placed in the conditioning oven at a temperature of 122 ± 5°F. for 24 hours. The specimens were weighed, measured, and placed in the oven at ten minute intervals so that each specimens was subjected to exactly the same drying time.

<u>Procedure:</u> The conditioned specimens were removed from the oven at ten minute intervals, were weighed, and were placed on edge and entirely immersed in the constant temperature bath. At the end of the 24 hours, the specimens were removed from the water at ten minute intervals, wiped dry, and weighed immediately. Any changes in appearance such as checking or blistering were noted at the time of weighing.

<u>Calculations:</u>

The percentage increase in weight during immersion was calculated to the nearest .01 percent as follows:

$$\text{Increase in wt., percent} = \frac{\text{Wet wt. - conditioned wt.}}{\text{Conditioned weight}} \times 100$$


Relative Water Absorption
of the Two Types of Fillers
Using Three Different Proportions of Filler and Resin
Percent Water Absorption
2.40
2.30
2.20
2.10
2.00
1.90
1.80
1.70
1.60
1.50
1.40
1.30
1.20
1.10
1.00
0.90
0.80
0.70
0.60
0.50
commercial filler
fibrous filler
70
60
50
Percent Filler
Form 17

Water Absorption Test Results

Spec. No.	Thick-ness	Orig. Wt.	Wt. after condit.	Wet Weight	% Absorption	Aver-age
1-1	.123	8.8158	8.8122	8.9950	2.19	
1-2	.123	8.8142	8.8038	8.9590	1.76	
1-3	.123	8.8173	8.8092	8.9606	1.72	1.89
2-1	.123	8.7725	8.7610	8.8540	1.06	
2-2	.125	8.6621	8.6510	8.7480	1.12	
2-3	.122	8.5866	8.5754	8.6660	0.94	1.04
3-1	.124	8.6208	8.6130	8.6710	0.67	
3-2	.123	8.6250	8.6182	8.6760	0.67	
3-3	.116	8.0400	8.0322	8.0904	0.72	0.69
4-1	.123	8.8556	8.8518	9.0820	2.60	
4-2	.122	8.8820	8.8684	9.0950	2.55	
4-3	.121	8.8015	8.7909	9.0100	2.49	2.55
5-1	.123	8.8897	8.8814	9.0350	1.73	
5-2	.124	8.8420	8.8317	8.9770	1.64	
5-3	.123	8.7836	8.7730	8.9150	1.62	1.69
6-1	.118	8.2508	8.2436	8.3250	0.99	
6-2	.124	8.7263	8.7205	8.8050	0.97	
6-3	.123	8.6305	8.6254	8.7070	0.95	0.97

Conclusion:

We can definitely conclude that the new fibrous filler absorbs more water than does the standard commercial type. From the data sheet and the accompanying graph we can see that the higher the flour content, the greater the water absorption. This, however, is true of all vegetable filler materials.

Except for the 70% filler, 30% resin combination, the disks made with the commercial flour filler did not show any signs of blistering or surface deterioration. The 70% filler disks did have water blisters, as did all of the new flour resin combinations. The severity of the blistering increased with the flour content and the water absorption. The absorption in some of these disks was high enough so that beads of water effused when the blisters were pressed.

We can see that this new type of flour could not be used wherever a low water absorption rate is desired. Some products requiring a low water absorption rate would be battery cases, telephones, and automobile distributor caps.

We must not conclude from this one test that the new type of filler is inferior to the standard commercial type. It may, in all of the other tests, be far superior. Even though it does have a high water absorption rate, and is, therefore, eliminated from certain uses, there still are a multitude of products for which it can be used.

SPECIFIC GRAVITY

Scope of Test:

This method of test procedure is conducted to determine the specific gravity of the molded plastic. This method of test is based on the displacement of an equal volume of liquid and the resultant change in weight of the specimen. The liquid used was water since a phenol-formaldehyde plastic is unaffected by it. The specific gravity of plastics is expressed as the ratio of the weight of a given volume of material at 25°C. (77°F.) to that of an equal volume of water at the same temperature.

Apparatus:

A. An analytical balance capable of weighing accurately to tenths of milligrams.

B. A pan straddle for the balance.

C. A circulating air oven capable of maintaining a temperature of 122°F. ± 5°F.

D. A dessiccator containing anhydrous calcium chloride.

Specimens:

The specimens for this test were cut from the 3/8" x 1/2" x 5" bars. The sides were made smooth by trimming so that no rough surface remained to entangle air bubbles. The specimen was of such a size as to fit conveniently in the beaker and also to conform to A.S.T.M. specifications stating that the specimen should weigh between one and five grams. A specimen between four and five grams was chosen since it would give more accurate results than a smaller specimen.

Conditioning:

The specimens were conditioned for a period of 48 hrs. at a temperature of 122 $\pm$ 5°F. The specimens were allowed to cool in a dessiccator over anhydrous calcium chloride for a period of at least 3 hours prior to actual testing.

Procedure:

The specimen was tied to a fine wire which was hung on one of the hooks of the pan support. The specimen was then weighed to the nearest 0.10 mg. This weight was called "a", the weight in air. The specimen was immersed in the beaker of distilled water maintained at a temperature of 77° $\pm$ 0.2°F., all adhering air bubbles were removed with a camel's hair brush, and the second weight was taken. This weight was called "b", the weight in water.

Calculations:

The specific gravity of the plastic is calculated and recorded as follows:

$$\text{Specific Gravity, } 25^\circ/25^\circ\text{C. } (77^\circ/77^\circ\text{F.}) = \frac{a}{a - b}$$

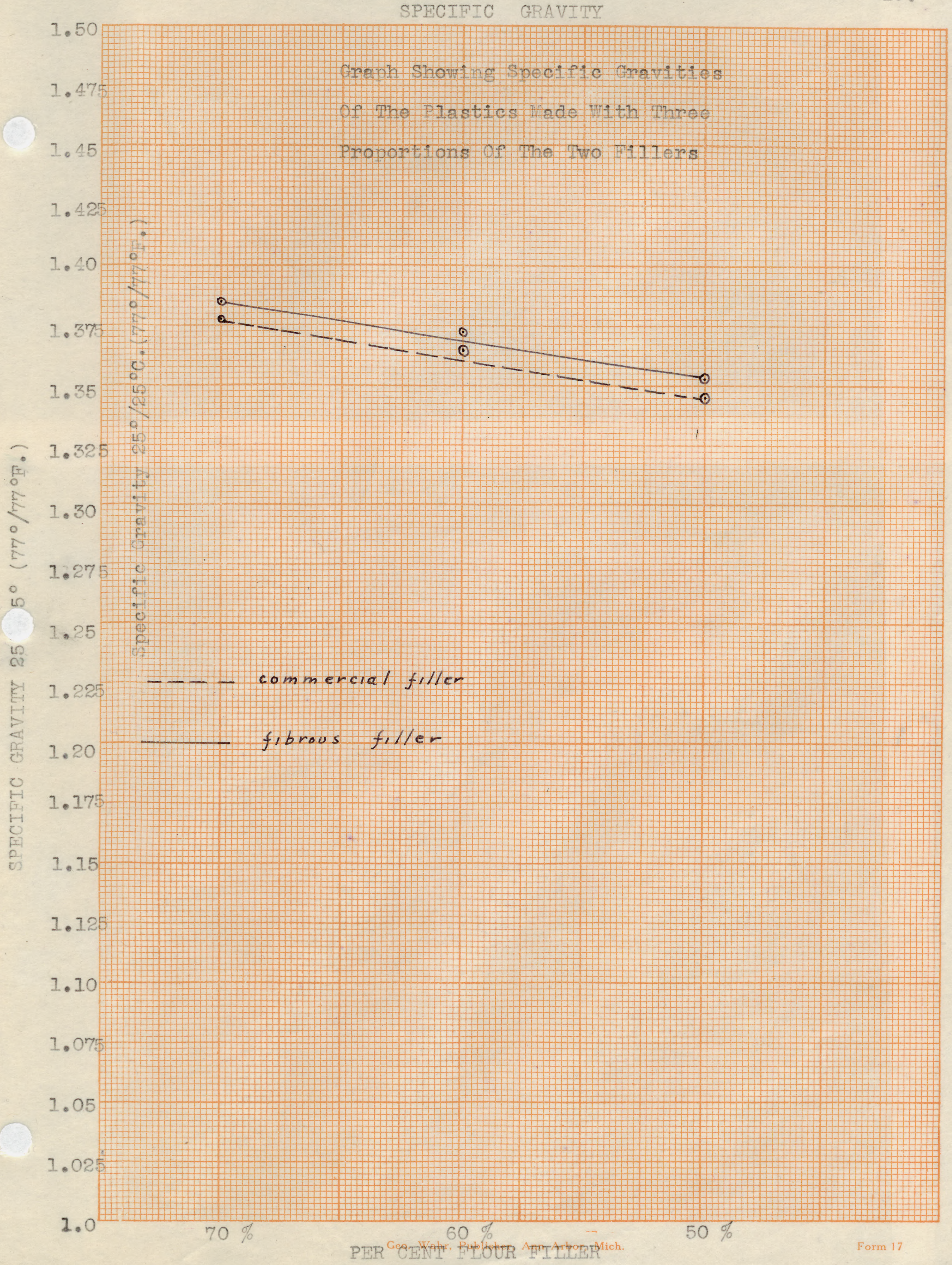
Where:

A = weight in gms. of sample in air.

b = weight in gms. of sample in water, at 77°F.

SPECIFIC GRAVITY DETERMINATIONS

Spec. No.	WT. in Air	Wt. in water	Spec. Gravity	Ave.
1-1-1	4.5490	1.2358	1.370	
1-1-3	4.5865	1.2520	1.375	
1-2-3	4.7514	1.3195	1.384	1.377
2-1-2	4.2430	1.1330	1.364	
2-1-3	4.2462	1.1454	1.369	
2-2-1	4.2258	1.1335	1.366	1.366
3-1-1	4.2048	1.0864	1.348	
3-1-3	4.2560	1.0960	1.347	
3-1-4	4.0940	1.0640	1.349	1.344
4-1-1	4.2504	1.1566	1.373	
4-1-3	4.3324	1.2180	1.391	
4-2-3	4.4675	1.2568	1.391	1.385
5-1-1	4.1101	1.1118	1.370	
5-1-2	4.1250	1.1218	1.373	
5-1-3	4.2962	1.1744	1.376	1.373
6-1-1	4.1029	1.0730	1.354	
6-1-4	4.1968	1.0930	1.352	
6-2-1	4.1410	1.0670	1.347	1.351


SPECIFIC GRAVITY
Graph Showing Specific Gravities
Of The Plastics Made With Three
Proportions Of The Two Fillers
Specific Gravity 25°/25°C.(77°/77°F.)
SPECIFIC GRAVITY 25°/25° (77°/77°F.)
1.50
1.475
1.45
1.425
1.40
1.375
1.35
1.325
1.30
1.275
1.25
1.225
1.20
1.175
1.15
1.125
1.10
1.075
1.05
1.025
1.0
commercial filler
fibrous filler
70 %
60 %
50 %
PER CENT FLOUR FILLER
Geo. Wahr, Publisher, Ann Arbor, Mich.
Form 17

Conclusion:

In most research projects, specific gravity determinations are made simply to give a relative indication of a material's weight per unit volume ratio. Very seldon is this data put to any great use. In the plastics industry, however, the specific gravity of a certain filler might very well be the factor determining its acceptance for use. (2). This is all because the plastics people buy their materials on a weight basis and sell them on a volume basis. If they buy a light filler they will obtain more articles per unit volume than if they buy a heavy filler.

Specific gravity determinations indicate that the new wood flour filler gives a more dense plastic than the commercial type of flour. Since exactly the same amounts of flour were used in both cases and similar preform and moulding conditions were used, one would assume that the specific gravities would be similar. The difference must lie in the fact that the fibrous filler compresses more than the commercial type. This is partly accounted for in the fact that the longer fibers tend to align themselves all in one direction and therefore are more compact. Everyone knows that you can pack more cans in a box if they are aligned correctly than if they are thrown in helter-skelter.

Assuming the costs of manufacturing the same for the two types of fillers, the new type of filler would be more expensive to use. This cost difference, if slight, however, could easily be outweighed if the flour imparted any outstanding physical or mechanical properties to the plastic.

HARDNESS

Scope of Test:

This method covers the procedure for determining the indentation hardness of the specimens by means of the Rockwell hardness tester.

Apparatus:

(a) A standard Rockwell Hardness Tester equipped with a flat anvil.

(b) A conditioning oven capable of maintaining a temperature of 122° ± 5°F.

(c) A desiccator containing anhydrous calcium chloride.

(d) Micrometers measuring to an accuracy of .001".

Specimens:

The specimens used for this test were the broken impact strength specimens. They met the requirements of being 1/2" wide and at least 1/4" thick. Although not having an area of 1 square inch, tests showed tht results were not affected since the specimens were thick enough so that no impression showed on the reverse side, and were wide enough so that no chipping or creeping resulted. The actual area was .625 square inches.

Conditioning:

The specimens were conditioned at 122° ± 5°F. for 48 hours. Upon removal from the oven they were cooled in a desiccator over anhydrous calcium chloride for at least 3 hours.

Procedure:

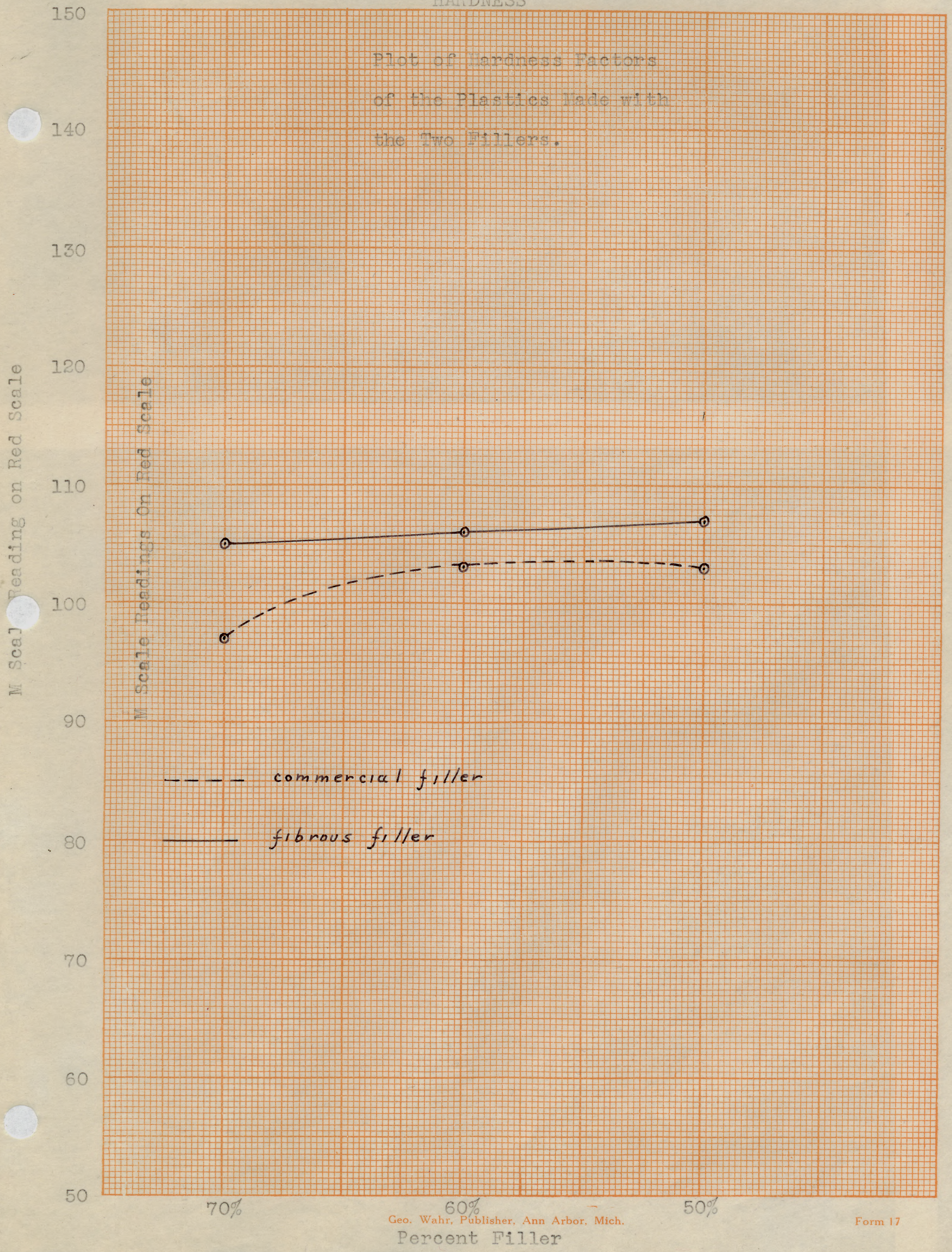
The specimens were first measured for thickness and were then placed on the anvil of the testing machine. The minor load of 10 kilograms was applied and the zero setting on the gauge made within 10 seconds. Immediately after the zero setting was made, the major load of 100 kilograms was applied. The major load was applied for a period of only 8 seconds to prevent creeping and the possibility of the weight arm resting on the link pin. The readings on the red scale were taken to the nearest full scale division reached within 45 seconds of removing the major load.

HARDNESS TEST RESULTS

M Scale Readings

Spec. No.	Thick-ness	1st Rdng.	2nd Rdng.	3rd. Rdng.	Ave.			
1-1-1	.386	97	95	97	97			
1-1-2	.398	95	92	94	93			
1-1-3	.408	104	103	102	103			
Ave.					97			
2-1-2	.382	104	103	101	103			
2-2-3	.366	104	102	102	102			
2-2-4	.407	104	105	106	105			
Ave.					103			
3-1-1	.375	103	103	103	103			
3-1-3	.380	104	104	104	104			
3-1-4	.392	103	102	102	102			
Ave.					103			
4-1-1	.371	109	104	109	107			
4-2-1	.383	106	104	105	105			
4-2-3	.382	105	103	103	104			
Ave.					105			
5-1-3	.378	106	106	107	106			
5-1-4	.380	108	104	104	105			
5-2-3	.384	107	108	107	107			
Ave.					106			
6-1-3	.389	105	106	106	106			
6-2-1	.368	109	106	105	107			
6-2-3	.368	109	109	108	109			
Ave.					107			

HARDNESS



Geo. Wahr, Publisher, Ann Arbor, Mich. Form 17

Conclusion:

Since there seems to be some unreasonable variation in the results obtained, we shall not consider them as being definitely conclusive. Since, however, there has been no purposeful or knowingly accidental misinterpretation of data or test procedure, we can definitely say the results obtained are indicative of the relative hardness factors of the tested plastic.

The plastic filled with the new type of filler is harder than the commercial flour filled plastic. The hardness increases with a decrease in flour filler content. This increase in hardness can be explained by the same reasoning given for the increase in specific gravity. The new type of filler compresses more than the commercial filler giving a more dense and harder end product.

There is no reason why batches 2 and 3 should have the same hardness factors. Although all of the hardness factors are rather close, these two batches would probably show a difference if more tests were run. If we conclude that the straight line relationship shown by batches 4, 5, and 6 is a true one, then we can also assume that batch number 2 is too high and batch number 1 is too low. Adjusting these two values, we have a straight line relationship with a slope equal to that of the other three batches.

A higher hardness factor, as shown by the new type of filler, is a desirable property in a plastic. Exeept in a very few specialized cases, a harder plastic is always a better plastic. Some people, on first thought, might think this an erroneous conclusion, because they always associate hardness with brittleness. The two factors are not corollaries, however, and what effect the new type of filler has on brittleness we shall have to see.

MECHANICAL PROPERTIES

Compression

Scope of test:

This test is designed to determine the compressive strength of the plastic under standard conditions of pretreatment and testing machine speed. Compressive strength is defined as the maximum compressive stress carried by a test specimen during a compression test.

Apparatus:

(a) A 60,000 pound Riehle Testing Machine.

(b) A compression tool for applying the load to the specimen. This tool (figure 5) was designed so that the loading was truly axial, and so that the contact surfaces were flat and parallel with the ends of the specimens.

(c) Micrometers reading to an accuracy of 0.001".

(d) Circulating air oven capable of maintaining a temperature of 122° ± 5°F.

(e) A desiccator containing anhydrous calcium chloride.

Specimens:

The specimens were prisms 1 inch in length, 1/2" wide, and 3/8" thick. They were cut from the molded 5" bars. The ends were machined so that they were parallel within 0.001".

Conditioning:

The specimens were preconditioned in a circulating air oven at a temperatute of 122 ± 5°F. for 48 hours. They were cooled in a desiccator over anhydrous calcium chloride for 16 hours prior to actual testing. The specimens were removed from the desiccator one at a time for testing.

Procedure:

The specimens were measured for length, width, and thickness, and were then placed in the compression tool. Care was taken to align the center line of the specimen with the center line of the plunger. The cross-head of the machine was brought down until it contacted the plunger which contacted the specimen. The load was applied at a rate of .20" per min. until the specimen ruptured. The maximum load was then recorded.

Calculations:

The compressive strength was calculated by dividing the maximum load by the original cross sectional area of the specimen. This strength is expressed in pounds per square inch.

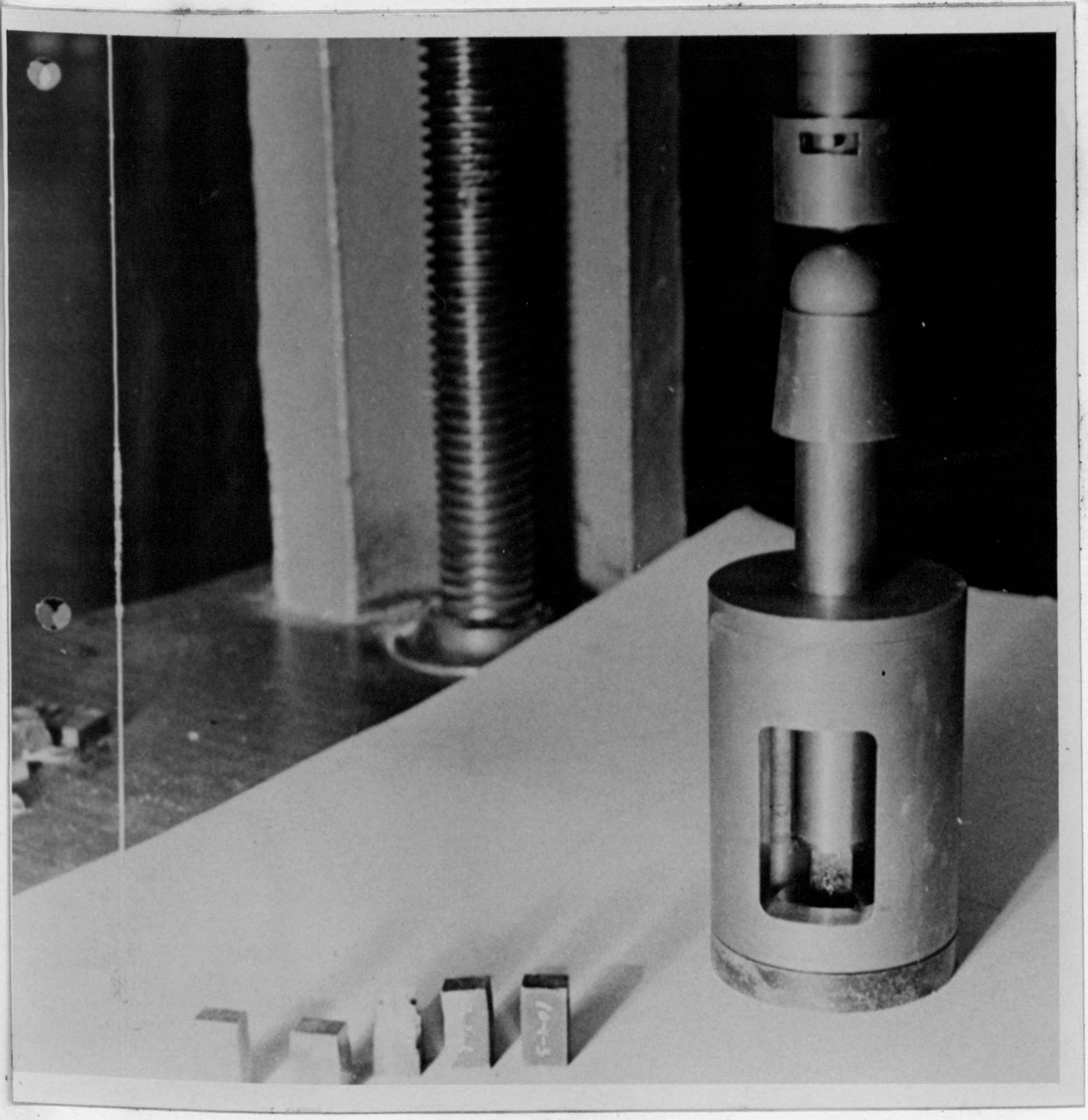


FIGURE 5

Tool Used In Making Compression Strength Tests

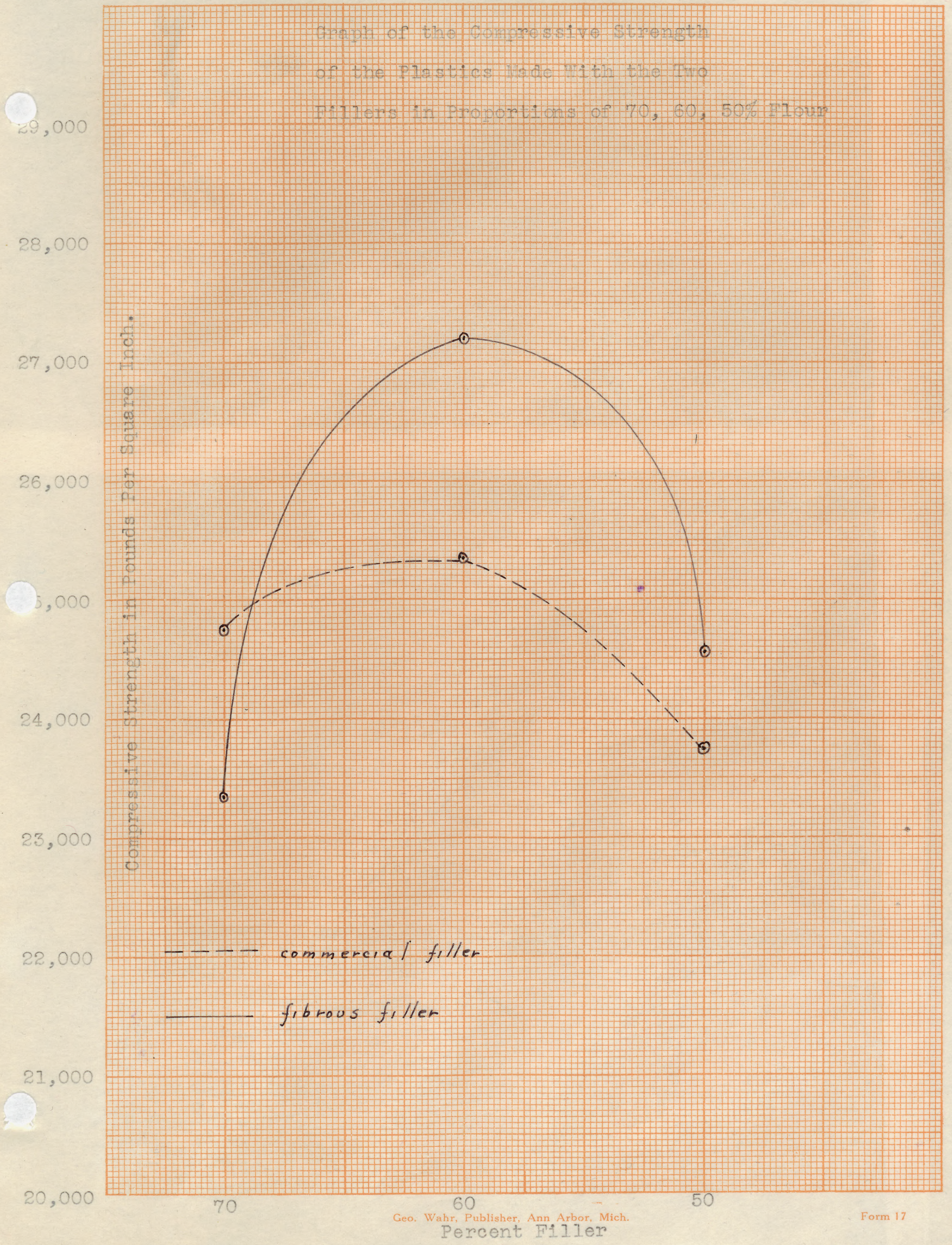
RESULTS OF COMPRESSION TEST

Compressive stress in pounds per square inch

Spec. No.	Length	Width	Thick-ness	Cross Sect. Area	Max. Load	Compr. Stress
1-1-1	.997	.501	.392	.1964	4,665	23,752
1-1-2	.995	.504	.391	.1971	4,665	23,668
1-1-3	.989	.507	.400	.2028	4,775	23,545
1-2-1	.999	.501	.403	.2019	4,760	23,576
1-2-2	1.000	.503	.408	.2053	4,540	22,125
Average						23,333
2-1-2	1.000	.503	.382	.1921	4,835	25,169
2-1-3	.995	.506	.385	.1948	4,835	24,820
2-2-1	1.000	.501	.376	.1884	5,445	28,901
2-2-2	.999	.503	.372	.1871	5,120	27,365
2-2-3	.999	.503	.374	.1881	5,340	29,650
Average						27,181
3-1-1	.998	.499	.385	.1916	4,815	25,130
3-1-2	.997	.501	.380	.1904	4,375	22,978
3-1-3	.996	.501	.386	.1934	4,800	24,819
3-1-4	1.000	.495	.385	.1906	4,900	25,708
3-1-5	1.000	.496	.381	.1890	4,560	24,126
Average						24,552

RESULTS OF COMPRESSION TESTS (continued)

Spec. No.	Length	Width	Thick-ness	Cross Sect. Area	Max. Load	Compr. Stress
4-1-1	.999	.500	.385	.1925	4,700	24,416
4-2-1	1.000	.504	.369	.1860	4,890	26,290
4-1-3	1.000	.507	.385	.1952	4,990	25,563
4-2-2	1.000	.505	.366	.1848	4,375	23,674
4-2-3	1.000	.507	.388	.1967	4,710	23,945
Average						24,778
5-1-1	1.000	.504	.373	.1880	4,925	26,196
5-1-2	1.000	.506	.374	.1892	4,850	25,634
5-1-3	.999	.505	.381	.1924	5,040	26,195
5-2-2	1.000	.505	.375	.1894	4,455	23,522
5-2-3	1.000	.506	.378	.1913	4,805	25,118
Average						25,333
6-1-1	1.000	.502	.378	.1897	4,500	23,722
6-1-3	1.000	.507	.382	.1937	4,990	25,761
6-1-4	.999	.497	.385	.1913	4,170	21,798
6-2-1	.997	.501	.376	.1884	4,385	23,275
6-2-3	1.001	.506	.369	.1867	4,500	24,103
Average						23,732


Graph of the Compressive Strength
of the Plastics Made With the Two
Fillers in Proportions of 70, 60, 50% Flour
29,000
28,000
27,000
26,000
25,000
24,000
23,000
22,000
21,000
20,000
Compressive Strength in Pounds Per Square Inch.
commercial filler
fibrous filler
70
60
50
Percent Filler
Geo. Wahr, Publisher, Ann Arbor, Mich.
Form 17

Conclusion:

In general we may conclude that the new type of filler is stronger in compression than the commercial filler. Although the commercial filler did show a higher compressive stress in the 70-30 proportion, this proportion of filler and resin is seldom used in industry and has been included here for experimental purposes only.

Upon examining the results and the included graph, we observe that the 60-40 proportion of filler and resin was the strongest. The 50-50 and 70-30 proportions not having much difference. For some inherent reason the 50-50 proportion of filler and resin is always weak in compression. This fact is supported in a work done by Professors Kynoch and Patronsky at this University in 1942 (9). If a 60% resin and 40% filler combination had been run, we probably would have found an increase in compressive strength equal to that of the 40% resin and 60% filler combination.

A high compressive strength is important in a plastic since most of the forces plastic articles are exposed to are compressive forces, or at least have components of compressive forces.

FLEXURAL STRENGTH

Scope of Test:

This test covers the procedure for determining the flexural properties of the plastic in question.

Apparatus:

(a) A Riehle Testing Machine with a constant rate of crosshead movement, and in which the error for indicated loads is less than one percent. The loading nose of the testing device (figure 6) has a radius of 1/8". The supporting arms are of the round-nosed type and have the same radius as the loading device nose. These supports are adjustable so that the span-depth ratio can be varied if necessary.

(b) A circulating air oven capable of maintaining a temperature of 122 ± 5°F.

(c) A desiccator containing anhydrous calcium chloride.

(e) Micrometers reading to an accuracy of 0.001".

Specimens:

The specimens used for this test were the 5" x 1/2" x 1/4" molded bars. The span used was 4 inches which gives a span-depth ratio of 16.

Conditioning:

All specimens were conditioned at 122 ± 5°F. for 48 hrs. after which they were dried for at least 3 hours over anhydrous calcium chloride.

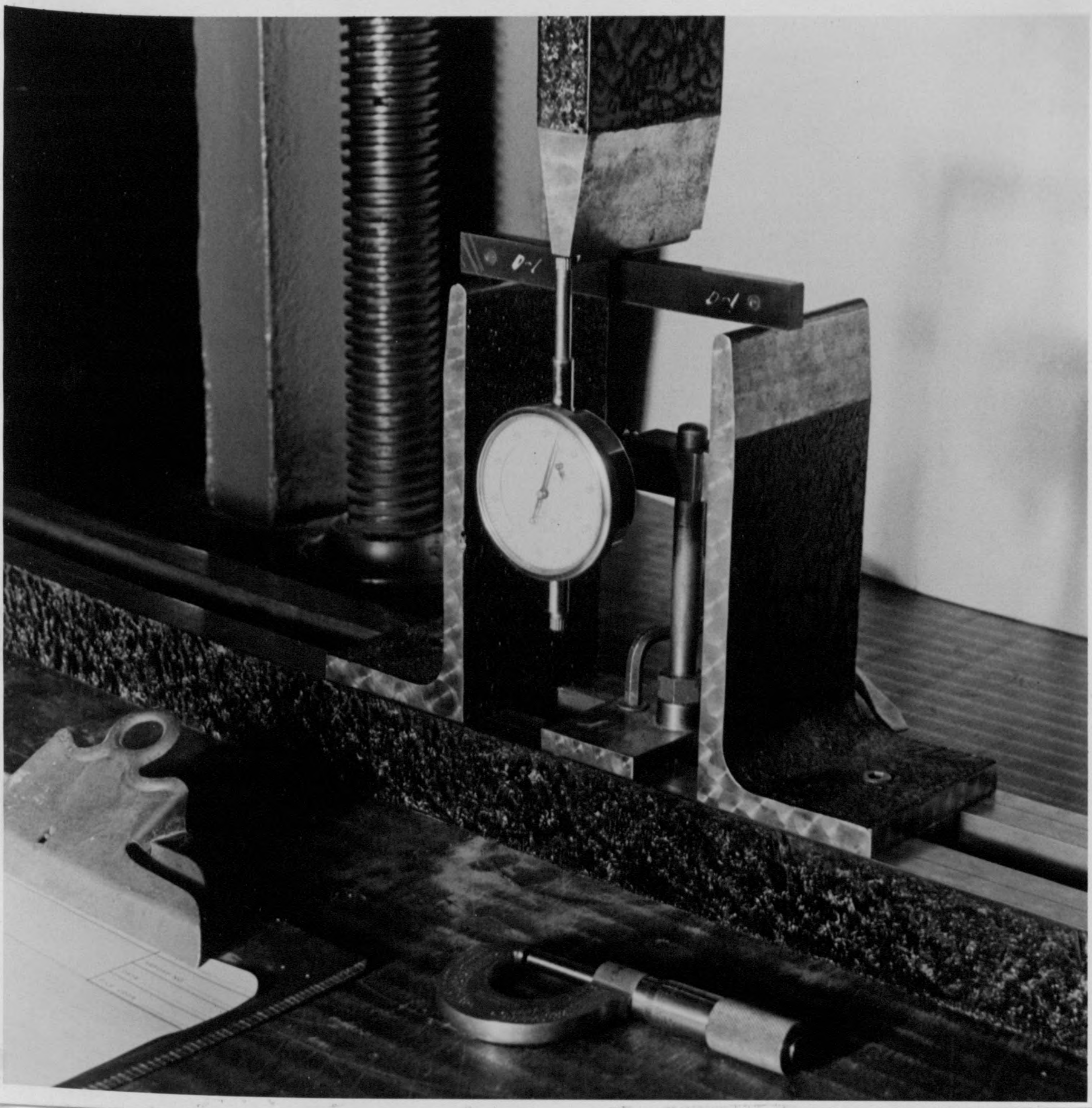


FIGURE 6

Apparatus Used In Making Flexural Strength Tests

Procedure:

The width and thickness of each specimen was measured at midspan to the nearest 0.001". The span length was constant at 4 inches. The specimen was properly aligned on the supporting arms and the loading nose was brought into contact with it. The Ames dial was set at zero and the load was applied. The rate of crosshead motion in this test was less than 0.05 inches per minute so that deflection gauge readings could be made accurately. Deflection readings were taken for each 10 pound increments of load until the load reached 90 pounds. The increments were then reduced to 5 pounds. Stress-strain curves were plotted from this data, and the maximum load was recorded. Figure 7 is an example of such a stress-strain curve.

Calculations:

The maximum fiber stress was calculated as follows:

$$S = \frac{3PL}{2bd^3}$$

Where: S = maximum fiber stress in pounds per square inch.

P = breaking point in pounds.

L = distance between supports in inches.

b = width of beam in inches.

d = depth of beam in inches.

The Modulus of Elasticity was calculated as follows:

$$E_B = \frac{L^3}{4\ b\ d^3}\left(\frac{P}{Y}\right)$$

Where: E_B = modulus of elasticity in bending in pounds per square inch.

L = distance between supports in inches.

b = width of beam in inches.

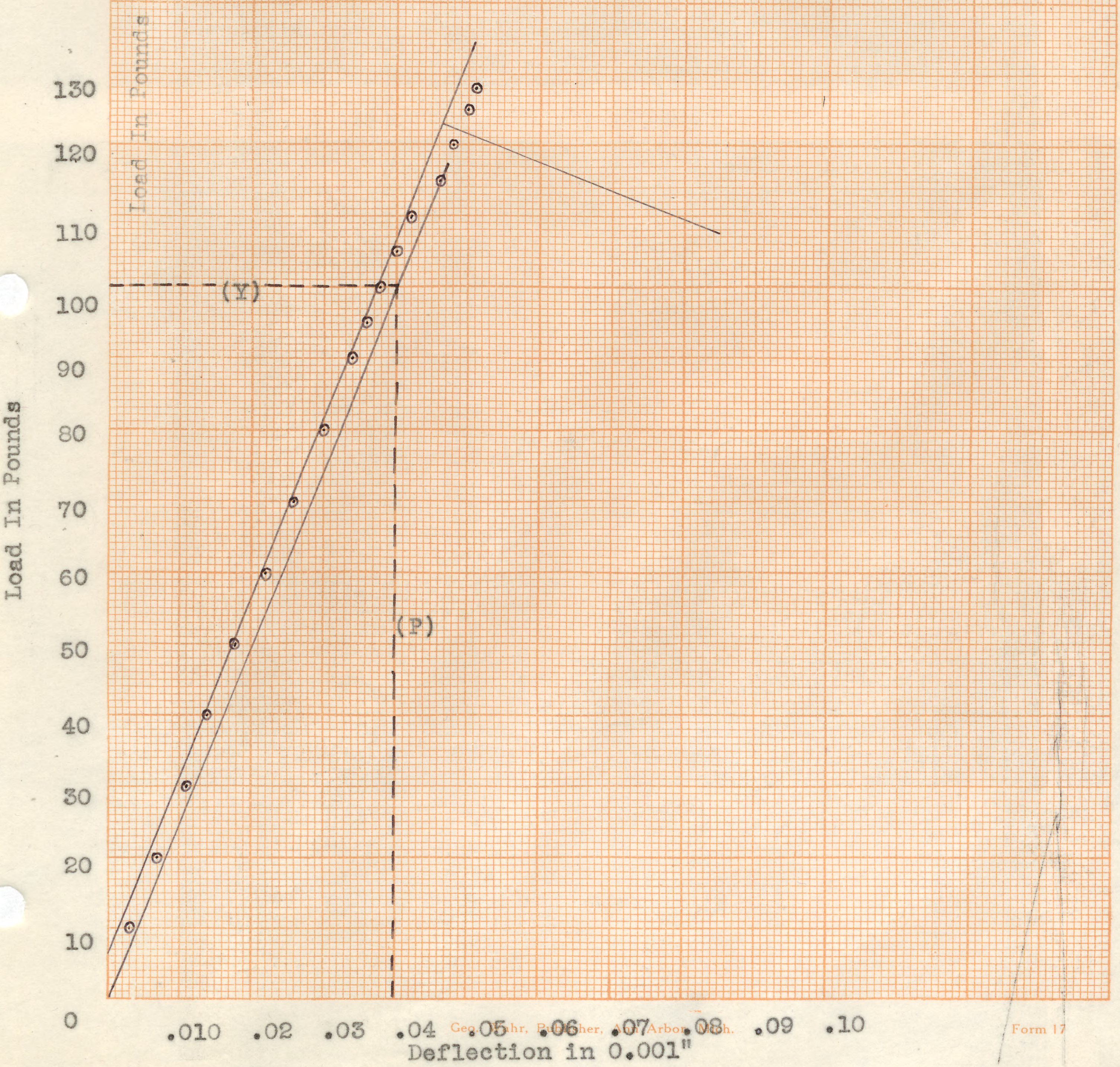
d = depth of beam in inches.

$\frac{P}{Y}$ = slope of load deformation curve in pounds per inch of deflection.

Modulus (in bending) Calculations from Load-Deflection Diagram

FIGURE 7

P/Y = 100/40



FLEXURAL TEST RESULTS

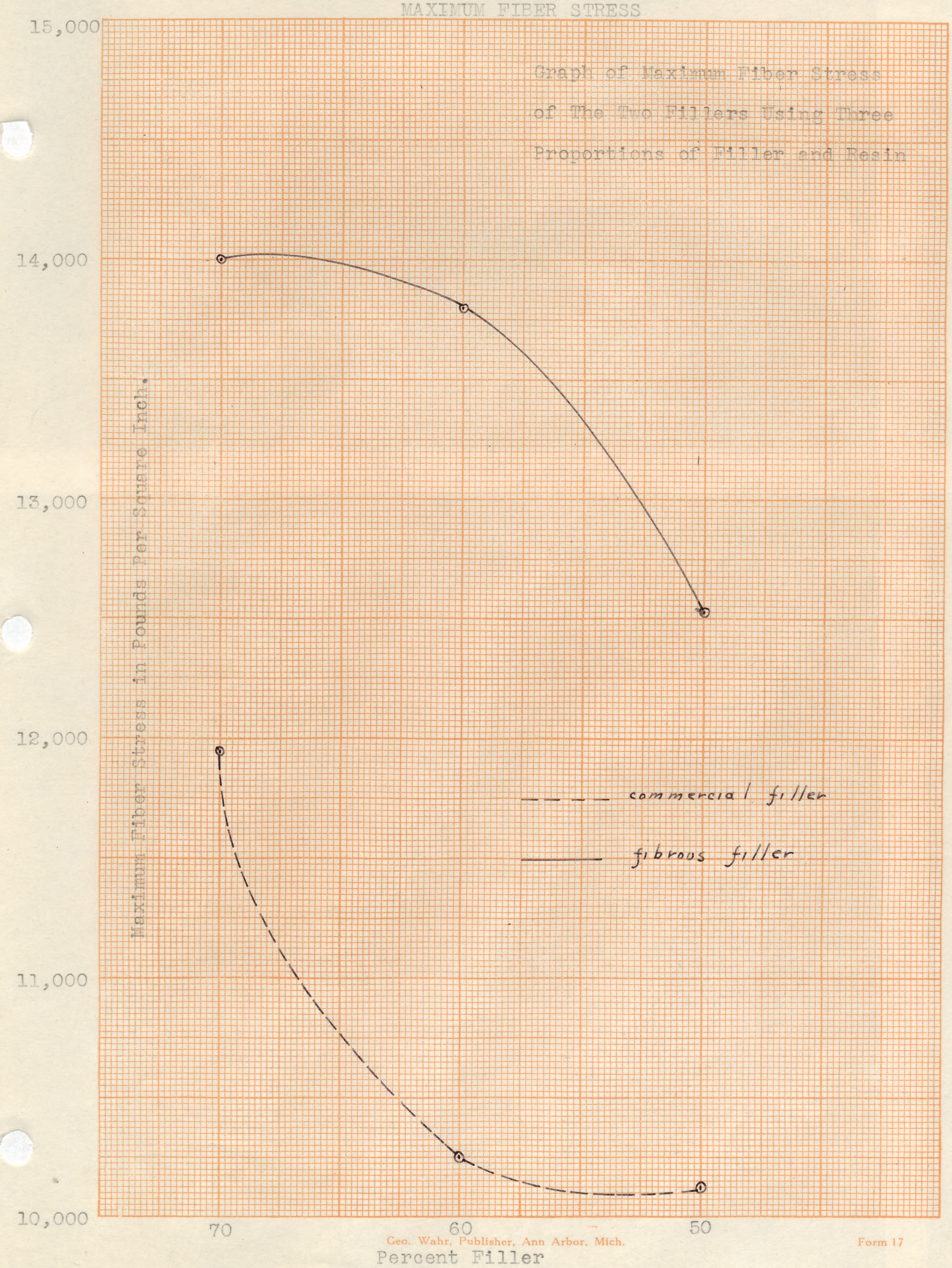
S = pounds per square inch.

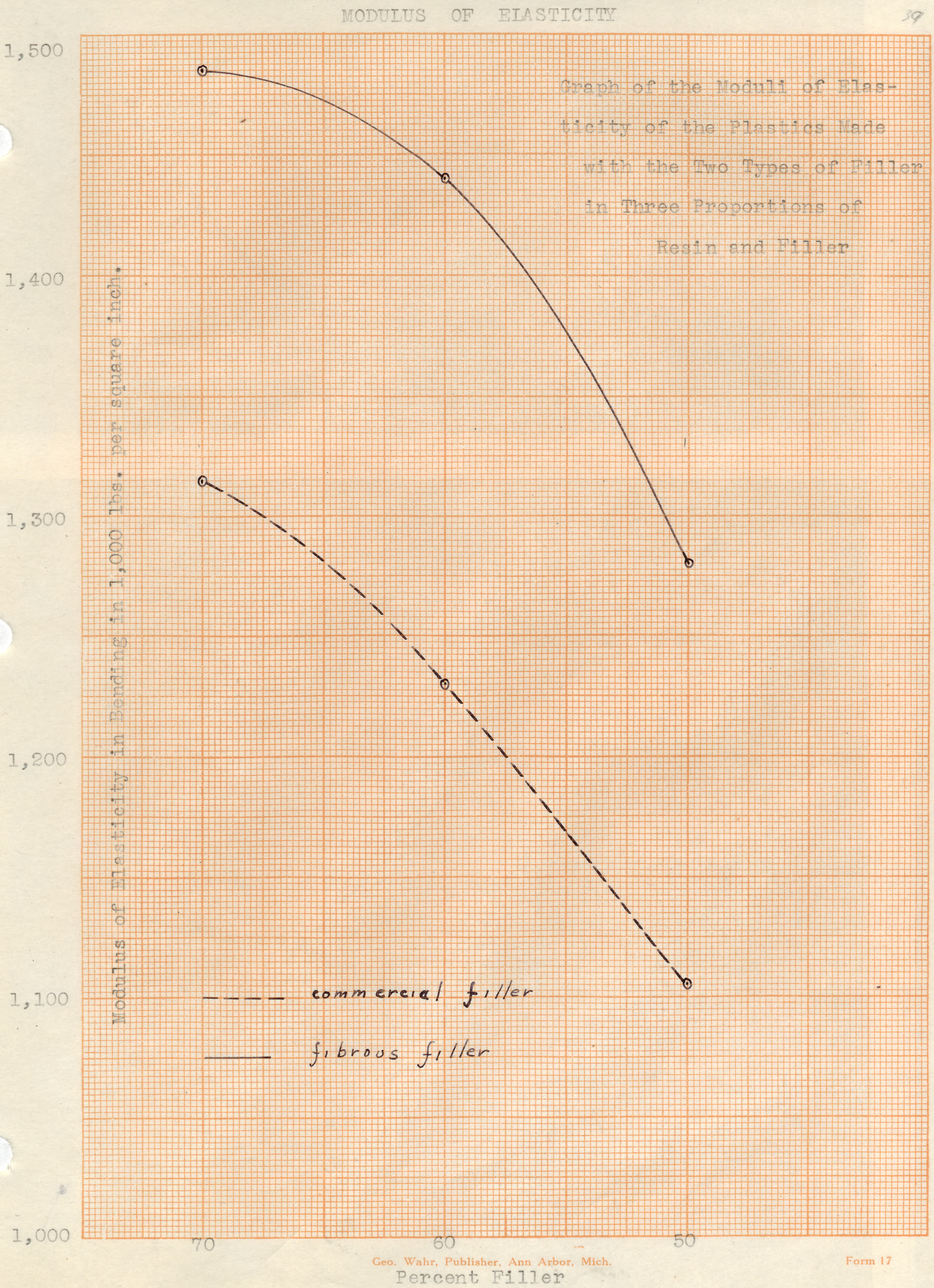
E_B = 1,000 pounds per square inch.

Spec. No.	Width	Thick-ness	Cross Sect. Area	Max. Load	Max. Fiber Stress		Modulus of Elasticity	
	(d)	(b)		(P)	(S)		(E_B)	
1-2-1	.501	.241	.1207	No	Results			
1-2-2	.500	.242	.1210	120	11,900		1,294	
1-2-3	.500	.243	.1215	130	12,850		1,307	
1-2-4	.497	.247	.1227	115	11,311		1,283	
1-2-5	.499	.247	.1232	120	11,707		1,388	
Average					11,942		1,317	
2-2-1	.500	.243	.1215	95	9,390		1,471	
2-2-2	.500	.244	.1220	100	9,836		1,169	
2-2-3	.502	.244	.1225	110	10,732		1,223	
2-2-4	.497	.246	.1223	105	10,378		1,169	
2-2-5	.497	.247	.1227	110	10,819		1,106	
Average					10,231		1,229	
3-2-1	.504	.237	.1194	90	8,970		1,078	
3-2-2	.506	.235	.1189	100	9,966		1,122	
3-2-3	.509	.240	.1222	110	10,611		1,123	
3-2-4	.497	.246	.1223	100	9,868		1,110	
3-2-5	.499	.248	.1237	115	11,183		1,093	
					10,119		1,105	

FLEXURAL TEST RESULTS (continued)

Spec. No.	Width	Thick-ness	Cross Sect-Area	Max. Load	Max. Fiber Stress		Modulus of Elasticity
	(d)	(b)		(P)	(S)		(E_B)
4-1-1	.499	.247	.1232	145	14,146		1,427
4-1-2	.501	.242	.1212	155	15,321		1,568
4-1-3	.502	.243	.1220	130	12,745		1,525
4-1-4	.493	.248	.1223	150	14,950		1,386
4-1-5	.492	.250	.1230	140	13,884		1,523
Average					14,209		1,486
5-1-1	.500	.242	.1210	140	13,884		1,498
5-1-2	.502	.242	.1215	145	14,262		1,352
5-1-3	.503	.244	.1227	155	14,587		1,497
5-1-4	.499	.242	.1207	135	13,455		1,409
5-1-5	.502	.242	.1215	135	12,786		1,776
Average					13,795		1,439
6-1-1	.500	.245	.1225	125	12,254		1,264
6-1-2	.501	.245	.1227	130	12,683		1,290
6-1-3	.503	.245	.1232	125	12,096		1,271
6-1-4	.498	.250	.1245	125	12,096		1,253
6-1-5	.499	.251	.1252	140	13,440		1,310
Average					12,514		1,278


MAXIMUM FIBER STRESS
Graph of Maximum Fiber Stress
of The Two Fillers Using Three
Proportions of Filler and Resin
15,000
14,000
13,000
12,000
11,000
10,000
Maximum Fiber Stress in Pounds Per Square Inch.
commercial filler
fibrous filler
70
60
50
Geo. Wahr, Publisher, Ann Arbor, Mich.
Form 17
Percent Filler



Geo. Wahr, Publisher, Ann Arbor, Mich. Form 17

Conclusion:

The new type of wood flour shows a higher flexural strength both in Maximum fiber stress and in Modulus of Elasticity than does the commercial filler. The flexural strength however, decreases with a decrease in filler content which was not true of either the compressive strength or the hardness factors. This is easily understood however, since we know that wood is a much more elastic material than pure phenol-formaldehyde resin. The term elasticity itself may be misleading, however, since it is the ability to resist bending and not break that determines flexural strength.

Although plastics are not often used in a beam form where they are exposed to pure bending stresses, flexural strength data is important in the design of certain plastic articles for industrial application and as a relative means of comparison where an all around stronger article is desired but no stress calculations are to be made.

Although the commercial type of wood flour is strong enough in flexural strength for almost all uses, some advantage might be made of the still higher flexural strength of the new filler.

IMPACT

Scope of Test:

This method of test is intended to determine the relative susceptibility to fracture by shock of the plastic material as indicated by the energy expended by a standard type of impact machine. The impact machine used in this test was of the Izod type. The specimen is tested as a vertical cantilever beam and requires a notch in all cases. The notch is intended to produce a standard degree of stress concentration.

Apparatus:

(a) Izod impact machine (figure 8).

(b) Means of clamping the specimen so that it is at 90° with the supporting edge.

(c) Means for determining the impact value of the specimen which is the energy expended in breaking it. This value is equal to the difference between the energy in the pendulum blow and that remaining in the pendulum after breaking the specimen.

(d) Circulating air oven capable of maintaining a temperature of 122° ± 5°F.

(e) Desiccator containing anhydrous calcium chloride.

(f) Micrometers reading to an accuracy of 0.001".

Specimens:

The test specimens conformed to the dimensions given in Figure 9. The specimens were machined to these specifications at the University Instrument shop. The notch was formed with

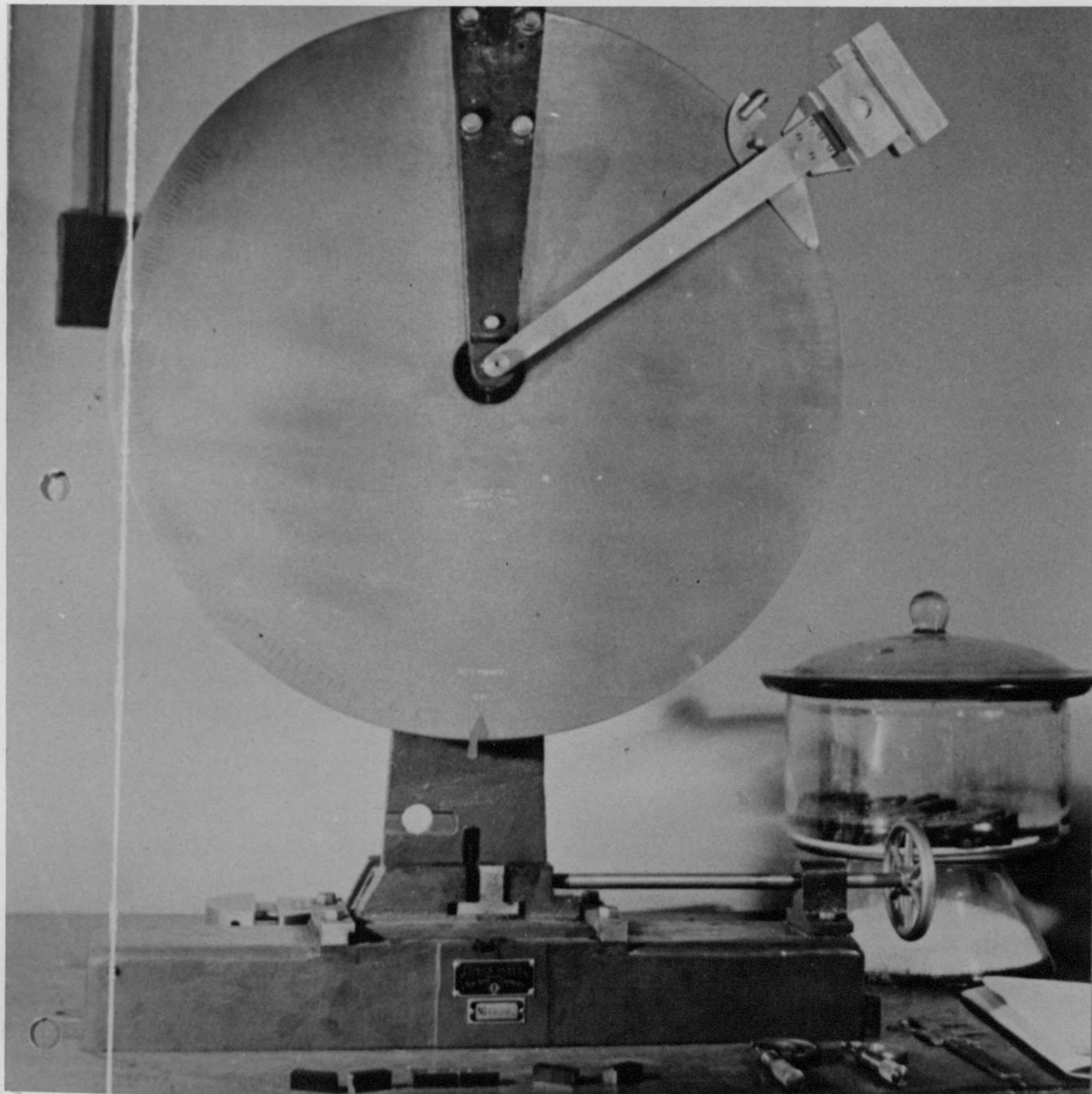
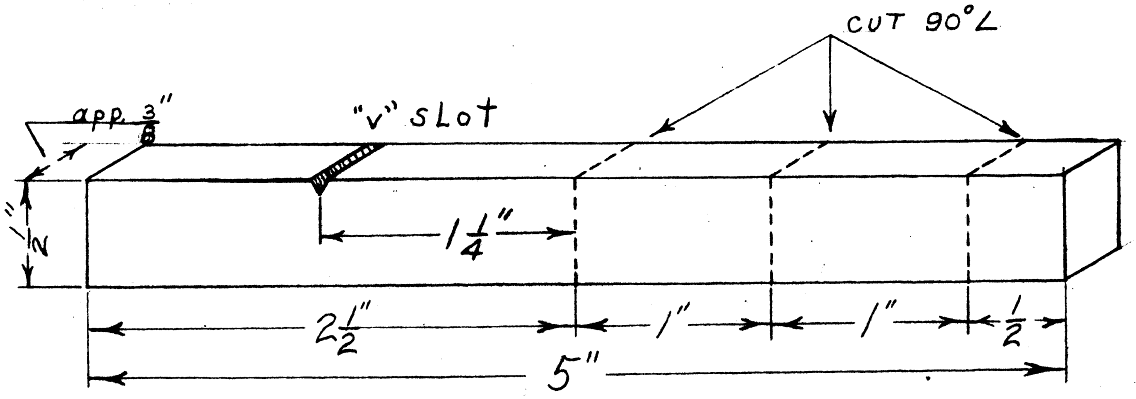
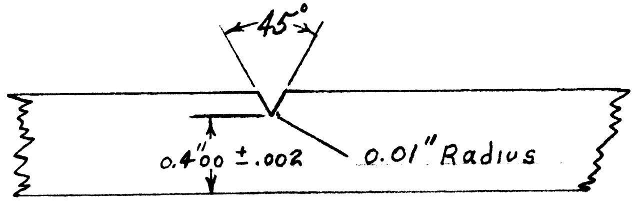


FIGURE 8

Izod Impact Machine





DETAIL OF "V" SLOT
ON IMPACT SPECIMEN

FIGURE 9
IMPACT SPECIMEN
(as cut from 5" molded bar)

a special type milling cutter so that it was straight, uniform, and scratch free.

Conditioning:

Specimens were conditioned in a circulating air oven at 122°F. ± 5°F. for 48 hours and were dried in a desiccator over anhydrous calcium chloride for at least 3 hours prior to actual testing.

Procedure:

Adjustments were made for friction and windage, and the width along the notch was measured. The specimen was rigidly clamped in the clamping device with the center line of the notch on a level with the top of the clamping surface, and the notch facing the direction of the blow. The pendulum was released with a trigger and the reading in inch pounds was taken.

Calculations:

Since the readings were in inch pounds and the impact values are expressed as foot pounds per inch of notch, it was necessary to make a conversion. This was done by dividing the recorded reading by 12 and the obtained value again by the length of the notch.

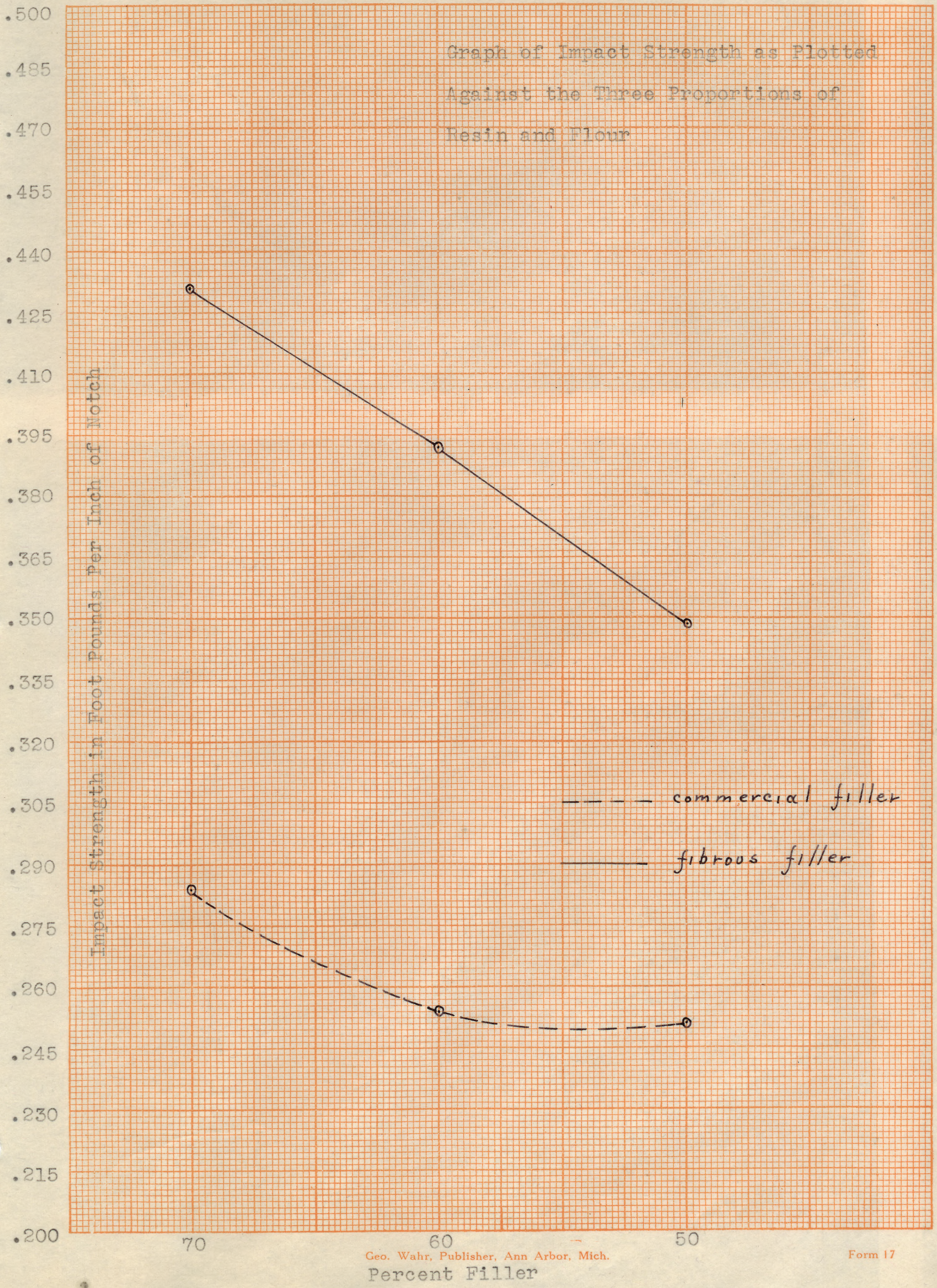
IMPACT STRENGTH TEST RESULTS

Spec. No.	Width Along Notch	Inch. lbs.	Foot lbs.	Foot lbs./inch of notch
1-1-2	.398	1.2	0.100	.251
1-1-3	.408	1.4	.117	.287
1-2-1	.397	1.4	.117	.295
1-2-3	.412	1.6	.133	.323
1-2-5	.386	1.2	.100	.266
Ave.				.284
2-1-2	.382	1.2	.100	.262
2-1-3	.393	1.2	.100	.254
2-2-1	.366	1.3	.108	.295
2-2-2	.363	1.2	.100	.275
2-2-4	.407	1.4	.117	.287
Ave.				.254
3-1-1	.375	1.1	.092	.245
3-1-2	.387	1.1	.092	.238
3-1-3	.380	1.0	.083	.218
3-1-4	.392	1.2	.100	.255
3-1-5	.395	1.4	.117	.296
Ave.				.250

IMPACT TEST RESULTS (continued)

Spec. No.		Width Along Notch		Inch lbs.	Foot lbs.		Ft. lbs./in. of notch	
4-1-1		.371		2.1	.175		.471	
4-1-3		.395		2.1	.175		.443	
4-2-1		.383		1.8	.150		.392	
4-2-2		.382		1.9	.158		.413	
4-2-3		.382		2.0	.166		.434	
Ave.							.430	
5-1-1		.377		1.7	.141		.374	
5-1-2		.375		1.8	.150		.400	
5-1-3		.378		1.8	.150		.396	
5-2-2		.380		1.8	.150		.394	
5-2-3		.384		1.8	.150		.390	
Ave.							.391	
6-1-1		.387		1.4	.117		.302	
6-1-3		.389		1.6	.133		.342	
6-1-4		.378		1.8	.150		.396	
6-2-1		.368		1.6	.133		.361	
6-2-5		.382		1.6	.133		.348	
Ave.							.349	

IMPACT



Graph of Impact Strength as Plotted Against the Three Proportions of Resin and Flour
.500
.485
.470
.455
.440
.425
.410
.395
.380
.365
.350
.335
.320
.305
.290
.275
.260
.245
.230
.215
.200
Impact Strength in Foot Pounds Per Inch of Notch
commercial filler
fibrous filler
70
60
50
Geo. Wahr, Publisher, Ann Arbor, Mich.
Form 17
Percent Filler

Conclusion:

As previously stated in this report, it was hoped that, due to the inherent physical characteristics of the new type flour, it would increase in particular the impact strength of the parent plastic. After viewing the results of the test, we can assuredly conclude that our particular goal in this research has been reached. On the average of all three filler resin combinations, the new type filler exceeds, in impact strength, the commercial type by 46%. This increase of nearly half the original strength should certainly suit the needs of most present day manufacturers.

As brought out by this report one would think that the industrialist finally has a general purpose plastic that can be dropped without shattering. A word of caution as to hasty conclusions concerning the industrial application of this data is due. According to a work done by the Monsanto Chemical Co. (4), the energy measured by the Izod type of impact test often obscures the true impact resistance of the material by including the energy absorbed in tearing apart and throwing the broken ends. The only significant portion of energy is that used in fracturing the specimen.

If any values obtained are to be of any value in correlating impact strength with other properties or fundamental properties of a material, special machines or test methods which measure energy only to rupture should be used.

Since, however, the same machine and test methods were used in testing both types of fillers, we can assume that they give us a relative indication of their impact properties. If special machines or test methods were used, both materials would probably be affected in a like manner.

GENERAL SUMMARY

An overall comparison of the effect of the new type of fibrous filler, as compared to the old commercial type, on the physical and mechanical properties of a phenol formaldehyde plastic is due.

Relatively speaking, the effect of the new filler on physical properties is positive in all three tests considered. The plastic with the new filler absorbs more water, is more dense, and is harder. Only one of these increases is desirable, however. An increase in water absorption is always undesirable. As explained previously, a filler that gives a more dense product, is more expensive to the producer. The increase in hardness and consequently to wear and abrasion is a desirable increase.

It may be noted that although the hardness of the plastic was increased, the impact strength did not decrease, but, on the contrary, showed an increase of almost 50%. These increases are very significant when considered jointly. An increase in impact strength is always possible if the product is made softer or more ductile. To increase both of these properties is truly an addition to the strength and utility of the product and not merely a modification of one property at the expense of another.

The increases in both compressive strength and flexural strength are also significant as far as indicating the overall superior strength of the plastic filled with the new type of filler.

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