DEPARTMENT OF COMMERCE

TECHNOLOGIC PAPERS

OF THE

BUREAU OF STANDARDS

S. W. STRATTON, DIRECTOR

No. 68

STANDARDIZATION OF AUTOMOBILE TIRE FABRIC TESTING

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ISSUED MARCH 17, 1916

WASHINGTON
GOVERNMENT PRINTING OFFICE
1916

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STANDARDIZATION OF AUTOMOBILE TIRE FABRIC TESTING

By Walter S. Lewis and Charles J. Cleary

The manufacture of automobile tires has become, with the increase in the use of motor vehicles, an industry of very considerable importance in the United States. American manufacturers not only supply almost all of the domestic demand, but also export large quantities to foreign countries. It therefore becomes very desirable, from the point of view both of the manufacturer and of the consumer, to provide the former with whatever information he requires to enable him to produce a serviceable article. The fundamental strength of the tire is provided by the several layers of cotton fabric used as the framework of the tire structure.

The cloth referred to in this paper is that known as 17 $\frac{1}{4}$ ounce per square yard builder fabric. This necessitates the procuring of an exceptionally good grade of fabric and the interests of the tire manufacturer demand that the strength be as high as practicable.

In order to enable the tire manufacturer to procure suitable fabric, specifications have been drawn up stating, among other things, the minimum strength that will be considered as answering the demands of the case. The differences which have existed in methods of testing have, however, given rise to some confusion in interpreting these specifications, i. e., serious differences have occurred in the results of tests obtained by different testers. The Bureau of Standards has therefore undertaken, in cooperation with certain fabric and tire manufacturers, to determine the methods of test most suitable for these fabrics, with the view to bringing about the adoption of uniform methods.

In making tests like these for comparative purposes, the method admitting the least variation may be assumed to be best. The

FIG. 1.—Tensile strength test specimens

FIG. 1.—Tensile strength test specimens
(Continued)

chief causes of variation in test results are due to different testing machines, dimensions of test specimens, moisture content of specimen at time of test, method of sampling, and lack of uniformity in the material.

Of these, the first will not be considered at the present, but the results of a preliminary investigation will be appended.

It is the purpose of this investigation to determine which of the several proposed dimensions of test specimens, moisture conditions, and methods of sampling may be expected to give the most consistent and therefore the most reliable results.

By taking the average of a long series of tests by several experimenters using the same fabric, other variable elements may be considered as equalized, i. e., results are comparable and the method showing the most uniformity may be considered the best to adopt.

In comparing different dimensions of test specimens, those marked A, B, and C, Fig. 1, were investigated. These three were selected because they were more generally employed and seemed the most practicable. All five forms of test specimens, however, are in common use in testing laboratories.

Each series of tests was made upon tire fabrics weighing approximately $17\frac{1}{4}$ ounces per square yard and the highest grade of cotton

fiber was employed in manufacture. This fiber also received the best of care throughout the various processes of producing yarn and fabric so that the finished cloth should show a high degree of uniformity.

The test specimens were prepared from samples that were selected in such a way as to give, as nearly as possible, identical specimens to the various testers. In this manner the variation in the materials was reduced to a minimum.

All fabrics were supposed to contain 23 threads per inch in warp and in filling; therefore, in test specimens A and B the width was actually determined by counting 23 and 46 threads, respectively. The adoption of this method of preparing test specimens was to lessen the variation in the material caused by irregularities and slight departures from the standard number of threads. This procedure could not be followed for C test specimens as they were not raveled to a certain number of threads.

Table 1 is a fair average illustration of the variation in the results found for breaking stresses.

TABLE 1
Tensile Strength Results of Tests Upon "A" Test Specimens

Samples of fabric	Tensile strength	Percentage deviation from mean tensile strength	Samples of fabric	Tensile strength	Percentage deviation from mean tensile strength
	Pounds			Pounds	
1.....	{ 251	1.62	6.....	{ 242	2.02
	{ 253	2.43		{ 245	.81
	{ 256	3.64		{ 260	5.25
2.....	{ 251	1.62	7.....	{ 249	.81
	{ 253	2.43		{ 245	.81
	{ 249	.81		{ 247	.00
3.....	{ 245	.81		{ 253	2.43
	{ 240	2.84	8.....	{ 247	.00
	{ 249	.81		{ 242	2.02
4.....	{ 245	.81		{ 241	2.43
	{ 251	1.62	9.....	{ 250	1.22
	{ 251	1.62		{ 253	2.43
	{ 249	.81		{ 245	.81
5.....	{ 242	2.02	10.....	{ 249	.81
	{ 249	.81		{ 252	2.02
			Mean of 30 tests.....	247	1.61

Each of the figures in Table 2 represents averages of long series of tests upon different fabrics. More than 2000 test results have been used in making this table. Deviations were figured by comparing the results of individual tests upon one sample with the average of these tests. The average of the deviations thus found was taken to be the average deviation of the sample using a certain method of testing. The results obtained from tests upon several different samples of fabric were then averaged, giving the mean percentage deviation for the method.

TABLE 2

Combed Sea Island Tire Fabric Results of Several Series of Tests

Tests made by—	Fabric manu- factured by mill—	Tensile strength and percentage deviations					
		A test specimens		B test specimens		C test specimens	
		Pounds	Per- centage deviation	Pounds	Per- centage deviation	Pounds	Per- centage deviation
Bureau of Standards.....	No. 1....	230	2.03	426	3.56	.....	.....
	No. 2....	224	2.22	433	3.18	.....	.....
	No. 3....	217	3.43	423	3.42	.....	.....
	No. 4....	226	2.80	423	3.10	.....	.....
Mill No. 1.....	No. 1....	214	3.44	416	4.13	.....	.....
	No. 2....	203	4.77	383	3.91	.....	.....
	No. 3....	194	4.89	381	4.51	.....	.....
	No. 4....	205	3.78	400	4.65	.....	.....
Mill No. 2.....	No. 2....	229	0.88	428	0.96	321	0.72
Mill No. 3.....	No. 3....	243	2.90	479	2.69	357	2.20
Mill No. 4.....	No. 4....	259	1.34	491	1.74	388	1.40

The results given in Table 2 were obtained from tests made upon dry test specimens (dried at 105° C), and five machines of four different makes were employed. These five machines were in laboratories located in different parts of the United States, viz, three in the North, one in the Middle Atlantic States, and one in the South.

These results show that there is very little difference between the 1-inch (A) and 2-inch strip (B) methods (Fig. 1), whatever preference there is being in favor of the former. The fact that the former method requires less material, is easier to apply, and admits of the use of a testing machine of smaller capacity indicates that

preference should be given to it. Regarding method C the percentage deviations compare very favorably with method A, but this method has several weak points, which will be briefly described:

(a) In making tests according to the A and B methods breaks occurring at the jaws are discarded, as they may have been caused by the crushing or shearing of the material by excessive tightening of the grips. Where method C is used, it is not possible to distinguish between breaks which may have occurred on account of excessive tightening of the grips and such breaks which were not influenced by such tightening, the shape of the test piece in this case causing the break always to occur at the 1-inch grip.

(b) The breaking stress obtained is a function of the lateral stiffness of the fabric, as well as the strength of the material. In other words, the test result is always influenced by yarns outside the 1-inch width under direct tension, and this influence is not constant in all fabrics.

(c) Great care is also required in placing these test specimens in the jaws of the testing machine. A specimen fastened at a slight angle in the jaws will cause a large difference in tensile strength from that which would occur if it was placed in properly. The latter series of tests was, however, rather inconclusive, owing to the relatively small number of tests made.

The fact that the three methods of tests were employed by persons already familiar with the application of one particular method of test furthermore tended to considerably reduce the variation as compared with the other two methods, which had not in some cases been used at all until this series of comparative tests was started.

From the results of preliminary tests it appears that the A method is fully as satisfactory from the point of view of accuracy and reliability as the others; this, however, will be substantiated by further tests.

The following results in Table 3 show the relation of tensile strength of fabric tested by five different methods. These, based upon several hundred tests in each case, were obtained from tests made upon test specimens prepared as shown in sketches A, B, C, D, E, Fig. 1.

TABLE 3

Comparing specimens prepared as shown in the diagrams, Fig. 1	Approximate percentage increase or decrease of tensile strength employing test specimen A as basis of calculation
A.....	B test specimens are approximately 90 per cent stronger than A test specimens
B.....	
A.....	C test specimens are approximately 45 per cent stronger than A test specimens
C.....	
A.....	D test specimens are approximately 25 per cent weaker than A test specimens
D.....	
A.....	E test specimens are from 15 to 30% stronger than A test specimens. This varies with warp and filling.
E.....	

In considering the element of moisture content of the specimen several points must be kept in mind. Samples of cotton material have been found to increase in strength very materially when they are caused to absorb moisture from the atmosphere. It, therefore, is necessary to adopt standard conditions in order to

FIG. 3.—Method of cutting samples from fabric

make any two tests comparable. This may be done either by drying the sample in such a way as to eliminate the question entirely or to expose samples to a previously accepted standard atmosphere until they shall have absorbed all the moisture they will and the samples and atmosphere will be in equilibrium. It has been assumed that the elimination of the possibility of difference in moisture content between samples rendered the former method more reliable.

Samples for this test were cut as shown in Fig. 3, the test specimen A, Fig. 1, being used in all cases. The upper or X specimens were exposed in an atmosphere of 65 per cent relative humidity and 21° C (70° F) temperature for several hours and tested. The

lower or Y specimens were placed in an oven, Fig. 2, in which a temperature of 105° C (221° F) was continuously maintained. After exposing for about two hours or until all uncombined moisture of the fiber is eliminated the specimens were removed, one at a time, and tested as quickly as possible. In each case the test specimen was broken within 30 seconds after being taken from the oven, and there is reason to believe that the amount of moisture absorbed before the completion of each test was entirely negligible.

In preparing the specimens, the samples were raveled down to their final width (along the 16-inch length) before separating the X and Y parts. This procedure insured exactly the same threads being tested by each method. The individual results were tabulated and deviations calculated from the average as shown in Table 4.

The following table is given to illustrate the method for ascertaining which condition (air conditioned or bone-dry) gives the more uniform results upon test specimens of identical dimensions:

TABLE 4

X Air-conditioned test specimens (65 per cent relative humid- ity at 70° F)		Y Bone-dry test speci- mens (dried at 105° C)		X Air-conditioned test specimens (65 per cent relative humid- ity at 70° F)		Y Bone-dry test speci- mens (dried at 105° C)	
Warp	Percentage deviation	Warp	Percentage deviation	Warp	Percentage deviation	Warp	Percentage deviation
Pounds		Pounds		Pounds		Pounds	
306	2.00	219	0.45	292	2.67	219	0.45
312	4.00	221	.45	291	3.00	218	.91
310	3.33	221	.45	300	.00	220	.00
304	1.33	218	.91	302	.67	221	.45
299	.33	220	.00	296	1.33	220	.00
308	2.67	221	.45	300	.00	223	1.36
310	3.33	218	.91	304	1.33	218	.91
312	4.00	221	.45	295	1.67	217	1.36
307	2.33	223	1.36	299	.33	221	.45
291	3.00	222	.91	296	1.33	221	.45
294	2.00	225	2.27	294	2.00	220	.00
239	3.67	221	.45	295	1.67	223	1.36
298	.67	217	1.36	293	2.33	220	.00
301	.33	216	1.82	298	.67	219	.45
294	2.00	221	.45				
301	.33	222	.91	Av. 300	1.81	220	.73

FIG. 2.—*Tensile strength machine and drying oven*

From four series of tests made in different mills using this method the average deviations were calculated. The results appear in Table 5 and comprise several hundred tests in each series.

TABLE 5

Comparative Tensile Strength Tests Upon Specimens Under Two Different Conditions

Series of tests	X samples		Y samples	
	Air-conditioned test specimens	Percentage deviation	Bone-dry test specimens	Percentage deviation
	Pounds		Pounds	
No. 1.....	300	1.98	220	1.21
No. 2.....	306	2.16	213	1.10
No. 3.....	289	1.38	192	1.03
No. 4.....	303	1.66	205	2.15

An analysis of Table 5 shows that, in general, the contention that bone-dry samples would give more uniform test results, owing to lack of uneven moisture distribution, has been sustained.

FIG. 4.—Method of selecting tensile strength test specimens

For this reason this method has been tentatively accepted for tire fabric testing.

In comparing the different methods of sampling, it was simply designed to show that, in general, similar results would be obtained, no matter how samples were taken. Table 6 gives the averages obtained on samples located as shown in Fig. 4. A large number of samples were taken from which to compute each average.

TABLE 6

Average Tensile Strength of Different Parts of Fabric

Tests made by—	Test samples			Individual rolls tested of each letter
	A	B	C	
	Pounds	Pounds	Pounds	Rolls
Bureau of Standards	214	219	220	51
Mill No. 1	196	199	197	89
Mill No. 2	217	217	217	12
Mill No. 3	234	241	239	10
Mill No. 4	262	262	263	14
Total				176

This Bureau's results were obtained from tests upon fabric manufactured by the four mills.

FIG. 5.—Method of sampling

The results of these tests show that there are only small differences in tensile strength at any place across the width. By taking test pieces well distributed from selvage to selvage, the weakest and the strongest parts of the fabric would be found and the average of all tests would more fairly represent the strength.

FIG. 6.—Method of sampling

The contention that the center of the fabric may be stronger than portions near the selvage does not warrant the latter being left out of consideration when the whole fabric is going to be used.

A method of sampling, both convenient and representative, is shown in Fig. 5 and Fig. 6. Samples chosen according to such a plan as this should show much better the relative strength of the whole fabric than samples taken only from a small portion near the center.

To summarize, the test considered best adapted to the conditions is the bone-dry test upon test specimens prepared from test pieces cut from different parts of the sample. If these conditions are carefully complied with, there appears to be no sufficient reason for being unable to make all work strictly comparable, assuming that proper means have been taken to eliminate possibility of difference in testing machines as outlined above.

WASHINGTON, December 3, 1915.

APPENDIX

TENSILE STRENGTH DETERMINATIONS UPON DIFFERENT TESTING MACHINES

During the past two years many disputes have arisen between buyers and sellers of tire fabric relative to tensile strength.

This investigation was undertaken to ascertain what differences in the tensile-strength tests are obtained with various testing machines commonly used by the trade. Five machines of four different makes were employed in these comparative tests.

The cotton-tire fabrics used in the tests were made from combed sea-island fiber and carded Egyptian fiber, the cloth weighing approximately $17\frac{1}{4}$ ounces per square yard.

Tensile-strength test pieces (A to F, inclusive) were cut from the fabric as indicated in Fig. 5.

FIG. 7.—Method of selecting test specimens

Fig. 7 illustrates two pieces of fabric, namely, X and Y. One piece was tested at the mill where the cloth was manufactured, and the other piece was submitted to this Bureau for test.

All test specimens were 8 inches long by 23 yards (approximately 1 inch) in width, and a half-inch fringe of yards extended beyond the specimens on the long sides. These specimens were placed in a ventilated drying oven and dried at 105°C for about

two hours, or until all moisture, except that of chemical composition, had been expelled.

Dry-test specimens were taken (one at a time) from the drying oven, and the breaking stress was obtained within 30 seconds.

Each specimen was securely clamped between the jaws of the testing machine, which were 3 inches apart, and the pulling jaw traveled at a uniform rate of 12 inches per minute. Except that different testing machines were employed, all test conditions were identical in this work, so that the results of this series of tests are comparable.

Table 7 shows the results of tensile-strength tests obtained at the particular mill indicated and the results obtained by the Bureau of Standards on test specimens cut from the same piece of fabric.

TABLE 7

Automobile Tire Fabric—Tensile-Strength Tests

Fiber used	Fabric made by—	Fabric tested by—	Tensile strength (pounds)		
			Warp	Filling	Average
Combed sea island..	Mill 1...	Mill 1.....	214	210	212
		Bureau of Standards.....	227	233	230
Do.....	Mill 2...	Mill 2.....	224	234	229
		Bureau of Standards.....	213	234	224
Do.....	Mill 3...	Mill 3.....	238	248	243
		Bureau of Standards.....	211	226	219
Do.....	Mill 4...	Mill 4.....	259	264	262
		Bureau of Standards.....	218	234	226
Carded Egyptian.....	Mill 3...	Mill 3.....	.....	.....	.....
		Bureau of Standards.....	181	199	190
Do.....	Mill 4...	Mill 4.....	206	214	210
		Bureau of Standards.....	180	199	190

Each of the figures in the above table represents the average of a series of tests upon different fabrics. More than 1000 test results have been used in making this table.

The figures shown in Table 8 give the relation of the mill results as compared with those of the Bureau of Standards.

TABLE 8

Mill—	Tensile strength (pounds)			Percentage difference in tensile strength. (Bureau of Standards result is basis of calculation)
	Mill results	Bureau of Standards results	Difference	
No. 1.....	212	230	—18	7.8 per cent weaker.
No. 2.....	229	224	+ 5	2.2 per cent stronger.
No. 3.....	243	219	+24	10.9 per cent stronger.
No. 4.....	262	226	+36	15.9 per cent stronger.

The differences between results obtained upon two testing machines are very large in some instances, probably owing to two causes: (a) Lack of calibration of instrument and (b) some inherent defect in the mechanism of the apparatus. The Bureau of Standards therefore strongly recommends that testing machines be calibrated at frequent and regular intervals. It would also suggest that a careful comparative study be made of several of the better types of jaws or clamps which are now upon the market.

MOISTURE CONTENT OF AUTOMOBILE TIRE FABRIC AND ITS INFLUENCE UPON THE WEIGHT AND TENSILE STRENGTH

It is well known that cotton fiber is hygroscopic. The extent to which it will absorb or give up its moisture content depends upon the condition of the material and the relative humidity and temperature of the air by which it is surrounded. Under changing atmospheric conditions, tire fabric may sometimes vary in moisture content from 3.5 to 8.5 per cent.

Automobile tire fabric is usually sold in rolls of from 100 to 500 yards each. In some instances moisture is intentionally added to the cloth when it is rolled for shipment. This moisture is sometimes added to increase the weight and strength of the fabric and sometimes to improve its appearance. Cotton tire fabric under such conditions may contain from 3.5 to 10.5 per cent of moisture per 100 parts of dry material.

The quantity of uncombined water present in the fiber has a marked influence upon the weight and strength of the fabric; to a less degree, the width and elongation and the crimp of the yarn.

From preliminary tests upon combed sea island tire fabric the results have shown that for each 1 per cent of moisture content, upon the basis of 100 parts dry material, there is an increase in tensile strength of approximately 7 per cent. This ratio of strength to moisture content was based upon results obtained from tests upon fabrics which contained from 0 to 10 per cent of moisture.

If dry fabric, therefore, has a tensile strength of 200 pounds per inch of width, it would test 249 pounds with 3.5 per cent moisture, 319 pounds with 8.5 per cent, and more than 325 pounds with 10.5 per cent moisture content. There is thus a difference of 70 pounds in tensile strength of the same fabric caused by a 5 per cent difference in its moisture content, i. e., between 3.5 per cent and 8.5 per cent.

A consideration of the variation in weight of fabric is also important, especially when it is bought upon the pound basis. What is known as a 17 $\frac{1}{4}$ -ounce tire fabric, under so-called normal atmospheric conditions,¹ will weigh approximately 16 $\frac{1}{2}$ ounces under bone-dry conditions. Therefore, with 3.5 per cent moisture it would weigh 17.08 ounces and with 8.5 per cent moisture 17.90 ounces per square yard, a difference of about 5 per cent in weight. On a roll of 500 yards a difference of 5 per cent in weight would mean 25 pounds.

Many tests for the determination of moisture have been made during the past year upon 17 $\frac{1}{4}$ -ounce tire fabric. The particular fabrics employed in this preliminary investigation were produced and tested by four prominent cotton mills, three located in the North and one in the South, and all tests were made upon cloth which did not have moisture added artificially when being wound into a roll. In other words, the rolls were shipped in box cars to the purchaser as wound under the normal conditions of the mill. The rolls were sometimes exposed for a few days only, while in other instances they were exposed for weeks to the different air conditions that obtain in the winter months in unheated cars and during the summer months in ordinary box cars.

¹ Refers to moisture content of fabric when received in 500-yard rolls.

The tests included altogether more than 200 rolls and more than 400 samples were tested. The results were as follows:

	Per cent
Mill No. 1.....	4.6
Mill No. 2.....	4.8
Mill No. 3.....	5.4
Mill No. 4.....	^a 4.6
Average.....	4.85

The extreme variation of moisture was between 3.5 and 6.5 per cent, no single sample reaching as high as 7 per cent.

^a Southern Mill.