DEPARTMENT OF COMMERCE
BUREAU OF STANDARDS
George K. Burgess, Director

TECHNOLOGIC PAPERS OF THE BUREAU OF STANDARDS, No. 318
[Part of Vol. 20]

ENDURANCE TESTS OF TIRES

BY

W. L. HOLT, Physicist
P. L. WORMELEY, Physicist
Bureau of Standards

May 25, 1926

PRICE 10 CENTS
$1.25 PER VOLUME ON SUBSCRIPTION
Sold only by the Superintendent of Documents, Government Printing Office
Washington, D. C.

WASHINGTON
GOVERNMENT PRINTING OFFICE
1926

ENDURANCE TESTS OF TIRES

By W. L. Holt and P. L. Wormeley

ABSTRACT

For the past two and one-half years the Bureau of Standards has been making endurance tests of various brands and types of tires. In this paper test results of 230 cord tires of the 3½, 4, 4½, and 5 inch sizes and of 36 different brands are shown graphically. Photographs and descriptions of two types of endurance-test machines installed at the bureau are shown, together with a description of each and a short history of their development.

CONTENTS

I. INTRODUCTION

During the past 15 years the tire industry has had a very rapid growth, and important changes have been made in the design of tires. Many new developments in rubber compounding and in the construction of tires have taken place, and with such changes a need arose with tire manufacturers for means of testing tires for durability other than by the slow and expensive process of road testing. During this time most tire manufacturers experimented more or less with various types of laboratory testing machines, but no type came into very general use.

The problem which confronted the Government purchasing agencies was similar to that which the manufacturers faced in that they were both interested in a reliable and reasonably rapid means for testing the durability of tires. The first specification for tires prepared for Government use went into considerable detail as to the quality of materials and the methods of construction, but with the many changes taking place in the art of tire building it soon became out of date.

One of the important steps in drawing up a specification of more general character was the development, with the aid of the tire manufacturers, of an endurance-test machine for measuring the durability of tires. The conditions under which tires are run on this machine are sufficiently severe to enable a test to be completed in less than 48 hours of continuous running, which, in the case of large purchases, provides a means for testing representative tires offered for delivery before acceptance of the entire order.

II. DEVELOPMENT OF TEST METHODS

In considering the type of test, it was recognized that, in general, the critical feature in tires is not the wearing quality of the tread but rather the general construction of the tire and the ability of the various component parts to function as a unit. While it would be desirable to have one test which would incorporate a wearing test for the tread rubber as well as a general construction or carcass test, it was not considered feasible to attempt to combine the two tests until more complete information should be available on each one separately. Accordingly, the aim was to develop a carcass test leaving out of consideration the abrasive resistance of the tread, which may be judged reasonably well from the tensile properties.

The machine shown in Figure 1 was built with this object in view. The tire is mounted on a wheel free to revolve on a spindle secured to a movable carriage and pressed against the drum with the desired axle load. The load is applied by means of weights acting through a bell crank lever (3 to 1 ratio). The drum (60 inches in diameter) is driven at a surface speed of 30 miles per hour, and in turn drives the tire. A speedometer connected to each drum shows directly the miles traveled by the tire. The spindles are mounted on ball bearings so that the effort required to turn the tires is small, and the whole arrangement constitutes what might be called a "front-wheel" test. There was some question as to whether or not a "rear-wheel" drive in which the tire is turned against a resistance would give more reliable results. Comparative tests were made on several sets of duplicate tires first by the drum driving the tire against no tractive resistance (front-wheel drive) and second, by the tire driving the drum against a considerable tractive resistance (rear-wheel drive). The results of these tests did not show any advantage of the latter method for a carcass test and accordingly the simpler type of test—that is, the one in which the drum drives the tire against no tractive resistance—was decided upon.

In the first tests of tires run on this type of machine no cleats were used on the drums. The tires tested in this manner often showed no indication of failure within the practical time limit of an accelerated test; in fact, the conditions of this first drum test appeared to be less severe than the usual conditions of road service. Furthermore, it was observed that the usual type of failure on the drum differed from the type of failure commonly found in tires. Due to the absence of cleats on the drum, the deflection of the tire was confined to the tread portion and did not extend into the side wall. For this reason failure in practically every case resulted from tread separation over a narrow strip under the central portion of the tread. With the view of producing in the tire a type of failure typical of the failure resulting

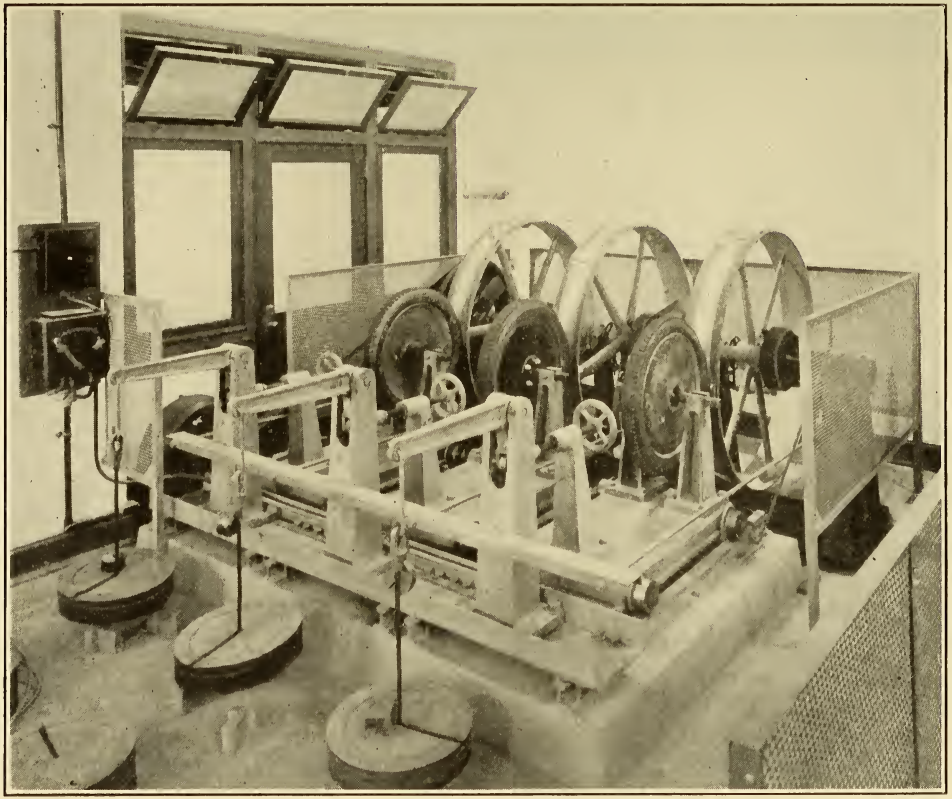


FIG. 1.—*Endurance tire testing machine type "A"*

from road service, and with the further object of accelerating the test, the drum was next equipped with six cleats three-eighths inch high and five-eighths inch wide. These cleats served to increase slightly the area over which deflection took place, but the change was not sufficiently great to influence appreciably the results of tests. The next step was to change the shape and increase the size of the cleats in order to produce greater deflections. Before deciding upon the dimensions of cleats, consideration was given to the logical suggestion that the size of cleat should bear a fixed relation to the size of tire being tested. However, the results of experiments seemed to justify the adoption of a standard cleat for all sizes of tires, which arrangement is in accord with the contention that all tires, regardless of size, have to meet the same irregularities of road surface.

The final size of cleats and the proper test loads for each particular size of tire were established as a result of cooperative tests made by the bureau and the Rubber Association of America. In establishing the test conditions, consideration was given to the fact that many manufacturers make more than one grade of tire. This test was designed to impose sufficiently severe conditions on the tire to eliminate all but the best commercial grades. The standard conditions as finally decided upon after receiving the approval of the Rubber Association of America are as follows:

Speed of Drum.—Thirty miles per hour (all tire sizes).

Cleats.—The same for all tires, three-fourths inch high, cut from a cylinder of 2⅞-inch diameter. Three cleats are equally spaced around the drum circumference at angles of 45° left and right hand and at 90°, respectively.

Table of test conditions

Size of tire (inches)	Type of tire	Axle load (pounds)	Air pressure (pounds per square inch)
3	Fabric	500	45
3½	do	700	55
3½	Cord, regular	825	55
3½	Cord, heavy-duty	900	60
4	Cord	1, 200	65
4½	do	1, 500	65
5	do	1, 800	70

The loads and air pressures were adjusted with the view of producing in the same length of time an equally severe test for different sizes of tires.

In seeking for a definite point in the life of a tire to serve as a basis for judging performance, two criteria were considered—first, the mileage at which signs of failure become apparent and, second, the maximum mileage obtainable from the tire. As stated before, the test is not designed to measure tread wear, and except in unusual cases the tread wear is very small. Practically all the tire failures are due to tread or ply separation, breaking of the carcass, or bead failure. The beginning of failures such as these can be detected by close examination of the tire very shortly after they develop. This point of incipient failure was chosen as a basis for the evaluation of tires because it can usually be determined quite definitely and is the point at which the tire ceases to function as a unit and at which disintegration starts. It also has the advantage that its use considerably reduces the time of test over that which would be required if tires were run to complete failure. Moreover it would be more difficult to define and to determine the point of complete failure than the point of incipient failure, and to settle definitely a question of complete failure might frequently require the use of two or more tubes.

The specification requirements finally adopted are as follows: A cord tire shall be subjected to the endurance test under the conditions shown in the table until it has run 1,250 miles (fabric tires, 600 miles). At the end of this period the tire is removed from the rim and examined. There must be no indication of failure at this time as determined by a visual examination of the tire when cut. It is obvious that this test is much more severe than average road service as "blow-out" usually occurs at from 2,000 to 4,000 miles, whereas in actual service it would not occur until the tire had run three or four times this distance.

Of all the tires tested under the above condition, indications of failure fall under four heads as follows: (1) Separation either between the plies, in the junction of the tread and carcass, or in some instances at the bead; (2) breaking of the carcass; (3) bead failures due to rim cutting; (4) cracking or splitting of the tread rubber.

The machine shown in Figure 2 operates on the same principle as the one in Figure 1. It is of much more rigid construction than the first one built and is designed to operate with axle loads up to 5,000 pounds. The drum on this machine is 67.23 inches in diameter (1/300 mile circumference) in place of 60 inches, which means that there are fewer cleats per mile of travel of the drum. For equal results on the two machines a somewhat greater mileage is required to compensate for this difference in drum size. This has been set at 1,350 miles compared with 1,250 for the smaller machine. It is customary to use the lighter machine for axle loads up to 1,200 pounds, and the heavier machine for tests when a higher axle load is required.

III. RESULTS OF TESTS

The results of endurance tests of 3½, 4, 4½, and 5 inch cord tires (230 tires of 36 different brands), all of which were run with cleats of the size as finally adopted are shown in Figure 3. The tires of each

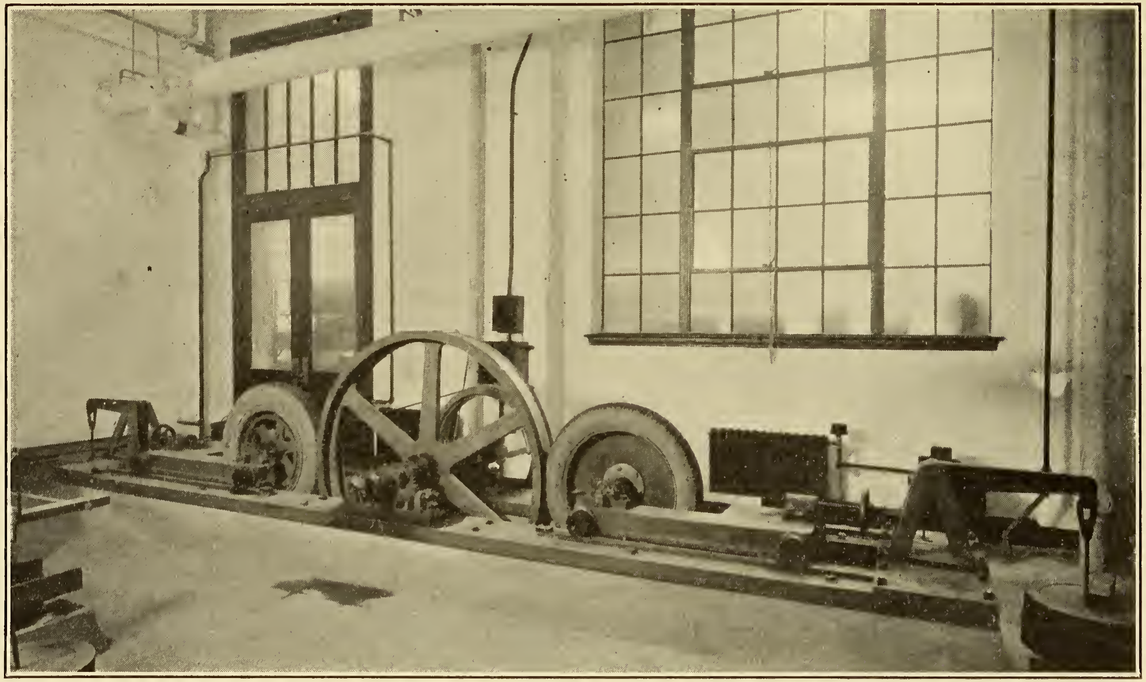


FIG. 2.—*Endurance tire testing machine type "B"*

manufacturer are grouped and designated by letter, the same letter being used for all sizes. These tires were not all run especially for this investigation, but the results are a record of tests made for various purposes on these sizes during a period of about two and one-half years and give an idea of the way in which commercial tires meet this test. It is probable that the results would be of greater value if the tires had been examined at more frequent intervals so as to indicate the time of failure more closely, and if each tire had been run at least until some indication of failure could be noticed. However, inasmuch as the majority of these tires were tested in connection with Government purchases the test was stopped at the end of the specified mileage and the tires removed for further examination. In quite a good many instances the tests were made at the request of tire manufacturers, or for other purposes, in which cases the tests were usually continued until "blow-out" occurred. The tires tested previous to March, 1924, were run to obtain information on the performance of commercial grades of tires on the machine, and the 3½-inch tires in these tests were run at 1,000-pound axle load instead of the axle loads subsequently adopted, namely, 825 pounds for regular size tires and 900 pounds for the oversize. This change to the lower axle loads seemed desirable inasmuch as several of the standard high-grade tires failed to meet the test requirements with the higher axle load; and, also, it appeared that as a whole the former test was relatively more severe on the 3½-inch tires than on the larger sizes.

A study of the charts in Figure 3 will show the following:

(1) *3½-inch tires.*—118 tested, of which 45 met test requirements; 27 brands tested, of which 13 met the specification requirements in one or more tests.

(2) *4-inch tires.*—61 tested, of which 35 met test requirements; 26 brands tested, of which 18 met the specification requirements in one or more tests.

(3) *4½-inch tires.*—18 tested, of which 10 met test requirements; 7 brands tested, of which 6 met the specification requirements in one or more tests.

(4) *5-inch tires.*—33 tested, of which 16 met test requirements; 15 brands tested, of which 8 met the specification requirements in one or more tests.

The reader's attention is called to the fact that where the results are given on a series of tires, they are not necessarily duplicate tires. Details of tire manufacture are changed from time to time, new rubber compounds are employed, etc., so that a tire made at one time often differs materially from one made at another time. The conditions of test, however, have remained constant for approximately two and one-half years and, accordingly, any changes in the durability of tires as indicated by test results during this period are due to changes in the tires.

As stated before, the conditions under which these tests were made precluded the possibility of running all tires to complete destruction, so that it is difficult to draw a conclusion as to whether the general trend of tires is toward better or poorer quality. However, several manufacturers have experimented with their tire constructions in an effort to build tires to meet this test and the result can be seen by noting progressive tests. For instance, manufacturer "G" shows quite an improvement over a four-month period in the way in which 3½-inch tires have met the test. The 4-inch tires under "H" show a decided improvement in an eight-month period in their ability to withstand the test. Several others, such as the 4-inch tires under "D," "K," and "GG," show similar tendencies. Whether or not such changes have served to increase the life of tires can only be determined by further comparison of laboratory test results with the actual service records of tires. In some cases, such as are noted, manufacturers have made up special tires and submitted them for test in order to try out some new feature of design. In general, however, the results are representative of standard commercial tires.

It is interesting to note the tests of three 4-inch tires under date of February, 1924, and designated as "H." These three tires were made duplicates as nearly as possible and were tested at the same time on the three-unit machine (fig. 1) under the conditions finally adopted as standard. The tires all showed signs of failure in the same way and at the same time so far as could be determined from periodical examinations. The maximum and minimum "blow-out" mileages differ by about 12 per cent. In general, it has been found that the mileages at which signs of failure became apparent check closely for a series of tires of a particular brand and that the character of failure is the same.

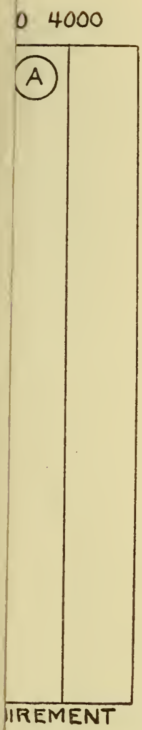
In most cases the details of construction of the tires tested and the exact composition of rubber composed used were not known. Based on an observation of the general performance of tires, however, and the results of tests in which details of construction were known, the following conclusions are reached:

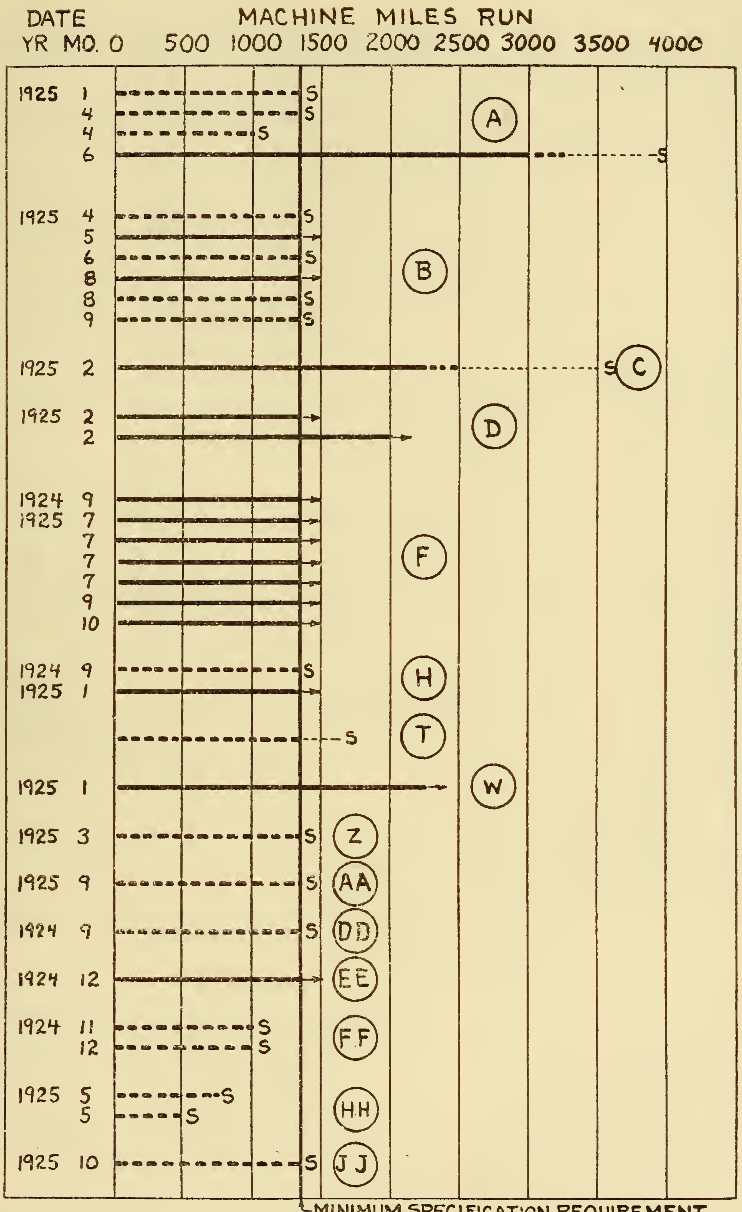
(*a*) A carcass in which the friction rubber is slightly compounded appears to withstand the test better than one in which "pure gum" is used.

(*b*) Within the customary limits of air pressures used in tires the higher the pressure the better the tire will stand up.

(*c*) Fabric tires develop a much higher temperature than cord tires, and their life is much less than cord tires.

(*d*) The cleats on the drums impose a severe condition on the tire, and are really the cause of failure.


0 4000
A
IREMENT


DATE
YR MO.
MACHINE MILES RUN
0 500 1000 1500 2000 2500 3000 3500 4000
1925 1
4
4
6
A
1925 4
5
6
8
8
9
B
1925 2
C
1925 2
2
D
1924 9
1925 7
7
7
7
9
10
F
1924 9
1925 1
H
T
1925 1
W
1925 3
Z
1925 9
AA
1924 9
DD
1924 12
EE
1924 11
12
FF
1925 5
5
HH
1925 10
JJ
S
MINIMUM SPECIFICATION REQUIREMENT

5" CORD TIRES

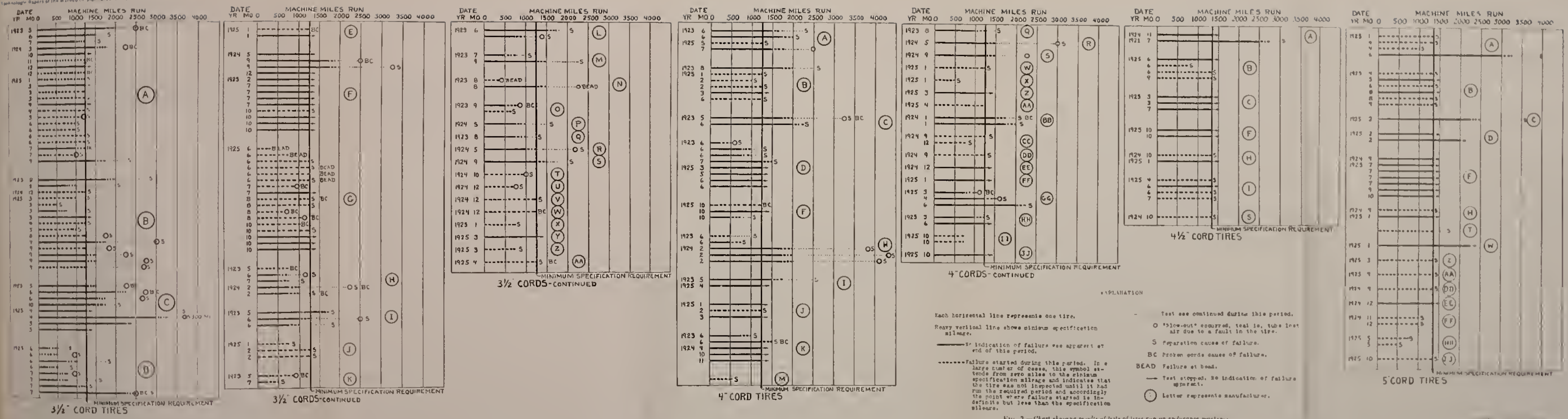


FIG. 3.—Chart showing results of tests of tires run on endurance machines

(e) Separation, which was the principal cause of failure in tires, did not always take place at the same location in the tire. It occurred in most cases between one or more of the following parts: Tread and breaker, breaker and cushion, cushion and carcass, or between the outer two plies.

(f) It was noticed that any particular brand of tire usually showed a characteristic type of failure.

(g) It was observed to be characteristic of some makes of tires to "blow-out" much sooner after separation had started than others.

(h) Compounded inner tubes for truck tires appear to withstand the action of heat better than those of the pure gum type.

IV. TESTS OF TYPES AND SIZES OF TIRES NOT SHOWN ON CHARTS

A good many fabric tires of the 3½-inch size have been run and it has been found that they fail much more quickly on this test than cord tires, which is in accordance with their relative road performance. The results of tests are not given, as interest in this type of construction is rapidly dying out, due to the great superiority of the cord tire.

Balloon tires of several different sizes have been tested under loads corresponding to the loads of high-pressure tires which they replace and with air pressures varying from 32 pounds for the 4.40-inch tire to 38 pounds for the 7.30-inch tire. The mileage obtained, in general, were about the same as for high-pressure tires, but the type of failure differed. In practically all cases the failures were due to the breaking of the carcass rather than separation, as is common with high-pressure tires. In some of these tests the wear of the tread was considerable. It was most pronounced on each side of the center of the tread and in one case the tread was abraded entirely through to the breaker before the carcass of the tire showed any signs of failure. This same type of tread abrasion is not uncommon in service and the reason seems to be that the greater deflection of balloon tires due to their lower inflation pressure produces a lateral movement or slip of the tread rubber as the tire is flattened against the drum or road surface.

Several 6 and 7 inch truck tires have been tested under axle loads of 2,400 and 3,500 pounds, respectively. These tires, in general, showed a higher mileage performance than the smaller sizes. It was also observed that a higher temperature was developed in these tires than in the smaller sizes and frequently the inner tubes failed under this excessive temperature before the test was completed. The types of failure were similar to those found with the smaller sizes, namely, separation and breaking of the carcass.

Washington, February 9, 1926.