tions should be started and vigorously prosecuted to secure information and data concerning

1 Relative stress effect under equal static and impact forces
2 Effect upon stress development of various velocities of applications of the impact force
3 The fatigue effect and endurance limit under impact conditions

DISTRIBUTION OF WHEEL LOADS THROUGH VARIOUS RUBBER TIRES

SAMUEL ECKELS

Chief Engineer, Pennsylvania Department of Highways

The purpose of the experiments was the determination of the distribution of the wheel load in the contact area of a pavement through solid, cushion and pneumatic rubber tires

The apparatus used in these experiments for determining the static load imparted by the tire at the various points in contact with the pavement, is a series of spring scales acting as the measuring medium It is designed to register the load in transverse segments two and one-half inches in width taken across the tread width of the tire Actual contact areas[1] of the tire with the several sections are determined from the properly oriented imprint of the tire by means of a planimeter Results are expressed in pounds per square inch per section

The greatest stress in the contact area of all the tire types is at the point where the plane of the center line of the axle is normal to the pavement and decreases in intensity in both directions from this point

APPARATUS (SEE FIGURES 1, 2, AND 3)

The apparatus consists of ten helical springs (*6*) four inches in height, and two and one-quarter inches outside diameter, arranged in pairs lying eighteen inches apart in a rigid frame, built of two sections of steel channels (*7*) connected by cross pieces (*8*) These springs are seated in cap plates top and bottom (*9*) Resting on the upper cap plate and moving freely in slots one-half of an inch wide, and lying two and one-half inches apart in the frame are steel beams (*10*) three inches wide with iron angles (*11*) screwed to the upper edges, beginning two inches from one end of the beam, and ending two inches from the other so that the upper surface of the machine, when leveled, is a plane fourteen

[1] By "actual contact areas" is meant the area of that part of the tire or lugs actually in contact with the road surface as indicated by the imprints taken under the various loadings and does not represent any included or subtended area

inches wide and twelve and one-half inches long, broken up into five transverse sections (*1*, *2*, *3*, *4*, and *5*). At the points where the beams rest on the springs they are fitted with iron angles (*12*) about two inches

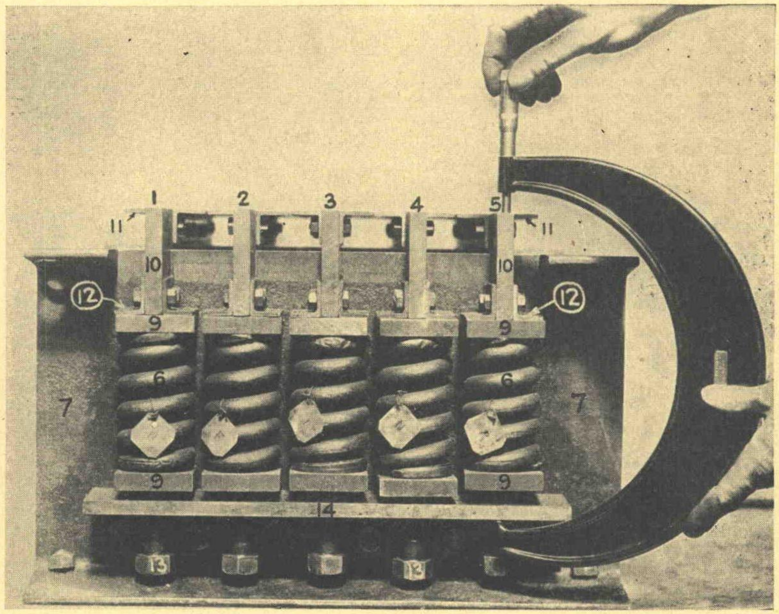


Figure 1

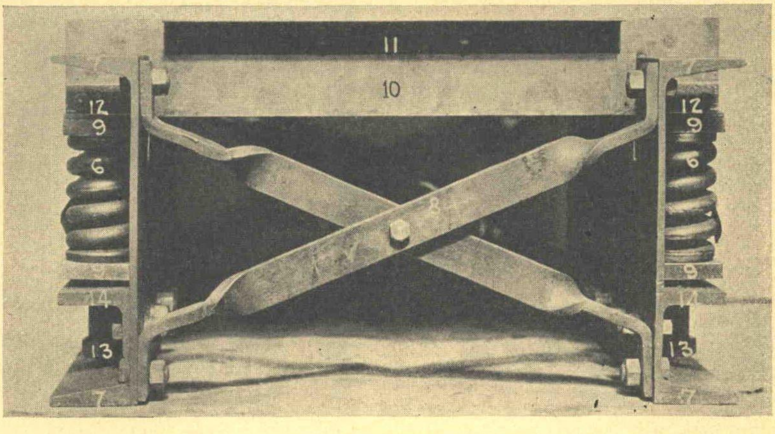


Figure 2

long on each side, and have small pins which fit into the center of the upper cap plates of the springs and prevent slipping. The lower cap plates of the springs on each side are seated on three-quarter inch bolts

(*13*) moving perpendicularly through a rigid steel bracket (*14*), fastened securely to the frame two inches from its base and projecting two and one-quarter inches from the side of the frame. The figures *6*, *7*, *8*, *9*, *10*, *11*, *12*, *13*, and *14* in parenthesis refer to parts of the apparatus as detailed in Figures 1, 2, and 3.

In choosing the springs for use in the machine, ten varieties of helical springs were considered. Each was loaded by means of a standard compression machine, the deflection being measured with an Ames dial. Readings were taken every fifty pounds on the smaller springs,

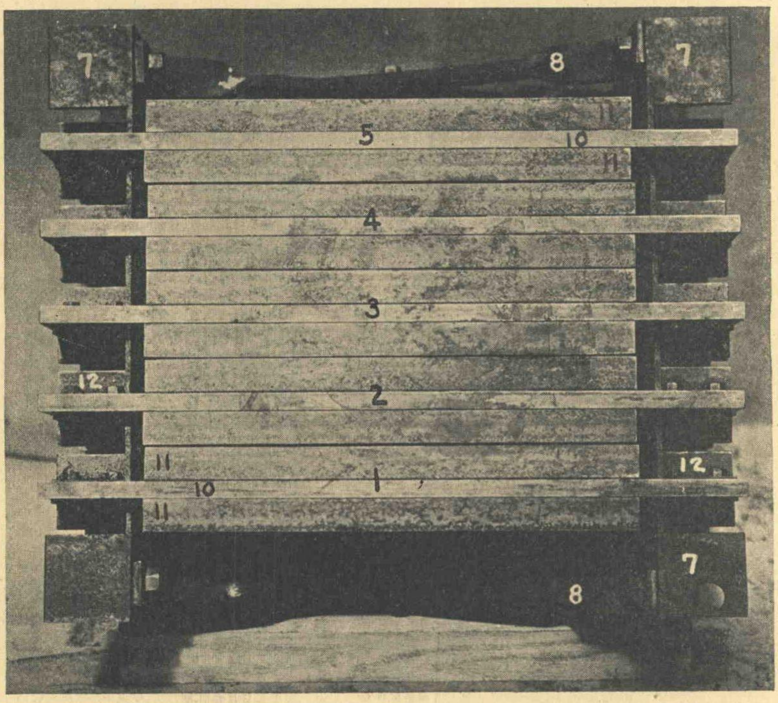


Figure 3. Top View Sectometer

and every hundred on the larger springs, the decrements being plotted against the load. The spring previously described was finally chosen as the best suited for the needs of the experiment. Thirty of these springs were procured and subjected to a procedure similar to that recorded above. Out of these thirty were chosen ten that approached each other in size and uniformity of behavior under various loads.

The machine was now calibrated one section at a time by loading it directly in the center of the cross member, and the results were carefully plotted and the charts used in calculating the loads during the experiment. These calibration curves are reproduced in Figures 17, 18, 19,

20, and 21. Using an individual curve for each of the sections insured the greatest accuracy.

IMPRESSION AND LOAD DETERMINATION

The experiment was run on a wheel attached to a truck (rear right), the truck being raised and lowered by means of jacks.

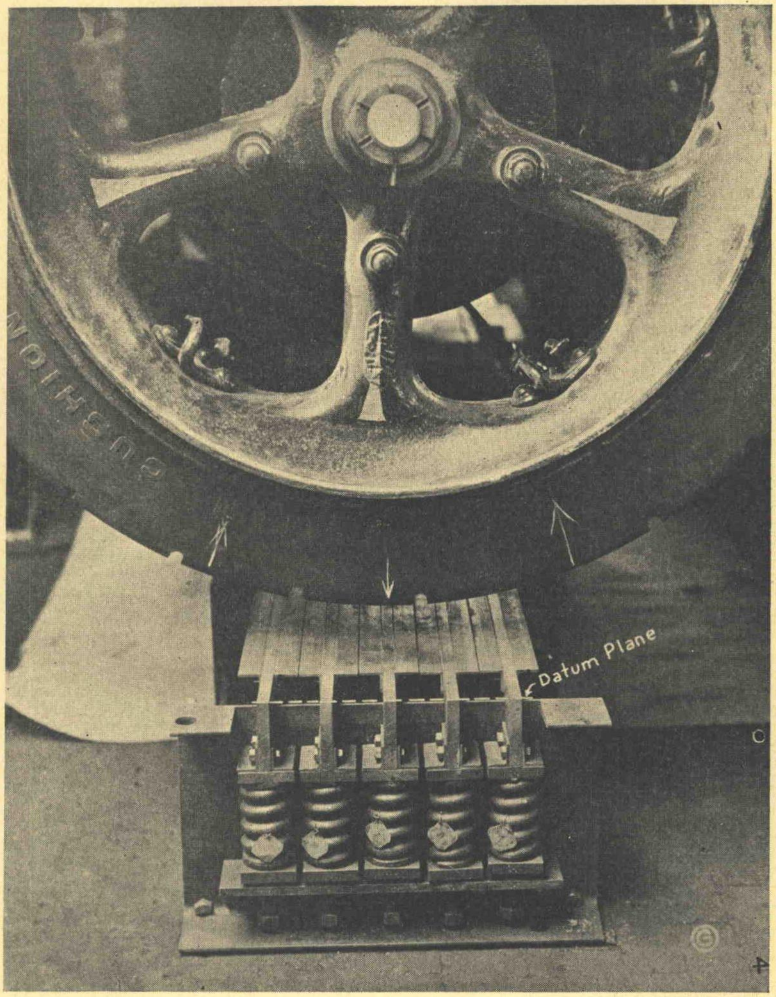


Figure 4

After a weight determination had been made by means of a loadometer, the "sectometer" was slid into place under the right wheel, and a platform the height of the sectometer under the left wheel, considerable care being taken that the center line of the middle section of

the machine was directly below the center line of the axle, and that the wheel, when lowered, would act directly on the center of the cross members. For this preliminary centering an ordinary plumb sufficed.

The "sectometer" was leveled (Figure 4), and the height of the springs were measured with nine inch micrometer calipers (Figure 1). The

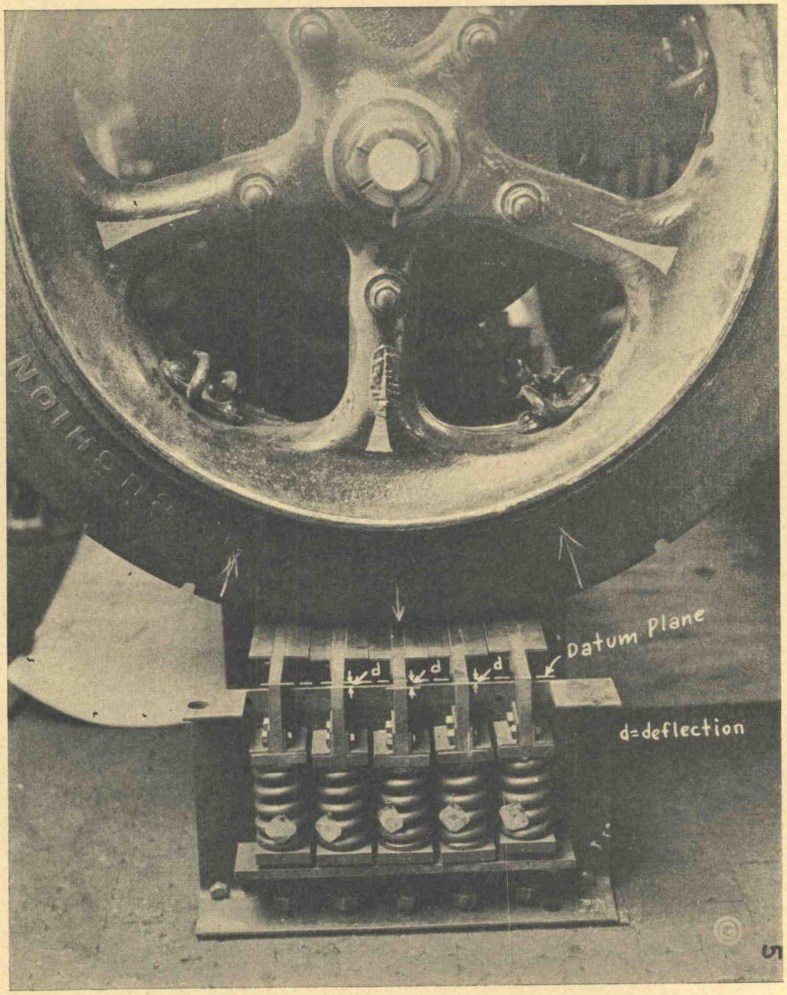


Figure 5

machine was now in position for the impression and also for the determination of the load distribution.

A steel plate of the same dimensions as the top of the machine was laid on it, and a section of the tire was chosen and inked with prussian blue. On the plate was laid a sheet of clean brown paper, and the jacks

were released slowly, with care that the two sides descend evenly and equally. When the entire load rested on the wooden platform on the left, and on the steel plate on the right, the center line of the impression was found by plumbing down from the geometric center of the axle. The truck was again raised and the impression and plate were removed.

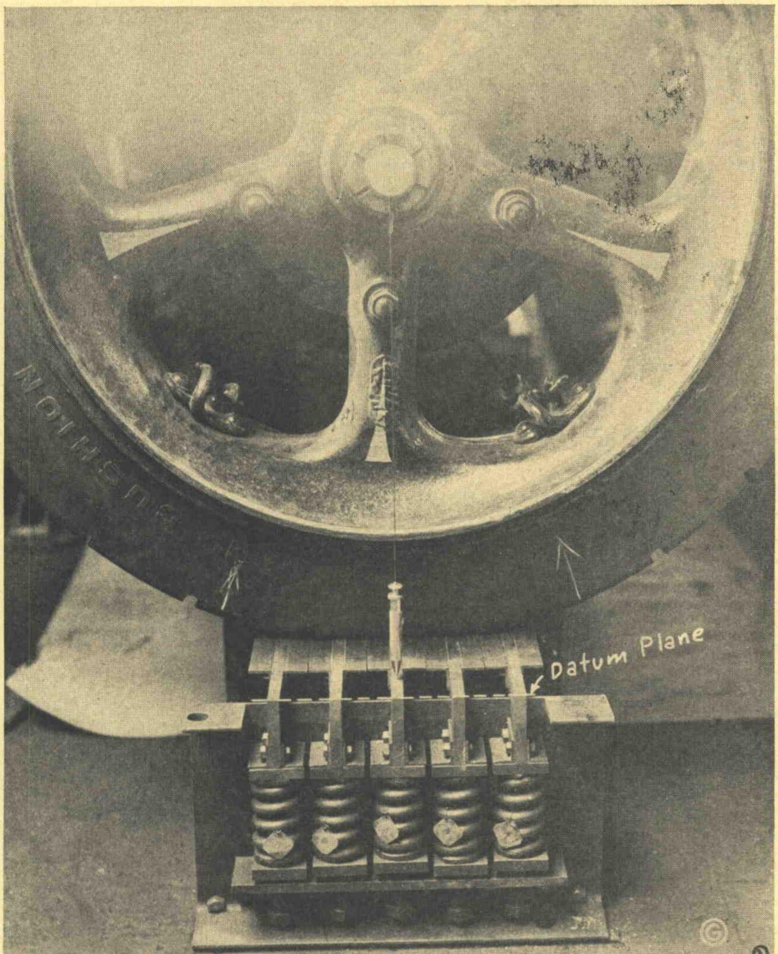


Figure 6

As above mentioned, prussian blue was the coloring used, although lamp black, dry and with linseed oil was tried.

Again the wheels were lowered (Figure 5), and permitted to rest on the platform (left), and "sectometer" (right), thereby causing certain deflections to occur in the springs.

While the entire wheel load rested on the "sectometer," the machine was releveled (Figure 6) by means of the screws, bringing the several deflected sections back into the datum plane. In this manner the resistance offered by a rigid surface is reproduced. The wheel was now

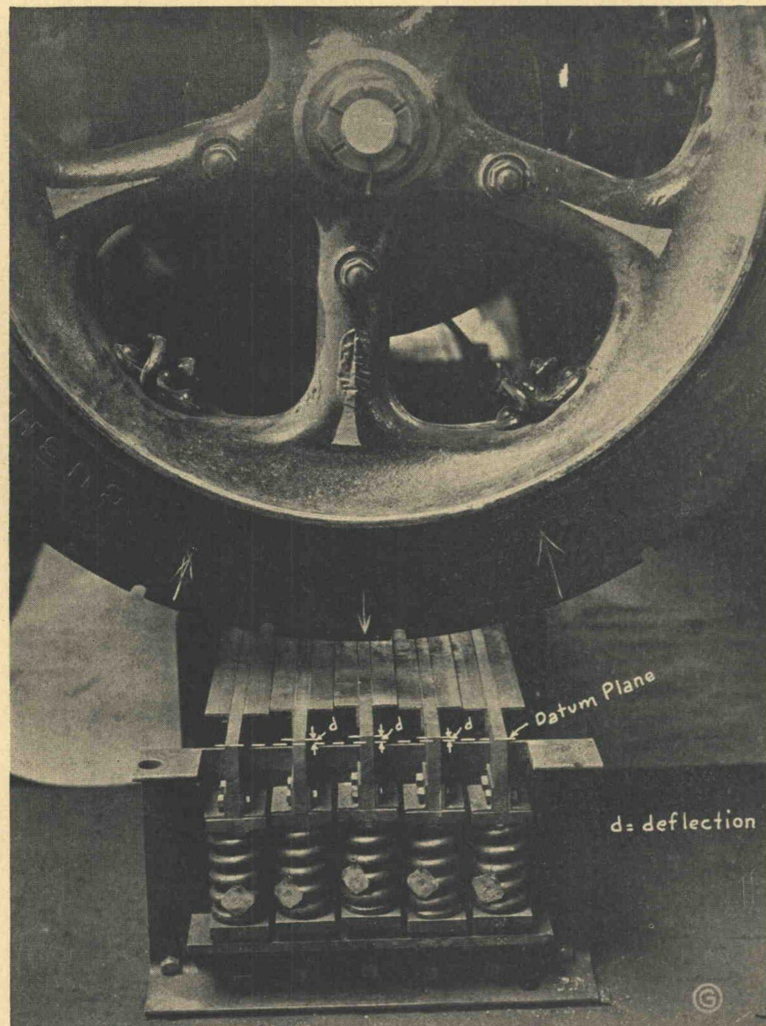
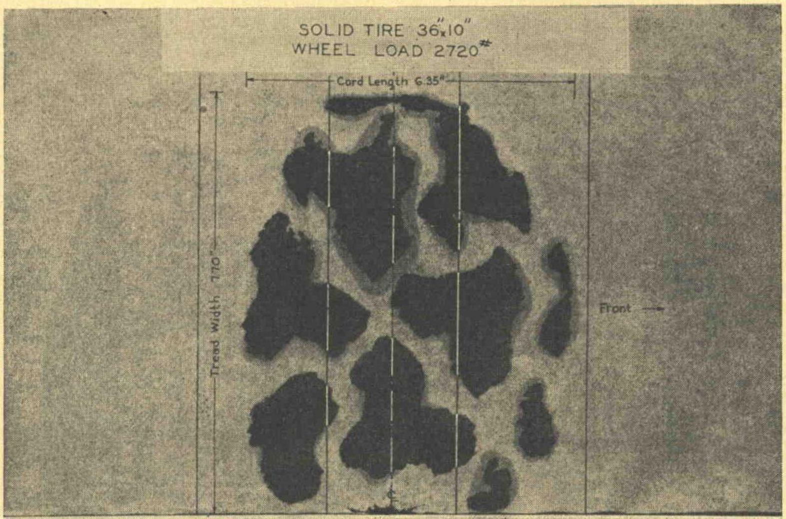


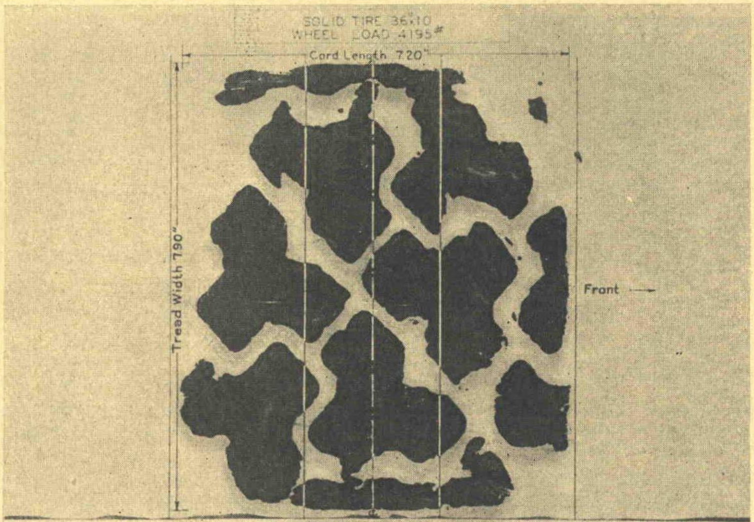
Figure 7

raised clear of the apparatus (Figure 7), and a series of readings was taken with the springs released from compression. The average increase in height for each unit was now found, and with these readings the loads could be read directly from the calibration charts, reproduced in Figures 17, 18, 19, 20, and 21.



SECTION NUMBER	2	3	4	
CONTACT AREA SQ IN	6.29	10.62	6.11	PENNSYLVANIA DEPARTMENT OF HIGHWAYS
LOAD IN LBS	627	1593	500	
LOAD, LBS PER SQ IN	100	150	82	
% LOADING	66.7	100.0	54.6	

Figure 8



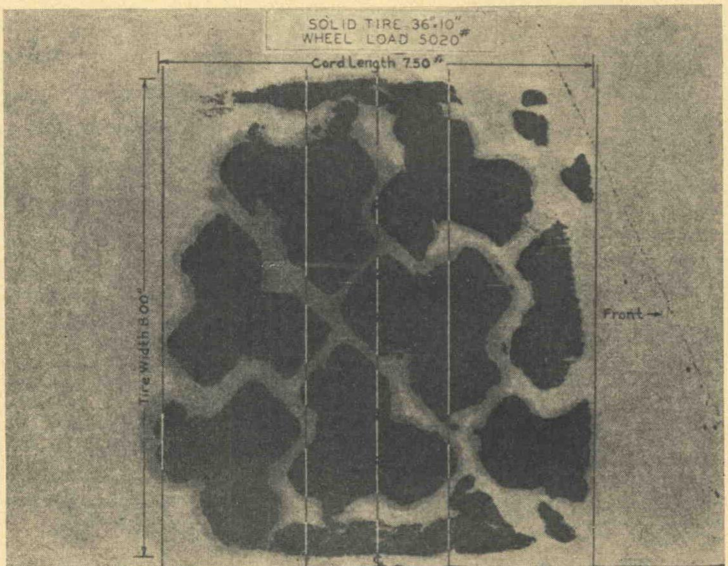
SECTION NUMBER	2	3	4	
CONTACT AREA SQ IN	9.92	14.52	9.90	PENNSYLVANIA DEPARTMENT OF HIGHWAYS
LOAD IN LBS	1140	2157	898	
LOAD LBS PER SQ IN	115	149	91	
% LOADING	77.2	100.0	61.1	

Figure 9

The check determination consists in reapplying the load to the apparatus with the sections in the position as in Figure 7. The springs are again thrown into compression and when the full load is applied the planes of the sections should coincide with the datum plane (Figure 6).

SUMMATION

As previously stated, the test consists in measuring the pressure exerted on five transverse sections of the area of the tire in contact. The test is comparative, in that, it indicates the actual contact area



Section Number	2	3	4	PENNSYLVANIA DEPARTMENT OF HIGHWAYS
Contact Area Sq In	11.52	15.61	10.95	
Load in Lbs	1410	2380	1230	
Load Lbs per Sq In	122	153	112	
% Loading	79.7	100.0	73.2	

Figure 10

loading in the several sections of the tire measured. Contact areas represent positive quantities, while included areas as accepted heretofore, represent abstract quantities. The conclusions reached are, therefore, based on contact areas.

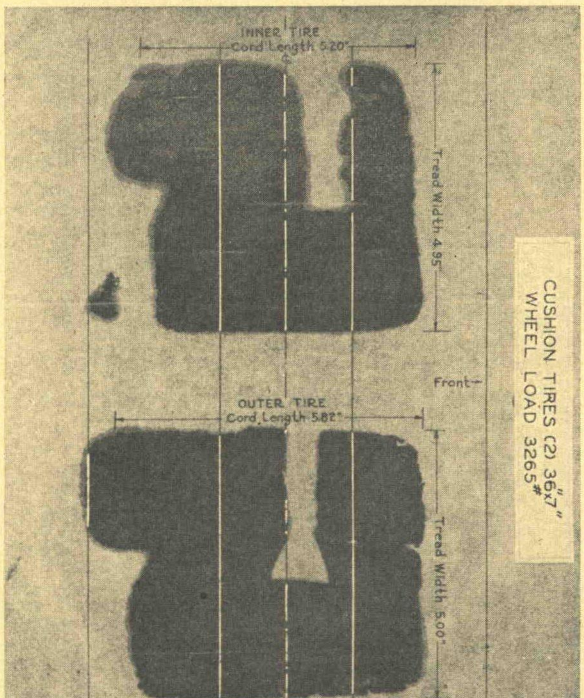
The photographs are reproductions of the construction of the apparatus and the method of testing. Figures 8 to 16 indicate the shape and extent of the imprints of the tires under various loadings. These imprints are divided into transverse sections two and one-half inches in width, and represent the areas in which the loading was measured. These sections are numbered serially from one to five.

Contact area in square inches indicates the actual area of the tire in contact in the several sections, measured by planimeter.

Load in pounds represents the actual load applied to the various sections, determined from calibration curves.

Load in pounds per square inch is the comparative unit. This is a function of the contact area and the total load for the section.

Per cent loading is calculated from the center loading (section No. 3), this is taken as one hundred per cent.



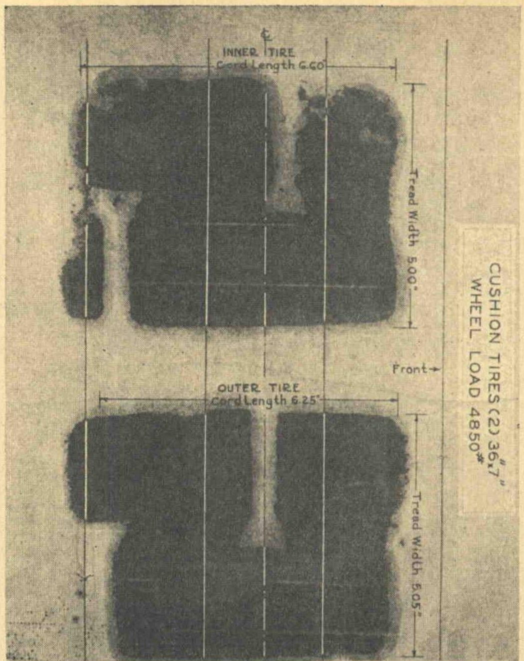
Section Number	2	3	4	
Contact Area, sq in	11.26	20.49	11.30	Pennsylvania Department of Highways
Load in Lbs.	1185	1498	582	
Load, Lbs per sq in	69	73	52	
% Loading	94.5	100.0	71.2	

Figure 11

SOLID TIRE (FIGURES 8, 9, AND 10)

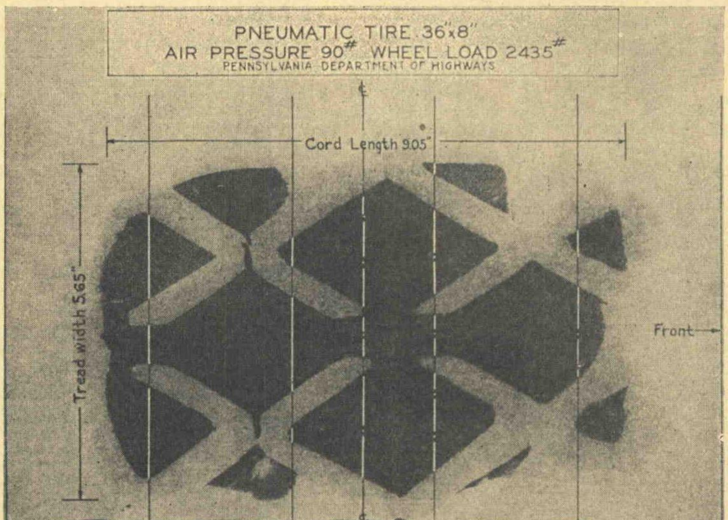
The section under greatest load is the one directly under the center line of the axle, and the load decreases in both directions from this point.

The load in pounds per square inch on the center section for each of the three wheel loadings remains practically constant at one hundred and fifty pounds, the loading on the adjacent sections increasing as the wheel load is increased.



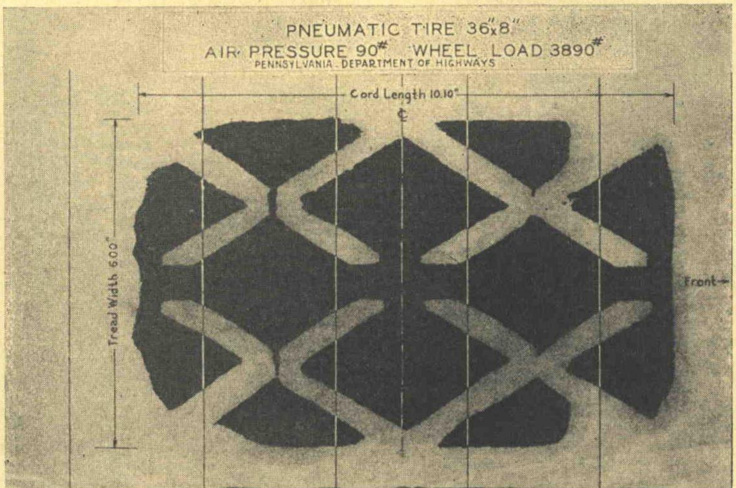
Section Number	1	2	3	4	
Contact Area, sq in	1.73	21.43	21.68	13.92	Pennsylvania Department of Highways
Load in Lbs	80	1840	2020	910	
Load, Lbs per sq in	46	86	93	65	
% Loading	49.5	92.5	100.0	69.9	

Figure 12



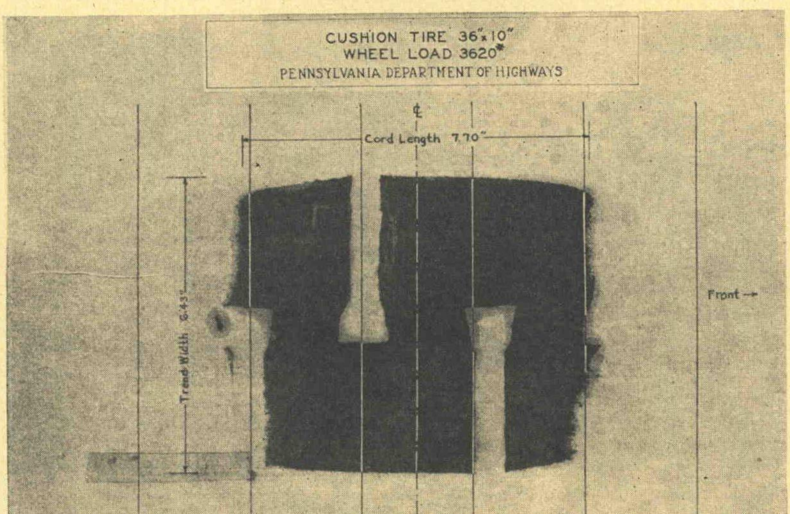
Section No.	1	2	3	4	5
Contact area, sq in	2.68	8.05	10.01	6.62	1.58
Load in Lbs	30	575	1165	640	25
Load Lbs per sq in	11	71	116	97	16
% Loading	9.5	61.2	100.0	83.5	13.8

Figure 13



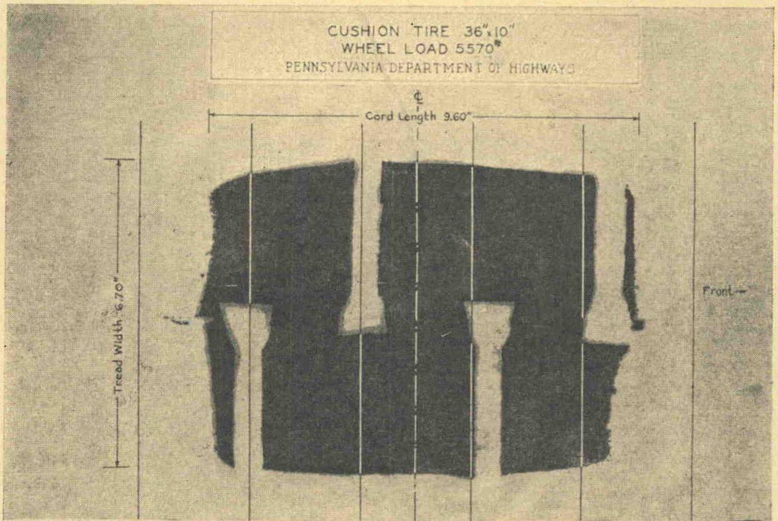
Section No.	1	2	3	4	5
Contact Area Sq. In.	4.47	9.53	10.94	8.96	5.19
Load in Lbs.	210	890	1410	1050	330
Load, Lbs. per Sq. In.	47	93	129	117	64
% Loading	36.4	72.1	100.0	90.7	49.6

Figure 14



Section Number	1	2	3	4	5
Contact Area Sq. In.	.66	13.18	14.39	12.57	.43
Load Lbs.	40	1125	1575	880	—
Load Lbs. Sq. In.	61	85	109	70	—
% Loading	55.9	77.9	100.0	64.2	—

Figure 15



Section Number	1	2	3	4	5
Contact Area Sq. In.	3.89	14.24	15.07	13.57	3.07
Load Lbs.	370	1600	1960	1500	140
Load Lbs. Sq. In.	95	112	130	111	46
% Loading	73.1	86.2	100.0	85.4	35.4

Figure 16

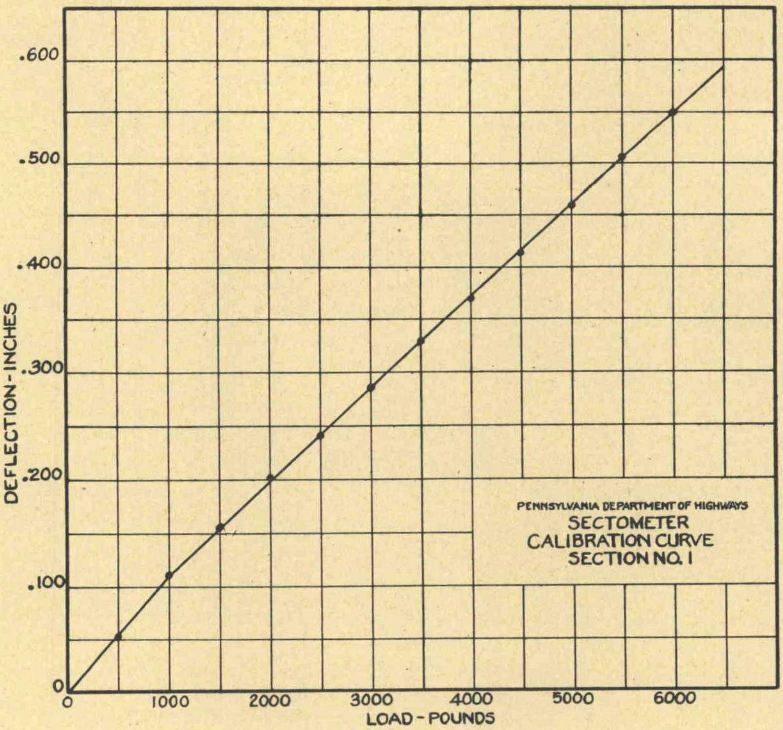


Figure 17

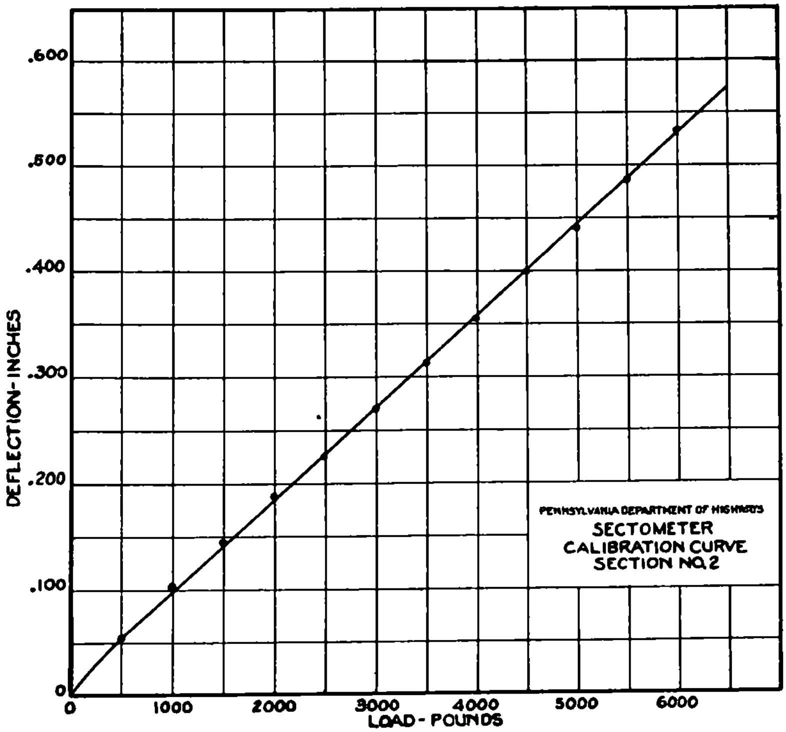


Figure 18

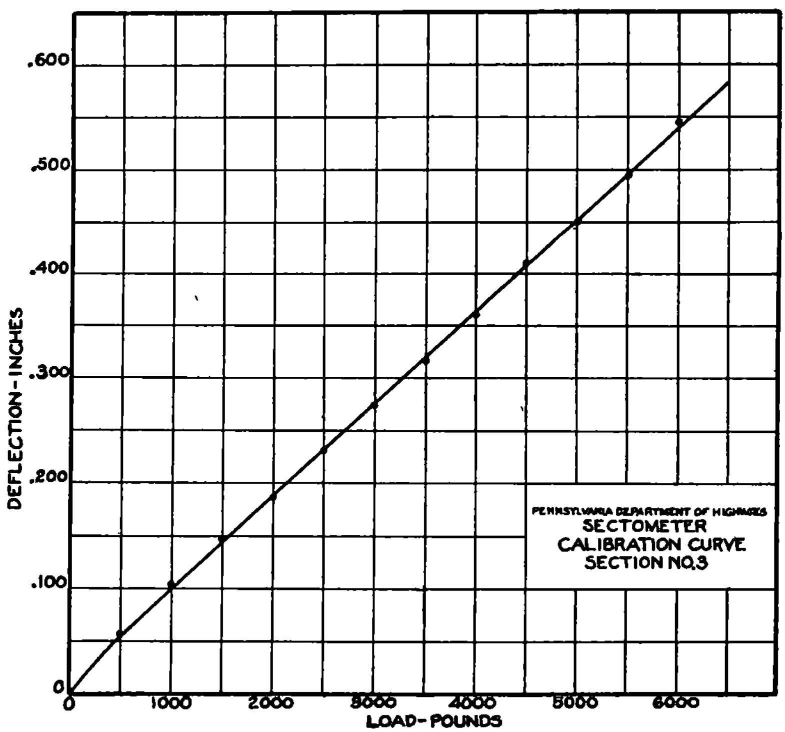


Figure 19

TABLE I

SUMMARY OF TESTS

Tire	Wheel Load† lbs		Load distribution					Tread width inches	Cord length inches
Solid 36 by 10 in.	2,720	Section number	1	2	3*	4	5	7.70	6 35
		Contact area, sq in.	—	6 29	10 62	6 11	—		
		Load, lbs	—	627	1,593	500	—		
		Load, lbs sq in	—	100	150	82	—		
		Per cent loading‡	—	66 7	100 0	54 6	—		
Solid 36 by 10 in.	4,195	Section number	1	2	3*	4	5	7 90	7 20
		Contact area, sq in	—	9 92	14 52	9 90	—		
		Load, lbs	—	1,140	2,157	898	—		
		Load, lbs sq in	—	115	149	91	—		
		Per cent loading	—	77 2	100 0	61 1	—		
Solid 36 by 10 in.	5,020	Section number	1	2	3*	4	5	8 00	7 50
		Contact area, sq in	—	11 52	15 61	10 95	—		
		Load, lbs	—	1,410	2,380	1,230	—		
		Load, lbs sq in	—	122	153	112	—		
		Per cent loading	—	79 7	100 0	73 2	—		
Cushion 2–36 by 7 in.	3,265	Section number	1	2	3*	4	5	5 00 (outer tire)	5 82 (outer tire)
		Contact area, sq in	—	17 26	20 49	11 30	—	4 95 (inner tire)	5 20 (inner tire)
		Load, lbs	—	1,185	1,498	582	—		
		Load lbs sq in.	—	69	73	52	—		
		Per cent loading	—	94 5	100 0	71 2	—		

Cushion 2-36 by 7 in.	4,850	Section number	1	2	3*	4	5	5 05 (outer tire)	6 25 (outer tire)
		Contact area, sq in	1 73	21 43	21 68	13 92	—	5 00 (inner tire)	6 60 (inner tire)
		Load lbs	80	1,840	2,020	910	—		
		Load, lbs sq in	46	86	93	65	—		
		Per cent loading	49 5	92 5	100 0	69 9	—		
Cushion 36 by 10 in.	3,620	Section number	1	2	3*	4	5	6 43	7 70
		Contact area, sq in	0 66	13 18	14 39	12 57	0 43		
		Load lbs	40	1,125	1,575	880	—		
		Load, lbs sq in	61	85	109	70	—		
		Per cent loading	55 9	77 9	100 0	64 2	—		
Cushion 36 by 10 in.	5,570	Section number	1	2	3*	4	5	6 70	9.60
		Contact area, sq in	3 89	14 24	15 07	13 57	3 07		
		Load, lbs	370	1,600	1,960	1,500	140		
		Load, lbs sq in	95	112	130	111	46		
		Per cent loading	73 1	86 2	100 0	85 4	35 4		
Pneumatic 36 by 8 in Air pressure 90 lb	2,435	Section number	1	2	3*	4	5	5.65	9.05
		Contact area, sq in	2 68	8 05	10 01	6 62	1 58		
		Load, lbs	30	575	1,165	640	25		
		Load, lbs sq in	11	71	116	97	16		
		Per cent loading	9 5	61 2	100 0	83 5	13 8		

* Denotes center line section or section directly under the center line of the axle

† Total wheel load indicated by Sectometer checked Loadometer readings within an average of 2 2 per cent.

‡ Per cent loading is based on the center line section load which is taken as 100 0 per cent.

TABLE I—*Continued*

Tire	Wheel Load† lbs		Load distribution					Tread width inches	Cord length inches
Pneumatic 36 by 8 in Air Pressure 90 lb	3,890	Section number	1	2	3*	4	5	6 00	10 10
		Contact area, sq in	4 47	9 53	10 94	8 96	5 19		
		Load lbs	210	890	1,410	1,050	330		
		Load lbs sq in	47	93	129	117	64		
		Per cent loading	36 4	72 1	100 0	90 7	49 6		

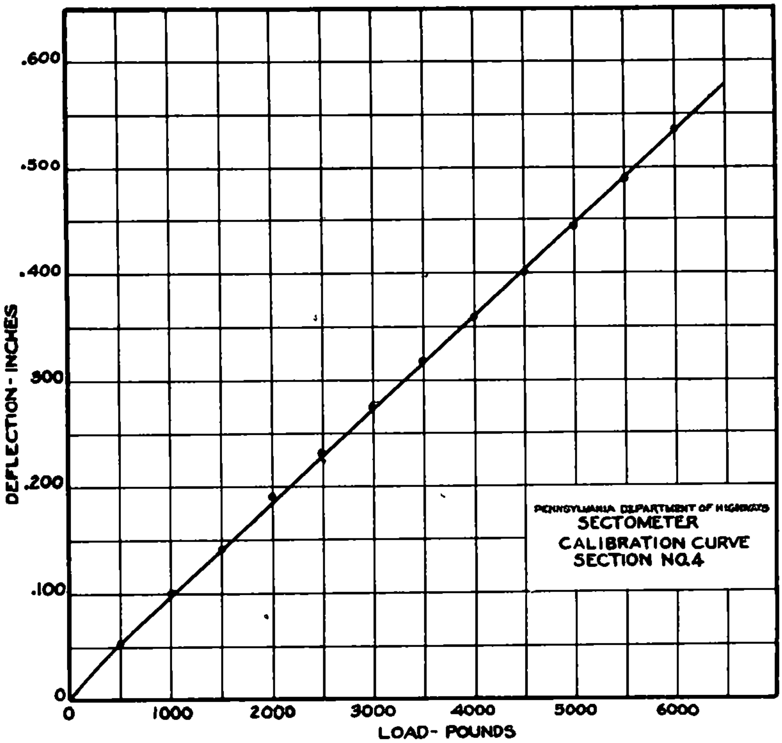


Figure 20

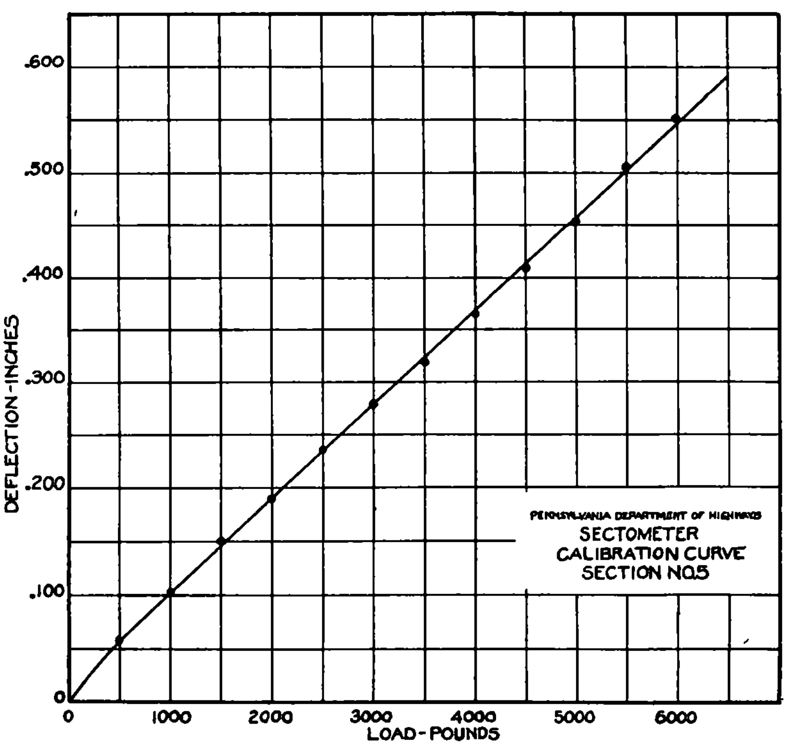


Figure 21

CUSHION TIRES (FIGURES 11, 12, 15, AND 16)

Again the section under greatest load is the one directly under the center line of the axle, and the load decreases in both directions from this point

The load in pounds per square inch increases proportionately on each of the sections as the wheel load is increased

This was the first type used in the test, but as the other tests were run on single tires, a single tire of this type was also procured and tested with the results noted above It might be stated however, that the results obtained on the dual type paralleled those obtained on the single tire

PNEUMATIC TIRE (FIGURES 13 AND 14)

Here again the section under the greatest load is the one directly under the center line of the axle, and the load decreases in both directions from this point

The load in pounds per square inch increases proportionately on each of the sections as the wheel load is increased

CONCLUSIONS

The greatest stress in the contact area of all the tire types is at the point where the plane of the center line of the axle is normal to the pavement, and decreases in intensity in both directions from this point

The uneven distribution of the load on the sections to the right and left of the center line section is attributed to the eccentric setting of the lugs in the periphery As the load is increased this difference is decreased

FURTHER STUDY OF FILL SETTLEMENT IN PEAT MARSHES

V R BURTON

Engineer of Research and Statistics

AND

A C BENKELMAN

Assistant Engineer of Research, Michigan State Highway Department

The State of Michigan has experienced unusual trouble in the construction and maintenance of roads over peat marshes Not only are the construction costs and subsequent maintenance expenditures invariably much greater than those of roads built upon upland soils but the long delays consequent to construction are a source of great