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INTERSTATE COMMERCE COMMISSION.

REPORT OF THE CHIEF INSPECTOR OF SAFETY APPLIANCES REGARDING INVESTIGATION OF A DERAILMENT ON THE CLEVELAND, CINCINNATI, CHICAGO & ST. LOUIS RAILWAY, NEAR STOCKWELL, IND., ON JANUARY 7, 1913, ACCOMPANIED BY REPORT OF THE ENGINEER-PHYSICIST OF THE BUREAU OF STANDARDS REGARDING HIS INVESTIGATION OF A BROKEN TIRE WHICH CAUSED THIS ACCIDENT.

SEPTEMBER 24, 1913.

TO THE COMMISSION:

On January 7, 1913, there was a derailment of a passenger train on the Cleveland, Cincinnati, Chicago & St. Louis Railroad, near Stockwell, Ind., resulting in the death of 1 passenger and the injury of 66 passengers and 4 employees.

After investigation of this accident, I beg to submit the following report:

The Chicago division of the Big Four Railroad at the place where this accident occurred is a single-track line running east and west, and trains are operated under the manual block system. The track is laid with rails weighing 90 pounds to the yard; there are about 20 oak ties under each rail, and gravel ballast is used. Approaching the point of derailment from the east the track is straight for a distance of more than 2 miles and there is a slight descending grade. Beginning 500 or 600 feet west of the point of derailment there is a 3½-degree curve. Rain was falling when the derailment occurred.

Train No. 15, known as the Chicago Express, consisting of a locomotive, 1 postal car, 1 baggage car, 1 smoking car, 1 coach, 1 café car, and 2 parlor cars, left Cincinnati, Ohio, at 8.30 a. m., and arrived at Indianapolis at 11.15 a. m. This train left Indianapolis at 11.36 a. m., and was derailed at about 1.07 p. m., at a point approximately one-half mile west of Stockwell, Ind., or 53 miles west of Indianapolis. At the time of the derailment the train was running at the rate of 55 or 60 miles per hour.

Conductor Kennedy of train No. 15 stated that at the time of the derailment he was in the baggage car standing near the door.

About a minute after the train passed Stockwell he felt the baggage car leave the rails and he pulled the conductor's valve wide open, making an emergency application of the brakes.

Engineman Snyder of this train stated that the first intimation he had of the derailment was when the brakes were applied, this application being due either to the parting of the train or the opening of the emergency valve by the conductor. The engineman immediately shut off steam and looking back he saw the cars leaving the track. He stated that at the place where the accident occurred the track was in first-class condition. The last stop made by train No. 15 before the derailment was at Thorntown, about 12 miles distant; two other stops had been made after the train left Indianapolis and the brakes on the train were in good condition.

The investigation of this accident disclosed the fact that it was caused by a broken tire on one of the wheels of the forward truck of the baggage car, the second car from the locomotive, and arrangements were made with the Bureau of Standards, of the Department of Commerce, to have the broken tire examined for the purpose of ascertaining the cause of its breakage. This examination was conducted by Mr. James E. Howard, engineer-physicist, and his report covering this examination, together with illustrations accompanying same, is attached to and made a part of this report.

Illustration No. 1 shows the relative positions of the derailed cars after the accident. The locomotive and mail car remained on the track and were not damaged; the baggage car was derailed on the north side of the track and was practically demolished, as is shown in illustration No. 2. The smoking car was derailed on the south side of the track and was badly crushed; the passenger who was killed and most of those injured were in this car. The coach was also derailed on the south side of the track, but was not so badly damaged. The other three cars were derailed but suffered comparatively slight damage. All the cars in this train were of wooden construction except the second car from the rear end, which was of steel.

The first marks of the derailment were found 18½ rail lengths to the rear of the point where the last car in the train came to a stop. Attention is called to the probable sequence of events at the time of the wreck as stated by Mr. Howard, and also to the detailed description of the wheel and broken tire which is contained in his report.

Inspections of the wheels of the cars of this train were made at Cincinnati and Indianapolis. The cars in this train arrived in Cincinnati from Chicago in train No. 16 in the evening of January 6, and started to return to Chicago the next day in train No. 15. The only car which was turned around before train No. 15 left was the café car.

Inspector Hankins, who was located at Cincinnati, stated that on the night of January 6 he made an inspection of the north side of these cars, including the baggage car, the inspection consisting of looking at the brake equipment and car wheels. In making this inspection he had a torch and got inside the wheels where he could see all parts of the truck. He found no defects on the train on that date. He stated that if a wheel appeared to be in bad condition he tested it by sounding it with a hammer. When he was employed he had been given only general instructions and had himself picked up from other inspectors the methods of making inspections which he pursued.

Inspector Betts, who was also located at Cincinnati, stated that he inspected the south side of the cars in this train. He stated that the examination consisted merely of looking over the equipment, and if the inspectors thought there was anything wrong with the wheels they tapped them with hammers. He said the wheels on the baggage car looked all right, and nothing was done to them other than just inspecting them. He stated that he had been employed as a car repairer. When he was assigned as a car inspector he was given no examination or instructions, but he had worked with an experienced car inspector who gave him some information.

Inspector Fuller, who was located at Indianapolis, stated that after train No. 15 arrived at the Union Station, Indianapolis, on the date of the accident and while engines were being changed, he inspected the north side of the two coaches and the baggage and mail cars; he carried a torch and went under each end of each car, looking at both sides of the wheels from front and rear. He stated that the practice of sounding wheels with a hammer had been discontinued almost universally, the inspection consisting merely of looking the equipment over.

Inspector Hickey stated that he inspected the south side of the first few cars of train No. 15 at Indianapolis, carrying a torch and examining the wheels, trucks, and brake rigging. He found nothing out of order.

Superintendent of Motive Power Garstang stated that with the wheels now commonly used, tapping the wheels with a hammer would not indicate anything, and the most approved method of inspecting car wheels was by observation. He stated that it was the practice of the company to select car inspectors from the repair men. The foreman of car inspectors was supposed to instruct the inspectors, and in addition they were furnished rules regarding inspections.

Mr. Garstang also stated that the wheel on which the tire was broken was known as a single-plate, solid-center wheel; the tire was applied to the wheel center by shrinkage, and there were two retaining rings which clamped the tire, one on each side, being held in position by 10 or 12 rivets.

Referring to the broken tire, Mr. Howard says:

The character of the fracture was such that while it is believed to have been the extension of a thermal crack previously existing in the tire, its development by stresses in the track and complete separation would take place very promptly when the final stage was reached. The shrinkage of the tire upon the wheel center was the chief element of strength or resistance which kept it in place when intact. When fractured this resistance was lost, and only the strength of the rivets of the retaining rings would then be available for holding it in place. Successive side lurches of the car, common to all train movements, overcame the strength of the rivets by flange blows, ultimately forcing the tire off the wheel center.

In discussing the cause of thermal cracks, Mr. Howard points out that the tires are placed on wheel center under shrinkage strains reported to range from $\frac{1}{80}$ to $\frac{1}{60}$ inches per foot of diameter; but shrinkage strains are variable factors under service conditions; they change as the tire becomes worn, and cold rolling of the metal at the tread has a tendency to modify the strains. He further states that—

The greatest factor in the case, however, is the application of the brakes. The tread is suddenly heated by the friction of the brake shoe and the tire expanded before the center is affected, no doubt causing wide fluctuations in the magnitude of the shrinkage strains. Momentarily the tire may be left with very little shrinkage resistance when there is a sudden application of the brakes. * * * But the sudden heating of the treads of wheels and the attainment of high temperature assumes a more serious aspect than causing the temporary reduction of shrinkage resistance. Thermal cracks in the steel are formed in this manner, the presence of which is a menace to the integrity of the tire. * * * They are caused by the rapid cooling of the intensely heated metal where free contraction is resisted.

In the tread of the tire which caused this accident there were a number of thermal cracks, as will be noted in illustration No. 6, these cracks being described in Mr. Howard's report.

He also states that—

Methods of inspection may need revision to meet current conditions of railway service, wherein is shown a marked tendency to increase the working stresses, and in so doing decrease the margin in strength remaining between them and rupturing loads of the materials. Inspection for the discovery of occasional structural defects and inspection for noting approach to the limit of endurance of materials are quite distinct problems, the latter presenting great difficulties. High-wheel loads and the introduction of high-speed brakes are factors in the present case.

A diligent inspection of the car wheels in this train would have disclosed the presence of thermal cracks. The presence of cracks of this character on the thread of a tire is a menace to safety and is sufficient reason for taking a wheel out of service. To avoid further accidents of this nature, more thorough examinations of car wheels should be made.

The following tabulation, compiled from the Commission's accident statistics, shows the number of derailments due to defects of equipment for the five fiscal years 1908 to 1912, inclusive, those due to defective wheels being segregated from those due to other causes:

Year.	Number due to defective wheels.	Number due to other causes.	Total number.
1908	1,031	1,765	2,796
1909	913	1,449	2,362
1910	1,046	1,688	2,734
1911	997	1,827	2,824
1912	1,235	2,612	3,847
Total	5,222	9,341	14,563

During this five-year period there were a total of 32,323 derailments from all causes and of this total, 14,563, or approximately 45 per cent, were due to defective equipment. Of the number due to defective equipment 5,222, or approximately 36 per cent, were due to defective wheels. The number of derailments due to defective wheels was approximately 16 per cent of the total number of derailments from all causes that occurred during this five-year period.

The following table taken from the Commission's accident bulletin No. 44 shows the number of derailments due to defective equipment, classified according to cause, that occurred during the fiscal year ending June 30, 1912. It will be noted that 1,235 derailments were due to defective wheels, or approximately 31 per cent of the total number of derailments due to defective equipment that occurred during the year.

Cause of accident.	Number.	Number of persons killed.	Number of persons injured.
Defective wheels:			
Broken or bursted wheel	357	3	27
Broken flange	627	8	64
Loose wheel	124	2	20
Miscellaneous	127	2	169
Broken or defective axle or journal	410	2	104
Broken or defective brake rigging	528	4	157
Broken or defective draft gear	177	6	48
Broken or defective side bearings	177	1	94
Broken arch bar	257	8	130
Rigid trucks	184	2	66
Failure of power-brake apparatus, hose, etc	216	5	29
Failure of couplers	208	2	30
Miscellaneous	455	23	259
Total	3,847	68	1,197

The statistics above quoted are sufficient to indicate the alarming frequency of accidents due to defective wheels and the seriousness of the problem confronting railroad companies in securing sound wheels and providing an adequate system of inspection, which will insure that defective wheels will not be placed or remain in service, and that worn wheels will be removed from service in ample time to provide for the safe operation of trains.

Respectfully submitted.

H. W. BELNAP,
Chief Inspector of Safety Appliances.

REPORT OF THE ENGINEER-PHYSICIST.

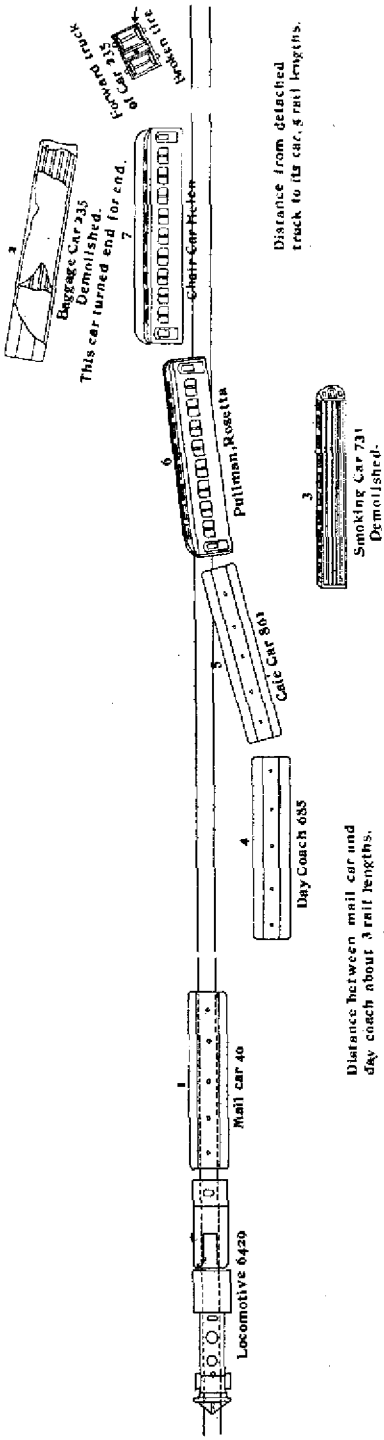
I have the honor to report upon the examination of a steel tire which appears to have caused the derailment and wreck of train No. 15, of the Cleveland, Cincinnati, Chicago & St. Louis Railway, near Stockwell, Ind., on January 7, 1913, at 1.07 p. m., killing 1 person and injuring 70 others.

The train consisted of a locomotive of the Pacific type and seven cars, and was proceeding from Cincinnati to Chicago. It was made up as follows:

	Weight.	Construction.
Locomotive No. 6429:	*Pounds.*	
Engine	236,000	
Tender	158,000	
Mail car No. 40	96,000	Wood.
Baggage car No. 235	77,200	Do.
Smoking car No. 731	84,000	Do.
Day coach No. 685	102,000	Do.
Café car No. 861	114,550	Do.
Pullman car "Rosetta"	....	Steel.
Chair car "Helen"	....	Wood.

Six cars of the train were derailed, the locomotive and the mail car remaining on the track uninjured, the damage to the train and the track occurring behind them. The baggage car was derailed to the right side of the track, turned end for end and faced toward the rear, and came to rest in a demolished condition. Its forward truck was 5 rail lengths to the rear, also turned nearly end for end. The smoking car was derailed to the left side of the track and came to rest bottom side up badly demolished. Most of the injured people and the passenger who was killed were in this car. The day coach and café car were on the left side of the track, the Pullman car "Rosetta" was over the track, while the chair car "Helen" overhung the embankment on the right side. The relative positions of the cars when they came to rest are shown on the diagram (fig. No. 1).

The track was torn loose abreast the derailed cars and for a distance of about 3 rail lengths to the rear. There were marks of derailment on the ties beginning at a distance of 18½ rail lengths to the rear of chair car "Helen," the last car of the train. The injury to the track was, however, comparatively slight. Rails were bent, but none was broken by the train. Subsequently one was broken in straightening.



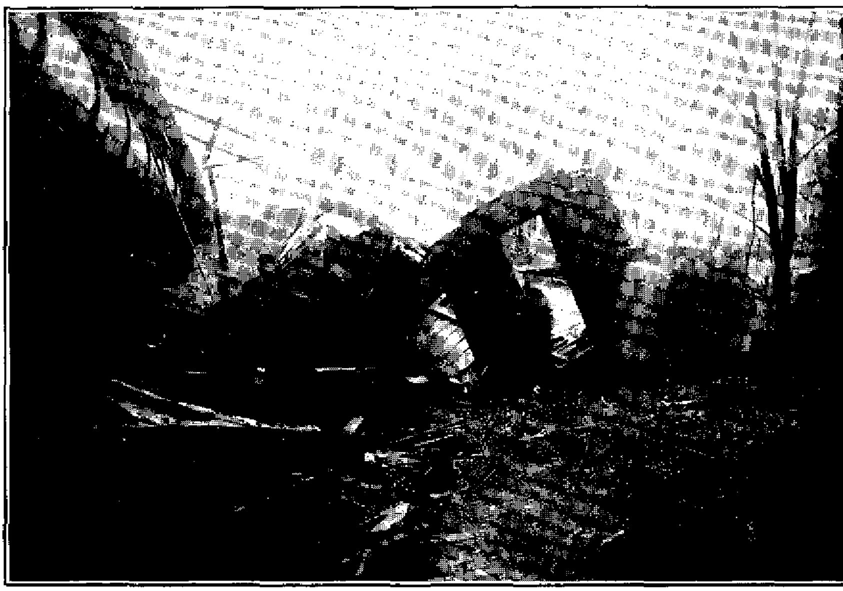
No. 1.—Relative positions of cars after derailment.

Events at the time of the wreck probably occurred in about this manner and sequence: The tire on the right-hand wheel of the forward axle of the forward truck of baggage car No. 235, fractured radially in one place, was forced off the wheel center onto the axle which it encircled, and was carried along by the latter throughout the time of derailment. The fracture of the tire caused the derailment of its truck and precipitated the wreck of the train, the first intimation of which came to the engineer and fireman by the setting of the brakes when the train parted. They testified they were running at 55 to 60 miles per hour at the time.

The train parted between the mail car and the baggage car. The baggage car made a half turn to the right and came to rest on the ground at the foot of the embankment. The smoking car, which next followed, was thrown to the left side of the track, the direction which the rear end of the baggage car would tend to give it. The rest of the train had a general tendency to leave the track toward the left, excepting the chair car "Helen," which overhung the right edge of the embankment. The damage to the track was done by the six derailed cars. The engineer took the locomotive and the mail car 50 car lengths ahead, where he called for a wrecking train over the telephone.

In point of time the fracture of the tire preceded the derailment of the train, but how much earlier is conjectural. Probably it occurred within a mile or a few miles of the place of derailment. The character of the fracture was such that, while it is believed to have been the extension of a thermal crack previously existing in the tire, its development by stresses in the track and complete separation would take place very promptly when the final stage was reached.

The shrinkage of the tire upon the wheel center was the chief element of strength, or resistance, which kept it in place when intact. When fractured this resistance was lost, and only the strength of the rivets of the retaining rings would then be available for holding it in place. Successive side lurches of the car, common to all train move-



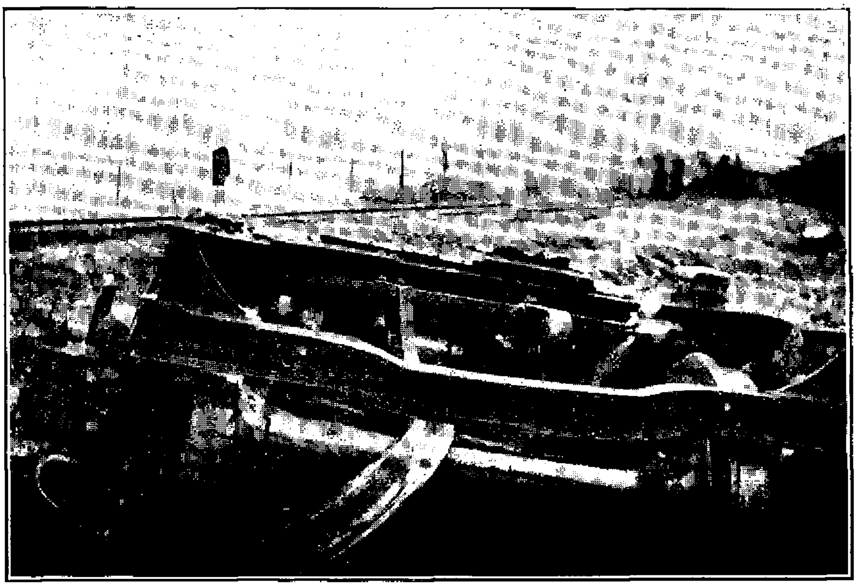
No. 2.—View showing demolished baggage car, portion of chair car Helen being seen at the left.

ments, overcame the strength of the rivets by flange blows, ultimately forcing the tire off the wheel center. Derailment would at once follow.

The changes in curvature of the tire at its inner cylindrical surface constitute the evidence on which is based the statement that this tire belonged to the forward axle of the truck, and this is in harmony with events attending the wreck.

Referring to the cuts which accompany this report, figure No. 2 is a view of baggage car No. 235, in the center of the illustration, chair car "Helen," on its side, balanced in an overhanging position, on the left. Figure No. 3 shows the detached truck of the baggage car, which was located five rail lengths to the rear of its car. The fractured tire is seen encircling the axle. This view is looking toward Lafayette in the direction the train was traveling. Figure No. 4 shows the axle with ruptured tire after removal from the truck, and one of the retaining rings, the latter much bent. The lip of the tire, which acted as a lock for the outer retaining ring, was generally broken from the body. The inner lip was not injured. This is one of the results of untiring which would be expected.

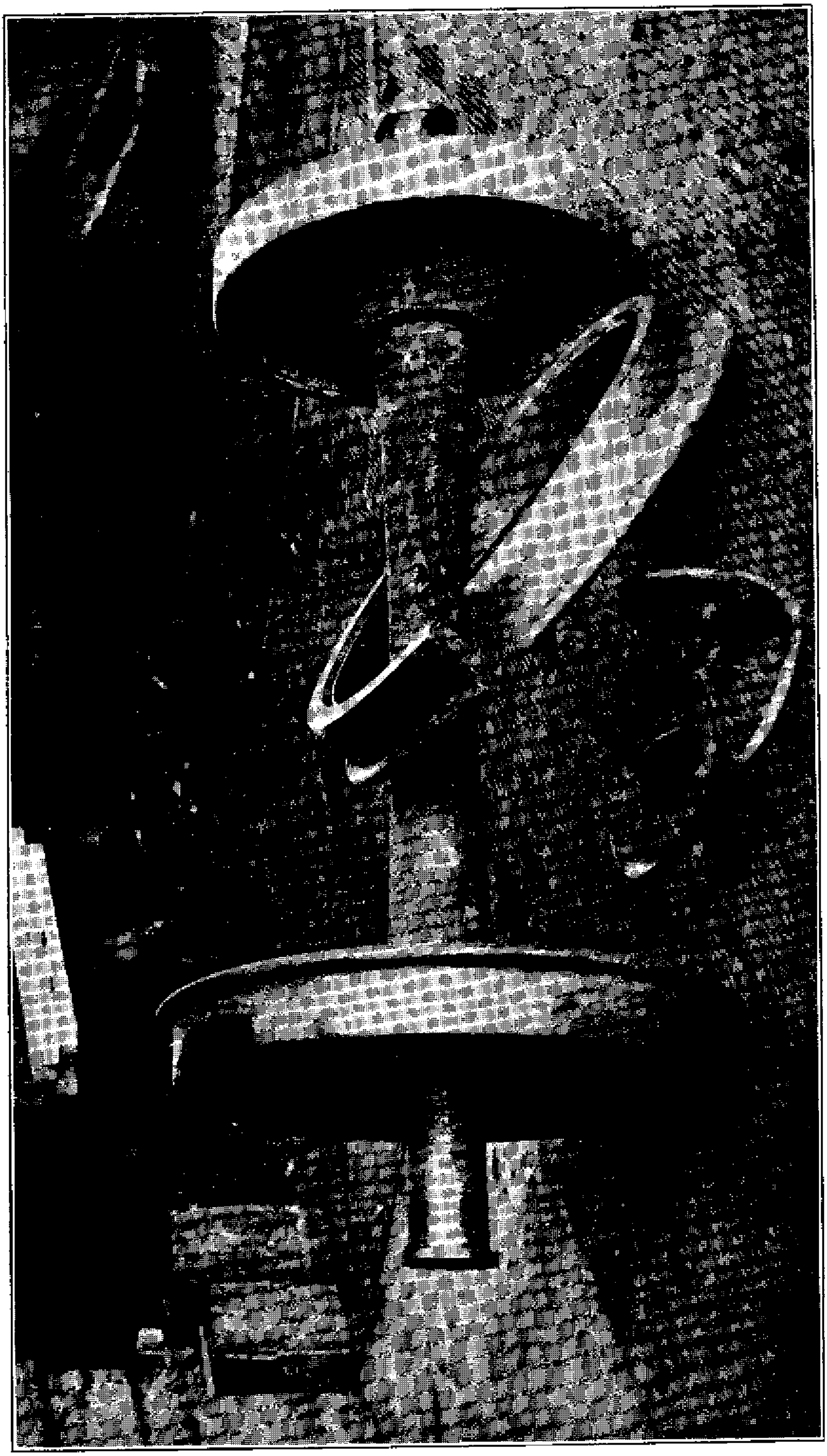
Baggage car No. 235 was built by the Pullman Co. and purchased by the railway company in September, 1906. It had four-wheel trucks, 36-inch wheels with steel tires on steel centers. Size of



No. 3.—View taken looking toward the north, showing forward truck of baggage car located five rail lengths behind that car. Fractured tire can be seen encircling the axle.

journals, 5 by 9 inches. The fractured tire was made by the Midvale Steel Co. and branded "★ Midvale ★ 2576 78." Its original thickness was $3\frac{1}{8}$ inches and was $2\frac{9}{16}$ inches thick at the time of derailment. Total mileage made was 111,113 miles, 60 million rotations in round numbers. The car was in the shop in March, 1912, and the tires were then trued up. The contour lines were satisfactory at the time of derailment and it was not a very much worn tire.

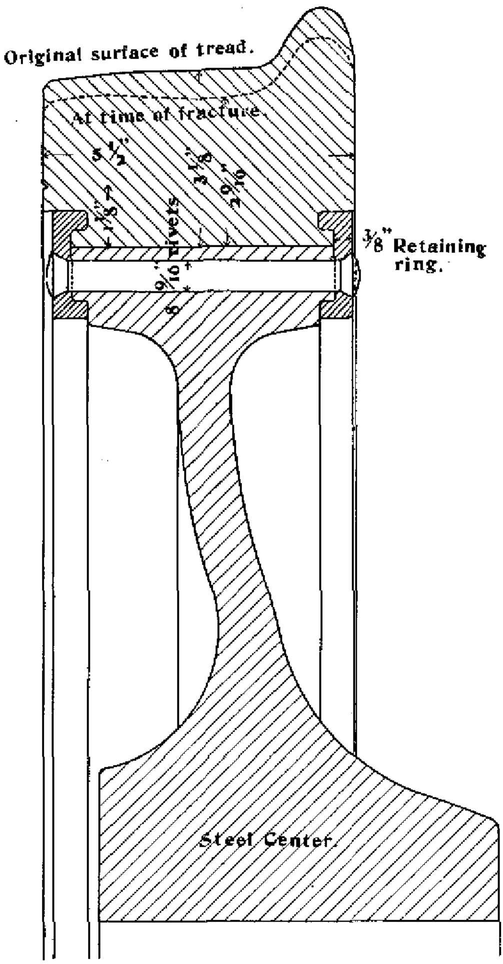
Figure No. 5 shows the cross section of the wheel center and tire with retaining rings and riveted connection. From the design of the wheel it is apparent that the retaining rings can act in two capacities—to hold fragments of a broken tire against outward centrifugal forces, and to restrain the tire against lateral thrust par-



No. 4. View taken in shops, showing intact wheel, axle, and fractured tire of forward truck of baggage car, together with bent retaining ring.

allel to the axis of the axle. The latter movement or tendency would ordinarily be an inward one, since the wheel flanges are on the inside.

Eight $\frac{9}{16}$-inch rivets are provided in the construction of the wheel to hold the tire against such an emergency as arose when this tire fractured. The total sectional area of these eight rivets is a little less than 2 square inches. The two retaining rings, however, have a sectional area of about 60 square inches to resist an outward radial force taken either in tension on the body of the rings or shear of the inner lips.



No. 5.—Cross section of tire and wheel center, showing details of construction of wheel.

A marked preponderance in area to resist centrifugal forces, not to mention, on the other hand, the effect of leverage of the retaining rings in reducing the effective strength of the rivets when the tire is exposed to side thrusts.

Concerning the manner of assembling these wheels during the process of manufacture, the tires are placed on the wheel centers under shrinkage strains reported to range from $\frac{1}{80}$ inch to $\frac{1}{60}$ inch per foot of diameter. That is, the tires are bored smaller than the centers and expanded by heating so they can be placed over the centers. The manufacturers heat the tires to a temperature of 450° F., a very moderate heat in no way calculated to impair the properties of the steel, yet sufficiently high to permit assembling.

Under the maximum shrinkage above mentioned tires having the tensile properties of this one would not be strained up to their elastic limits when assembled. Shrinkage strains, however, are variable factors under service conditions. They would change as the tire becomes worn. Cold rolling of the metal at the tread would have a tendency to modify the strains. The greatest factor in the case, however, is the application of the brakes. The tread is suddenly heated by the friction of the brake shoe and the tire expanded before the center is affected, no doubt causing wide fluctuations in the magnitude of the shrinkage strains.

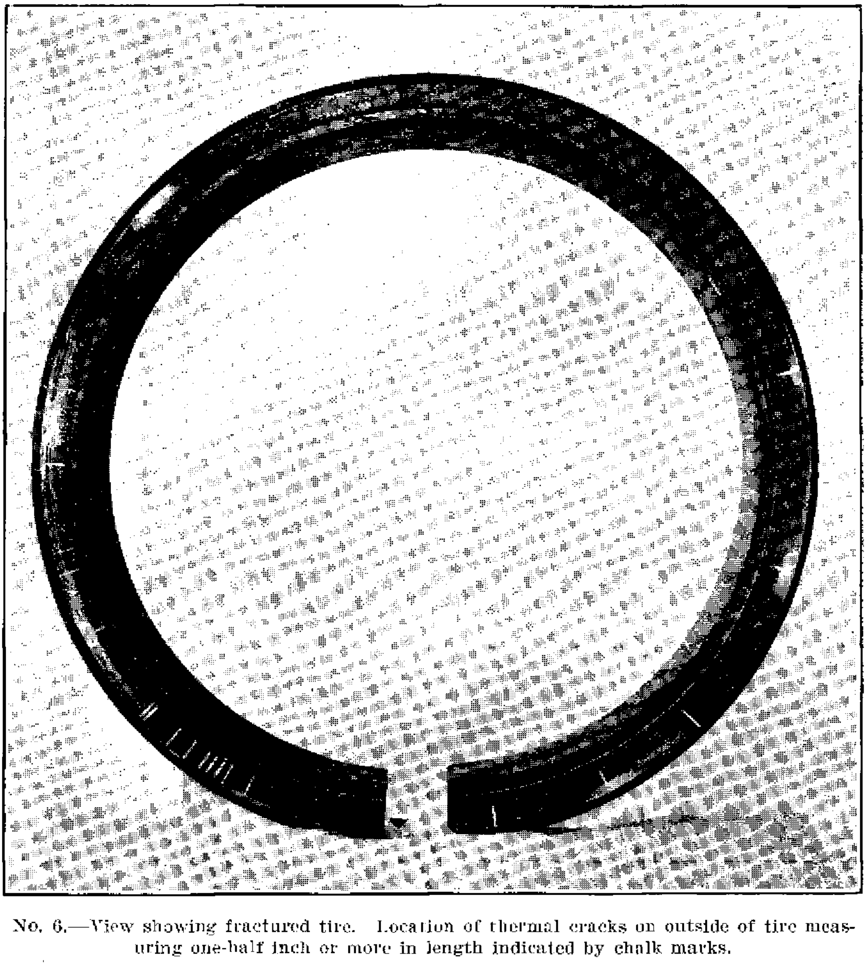
Momentarily the tire may be left with very little shrinkage resistance when there is sudden application of the brakes, causing the tire to reach a high temperature before the wheel center becomes heated by conductivity. An increase in temperature of only 214 degrees above the temperature of the center should relieve the tire of a shrinkage of one-sixtieth inch per foot. At the immediate surface of the treads much higher temperatures are reached. Superficially the temperature is such as to throw off a shower of sparks between the tire and the brake shoe. The brake shoes are not infrequently heated until portions reach a blue color. Intermittingly the shrinkage strains of tires must pass through wide fluctuations.

But the sudden heating of the treads of wheels and the attainment of high temperatures assume a more serious aspect than causing the temporary reduction of shrinkage resistance. Thermal cracks in the steel are formed in this manner, the presence of which is a menace to the integrity of the tire. Such thermal cracks are probably present in all brake shoes after they have been but a few hours in service. Occasionally thermal cracks are developed on the running surface of rails and are there known as "wheel burns." They are caused by the rapid cooling of intensely heated metal, where free contraction is resisted. They result from internal strains of tension, the metal passing through a reversal of internal strains in their formation.

The present tire exhibited on its tread many such thermal cracks, leading to the belief that the complete fracture of the tire was the direct consequence of their being present.

Figure No. 6 shows the outer end of the tire on which a number of cracks of pronounced size were visible. The location of those which measured one-half inch or more in length, 21 in number, is indicated by chalk marks. A further exhibit of these cracks is made by figures Nos. 7 and 8. The outer edge of the tread is shown in these figures, on which appear a number of the longer cracks between which are numerous small ones. The wider and longer cracks were conspicuous, admitting of discovery upon inspection of the tire. Such cracks in steel have grave significance. They lead to early ultimate failure, especially when the causes which occasioned their formation are aided and combined with independent straining forces. The shrinkage strains are always present in the cold tire, and they alone would have a tendency to complete the fracture of the tire when a thermal crack had reached a certain stage of development.

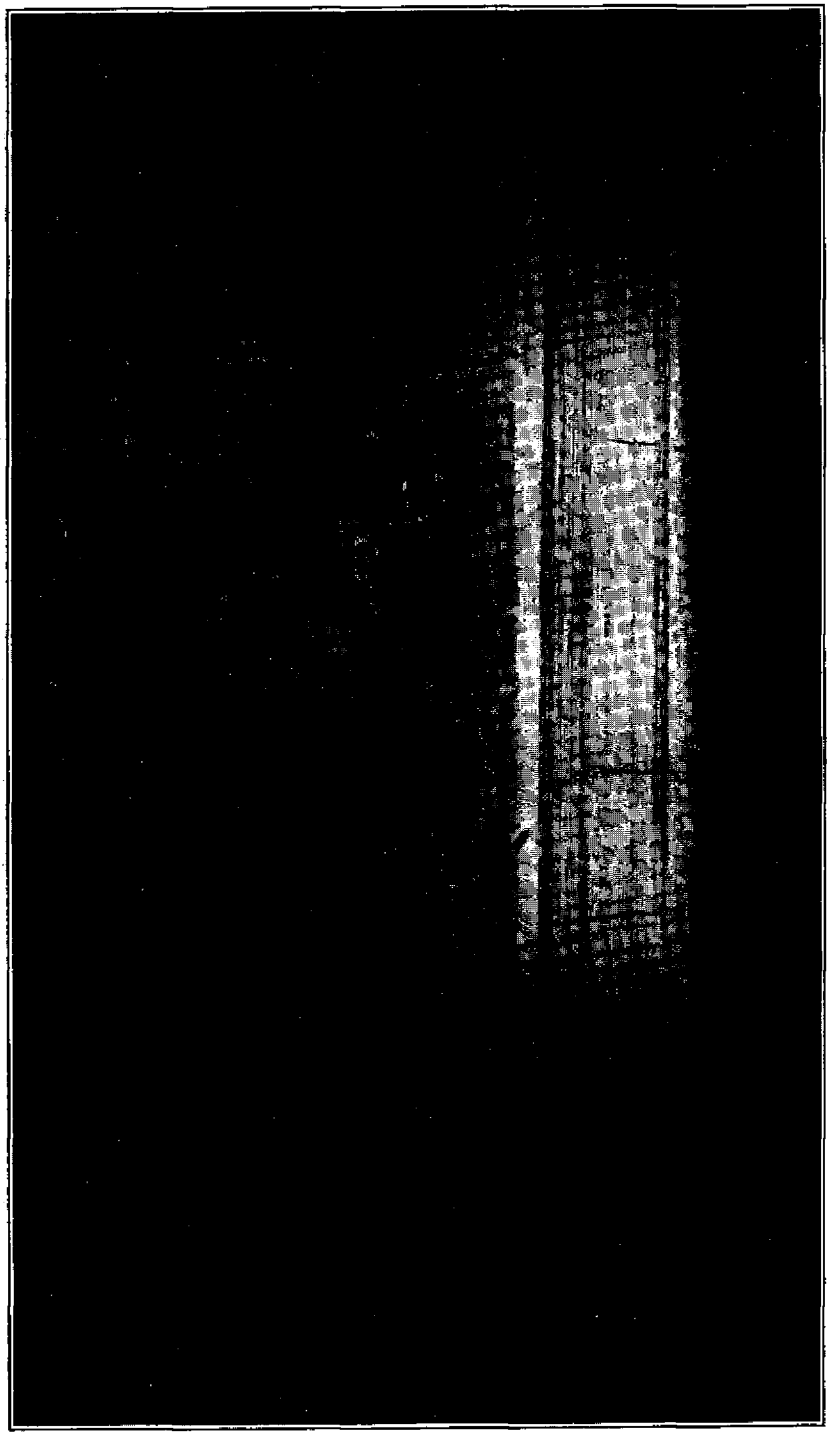
Thermal cracks are usually progressive in their character, but the rate of their development, a question of deep interest in the case of a tire, does not admit of a definite answer. The depth to which they have penetrated the metal is uncertain. A risk is assumed in running a wheel of this type in which there are thermal cracks. A more satisfactory solution of the problem than judging of the degree of risk



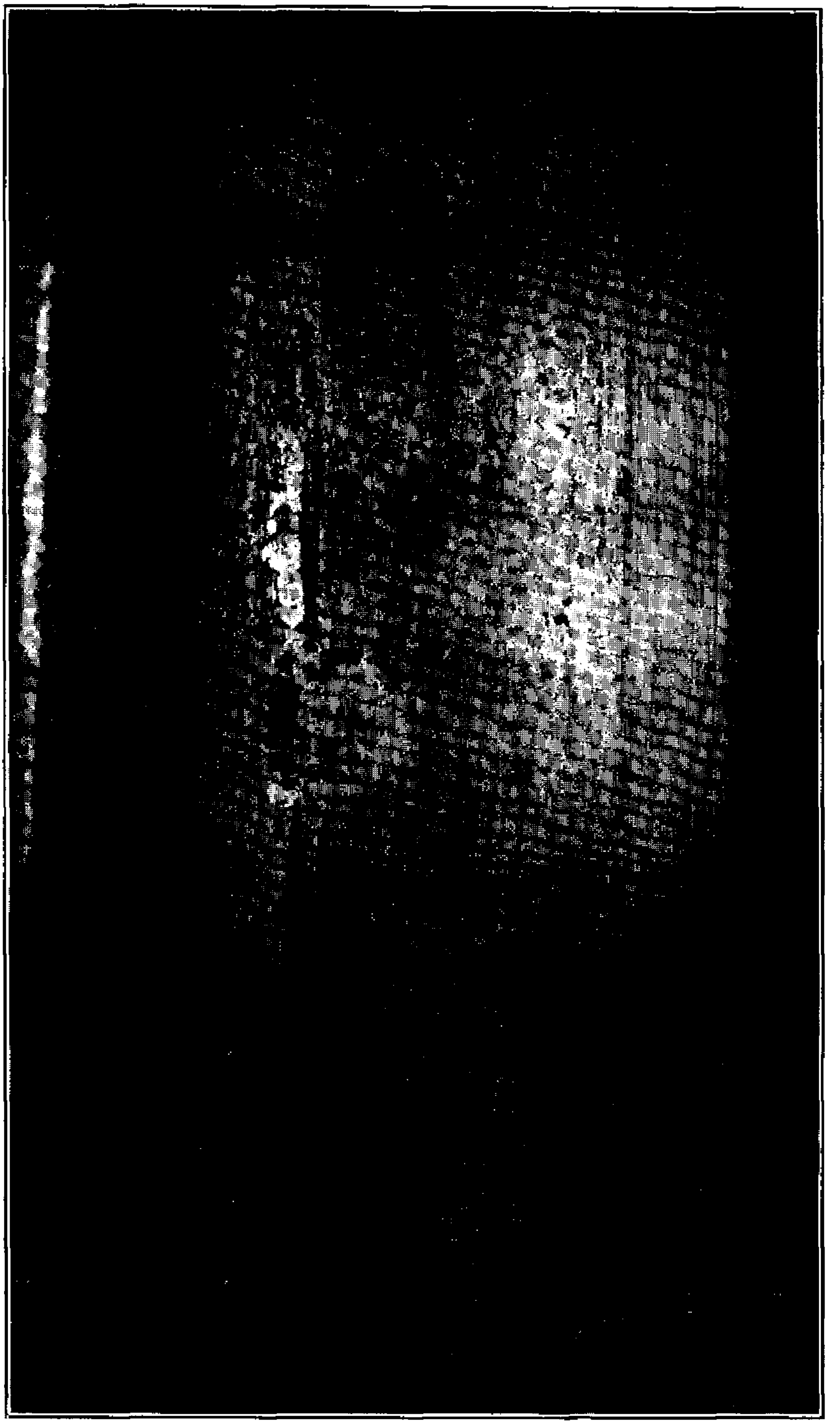
No. 6.—View showing fractured tire. Location of thermal cracks on outside of tire measuring one-half inch or more in length indicated by chalk marks.

involved and reaching a decision as to when to remove from service a wheel of this type in which thermal cracks have appeared would be a modification of the design of the wheel to the end that the element of safety is more amply provided for at a time when the shrinkage resistance between the tire and the wheel center is menaced.

Tensile tests and chemical analyses were made of the metal of this tire. One test piece was taken out in a radial direction; three test pieces tangentially. Diameter of stems, 0.564 inch.



No. 7.—View of fractured tire, showing thermal cracks on face of tire at outer edge of tread.



No. 8.—Another view of fractured tire, showing thermal cracks on face of tire at outer edge of tread.

Tensile tests.

Mark.	Location.	Elastic limit per square inch (approximate).	Tensile strength per square inch.
		Pounds.	*Pounds.*
A	Longitudinal, middle of tire		110,400
B	Tangential, flange	46,000	115,440
C	Tangential, middle, flange end	49,600	114,400
D	Tangential, outside end, 1 inch in from tread		34,000

Mark.	Elongation.	Contraction of area.	Appearance of fracture.
	Per cent.	*Per cent.*	
A	5.5	4.8	Fine granular.
B	15.3	18.4	Do.
C	12.7	18.4	Do.
D	None.	None.	Fractured at a thermal crack; 40 per cent of surface discolored, 60 per cent fine granular.

It appeared from the discolored portion of the fractured surface of specimen D that the thermal crack in the tire at the location of this specimen had penetrated the tire to a depth of 0.90 inch.

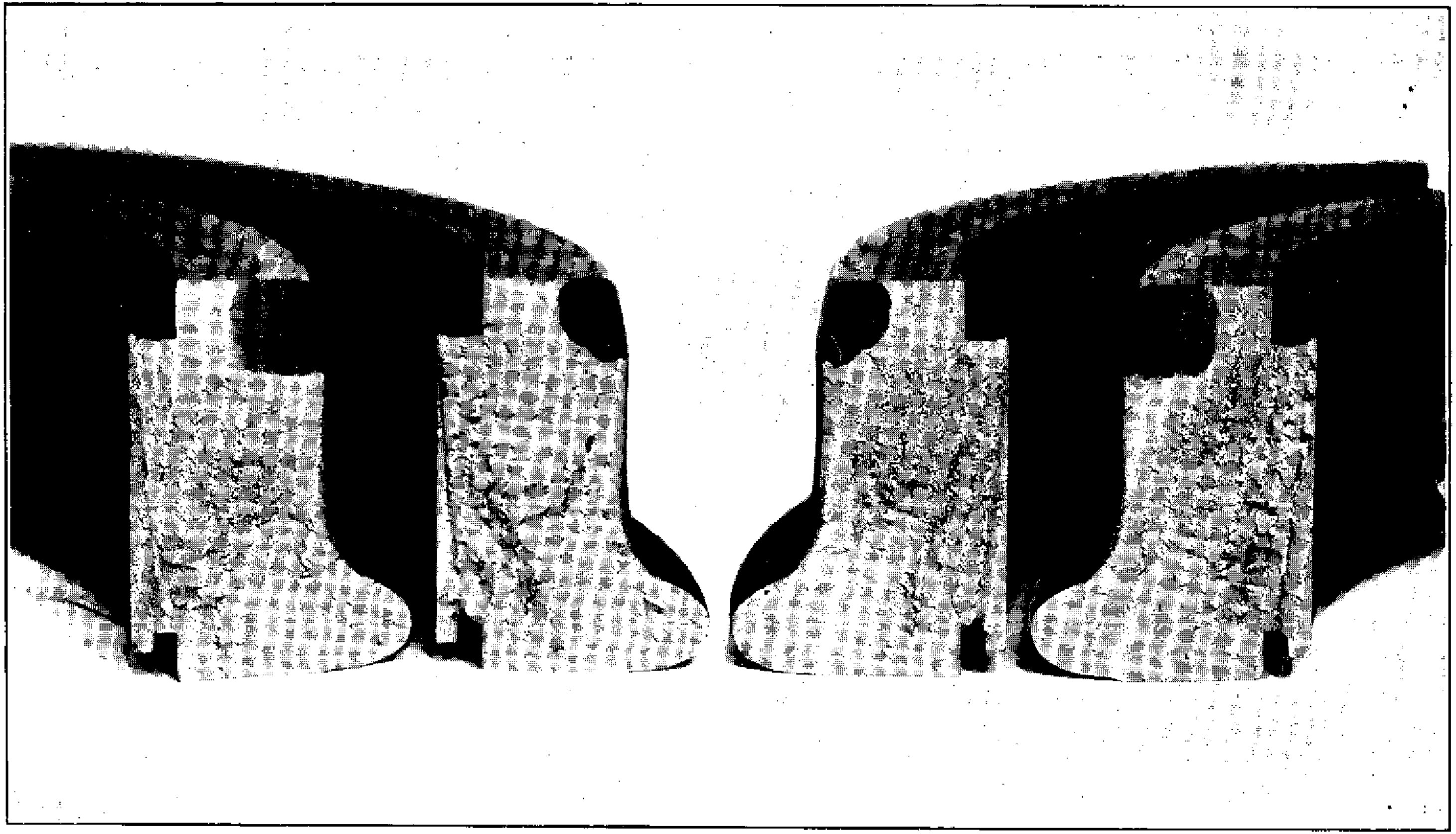
Chemical analyses.

Mark.	Carbon.	Sulphur.	Phosphorus.	Manganese.	Silicon.
A	0.67	0.034	0.039	0.63	0.249
B	.70	.033	.043	.68	.254
C	.67	.026	.031	.67	.256
D	.65	.024	.041	.65	.255

The chips for chemical analysis came from the metal of the stems in turning the tensile specimens.

A further examination was made of the tire for the purpose of ascertaining the depth to which some of the thermal cracks had penetrated the metal. It was cut apart in a slotter, for convenience, and fractures made in two places by bending stresses, the surface of the tread being on the tension side of the bend. The cracks opened slightly, then fracture suddenly took place across the full section. Figure No. 9 shows the progress which the cracks had made, while the tire was still in service, toward its ultimate complete fracture.

Sections measuring $1\frac{1}{8}$ inches by $\frac{7}{8}$ inch and $1\frac{1}{4}$ by $1\frac{1}{4}$ inches, respectively, which appear dark-colored on the figure, mark the extent of



No. 9.—View showing thermal cracks which developed in the tire while in service.

these thermal cracks. They had reached nearly half through the thickness of the tire. The gravity of the case is well illustrated in the discolored portions of these surfaces. A series of photographic prints of this kind could properly be placed before car inspectors for their information and guidance.

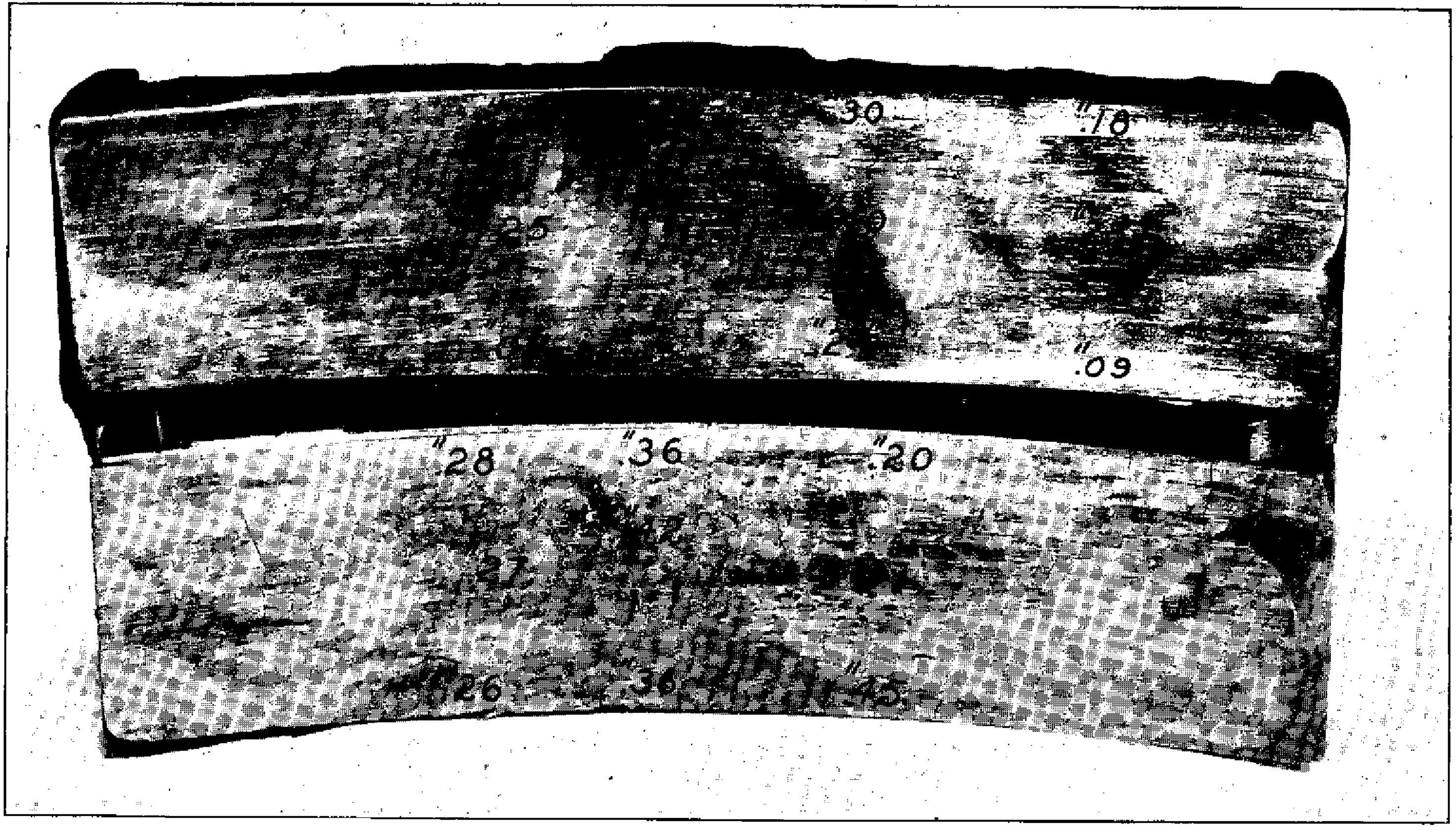
Methods of inspection may need revision to meet current conditions of railway service, wherein is shown a marked tendency to increase the working stresses, and in so doing decrease the margin in strength remaining between them and the rupturing loads of the materials. Inspection for the discovery of occasional structural defects and inspection for noting approach to the limit of endurance of materials are quite distinct problems, the latter presenting great difficulties. High-wheel loads and the introduction of high-speed brakes are factors in the present case.

The prevalence of thermal cracks in brake shoes is a conspicuous feature. They are present commonly, if not invariably, in shoes, even those which have been but a short time in service. The conditions of exposure are the same, for the time being, for the rubbing surfaces of the shoe and the tire. The same tendencies necessarily exist for the formation of thermal cracks in each, but more accentuated in the shoe. This is on account of the shoe being constantly exposed to abrasive action during the period of braking, while the rotation of the wheel continually changes the surface of the tire. The smaller mass of metal of the shoe would cause it to reach a higher mean temperature, but that in itself is not the vital feature of the case. It is the suddenness of the changes in temperature which lead to the formation of thermal cracks, by reason of one part of the tire or shoe reaching a widely different temperature from another part, introducing internal strains which find relief in the rupture of the metal.

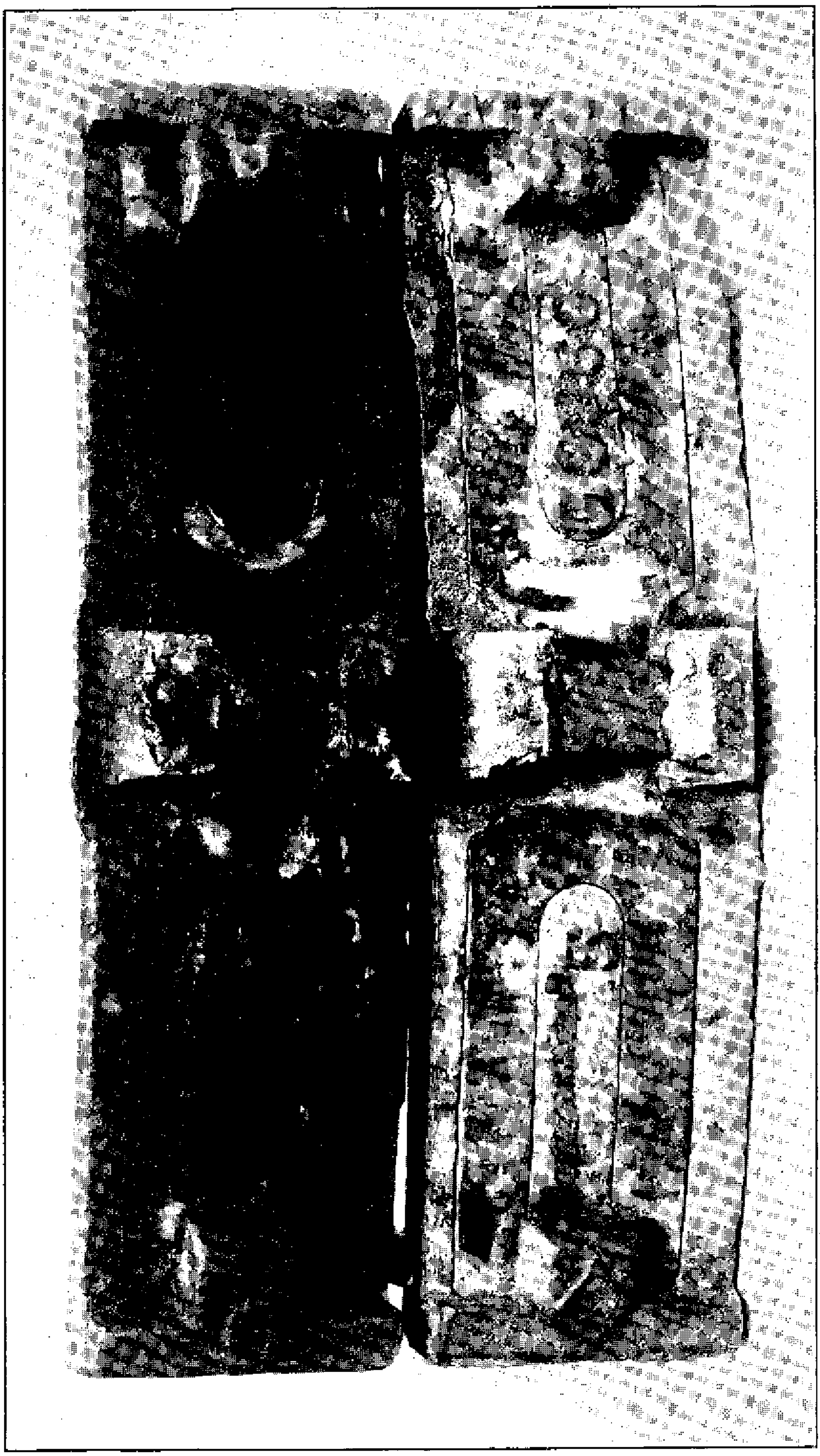
Thermal cracks in brake shoes are guarded against in manufacture by casting in place in the backs of the shoes strips of forged or rolled steel which hold the fragments together. The appearance of two shoes, each nearly new, is shown in figures Nos. 10, 11, and 12. One is a plain cast-iron shoe with steel-strip backing, the other has interlaced steel wire inserted, together with the steel-strip backing. As shown in the cuts they are described as follows:

	Brand.	Dimensions.	Weight.
Upper shoe	V 7434	$3\frac{5}{16}$ by $13\frac{3}{8}$ by $1\frac{1}{4}$ inches	$18\frac{1}{2}$ pounds.
Lower shoe	G 3960 (Pullman).	$3\frac{3}{8}$ by $13\frac{9}{16}$ by $1\frac{5}{8}$ inches	$23\frac{1}{2}$ pounds.

Shoe branded "V 7434" had thermal cracks extending across its face at intervals of 0.75 inch to 1.25 inches; that branded "G 3960"

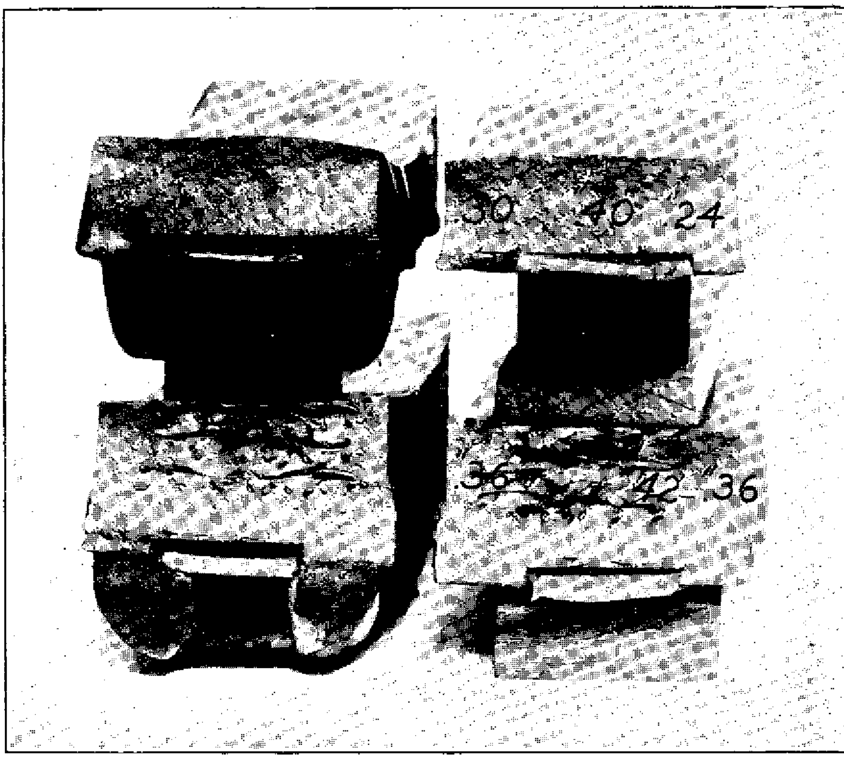


No. 10.—View showing thermal cracks developed on the working faces of brake shoes. Figures appearing on the illustration state the depth of penetration of the cracks at the places indicated. The upper figure of illustration shows a cast-iron shoe with steel-strip backing. The lower figure shows a cast-iron shoe, steel-strip backing, with interlacing steel wires cast in the shoe near its working face.



No. 11.—Back sides of brake shoes shown in illustration No. 10, showing steel strips which retain fragments of shoe in place after the development of thermal cracks on the working faces.

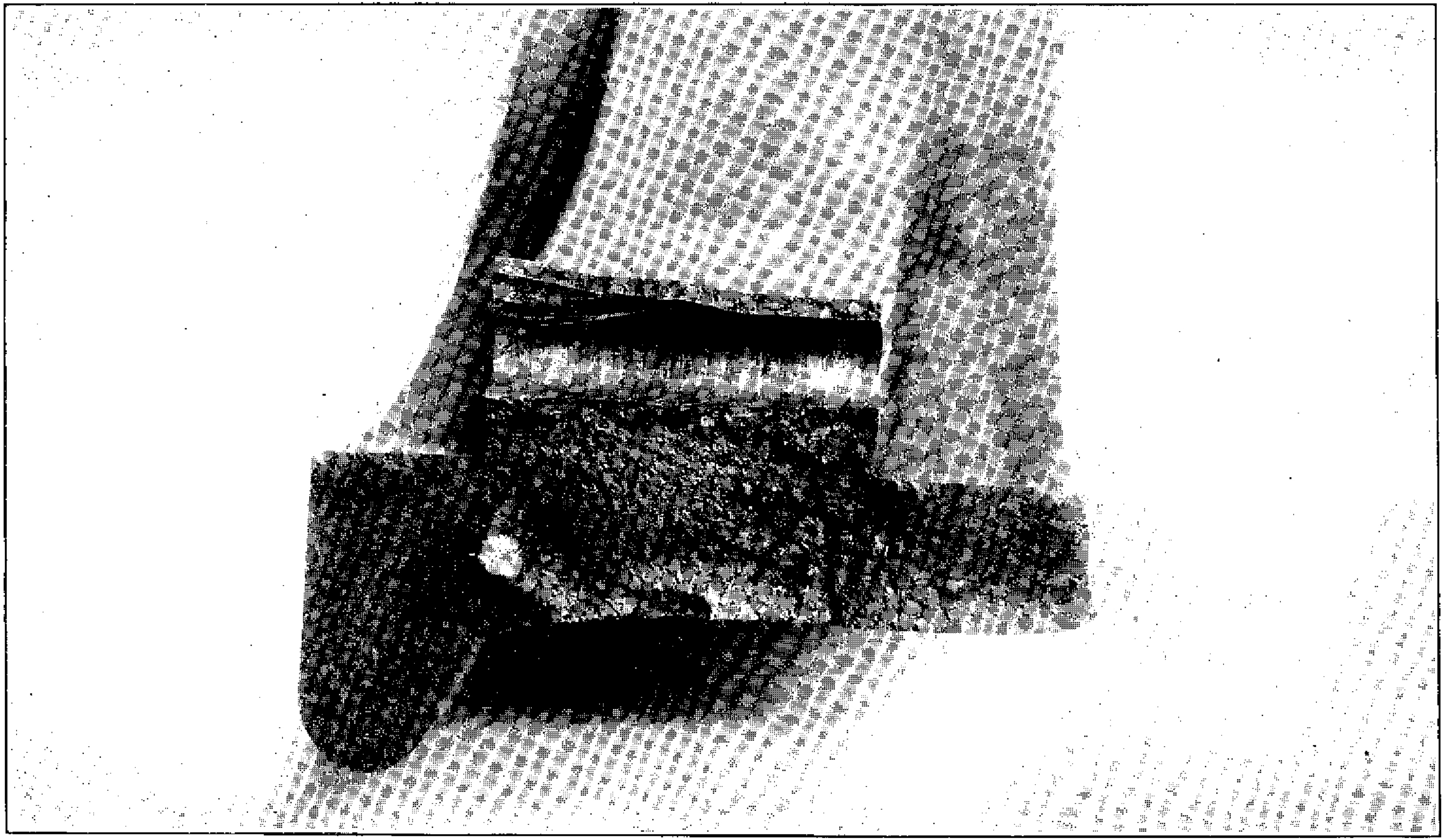
at intervals of 1 inch each. The shoes were subsequently broken apart in several places by the blows of a sledge hammer and the depths of the cracks noted, which are entered on figure No. 10. The maximum depths were 0.40 inch and 0.45 inch, respectively. End views of the fractures are shown by figure No. 12. Thermal cracks are not confined to railway material, hence their development in tires, brake shoes, and rails do not present new or novel examples in constructive materials.



No. 12.—Fractured surfaces of brake shoes shown in illustrations Nos. 10 and 11. Depth of penetration of thermal cracks shown by figures appearing on the illustration.

The investigation of a specific case of failure, one wheel out of several millions in use, would not in itself possess great interest unless the manner of failure was representative of a general type or class characteristic of other wheels. Failure of the present wheel, however, was reached through conditions which affect others through a common danger to be reckoned with. The cause of the wreck of train No. 15 was not material defective in its primitive state, but that which had become so apparently from braking conditions.

The fractured surface of a steel tire is shown by figure No. 13, which fractured in service but was discovered and removed, no dam-



No. 13.—View showing appearance of a steel tire, worn down to the "limit groove," which fractured in service. The fracture was discovered and the wheel removed from service.

age to equipment having been done. It furnishes an example of a tire which was held by cheek plates of sufficient strength to resist the side lurches of the train and did not leave its wheel center. This was a case of a worn-out tire, worn to the "limit groove" when it fractured, which apparently started at the interior angle of the flange end.

In conclusion, it appears that the derailment and wreck of train No. 15 was caused by the fracture of the steel tire on the right-hand forward wheel of the forward truck of baggage car No. 235.

That the retaining rings and rivets in the construction of the wheel did not have adequate strength, shrinkage resistance having been lost, to hold the fractured tire on its wheel center.

That the fractured tire, insecurely held, was forced off its wheel center by side thrusts usual to train movements, thus precipitating the derailment.

That the fracture of the tire was occasioned by the presence of deep thermal cracks in the tread, one of which had separated the metal of the tire to a depth of one-half its thickness and had an area of over $1\frac{1}{2}$ square inches.

That these cracks were visible on the surface of the tread and the edge of the outer end of the tire.

That the formation and extension of these cracks was due to the heat generated under the brake shoe.

That adequate means should be employed to hold a tire of this type on its wheel center independent of shrinkage resistance.

That the presence of thermal cracks on the tread of a tire is sufficient cause for the removal of the wheel from service, which should be done.

Respectfully submitted.

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