# INTERSTATE COMMERCE COMMISSION

## REPORT OF THE CHIEF OF THE DIVISION OF SAFETY COVERING THE INVESTIGATION OF AN ACCIDENT WHICH OCCURRED ON THE CHICAGO, MILWAUKEE & ST PAUL RAILWAY AT OAKWOOD, WIS , ON JANUARY 30, 1915

APRIL 28, 1915

*To the Commission*

On January 30, 1915, there was a derailment of a passenger train on the Chicago, Milwaukee & St Paul Railway at Oakwood, Wis , which resulted in the injury of 21 passengers After investigation as to the nature and cause of this accident, I beg to submit the following report

The train involved in this accident was westbound passenger train No 5, en route from Chicago, Ill , to Minneapolis, Minn It consisted of an engine, 1 mail car, 1 combination mail and express car, 1 baggage car, 3 coaches, 1 dining car, and 1 parlor car, and was in charge of Conductor Wood and Engineman Collins It left Chicago at 8 30 a m , and at 10 12 a m was derailed at a crossover frog a few feet east of the station at Oakwood while traveling at a speed estimated to have been about 55 miles per hour

The entire train was derailed with the exception of the locomotive and first two cars, the baggage car coming to rest on its side, while the other cars remained practically upright and none was materially damaged Illustration No 1 is a view of the rear portion of the train, looking east

This part of the Chicago, Milwaukee & St Paul Railway is a double-track line and is equipped with automatic block signals At the point of accident the track is straight, laid with 100-pound steel rails, 33 feet in length, with about 19 oak ties under each rail, ballasted with 2 feet of gravel At the time of the accident the weather was clear

Examination of the equipment of the train showed that there was a broken wheel under the baggage car The trucks under this car

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were 6-wheel trucks, and the wheel which broke was the middle wheel on the right side of the forward truck. When the track was examined pieces of a journal box, packing, and several small parts of the truck were found at a point about 2,300 feet east of the point of derailment. About five rail lengths west of this point was a broken rail, apparently broken as a result of the pounding of the broken wheel upon it. Nearly 850 feet west of the point where the parts of the journal box were found was a piece of the tire from the broken wheel, this piece being found at the foot of the embankment on the south side of the eastbound track. Nearly 650 feet west of this point a second piece of this tire was found, this piece being between the two main tracks. About 450 feet beyond the point of derailment a third fragment of the tire was found, while one other piece could not be located.

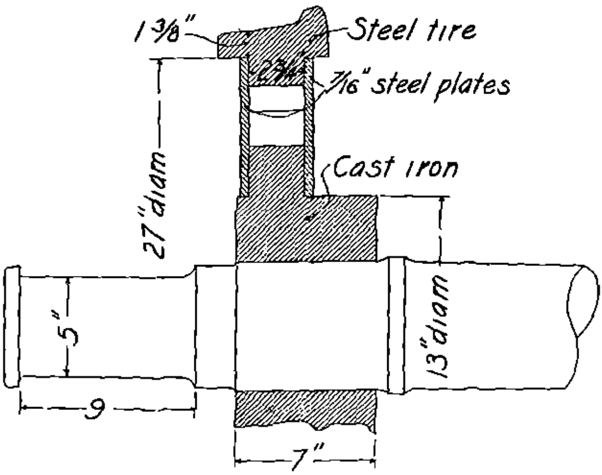
The night car inspector in the coach yard in Chicago stated that the baggage car arrived in Chicago on January 29 and on being brought to the coach yard was inspected by him. He found one pair of defective wheels on the same truck under which the broken wheel which caused the accident afterwards failed. The car was then sent to the wheel pit and a new pair of wheels was put under the car in place of the defective pair. After this had been done the car was again inspected by him, as well as by two car repairmen, but no other defects were found.

The investigation to ascertain the reason for the failure of this wheel was conducted by Mr. James E. Howard, engineer-physicist, tests being made in conjunction with representatives of the Chicago, Milwaukee & St. Paul Railway Co. at the shops of that company in Milwaukee, Wis. The report covering the results of this investigation follows:

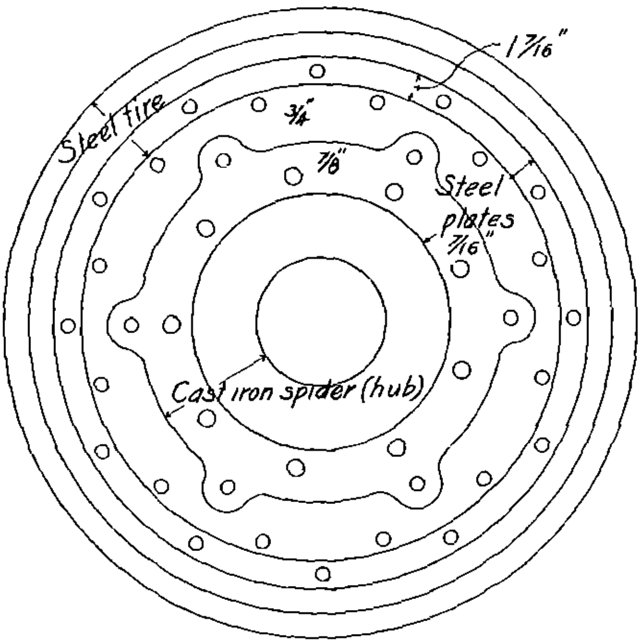
## REPORT OF THE ENGINEER PHYSICIST

The wheel the tire of which failed, apparently leading to the derailment of train No. 5, was one of a built-up type, which consisted of a cast-iron hub, or spider—so called—two rolled-steel cheek plates, and a rolled-steel tire. The several parts, during fabrication, were assembled by forced mechanical fits, to insure the proper unity of their action in the completed wheel. In a subsequent operation the plates, hub, and tire were drilled and were further secured to each other by through bolts. The usual number of bolts in wheels of this type is 39, of which 30 are three-fourths inch diameter and 9 are seven-eighths inch diameter. The smaller bolts form three concentric circles of the outer part of the wheel, the larger bolts are those of the inside circle at the hub, the heads of the latter being countersunk.

Figure No 2 shows the construction of this type of wheel, in l cross section, with cast-iron spider in place on the axle, inner : outer steel plates, and rolled-steel tire The thickness of the t here shown, 1⅜ inches in the plane of the outer plate, represents thickness at time of derailment




No 2 —Sectional view showing details of construction of built-up wheel consisting of cast iron hu two 7/16-inch steel plates and rolled steel tire




No 3 —Side view of built-up wheel showing cast-iron spider with one 7/16-inch steel plate and steel tire in place the outside 7/16-inch steel plate removed

Figure No 3 is a side view of the wheel showing the cast-iron spider and the tire, with one of the plates, the outer one, removed

In machining these parts, for obtaining proper mechanical fits, the plates are made slightly over and under the diameters of the tire and the hub, respectively, the assembling then being done by forcing the plates over their seats with a hydraulic press The mechanical fits thus secured are relied upon in lieu of assembling by shrinkage fits

The outer circle of bolts clamp the check plates directly to the interior web of the tire The bolts of the next circle, which are located just within the inner diameter of the tire, draw the plates toward each other Since there is no direct support opposite this second circle of bolts the plates are bent slightly inward, in consequence of which any radial movement of the tire with reference to the plates tends to wear a shoulder where the inside faces of the plates are deflected against the corners of the web of the tire The plates used are seven-sixteenths inch in thickness each

The third circle of bolts clamps the plates to the lugs of the cast-iron spider and the fourth circle to the main web of the hub

In wheels of this type the axle loads are transmitted to the tire through the two seven-sixteenth inch plates The efficiency of the bearing surface, seven-eighths inch total width at the edges of the plates, is augmented in sustaining the axle load by the frictional resistance set up between the plates and the interior web of the tire

The cast-iron spider shown in figure No 3 represents the pattern used in 33-inch wheels, the size which failed in the truck of baggage car No 522 In wheels of larger diameter cored spiders of greater size are used in order to provide for the desired distribution of the bolts over the flat surfaces of these plates of increased width

The completed wheels are pressed on the axles in the usual manner of assembling, a forced fit being made between the hub and the wheel seat of the axle Such are the constructive details of wheels of this type

On the occasion of the derailment of train No 5, the tire of the middle wheel of the forward truck of baggage car No 522, right-hand side of the train, broke at four places, at each place separating the tire by radial lines of rupture Each line of rupture passed through a bolt hole of the interior web of the tire The smallest fragment comprised two-twelfths of the circumference There were two fragments of intermediate size of three-twelfths each and one fragment of four-twelfths the circumference Three of these fragments were recovered after the derailment, the smallest one not having been found

An examination of the fractured surfaces showed that each line rupture had its origin at the inner diameter of the tire, thence passi through the metal in an outward direction to the surface of the tre and through the flange

The thin sections of metal between the bolt holes of the inter web and the inner diameter of the tire were fractured at each bo hole These incipient fractures, however, did not extend beyon the thin sections, excepting at those places where the full cross se tion was separated in forming the four detached fragments

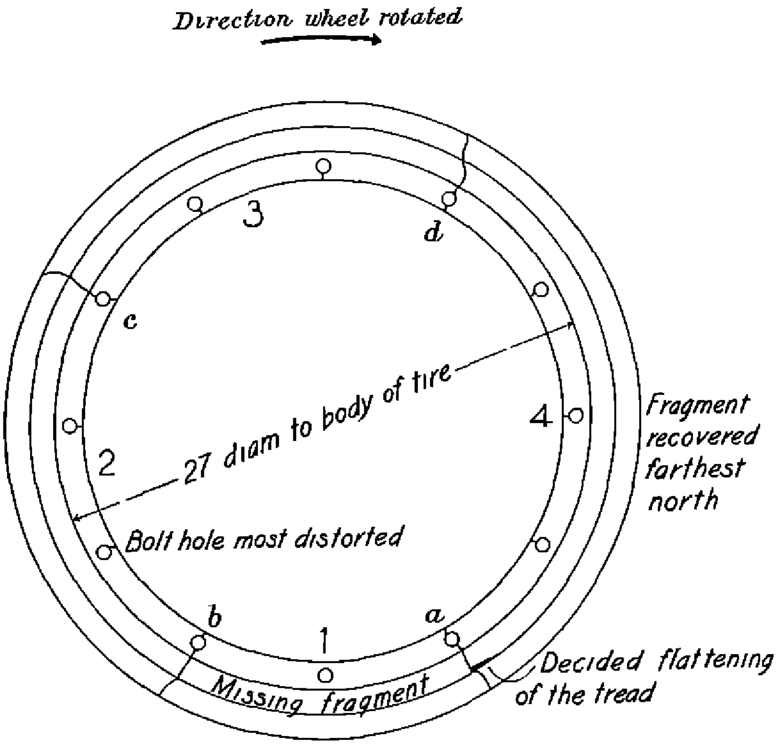
The principal lines of rupture are shown on figure No 4, mark "*a*," "*b*," "*c*," and "*d*," on which the incipient fractures at the bo holes are also indicated The initial line of rupture of the tire believed to have occurred between fragments 1 and 4, on the li marked "*a*," followed by that marked "*b*," thereby detaching t short fragment which was not recovered The indications are th the line of rupture next to occur was that marked "*d*," in the d velopment of which one-half of the tire was detached from the plat This half, in its flight, evidently came into collision with some obje which caused it to break apart at the middle of its length, at the li marked "*c*," in this manner forming the two fragments number 2 and 3

In the course of their flight fragments Nos 2 and 3 crossed ov to the left-hand side of the train, emerged therefrom and came rest, one at the foot of an embankment about 850 feet from the pla where the first evidence of damage to the truck was found, whi the other fragment came to rest between the eastbound and th westbound tracks, 650 feet beyond the first recovered fragmen Fragment marked 4 remained with or in the vicinity of the train further distance of 1,267 feet, making a total distance of 2,767 fe beyond the place where the first evidence of damage to the truc was found, and 440 feet beyond the place of derailment of the trai at the crossover frog This fragment was recovered in the vicinit of the rear coaches of the derailed train, where they came to rest

The relation of the distance of fragment 4 to the crossover fro leads to the inference that this fragment played an important part i the derailment when the train encountered the frog in question Although portions of the tire had been detached from the plates of th wheel for some distance to the rear, still the train remained on th rails until the crossover frog was reached, beyond which the train wa derailed and the track destroyed Up to the location of the frog n injury had been done the track excepting the fracture of one rai which was located at a considerable distance to the rear

This broken rail was on the side of the track of the broken wheel located at a distance of 2,177 feet from the place of derailment, an

150 feet beyond, in the direction the train was traveling, the place where first indications of damage to the truck appeared, the latter consisting of journal-box packing and a broken pedestal The rail was a 100-pound A S C E section branded "10001 Illinois Steel Co South Wks X 1906," heat No 7889 It had a square break 27 inches from the receiving end and just beyond its seat upon a tie The line of rupture started in the base, thence passing upward through the web and the head There was a longitudinal seam at the center line of the base 11 inches long, the presence of which appeared to have led to this fracture




No 4 —Tire of built up wheel showing location of the four lines of rupture which were found at time of derailment separating the tire at bolt holes a b c and d Incipient lines of rupture present at each of the other bolt holes of the recovered fragments

It is of interest to note the conditions which were probably responsible for the fracture of this one rail It was a case of streaked steel, seams or streaks in the base, which successfully endured the stresses of ordinary traffic but failed when subjected to an exceptionally severe stress, in this case incident to a broken wheel, from which a portion of the tire had probably just been detached Evidence of the streaked state of the metal in this rail was presented at another place along its length where a short strip of the flange was sheared off No other rail was broken nor were any bent until the point of derailment was reached, 2,177 feet beyond

The causes which led to the fracture of the wheel were looked for in the evidence furnished by the recovered fragments and in the condition of the mate of the fractured wheel The inquiry was also extended to the examination of other wheels of this type, some of which had been removed on account of cracked tires and others by reason of having been worn down to the minimum thickness permitted

In the ruptured wheel it was found that appreciable wear had taken place at the bearing between the rims of the plates and the inside diameter of the tire, that is, at the junction of the inside web and tread The tire was grooved, in some places the groove reached a depth of three-hundredths of an inch This grooving evinced that a movement had occurred between the tire and the plates during the time the wheel was in service, and which doubtless had an influence in promoting rupture

The incipient cracks at the bolt holes furnished other evidence of local movement and bending of the tire when the wheel was in service Some of the bolt holes in the recovered fragments were considerably distorted, a secondary occurrence, incidental to shearing the bolts when the fragments were detached from the plates

Still another effect was noticed, the broken pieces of the tire assumed a radius of curvature slightly less than that which the intact diameter of the tire called for This change in curvature resulted from the introduction of internal strains in the metal in the zone next below the surface of the tread and was due, it is believed, to the cold-rolling effect between the wheels and the head of the rail Such internal strains correspond to stresses of considerable magnitude and are not negligible quantities when judging of the endurance of steel under the conditions of railway service The presence of such internal strains was made manifest by the springing together of the ends of tires when they were cut apart radially, a matter to be referred to in a later part of this report

The mate of the ruptured wheel was dismantled and the condition of its parts examined, previous to which, however, it was sounded with a hammer Under the hammer test the wheel did not appear to be loose in any of its parts In dismantling, the nuts of the plate bolts were removed and the bolts driven out Those of the inner circle, ⅞ inch diameter, required hard driving in their removal The ¾-inch bolts in general drove out easily, particularly those of the outer circle—those which passed through the web of the tire

The outside plate of this wheel was removed, furnishing access to the surface next the tire and the spider, also permitting inspection of the seat of the plate in the tire and of the condition of the bolt holes.

Grooving had taken place in the tire where the rims of the plates seated, although not to the same extent as that which was witnessed in the fragments of the broken wheel. Incipient cracks were found at each of the 12 bolt holes in this tire, across the thin sections between the bolt holes and the interior diameter of the web. None had extended to the metal on the opposite sides of the holes. When such extension occurs an early and complete failure of the tire would be expected, resulting in a cracked tire, visible at the tread. These incipient cracks, which were found to be comparatively numerous in wheels which were dismantled in quest of them, are not visible until the outer circle of bolts are taken out or one of the plates removed.

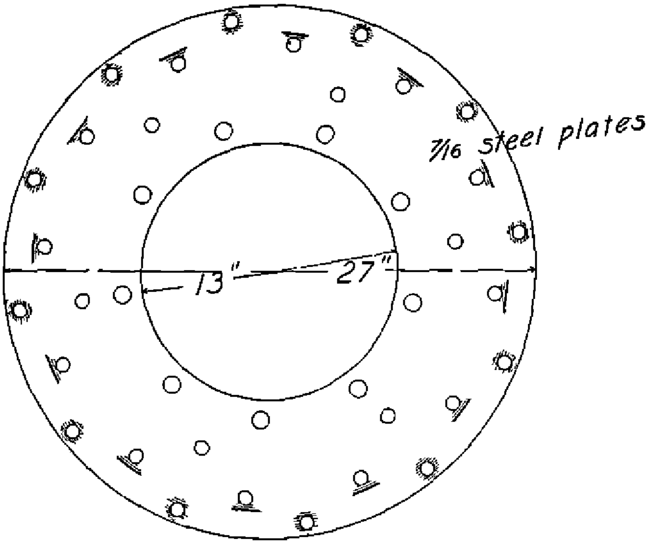
The thickness of the metal at this place is insufficient to afford substantial aid to the strength of the tire. The presence of such incipient fractures, however, is held to be significant that the wheel in service carried loads which successively bent and flattened the tire as it rotated.

The rupture of the metal is regarded as evidence of the effect of repeated stresses, endured in regular service, the fractures pointing to the place in which strength and rigidity seem deficient.

The lack of rigidity and unity of action was illustrated in the effects which the use of the wheel produced on the metal of the plates, as shown by the brightened annular surfaces surrounding the outer circle of bolt holes, and accompanied by the formation of perceptible shoulders on the faces of the plates where the corners of the web of the tire bore against them. Figure No. 5 is shaded to represent the places where these movements occurred. In some of the wheels examined, there was evidence of the movement of the plates having occurred as far down as the lugs of the spider, but in general the effects were not visible beyond that part of the plate covered by the outer two circles of bolts.

Structurally, a weak part of the wheel, at least in one with a worn tire, is thus shown to be in the vicinity of the rim, where these movements between the tire and the plates occur. The stresses which attend these alternate movements it would appear, eventually lead to rupture of the metal after the manner of repeated or fatigue tests. A direct measure of the magnitude of the stresses experienced in service does not admit of determination but the results of such stresses in causing rupture may be taken as indicative of their magnitude, and the frequency of their application.

Wheels of this type, which fail with cracked tires, commonly hav their lines of fracture pass through the bolt holes, with their origi at the interior diameter of the tire, extending thence in an outwai direction, nevertheless there are occasional exceptions to this mai ner of failure There are instances in which the incipient places ( rupture are located at the surface of the tread, at the corner of th rim, or at the flange In such tires the lines of rupture travel in th opposite direction to those first described, that is radially inwar instead of outward Such fractures owe their origins to other an distinct causes from those above mentioned




No 5 —Plate of built up wheel Evidence of movement between plate and tire found as indicated b the annular shaded zones around outer circle of bolt holes, the formation of shoulders on the face ( plate by lines at the sides of the second circle of bolt holes

Chemical analyses and tensile tests were made upon the metal of the ruptured tire, the results of which next follow

*Chemical analyses*

[Results furnished by the Chicago, Milwaukee & St Paul Ry Co ]

| Carbon | Manganese | Silicon | Sulphur | Phosphorus |
|---|---|---|---|---|
| | 0 59 | 0 25 | 0 032 | 0 026 |
| | 64 | 29 | 032 | 029 |
| | 64 | 31 | 032 | 031 |

[Results furnished by the Railway Steel Spring Co ]

| | | | | |
|---|---|---|---|---|
| 0 71 | 0 64 | 0 28 | 0 030 | 0 035 |

Independent check determination, carbon only, on chips taken from tensile test piece, gave carbon 73

*Tensile tests*

[Specimens 0 505 inch diameter by 2 inches long ]

| Description | Elastic limit per square inch | Tensile strength per square inch | Elongation | Cont of area |
|---|---|---|---|---|
| | *Pounds* | *Pounds* | *Per cent* | *Per cent* |
| Tangential specimens | | | | |
| Outside part of tread | 41 900 | 103 500 | 21 3 | 32 5 |
| Center of tread | 53 500 | 104 950 | 18 7 | 29 5 |
| Near flange | 40 750 | 102 500 | 21 5 | 29 5 |
| Crosswise specimen | | | | |
| Center of tread | 66 300 | 104 700 | 11 0 | 16 1 |

[Results furnished by the Railway Steel Spring Co ]

| | | | | |
|---|---|---|---|---|
| | 57 570 | 114 370 | 15 0 | 21 0 |

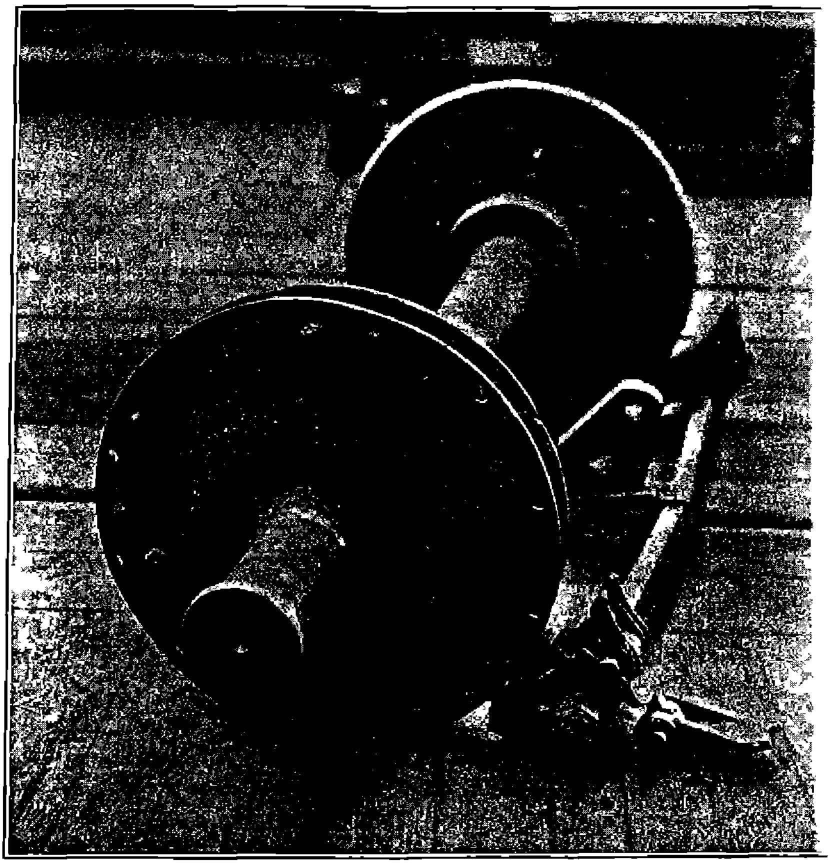
Appearance of the fractures, granular

Figures Nos 6 and 7 show the axle and wheels, one of which had the fractured tire All of the fragments of the right-hand wheel were detached from the plates, as shown in figure No 6, prior to the time the train came to rest The left-hand wheel, shown in figure No 7, which was otherwise intact was found upon examination to have incipient cracks at each of the bolt holes of the interior web of the tire Heavy lines have been sketched on the cut to indicate more clearly the positions of these lines of rupture

The total mileage of the wheel which failed under baggage car No 522 was 276,396 miles, up to the end of December last It was run in the trucks of different cars during its term of service as the accompanying table shows

*Record of wheel which failed under baggage car No 522*

| In service | Months | Days | Under car | Weight of car | Mileage of wheel | Ave load wh |
|---|---|---|---|---|---|---|
| | | | | *Pounds* | | *Pou* |
| Jan 7 to Jan 21 1912 | | 14 | Mail and baggage, 3510 | 118 700 | 6 874 | |
| Jan 23 to Feb 28 1912 | 1 | 5 | Baggage, 515 | 119 000 | 16 566 | |
| Mar 14 to May 13 1912 | 1 | 29 | Passenger, 612 | 135 000 | 26 245 | 1 |
| June 14 to Nov 5, 1912 | 4 | 21 | Baggage, 3031 | 129,160 | 66 160 | 1 |
| Nov 18 1912 to May 3 1913 | 5 | 15 | Mail and baggage, 518 | 118,700 | 75,611 | |
| May 10 to Dec 2 1913 | 6 | 22 | Mail and baggage, 3500 | 112,500 | 42,220 | |
| Sept 25 to Dec 31 1914 | 3 | 5 | Baggage 522 | 129,750 | 42,720 | 1 |
| Total | | | | | 276 396 | |



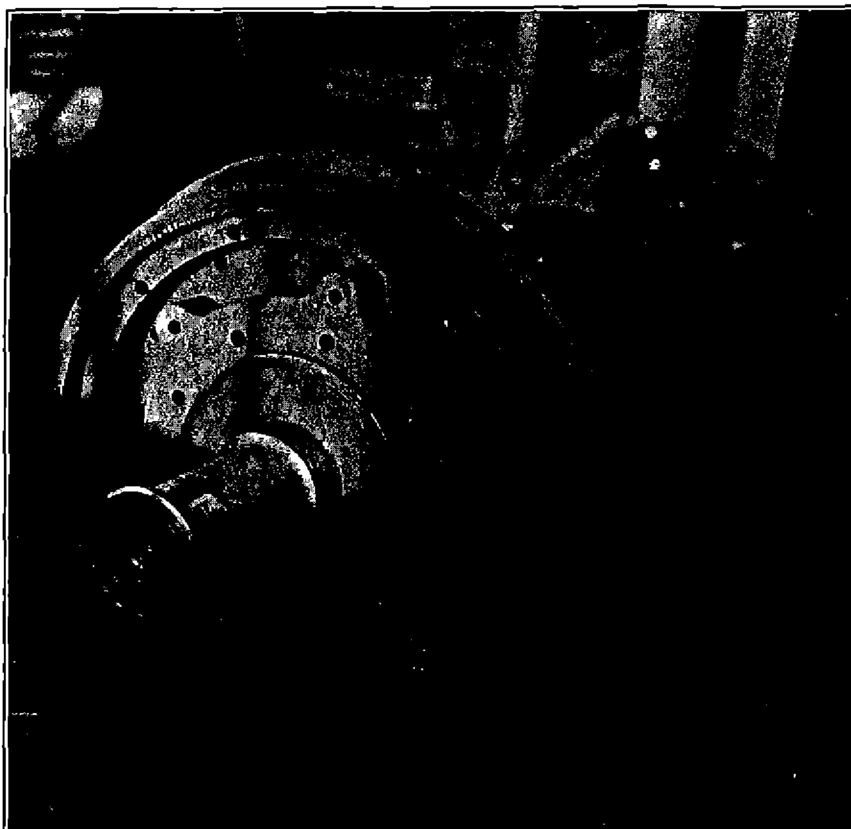
No 6 —Appearance of fractured wheel on axle as removed from truck after derailment All fragm of tire were detached when train came to a rest

Six-wheel trucks were used under each of the above cars

Actual time of wheel in service, 23 months, 21 days

The loads under which this wheel was run, were of moderate degree, not reaching the higher loads which are current in certain kinds of freight-car equipment

There were four kinds of wheels under train No 5, 18 of the type which fractured, as the following table shows



No 7—Wheel on opposite end of axle mate to fractured wheel Outside plate removed showing cast iron hub or spider steel tire and inside plate There were incipient cracks at each bolt hole of the tire as indicated in the cut

*Weight of cars and kinds of wheels used in train No 5 at time of derailment*

| Car | Number | Weight of car | Average wheel load | Size of wheels | Number of wheels | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | Schoen | Standard | Paige | Chilled iron |
| | | *Pounds* | *Pounds* | *Inches* | | | | |
| Mail | 518 | 118 700 | 9 890 | 33 | 4 | 4 | 4 | |
| Mail and express | 352 | 95 500 | 7 958 | 33 | | | | |
| Baggage | 522 | 129 750 | 10 810 | 33 | 6 | 4 | 2 | |
| Coach | 667 | 131 980 | 11 000 | 33 | 8 | 4 | | |
| Do | 608 | 135 000 | 11 250 | 33 | 6 | 2 | 4 | |
| Do | 604 | 135 000 | 11 250 | 33 | 6 | 4 | 2 | |
| Diner | P | 130 500 | 10 875 | 38 | 4 | 2 | 6 | |
| Parlor | Mineola | 140 000 | 11 667 | 36 | 12 | | | |
| Total | | | | | 46 | 20 | 18 | |

The number of incipient cracks which were disclosed at the bo holes of the tires of the two wheels from baggage car No 522 led a further examination of wheels of this type taken from other sourc Some of the additional wheels examined, as previously remarked, h tires which cracked in service and had been removed for that caus while others had been removed on account of having been worn the minimum thickness permitted

The tires of 20 wheels were examined Of this number 9 ti had incipient cracks at 56 of their bolt holes In addition to the incipient cracks there were 13 lines of rupture which complete separated the metal of 5 tires, and 6 incipient cracks in the sho fragments of the tenth tire In all, the total number of incipie and complete fractures at bolt holes in 10 tires was 75 In t other 10 tires of the 20 examined, no fractures at the bolt holes we found

In the table following are given the results of this examinatio including in the tabulation the two wheels of baggage car No 522

### STEEL-TIRED BUILT-UP WHEELS

*Incipient cracks in webs of tires, between bolt holes and interior diameter of tire, found in worn wheels when dismantled for examination*

| Car | Diameter of wheel | Marks on tires | Number of incipient cracks | Remarks |
|---|---|---|---|---|
| | *Inches* | | | |
| Baggage No 522 | 33 | Z215717 Latrobe | 7 | On fragments of broken tire |
| Do | 33 | 999002-4 Latrobe | 12 | On mate of wheel with broken tire |
| Axle removed from truck | 33 | 953983 Latrobe | 9 | Wheels from same axle |
| Do | 33 | A8965-2 Latrobe | 0 | Comby tread (Wheels from same axle) |
| Do | 33 | 998817-5 Latrobe | 6 | Tire cracked in service across bolt hole |
| Do | 33 | 998852-3 Latrobe | 2 | |
| Sleeper Beaver Dam | 38 | | 1 | Do |
| Do | 38 | | 6 | |
| Sleeper detached wheel | 36 | A45382-4 Latrobe | 7 | Do |
| Do | 36 | | 6 | |
| Total | | | 56 | |

The incipient cracks which were found in the tires of wheels on an axle from sleeping car Beaver Dam are shown by figures Nos 8 and 9 These were 38-inch wheels, one of which developed a crack in service separating the tire at a bolt hole as shown by figure No 8 In this tire there was an additional fracture, an incipient crack at the fourth bolt hole from the line of rupture which separated the tire

In the mate to this wheel there were six incipient cracks at bolt holes, the positions of which are shown on figure No 9 These two cuts represent the wheels with their outside plates removed, crosses sketched thereon indicating the positions of the fractures Cored spiders are used on wheels of this diameter, as shown in these cuts

The feature to which attention was next directed, was the state of *internal strain which had been introduced into the metal below the* treads of the tires by reason of the cold rolling action of the wheels upon the rails, alluded to in the remarks concerning the reduction in the radius of curvature of the fragments from the wheel of baggage car 522 and the springing of the tires when cut apart radially

This cold rolling sets up strains both in the head of the rail and in the tread of the tire, parts which react upon and influence each other The zones of metal immediately affected are next the surfaces of the treads of the tires and the running surfaces of the heads of the rails Internal strains of compression are introduced at these places, which remain as permanent effects in the steel, unless the metal is subsequently annealed, by which treatment such strains may be removed

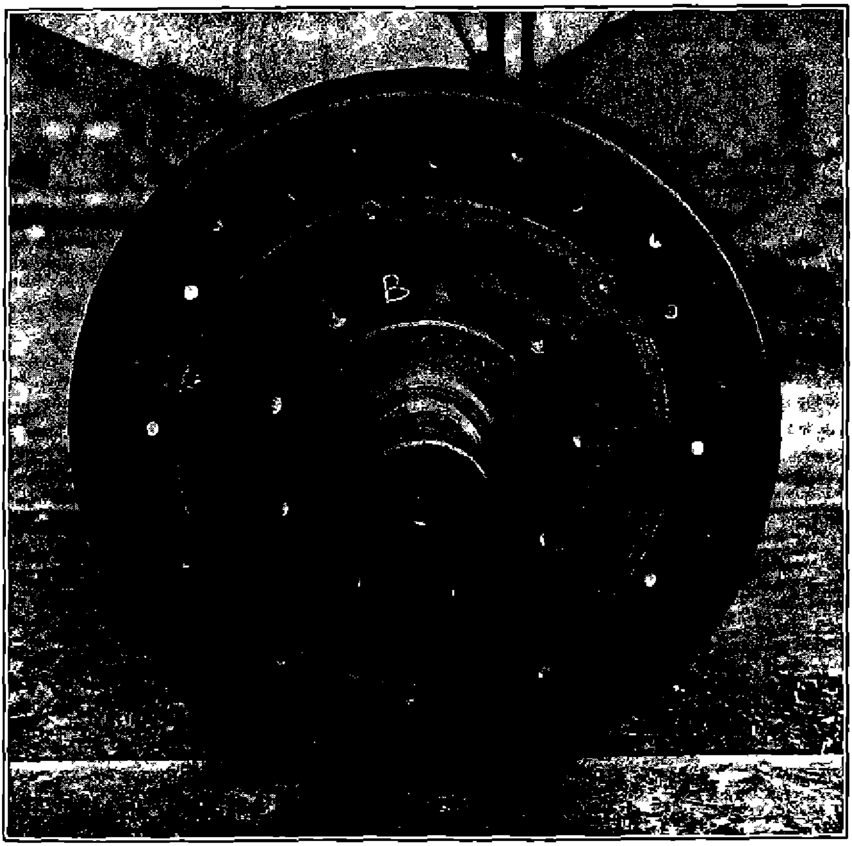
The presence of and the kind of internal strains, whether of tension or compression, is made known by affording the metal an opportunit to assume a state of repose When relieved from restraint, th direction of the resilient movement of the steel indicates the kind o strain which was in the metal, the magnitude of which is proportiona to the amount the metal recovers in its length

Internal strains of compression, immediately below the surface c the tread, tend to cause the tire to assume a larger diameter whe the wheel is intact In the case of a detached tire the effect of suc strains is to cause the ends to spring toward each other when the tu

No 8 —38-inch built-up wheel from sleeper Beaver Dam A Removed from service on account of cracked tire One additional crack at bolt hole shown when wheel was dismantled Complete line of rupture of tire and incipient cracks indicated by crosses sketched on the cut is cut apart radially That is, a chord measurement on a tire decreases in length when a radial cut bisects it

The ends of these tires, as will appear, sprung together when cut radially, indicating the release of internal strains of compression in the metal next below the treads

Eight tires were slotted apart radially, and the relief to the metal thus afforded, was noted Included in this examination was a tire of a fused cast iron center coach wheel, that is, a steel-tired wheel which had a gray iron center cast or fused in place The fused wheel had had a large part of its rim broken off in service




No 9—38 inch built-up wheel from sleeper Beaver Dam B Mate of wheel A Six incipient cracks at bolt holes revealed when outside plate was removed and web of tire examined Position of cracks indicated by crosses sketched on the cut

The ıesults obtaıned wıth these tıres aıe shown on the table whıcl follows

*Table showıng the amounts the ends of steel tıııes spıung together when ıadıal cuts wei made*

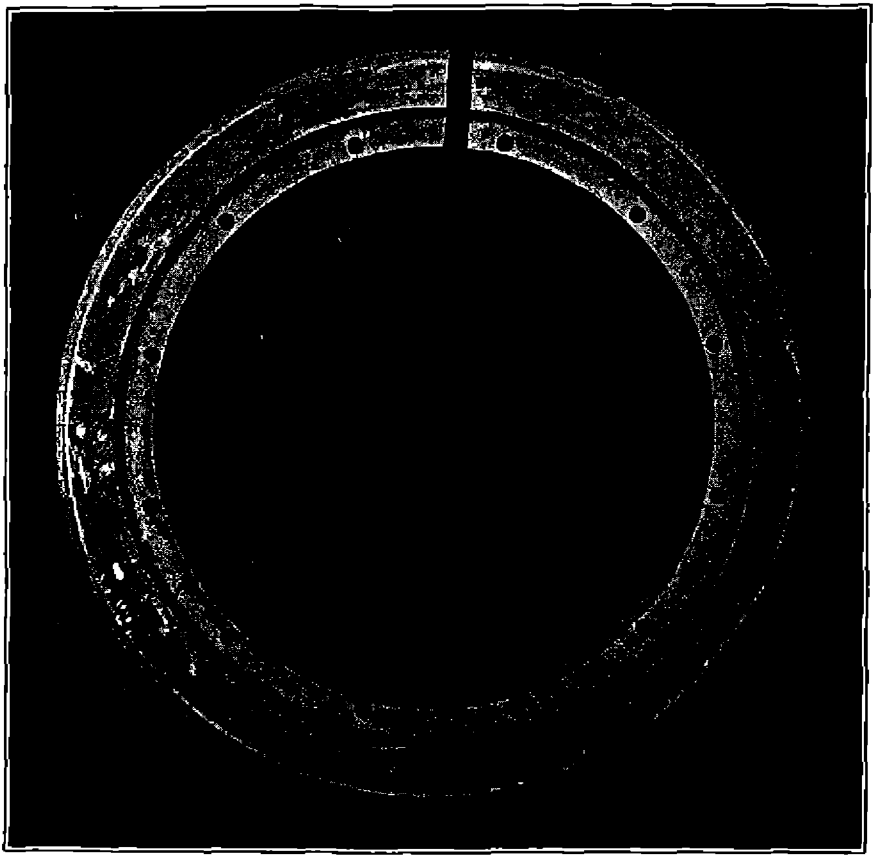
| Car | Diameter of wheel | Marks on tıres | Amount ends sprung together | Remarks |
|---|---|---|---|---|
| | *Inch* | | *Inch* | |
| Baggage 522 | 33 | 999002-4 Latrobe | 11/16 | Mate of wheel that fractured at tıme derailment of train No 5 |
| Sleeper Deaver Dam | 36 | 1955-3 Latrobe | 15/16 | This tire cracked ın serııce across a bo hole It was slotted at the crack |
| Do | 38 | 995010-4 Latrobe | 15/16 | Mate of wheel next above Tıre was ıntac excepting 6 ıncıpıent cracks at bolt holı |
| Detached wheel | 33 | Z 170938 | 7/16 | 3/16-inch on a sıde was turned off the tre and flange of thıs tıre before ıt was cı apart |
| Do | 33 | 953963 Latrobe | 0 | Tıre was annealed heated to a brıg yellow and cooled oıer nıght ın furnaı then cut apart |
| Sleeper Vınara | 36 | | 13/16 | The ınterıor web of the tıre was turned before cuttıng apart radially |
| Detached wheel | 36 | A 26765-5 Latrobe | 1/2 | Tire cracked ın service Line of ruptı 1¼ ınches from bolt hole Incıpıent poı of rupture, outsıde corner of tread |
| Sleeper Shasta | 38 | Cast ıron center branded 'Rail way Steel Sprıng Co, Feb 12 1907 | 3/4 | Steel tired gray ıron fused center |

As shown ın the table, the ends of the tıres when cut apart ıadıall sprung together amounts noımally appeaııng to range from elevei sıxteenths to fifteen sıxteenths ınch

These results ıepresent the state of ınıtıal straın exıstıng ın tl tıres of wheels whıch have been ın servıce They are straıns whıı aıe ıntıoduced chiefly by servıce condıtıons, and ıt ıs ımmaterıal, far as dıslodgıng them goes, whetheı the tııe ıs cracked ın seıvıce not, the straıns remaın The second tıre ın the tabulatıon failı ın servıce developıng the crack whıch ıs shown ın ıllustratıon No but notwıthstandıng whıch, the ends sprung together fifteeı sıxteenths ınch when removed from the plates and slotted acıoss on t lıne of rupture Its mate, whıch had ıts ıım ıntact, closed ın tl same amount, when cut apart radıally The resıdual effect of co rollıng was the same ın each tıre

The dırect effect of cold rollıng ıs confined to a zone of metal ne the tread Turnıng off the metal of the tread removes some of tl metal whıch ıs ın a state of ınıtıal compressıon, and lessens tl dıstance whıch the ends sprıng together when a ıadıal cut ıs mad The fourth tıre was turned off at the tread and flange three-sıxteentl ınch on a sıde Thıs sprung togetheı seven-sıxteenths ınch whı cut radıally Annealıng the steel elımınates ınıtıal straıns and wıll be noted ın the case of the fifth tıre that no closıng ın occurrı when cut apart, all measurable initial strains having been removed by the process of annealing.

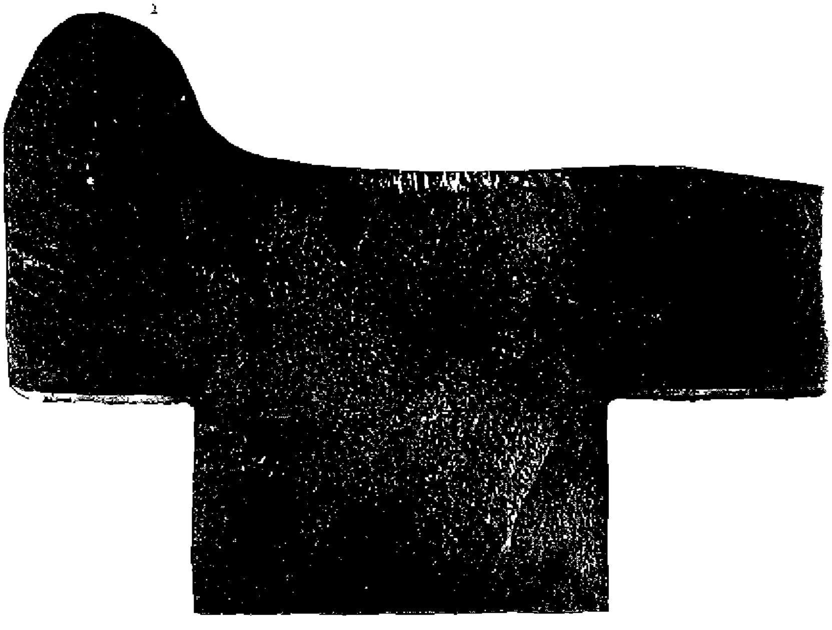
Figure No. 10 shows a tire which had been cut apart radially. Two cuts in the slotter were made on this tire, each cut being 1 inch wide. After the first cut was made the ends sprung together, leaving an opening one-sixteenth inch wide. A second cut, 1 inch wide, was made which left the ends $1\frac{1}{16}$ inches apart as shown in the illustration.



No. 10.—Tire of built up wheel cut apart radially. Ends closed in $\frac{15}{16}$ inch. Two inches width of metal was slotted out leaving the opening between the ends $1\frac{1}{16}$ inches as shown in this illustration.

The first five tires of the table belong to one group of wheels. The sixth tire was the mate of a wheel which broke in service. The latter separated into six main fragments and five smaller ones, comprising parts of the tread and flange. The interior web of the sixth tire was turned off before slotting. The removal of this metal did not materially affect the amount of springing of the ends when slotted ap which closed in fifteen-sixteenths inch, an amount which seems ab normal in these tires

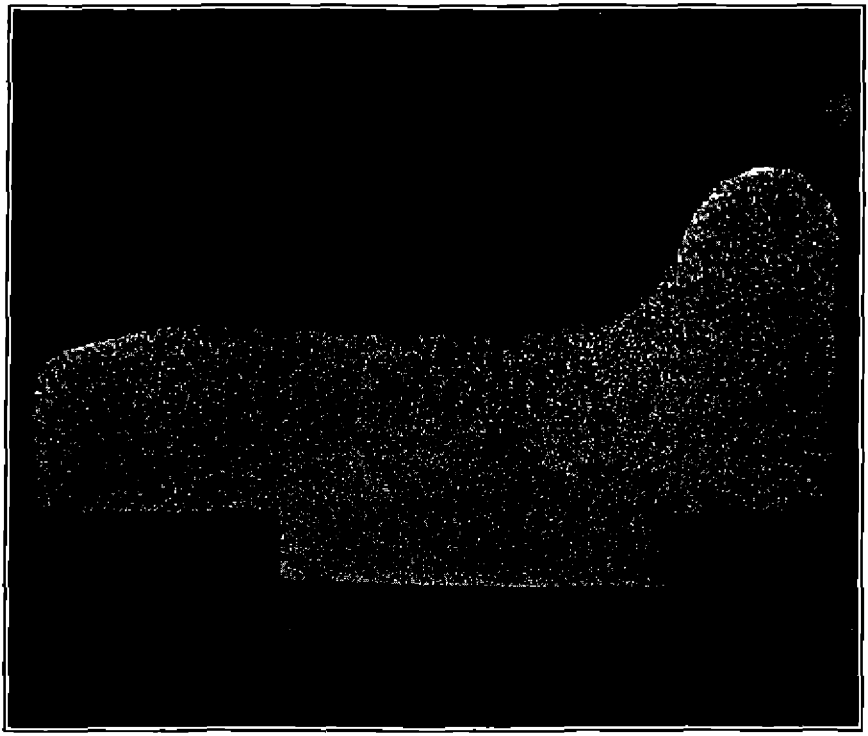
The seventh tire was from a detached wheel, which had been moved from service on account of a crack separating it The fi ture of this tire differed from the others which were included in present examination, in respect to its passing through the full ci section between bolt holes Furthermore, in its development traveled in an opposite direction, starting from the outside or tre of the tire and extending across and radially inward



No 11 —Cross section of tire of built up wheel which fractured across full section of metal 1¾ inches i n bolt hole The line of rupture started at the corner of the outside face of the tire indicated by sketched on the illustration

The incipient point of rupture was at the corner of the tread, the outside face of the tire It was slotted along the line of ruptu whereupon the ends closed in one-half inch The appearance of t fractured surface of this tire is shown in figure No 11, on which star has been sketched to indicate the place where the line of ruptu had its origin This fracture had its origin at that part of the ti which is not exposed to cold rolling on the rail head, and only reach by the brake shoe The metal appeared sound in that vicinity, bu harder than at other parts of the tire This illustrates a fractu occurring where increased hardness and brittleness of the steel ha probably been induced by the action of the brake shoe, the severi of such action not having reached, however, a stage in which th development of thermal cracks had formed Evidence of heating of the tire if such had occurred was not present It is of interest to determine the characteristics of these early changes in properties which culminate in rupture and make observations which will lead to their recognition, that danger zones may be made known

Alternate heating and cooling through brake action induces loss of integrity by the development of thermal cracks Examples of the kind furnished by the rupture of this tire lead to the query whether limiting stresses may not be received and rupture approached



No 12 —Cross section of tire of built up wheel showing the darkened surface of an incipient crack in the thin section of metal at side of bolt hole of the web Line of rupture extended outward radially from the bolt hole

under service conditions unattended by outward, visible manifestations The failure of this tire, excepting the local hardening of the metal, which was not extreme, bears a close resemblance to fatigue fractures, those resulting from repeated alternate stresses in which the approach to rupture is not heralded by outward signs Wheels are, preeminently, good examples of material subjected to repeated stresses The mileage of this particular wheel is not known, but that of baggage car No 522 furnishes a convenient illustration The mileage of the latter, ending with December last, was 276,396 miles This calls for 170,000,000 rotations, in round numbers, at each rotation of which alternate stresses were received Brake-shoe action, which had not, however reached the stage in which the metal of ~~the tire was~~ actually ruptured, combined with repeated stresses were probably potential influences in the fracture of this tire

Figure No 12 is introduced to show a line of rupture which traveled in the opposite direction from that illustrated in cut No 11 This line of rupture traveled radially outward from the bolt hole to the surface of the tread and through the flange It represents also a section of tire in which an incipient crack had formed, shown by the darkened metal between the bolt hole and the inner diameter of the web

The eighth tire in the tabulation of results on those which were cut apart radially was taken from a steel-tired wheel which had a gray iron fused center Two pieces of the tread, each about 2 feet long, had been split off in service The steel tire was removed from the gray iron center by a circular cut in a boring mill after which it was cut apart radially, midway the side from which the two fragments were detached When the radial cut was made the ends closed in a distance of three-fourths inch

The springing of these tires, when cut apart, corresponds to the movement observed in steel rails when the heads of those which have been in service are detached from the webs The heads of such rails assume a curved shape, convex on the running surface, while these tires behave in a similar manner, increasing their convexity when allowed to do so The introduction of internal strains, in conjunction with the effects of repeated stresses, in the manner in which each are received in service are factors which affect the integrity of materials of this kind

The examination of the steel-tired, fused cast-iron wheel was carried along jointly with those of the type which failed under baggage car 522 The fused wheel did not cause a derailment It was on the middle axle of a 6-wheel truck One fragment of the rim was found 26 miles, and the other fragment 35 miles to the rear of the place where the injury to the wheel was discovered The axle had become considerably sprung at the time the train was stopped When this examination was made the axle, placed on dead centers, ran out at the middle of its length $1\frac{1}{8}$ inches The journals and wheels were correspondingly out of true, the maximum and minimum distance between the inside faces of the wheels now being $53\frac{3}{4}$ and $52\frac{7}{16}$ inches, respectively, a difference of $1\frac{5}{16}$ inches The two detached fragments covered nearly one-half the circumference of the tread, notwithstanding the loss of which and the bent condition which the axle eventually reached, the truck was not derailed The train was brought to a stop without injury

The fractured surface of the tire showed seamy metal, and in appearance resembled the surfaces witnessed in certain rails having split heads Figure No 13 shows a part of one of the seams in this tire, along the line of which one of the fragments was detached The metal at the immediate surface of the tread was flaky, and at a stage prior to actual failure the wheel probably showed an increased width of tread The fractures of the tire are attributed to the presence of the seams, one of which was 8 inches long, which were revealed on the surfaces which were brought into view Lateral flow of the metal at the tread caused, it is believed, the enlargement of the seams which resulted in the detachment of the two fragments

No 13 —Steel tired fused cast-iron wheel Fractured at a seam 8 inches long located ½ inch below the surface of the tread Surface metal at tread exhibited a laminated appearance with evidence of lateral flow

The metal in other parts of the tire was found to be seamy Tension tests showed the metal to possess only limited elongation in a tangential direction, while taken crosswise the tread the metal in one test fractured at a seam without appreciable elongation A supplementary crosswise test piece showed an elongation of 0 8 per cent The results of the chemical analysis and tension tests next follow

*Metal of steel tire of wheel with fused cast iron center*

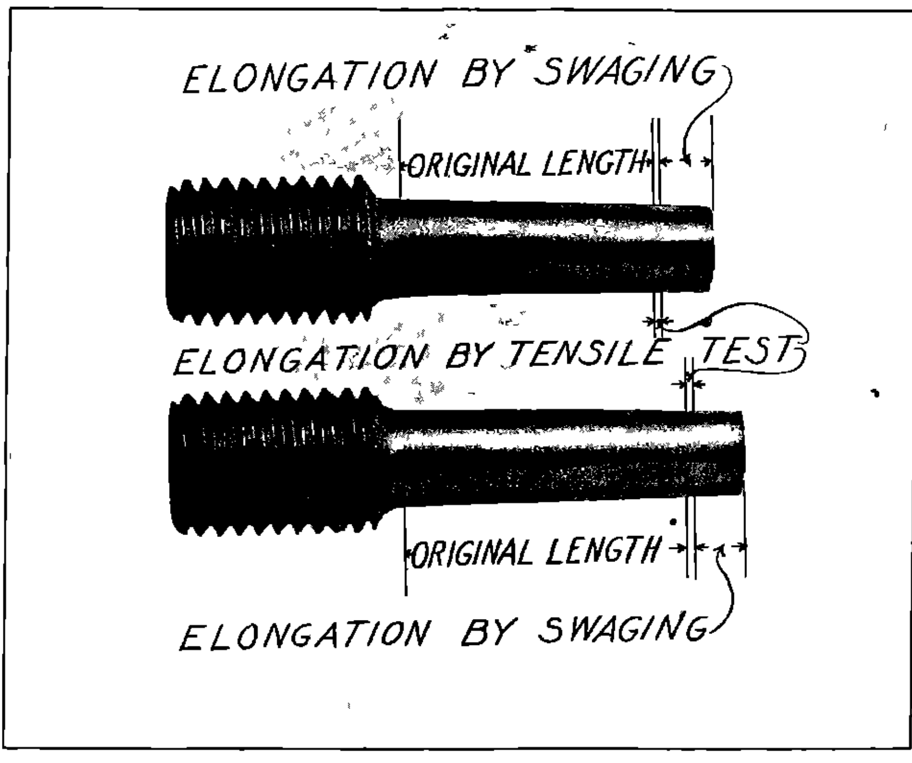
CHEMICAL ANALYSIS

| | |
|---|---|
| Carbon | 0 69 |
| Manganese | 58 |
| Silicon | 32 |
| Sulphur | 031 |
| Phosphorus | 03 |

TENSILE TESTS

| Direction tested | Diameter | Sectional area | Elastic limit per square inch | Tensile strength per square inch | Elongation | Contraction of area | Appearance of fracture |
|---|---|---|---|---|---|---|---|
| | | | *Pounds* | *Pounds* | *Per cent* | *Per cent* | |
| Tangential | 0 505 | 0 20 | 52 150 | 96 800 | 2 3 | 3 5 | Granular |
| Supplementary crosswise specimen | 356 | 10 | | 97 740 | 8 | | Do |

The display of a limited amount of extension or its entire absence in tensile test piece does not necessarily signify that the steel is devoid of the ability to flow under wheel pressures There is a distinction to be made between the elongation which steel is capable of developing when extended by its own tensile strength and its malleability or the elongation which it may display under cold rolling pressures or by swaging When deformed by an independent force steel admits of greater extension than witnessed in the tensile test The fractured ends of the tangential test piece, which developed 2 3 per cent elonga-




No 14 —Fractured ends of tangential test piece This specimen displayed 2 3 per cent extension in the tension test Fractured ends subsequently cold swaged an additional extension of 16 per cent the metal still remaining intact tangentially tion, were swaged cold, and each given 16 per cent additional stretch The swaging was discontinued when interior shearing fractures were developed, the metal still remaining intact as regards longitudinal extension

Figure No 14 shows the fractured ends of the tangential test piece after swaging Lines are sketched across the stems indicating the amount of extension which was displayed in the tension test and the additional extension which was subsequently given the steel by the operation of swaging, representing its malleability

Across the line of a streak or seam the malleability of the steel is impaired, whence it follows that split treads of steel tires necessarily result when in the lateral deformation of the metal interior defects of this kind are encountered Split heads in rails are formed in a similar manner The elimination of streaked or seamy metal is a matter of the highest importance to attain in steel that is used in situations in which there is exposure to overstrains normal to the direction of the seams

Referring to the fracture of the built-up wheel which led to the derailment of train No 5, and in summation of the results of this inquiry, it appears—

That this wheel and others of this type do not show unity of action in the component parts under service conditions as manifested in the evidence of movement between the tires and the plates, which in some cases pertained also to the relations between the plates and the spiders of the hubs

That incipient cracks are developed in the tires separating the metal between the bolt holes and the interior diameter of the web

That complete fractures of tires very frequently extend across the bolt holes, having their origins at the inner diameter of the webs or at the sides of the bolt holes, thence extending radially outward through the tread and flange

That service conditions induce the formation of incipient cracks on one side of the bolt holes, and lead to their extension on the opposite side of the bolt holes, culminating in the complete fracture of the tire

That the presence of incipient cracks does not admit of detection, without partially dismantling the wheel and giving access to the interior web of the tire or to the sides of the bolt holes

That looseness of the tires under the wheel loads takes place, but does not admit of detection by hammer test or by external inspection of the wheels in the truck

That internal strains are introduced in the metal of the tires by reason of the cold-rolling effect of the wheels on the rails, and that the combined strains from wheel loads and internal strains require to be considered in judging of the ultimate effects of repeated loads in promoting rupture

## SUMMARY

The results of the investigation of this accident and the study of other wheels similar in type and construction to the wheel that failed in this instance, as set forth in Mr Howard's report, call into question the strength and durability of wheels of this type for modern railroad service

In this instance a tire broke in a wheel which had not been subject to loads as high as are frequently experienced in certain other branches of railway service The loads carried by this wheel in fact are regarded as moderate loads for general equipment, since they ranged from 9,375 pounds to 11,250 pounds The investigation revealed the presence of incipient cracks in a considerable number of wheels of this type Out of 20 wheels examined, one-half were found to have incipient cracks in the interior web of the tire, 56 incipient cracks and 19 fully developed fractures were discovered It is true that these wheels had been removed from service for cause, but the presence of these incipient cracks was not among the causes which led to their removal

That wheels run for a length of time with incipient cracks in the tires is probable, and, obviously, cracks that have started in one part of a tire are liable to extend and cause the complete failure of the wheel Those wheels which were removed from service, containing the 75 fractures, undoubtedly had such cracks in them for a time prior to their removal

A sufficient number of wheels were included in this investigation to establish the general development of incipient cracks in this type of wheel, although the period of their formation is unknown

The stresses to which the wheels are exposed do not admit of direct measurement, since the parts which are failing are inaccessible, but the development of incipient cracks in the thin sections between the bolt holes and the interior diameter of the web is taken to be evidence that disruptive strains are there found The introduction of internal strains of magnitude in the metal of the tires immediately below the surface of the treads was found to be a common result of service conditions All tires examined were so affected The same results appear in this investigation in respect to the influence of cold rolling in the case of tires, as have been found in the case of rails These two parts react upon each other and whatever has an influence upon one must affect the other Conditions which attend the failure of rails have their counterpart in the case of tires

In the light of this examination the details and design of this type of wheel seem inadequate for the wheel loads which are commonly used in passenger service The wear at the edges of the plates, the grooving of the tires at the plate seats, and the wear and shoulders formed on the inner faces of the plates all go to show a state of insufficient strength to meet present requirements

There is but little strength in the thin sections in which the incipient cracks made their appearance, and it was noted that the drilling of the holes was made in such a manner that the sections were not of uniform thickness, further, that the thinner sections in the majority of cases were those in which incipient fractures were discovered A state of uncertainty nevertheless exists which is brought out in this investigation and further data are required to remove the doubts which have arisen in respect to the present condition of wheels of this kind which are now doing service

In the derailed train there were 18 wheels of the type which fractured In the ordinary course of maintenance, wheels are removed, sent to the shop to be trued up, and are returned to service under different cars than those from which originally taken It therefore follows that a mixed lot of wheels may be found under a given car In the present instance there were four makes of wheels in the same train and three kinds in the trucks of the car which had the broken wheel

If the wheels of this type are in a state of uncertainty as to strength, as inferred to be the case according to this investigation, then their distribution under different cars complicates the matter, for their presence may occur under any equipment and in any train, and incidentally they may be placed under high-speed trains quite as likely as under those of other classes

Under the most diligent inspection and thorough tests that can be made with the wheel in the truck, those with incipient cracks might appear sound The critical places in the construction of wheels of this type are obscured from view, and can be made visible and accessible only by the partial or complete dismantling of the wheel Inspection, however critical it may be, will not reveal incipient cracks which are hid by bolts and plates This feature of the case is a serious one, since there appears no way in which the condition of wheels when in service can be determined and those having incipient cracks in the tires discovered

It is clearly established that the usual inspection of wheels of this type in service is not adequate to discover these incipient cracks and that no inspection which can be made of the wheel in the truck can detect the presence of a defect such as led to the failure of the wheel in this instance It is understood that wheels of this type are not being used so extensively as formerly, although a very considerable number of them are in service at the present time To determine definitely whether or not wheels of this type now in use are in proper condition for service, the ordinary wheel inspection should be supplemented by inspection of the metal at the bolt holes as one of the methods of ascertaining the probability of approaching rupture

Respectfully submitted

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*Chief, Division of Safety*

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