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INTERSTATE COMMERCE COMMISSION

REPORT OF THE CHIEF OF THE BUREAU OF SAFETY IN RE INVESTIGATION OF AN ACCIDENT WHICH OCCURRED ON THE ATLANTA, BIRMINGHAM & ATLANTIC RAILWAY NEAR BEN HILL, GA, ON MARCH 12, 1922

October 7 1922

To the Commission

On March 12, 1922, there was a derailment of a passenger train on the Atlanta, Birmingham & Atlantic Railway near Ben Hill, Ga, which resulted in the death of 4 passengers and 3 employees off duty, and the injury of 16 passengers

LOCATION AND METHOD OF OPERATION

This accident occurred on that part of the Birmingham division extending between Manchester and Atlanta, Ga, a distance of 78 2 miles, which in the vicinity of the point of accident is a single-track line over which trains are operated by time-table and train orders, no block-signal system being in use The accident occurred about 2 miles east of Ben Hill, approaching this point from the west the track is tangent for a distance of about 2,300 feet The grade is descending for eastbound trains, varying from 0 6 to 1 per cent The track in this vicinity is laid with 80-pound rails, 33 feet in length with an average of 20 pine or oak ties to the rail-length, the roadbed is of clay, surfaced with slag ballast about 8 inches in depth Approximately 462 feet east of the first mark of derailment is a single-span steel plate-girder bridge spanning Camp Creek, 80 feet in length and about 40 feet in height Its supports consist of reinforced concrete abutments, with wings that slope gradually downward and outward The weather was clear at the time of the accident, which occurred at about 8 21 a m

DESCRIPTION

Eastbound passenger train No 2 consisted of 1 baggage car and 2 coaches, all of wooden construction, hauled by engine 124, and was in charge of Conductor Dixon and Engineman Bosworth This train left Bellwood at 7 59 a m, and after having proceeded about 13 miles the rear car was derailed on account of a broken wheel while traveling at an estimated speed of 30 miles an hour

The rear end of the derailed car slewed to the right at the bridge, overturning as it left the west abutment, and turned bottom up as it dropped, its momentum carrying it to the east bank of the creek It came to rest broken in two at about its center, with the front portion of the car resting against the east abutment, pointing almost straight upward, the car was completely demolished Figure No 1 shows the condition of this car after the accident, the view being taken from the west abutment of the bridge

SUMMARY OF EVIDENCE

At the summit of the descending grade, before reaching the point of derailment, train No 2 was traveling at a speed estimated to have been between 20 and 25 miles an hour, Engineman Bosworth shut off steam, but made no brake application, the train drifting at slightly increased speed until the engine reached the bridge, at which point Engineman Bosworth and Fireman Powell felt a severe jerk, and on looking back saw the rear car derailed The engineman immediately made an emergency application of the air brakes Conductor Dixon had just left the rear car when this sudden jerk occurred, immediately afterwards he saw the rear car rocking, but before he had time to reach the emergency air valve the air brakes were applied in emergency, the rear car breaking away at the bridge Flagman Greatorex was riding in the baggage car at the time of the accident None of these employees had noticed anything unusual prior to the accident and stated that the air brakes were working properly

The investigation made by these employees showed that the derailment of the car was due to a broken wheel, a fragment of this wheel was still warm when Conductor Dixon and Fireman Powell handled it about one and one-half and two hours, respectively, after the accident The statement of Chief Engineer Beal was that he arrived at the scene of the accident about two hours after its occurrence, and at that time the fragment of the wheel was still warm

An inspection disclosed that a sector comprising approximately one-third of its area was broken out of the right front wheel of the rear truck of the last car This allowed the opposite wheel to drop inside the north rail, the first mark of derailment being a flange mark on a tie on the north side of the track, 6 inches inside the gauge of the north rail, at a point 462 feet west of the west end of the bridge This mark paralleled the rail for a distance of 82 feet, then gradually extended diagonally toward the center of the track, after which it again paralleled the rail for a distance of about 70 feet, and then veered to the south at a gradual angle until the gauge side of the south rail was reached From this point the south rail was beveled until the pressure of the wheel increased sufficiently to push the rail out of line and turn it over, the wheels, however, continued on the ties, inside the rail location, onto the bridge The left rear wheel was derailed at a point 115 feet east of the first point of derailment, and marked the ties for a distance of 25 feet, at which point these marks joined the flange marks of the front wheel The first mark on the outside of the south rail was 33 feet east of the first mark opposite the north rail, the alternate battering of ties, followed by ties which were flange marked, indicating that the broken wheel continued to rotate for a distance of about 36 feet, after which the wheels were dragged the remainder of the distance, the truck came to rest parallel to and about 10 feet north of the rear end of the car on the east bank of the creek, as shown in Figure No 1

The testimony at the hearing upon this accident was to the effect that none of the brakes on the derailed car was sticking at any time on this or previous trips, nevertheless it was brought out at that time that the sector of the broken wheel was still warm when employees handled it as late as two hours after the accident occurred Subsequent examination indicated that all of the wheels of the rear truck of the derailed car were in a heated condition at the time of the accident, the brake shoes and wheel treads being blued on the bearing surfaces, with cracks of various lengths existing on them The wheel immediately behind the one which failed was found to have a crack in the plate 23 inches long It is also important to note that the speed of the train did not appear to materially increase while drifting down a 1 per cent grade, although no application of the air brakes was made This engine had 60-inch driving wheels, and the train consisted of three cars, on March 20, 1922, a test was made at this point with an engine of the same type, with 56-inch driving wheels and a four-car train It was found that the speed while drifting increased from 20 to 36 miles an hour, an increase of 16 miles an hour The statements of the air-brake inspection force were to the effect that the air brakes had been tested and were working properly before the train left the initial terminal

The wheel which broke was of chilled cast iron manufactured by the Southern Wheel Co , No 57293, and cast on October 18, 1920, it weighed 701 pounds, and was applied to this coach on January 13, 1921, since which time it had traveled approximately 36,923 miles The broken sector measured $6\frac{3}{8}$ inches at the hub and 45 inches at the tread, there was a flat spot at one of the two points of rupture on the tread measuring $1\frac{2}{16}$ inches in diameter

This accident was caused by a broken wheel, apparently due to the air brakes sticking An investigation into the reason for the failure of this wheel was conducted by Mr. James E. Howard, engineer-physicist, whose report immediately follows.

REPORT OF THE ENGINEER-PHYSICIST

The derailment of the rear car of train No. 2, first-class coach No. 501, obviously resulted from the rupture of the forward right-hand wheel of the rear truck of that car. This car remained on the roadbed, in part derailed, but overturned when the bridge spanning Camp Creek was reached. The forward end of the car struck the farther abutment. The rear end, in falling, struck the bed of the creek and broke the car in two, the fatalities occurring in the rear portion of the car. The circumstances attending the derailment and subsequent investigation of conditions presented by the track, together with the examination of the fragments of the broken wheel, left no doubt as to the proximate cause of the accident, which attached to the wheel in question.

The broken wheel, a 33-inch chilled cast-iron wheel, No. 57293, was made by the Southern Wheel Co., at their Birmingham works, October 18, 1920, weight 701 pounds, tape size 3, and came from the middle part of the annealing pit. Six other wheels under this car were made by the Southern Wheel Co., while one was made by the American Car & Foundry Co., Buffalo, N. Y. The date of manufacture of the latter was June 12, 1917, those made by the Southern Wheel Co. being cast in 1920 and 1921.

The wheels and trucks of car No. 501 were shipped to Atlanta, Ga., from the scene of the accident. They were examined in the Bellwood yard. They showed evidence of recent overheating, indicated by the blue-black surfaces of the rims. Similar indications were shown by the brake shoes—a more common occurrence, however, in brake shoes, since heating effects are confined to a much smaller volume of metal in the shoe than in the wheel. On the shoe the heating influence is continuous while braking conditions continue, whereas such influence is intermittent referring to any given portion of the running surface of the rim, unless perchance the wheel is slid, intense local heating then occurring between the tread of the wheel and the head of the rail. In general brake shoes are exposed to more intense and destructive thermal influences than the rims of wheels.

In the present case the brake shoes displayed thermal cracks, to which special importance does not necessarily attach since brake shoes commonly present such a condition. Such an early result is provided for in the manufacture of brake shoes which are fabricated with a strip of forged steel to retain the parts of the shoe in place after the formation of thermal cracks, and which promptly take place when the shoes are exposed to sudden variations in temperature While not regarded of peculiar importance in the present accident, nevertheless a consideration of the influences which act upon brake shoes and their effects, as witnessed in brake shoes themselves, directs attention to corresponding effects which take place in the metal of the treads of wheels Thermal effects represent sources of danger to the integrity of the metal against which no wheel, of whatever type it may be, is exempt

Internal strains induced by differences in temperature depend upon the ranges in such differences and upon the relative volumes of hot and cold metal which are in opposition, referring to differences in temperature in a wheel of one integral unit The greater the difference in temperature the greater will be the induced internal strains Again, the greater the volume of metal affected the greater will be the gross force required if exerted to restrain the effect of such thermal result Increase of weight of wheel may increase the gross force exerted on the one hand, or by presenting a greater volume of metal to absorb the heat, representing the mechanical equivalent of the work done, result in a lesser rise in temperature and therefore cause lesser internal strains in adjacent parts These are considerations which present themselves in the discussion of the causes of failure of wheels where thermal conditions are responsible factors They present themselves in connection with this derailment, concerning which there are insufficient data to formulate a direct and positive explanation of the failure of the wheel in the truck of car No 501

These remarks point to investigative work which will be necessary to establish a foundation upon which to base an entirely conclusive explanation of the manner of failure of this wheel and upon which extended cooperation of the Southern Wheel Co and the Association of Chilled Wheel Manufacturers, through their consulting engineer, Mr F K Vial, has been offered The present report will therefore be submitted as one descriptive of the conditions pertaining to this wheel without undertaking to describe the exact phases through which the metal of the wheel passed and which led to its ultimate rupture

The immediate examination of the wheels at the Bellwood yard showed the rims to have been recently heated to such a degree that oxide tints had been acquired on the running surfaces, that thermal cracks were present on the tread of one of the wheels of the leading axle of the forward truck, in the vicinity of a slight "comby spot" and at other parts of the tread, and that a circular crack had been found on the American Car & Foundry wheel on the rear axle on the same side of the truck as the broken wheel, which extended for a distance of some 23 inches in the single plate, located in the vicinity of the junction of the outer and inner plates

The broken wheel showed two lines of rupture, each approximately radial, passing through the core leg openings of the inner plate and the chaplets of the outer plate Substantially one-third of the wheel was separated by the sector thus detached at the time of the accident It was also found that one of these radial lines of rupture separated the metal of the rim at a "slid-flat" spot This line of rupture was the leading one with reference to the rotation of the wheel when in the truck

This slid-flat spot may have been instrumental in causing the rupture of the wheel, and possibly was the immediate cause Information is not at hand whereby the time this slid-flat spot was formed can be ascertained, whether on the particular run on which the accident occurred or on some former occasion All the wheels of the rear truck, in fact, those of both trucks, are believed to have been heated above an ordinary braking temperature on this particular run of the train

When heated by frictional contact with the brake shoe the rim of the wheel necessarily becomes the hotter portion, and that part attains a state of internal compression, introducing radial tension in the plates as the necessary reaction to the hotter rim Such a state would at such a time militate against a line of rupture having its origin at the rim Commonly segments instead of sectors are detached in broken wheels, the extension of such lines of rupture as witnessed in the plate of the wheel made by the American Car & Foundry Co

The line of rupture separating the slid-flat spot, at the middle of its length, is suggestive, however, of the explanation that the initial point of rupture of the wheel occurred at this place, and, if so, necessarily at a time when the metal at this particular part of the rim was in a state of tension

Overheating the rim locally puts, for the time being, that part into a state of intense compression, into a state of overcompression, which subsequently reverses to one of tension when equalization of temperature in the wheel is reached It seems tenable to believe that this flat spot was formed during the run on which the accident occurred at a time when the wheel as a whole was abnormally hot, the result of some temporary arrest in its rotation, that is, a flat spot was formed on a wheel of which both the rim and the plate was above the normal temperature When rotation was resumed this slid-flat spot would promptly cool to the temperature of the adjacent parts of the rim, and in so doing reverse the internal strains to a state of tension, and thus furnish the opportunity to originate the line of rupture which was followed by complete failure of the wheel It seems a coincidence that this slid-flat spot chanced to be radially in line with the core leg opening and chaplet of the double plate

The brake shoe from the broken wheel showed abrasive wear, oblique in direction across its face, the abraded part covering only a portion of the usual contact surface Unusual conditions prevailed affecting this wheel some time during its period in service and not unlikely the major part occurred shortly before the time of its rupture

As thus conjecturally described, a condition would be introduced tending to cause a line of rupture to form at the tread, by reason of a state of tension being acquired at that surface, notwithstanding the wheel as a whole was in an overheated condition It will be borne in mind that a range in temperature of 340° F causes a dilatation in cast iron equal to a stress of 30,000 pounds per square inch with the modulus of elasticity taken at 15,000,000 At the high temperature of the slid-flat spot the tensile strength of the iron is dobtless much reduced Ordinary cast (gun) iron, which displays a tensile strength of not less than 30,000 pounds per square inch at atmospheric temperatures, has a tensile strength at 1,500° F of only 10,000 pounds per square inch Therefore a range in temperature much less than 340° F would be sufficient to strain the iron to its tensile limit, allowing a liberal modification in its coefficient of expansion and modulus of elasticity for elevation of temperature

Evidence is frequently presented in the treads of wheels of the formation of incipient cracks which were in evidence in the wheels of this derailed car Such a crack in the broken wheel penetrated to a depth of nine-sixteenths inch These cracks, hair lines in appearance, represent the relief of internal strains of tension by rupture of the metal and doubtless formed at a time when the surface of the tread was momentarily at a lower temperature than the metal of the interior of the rim Such a condition arises when the surface of the tread has been raised to a high temperature, and air cooled over the hot core or interior portion of the rim Photographs herewith illustrate thermal cracks of this kind which were found in the wheels under examination

Such cracks have been experimentally formed by heating the rim of a chilled iron wheel by means of a torch, raising the temperature to a red heat, and allowing the wheel to cool in the air The immediate effect of the heating was overcompression of the surface metal, straining the interior metal in tension Upon cooling, the surface strains were reversed, becoming strains of tension, and cracks were thus formed on the surface of the tread while under macroscopic observation

The fractured surfaces of cast iron do not afford the same ready means of showing the points of origin of fractures as those which steels commonly display. Other evidence must be sought to determine the points of origin of fractures in cast irons. A probable or possible cause of failure has been pointed out, as above, in the present wheel, one which would explain why the line of rupture was located separating the tread at a slid-flat spot. This explanation of the proximate cause of rupture will be held until more extended data are acquired upon the internal strains present in chilled iron wheels and information acquired, if attainable, upon the effects of repeated brake applications in which the rims are successively heated and cooled.

Earlier observations have been made upon the internal strains in the rim, plates, and hub of a chilled iron wheel in which internal strains of tension were found present in the plate with a high state of compression at the hub. So-called split hubs are said to have their origins in the plate, thence extending in each direction through the hub to the wheel fit, and through the rim to the running surface of the tread. Measured strains in the hub of one wheel amounted to some 20,000 pounds per square inch compression. Strains of tension somewhat irregular in magnitude were found in the plate, likewise those of compression varied in degree in different parts of the wheel.

Importance attaches to these internal thermal strains, since they may easily exceed in magnitude the direct strains caused by the axle loads. They may augment or diminish the strains due to axle loads according to position. A complete understanding of the wheel problem involves the consideration of these coacting forces, internal strains and external stresses, with numerical data upon the magnitude of each. Provided with such information a closer approach can be made in predicating the margin in strength which is in reserve in chilled iron wheels after they have been in service than can now be offered.

Certain customary tests were made with the different wheels which were under car No. 501. Attention is often directed to the force required to dismount wheels from their axles, and tests were made on this feature. The tons pressure required to remove the several wheels from their axles were as follows: Forward axle, right and left wheels, respectively, 90 tons and 135 tons; rear axle, forward truck, 87 and 90 tons; forward axle of rear truck, left wheel, 95 tons; rear axle, rear truck, 100 (wheel with cracked plate) and 120 tons, respectively. A thermal test, molten metal poured against the rim, was made with wheel No. 57287, made by the Southern Wheel Co., and cast October 18, 1920. It withstood this treatment 8 minutes 58 seconds before cracking.

Although a thermal test is frequently made, its relation to the endurance of the wheel under service conditions does not appear to have been definitely established, a comment in respect to specifications governing the acceptance of material which need not be restricted to chilled-iron wheels A wide gap exists between the information acquired in customary routine testing and knowledge of the behavior of the material when it reaches the track whereby a proper margin in strength and safety may be retained in the materials of both track and equipment Efforts are being made, however, to close this gap somewhat and establish more closely definite relations between physical properties and structural states and the endurance of materials under service conditions Such a problem necessarily involves a consideration of all the elementary factors which service conditions call into play

The present report is submitted as a tentative one based upon the general information at hand upon the properties of chilled-iron wheels, which is admittedly meager in relation to the state of internal strains the wheels are in when first put into service and that relating to the successive phases through which the different zones of chilled, mottled, and gray iron pass during their term of service, in which thermal strains and mechanical strains each are recognized factors In summation, evidence leads in the direction of attributing responsibility for the rupture of the present wheel to the local strains set up at the slid-flat spot on the tread Other explanations which might be advanced are more or less in opposition to each other, and consequently untenable

SUMMARY

A type of rupture not of common occurrence was witnessed in the failure of this chilled-iron wheel which was under derailed car No 501, from which a sector was detached by the formation of two radial lines of rupture The engineer-physicist points significantly to the presence of a slid-flat spot on the tread of the wheel, through which the leading line of rupture passed, and regards this slid-flat spot as the probable factor which caused the failure

This was comparatively a new wheel, the marks of the chiller not having been fully effaced Whatever deterioration there may be in wheels after a period of time in service, such could not be urged as a cause for the rupture of the present wheel When the rim of a wheel is heated to a higher temperature than the plate, rupture by tension at the rim is hindered, since the rim under such a condition is in a state of internal compression, a state the reverse of one permitting a tensile fracture and there are slid-flat spots in great numbers on wheels which are in service and which continue to endure the strains of service without rupture However, the engineer-physicist makes this distinction, that a slid-flat spot formed on a hot wheel presents a different set of conditions than experienced when a cold wheel is slid flat and which seems competent to cause rupture in a hot wheel, and advances this explanation as a tenable one in the present instance

Unquestionably tensile lines of rupture form on the treads of wheels, they are in abundant evidence They even have been formed in the shop experimentally, hence their manner of formation is known Thermal cracks in the present investigation were found to have penetrated to a depth of nine-sixteenths of an inch, and greater depths of penetration have been witnessed, showing that rims of wheels are at times in a state of tension of such degree that partial rupture ensues

The explanation that the wheel under car No 501 failed by reason of a thermal crack forming on its tread while in a heated condition, promptly precipitating total failure, seems in the light of present knowledge a reasonable one The report therefore is submitted with this explanation of the cause of the derailment as a tentative one, not involving inconsistencies which certain other explanations would introduce It is not sufficient to attribute failure merely to overheating, unless the phases through which rupture is reached are known to be reasonable and consistent The attributed cause is the only one which seems to involve no discordant details exhibited in the circumstances attending the accident

Respectfully,

W P BORLAND,
Chief Bureau of Safety

Note: This report [illegible] There were eight illustrations following the [illegible] of the report

FIG. 1.—General view of derailed coach lying bottom side up on bed of Camp Creek with forward end leaning against east abutment of bridge.

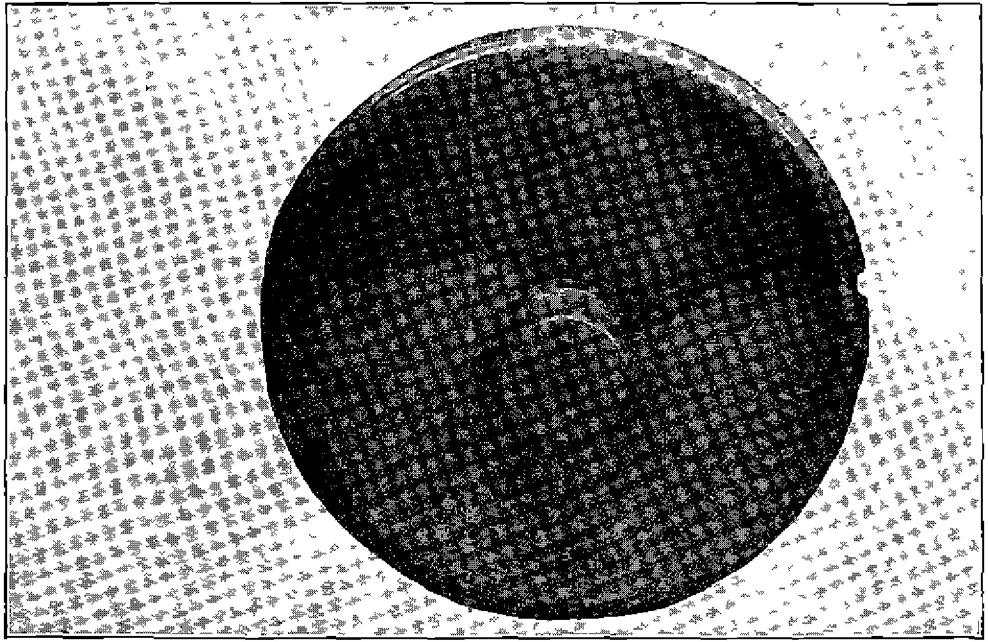

FIG. 2.—Front view of broken wheel No. 57293, showing radial lines of rupture passing through chaplets in front plate. Initial point of rupture believed to be at rim on right side of this cut.

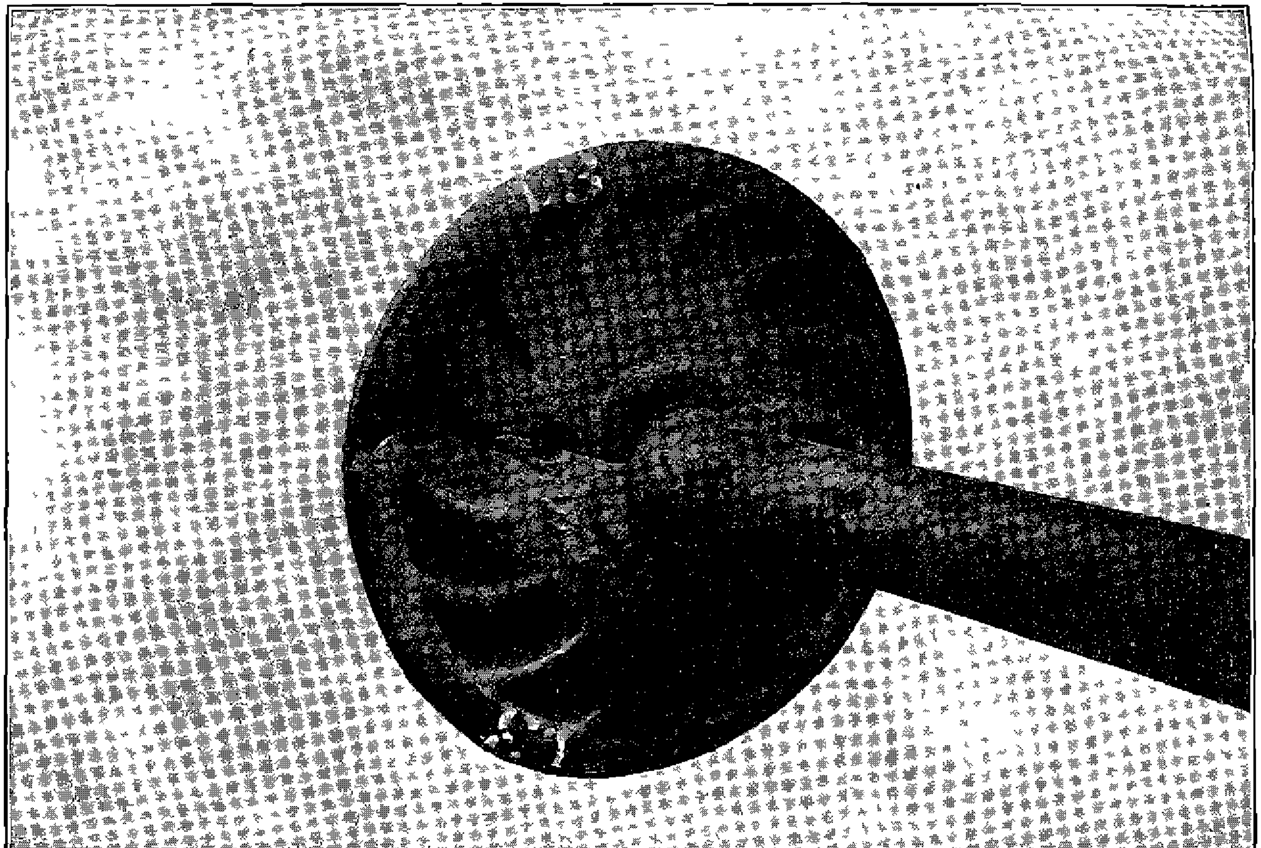

FIG 3—Rear view of broken wheel No 57293 showing radial lines of rupture passing through core leg openings of rear plate Initial point of rupture believed to be at rim on left side of this cut

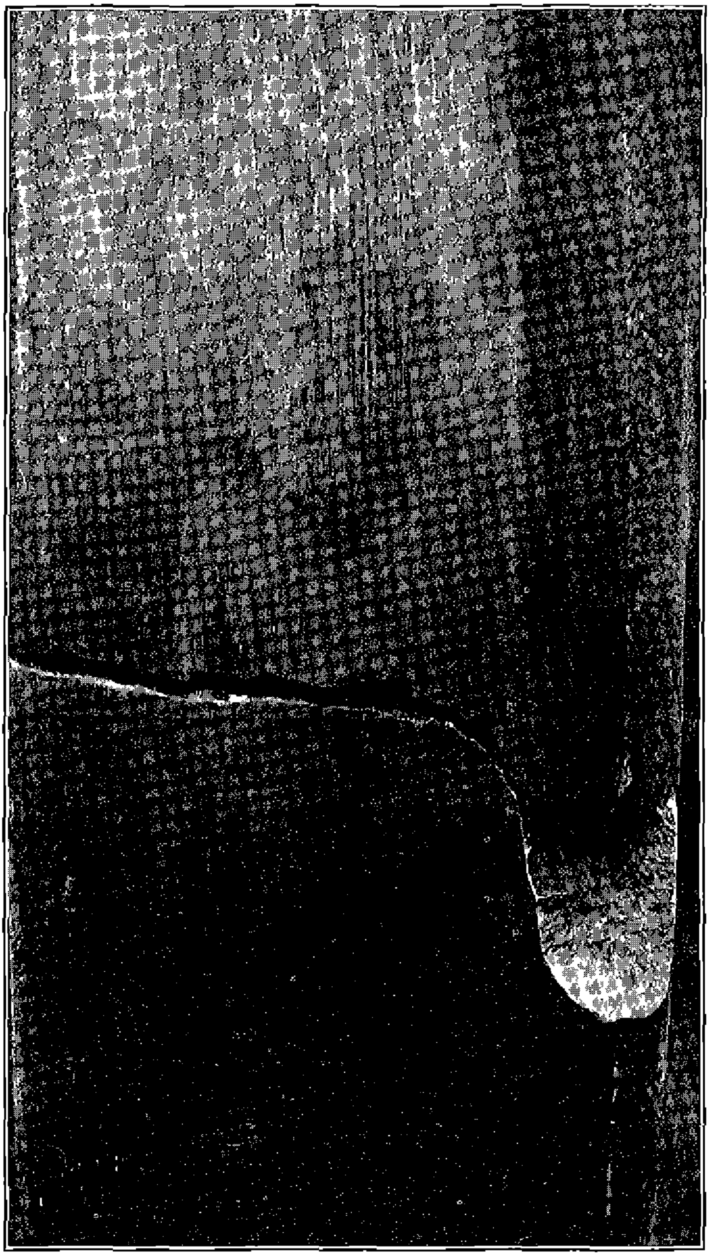

FIG. 4.—View of tread of broken wheel No. 57293, showing line of rupture located at a slid flat spot believed to be the initial point of rupture.

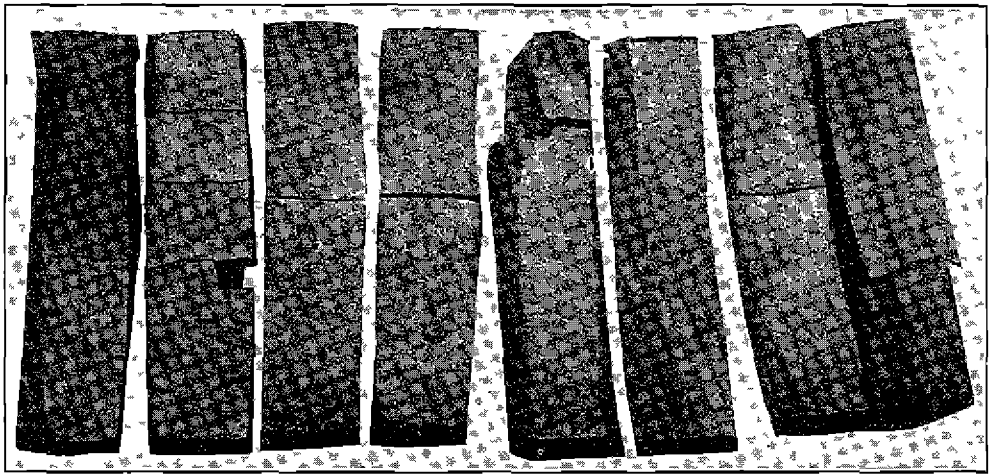

FIG. 5.—Appearance of brake shoes from wheels of derailed car No. 501

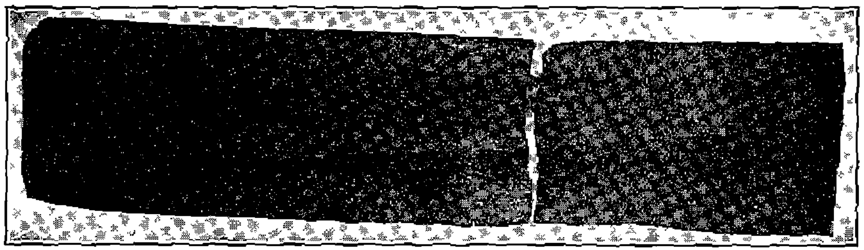

FIG 6—Appearance of brake shoe from broken wheel No 57293, showing obliquely abraded surface

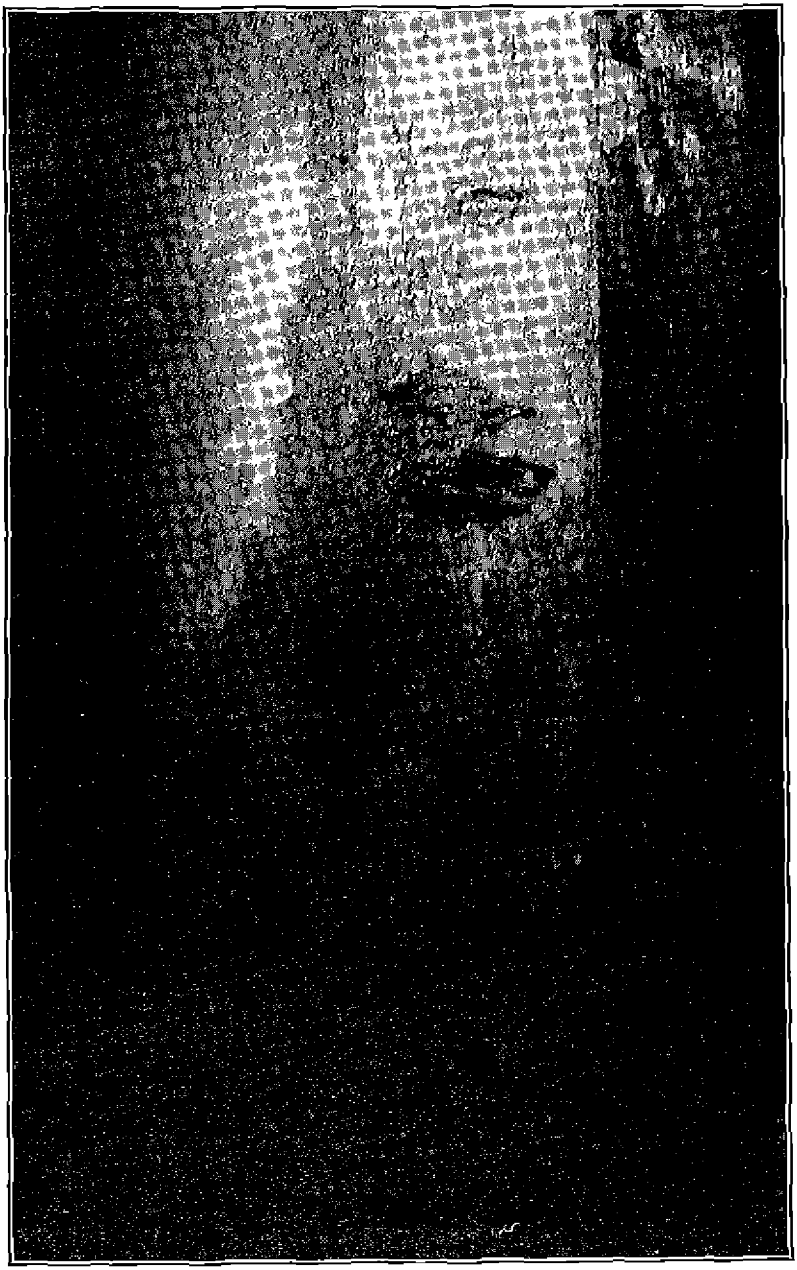

FIG. 7.—Thermal cracks in tread of wheel No. 37296, left hand wheel on forward axle of front truck, derailed car 501. Comby spot in vicinity of thermal cracks.

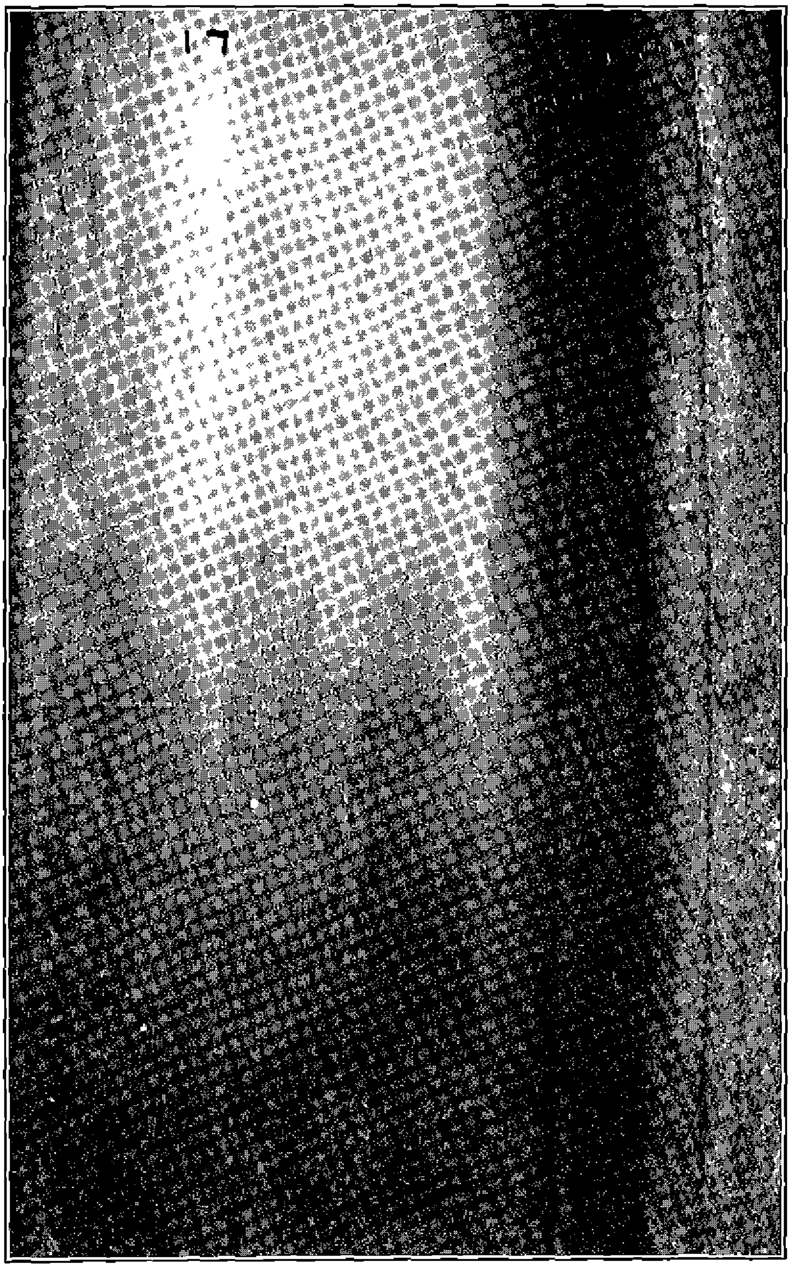

FIG. 8.—Thermal cracks in other part of tread of wheel No. 57296, shown in Fig. 7.

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