INTERSTATE COMMERCE COMMISSION

REPORT OF THE DIRECTOR OF THE BUREAU OF SAFETY IN RE INVESTIGATION OF AN ACCIDENT WHICH OCCURRED ON THE NASHVILLE, CHATTANOOGA AND ST LOUIS RAILWAY AT KENNESAW, GA, ON DECEMBER 22, 1923

February 27, 1924

To the Commission

On December 22, 1923, there was a derailment of a passenger train on the Nashville, Chattanooga & St Louis Railway at Kennesaw, Ga, resulting in the death of one employee, and the injury of one passenger and two employees

LOCATION AND METHOD OF OPERATION

This accident occurred on that part of the Atlanta Division extending between Junta and Atlanta, Ga, a distance of 47 66 miles, trains of the Louisville & Nashville Railroad also use this portion of the track In the vicinity of the point of accident this is a single-track line over which trains are operated by time-table, train orders, and a manual block-signal system The accident occurred just south of the station at Kennesaw Approaching this point from the north there is a short tangent, followed by a compound curve to the left 1,578 feet in length, with a curvature varying from 4° 09′ to 5° 08′, the accident occurring on this curve at a point 1,190 feet from its northern end, where the curvature is at its maximum The grade for southbound trains is ascending for about 6 miles, being 0 9 per cent at its maximum, to within 340 feet of the point of accident, from which point it is 0 28 per cent descending for a considerable distance beyond the point of accident The track in this vicinity is laid with 90-pound rails, 33 feet in length, with an average of 18 oak ties to the rail length, and ballasted with cinders, tie plates are used on curves The weather was cloudy at the time of the accident, which occurred at about 7 05 a m

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DESCRIPTION

Southbound passenger train No 91 consisted of one baggage car, two Pullman sleeping cars, one dining car and two Pullman sleeping cars, in the order named, hauled by engine 550, and was in charge of Conductor Hilley and Engineman Brown The cars were of all-steel construction with the exception of the fourth car, which had a steel underframe This train left Junta, 19 44 miles from Kennesaw, at 6 38 a m, eight minutes late, passed Kennesaw at 7 05 a m, two minutes late, and on reaching a point about 650 feet south of the station was derailed by a broken rail while traveling at a speed estimated to have been between 35 and 40 miles an hour

Engine 550, its tender, the first three cars, and the forward truck of the fourth car were derailed to the right, the engine coming to rest on its right side on an adjacent passing track, with its head end 306 feet from the initial point of derailment, the cars remained upright The employee killed was the engineman

SUMMARY OF EVIDENCE

The first knowledge members of the crew had of anything wrong was when the accident occurred Fireman Young stated he noticed nothing wrong with the riding qualities of the engine en route, and estimated the speed to have been 40 miles an hour at the time of the accident, also that the engineman applied the air brakes in emergency just after the engine became derailed Conductor Hilley estimated the speed to have been about 35 miles an hour at the time of the derailment, immediately after the accident he found a broken rail in the track, near the dining car

The rail which broke was on the west side of the track, this being the high rail of the curve, the break occurring at a point 11¾ inches from the leaving end, at the end of a splice bar The first 6 feet of the receiving end of this rail remained intact, but from this point to where the break occurred the rail was turned over There were no marks on the north end of the leaving portion of the rail, located immediately south of where the break occurred, to indicate that any wheels passed over it

Inspection of the track starting at the twenty-second rail joint north of the joint where the rail broke, the joints being staggered, showed the gauge to be standard or slightly wide, down to and including the fifth joint from the broken rail, from the fourth to the second joint, inclusive, it was one-eighth inch narrow, and at the joint immediately adjacent to the broken rail the gauge was one-sixteenth inch narrow The elevation of the outside rail on the curve varied from 3½ to 3¾ inches

Section Foreman Garrett passed over the track at the point of accident on his motor car in the afternoon of the day prior to the accident, and on foot with a level board on December 19, but noticed nothing unusual on either occasion He arrived at the scene of accident shortly after its occurrence and on examining the track found no marks on the ties north of the point where the rail broke He was of the opinion the accident was caused by a broken rail

Track Walker Flynn walked over this section of the track in the morning and also in the afternoon of the day prior to the accident but observed nothing unusual at the point of accident on either trip

Southbound passenger train No 3 passed this point less than one hour prior to the occurrence of the accident, and at that time the members of the crew in charge noticed nothing unusual, while examination of the equipment of that train, as well as of train No 91, made subsequent to the accident, failed to disclose any defect that could have contributed to the accident

This accident was caused by a broken rail An investigation into the reason for the failure of this rail was conducted by Mr James E Howard, engineer-physicist, whose report immediately follows

REPORT OF THE ENGINEER-PHYSICIST

The derailment of train No 91, at Kennesaw, Ga, on December 22, 1923, was due to a broken rail, the high rail of a curve The weight of the rail was 90 pounds per yard, section A R E A,–A, ingot letter C, heat number 47962, rolled by the Tennessee Coal, Iron and Railroad Company, in 1920

The rail fractured at a distance of 11¾ inches from the leaving end, in close proximity to the splice bars The long end was overturned outwardly, the flanges of the wheels traveling upon the web at the fillet under the head There were no battering effects from the wheels on the fractured surface of the short fragment

The fracture was one of tension having its origin at the lower corner of the head on the gauge side of the rail This circumstance indicated that a centrifugal force, or outward nosing of the engine was the immediate cause of the fracture, and since the derailed wheels passed through the opening in the track without striking the facing end of the short fragment that the train was not running at a high rate of speed

The fractured surfaces showed no defect in the steel, nor was it a fracture of a progressive type Rupture began at the lower corner of the flange-worn side of the head where the metal had been embrittled by the action of the flanges of the wheels

The longer fragment of the rail was sent to the shops of the N , C & St L Ry , at Nashville, Tenn , where bending tests were made upon it The rail was placed upon supports 36 inches apart and loaded at the middle, in three positions First, sidewise, with the outside of the head in tension In this position it showed ample toughtness of the metal, taking a deflection set of 4 inches on a chord of 36 inches, without fracture

The second test was made also in sidewise direction but with the gauge side of the head in tension In this position the rail fractured in a brittle manner without the display of measurable ductility The origin of rupture was at the lower corner of the head, gauge side It was in the same part of the rail as the original fracture made at the time of the derailment

The third test was made with the running surface of the head on the tension side Brittleness was displayed in this fracture The origin was at the lower corner of the head, gauge side, as before A portion of the fractured surface located next the running surface of the head, having a depth about one-sixteenth of an inch, showed an oblique shearing fracture This is a common feature in the fracture of rails which have been in the track and exposed to the cold rolling effects of wheel pressures Early illustrations of this kind are matters of record

A fourth test was undertaken with the rail in upright position applying the load on the top of the head, the base being in tension Injury occurred to the bending press and this test was discontinued without rupture of the rail

Chemical analyses of the steel, in two places, at the corner of the head and at the junction of the head and web, gave the following results

	C	Mn	P	S	Si
Corner of head	66	74	024	048	135
Junction of web	68	75	028	059	135

Macroscopic and microscopic examination was made of the rail on a section taken from the leaving end, from the immediate vicinity of the fractured surface Figure 1 shows the appearance of the fractured surface at the leaving end The incipient point of rupture was at the lower corner of the head on the gauge side, at the place marked by a star on the cut From this initial point the plane of rupture extended across the head, thence downward through the web and the base, ending at the edges of the flanges An oblique shearing fracture, as previously mentioned, was displayed by the metal adjacent to the running surface, representing the cold rolling effects of the wheel pressures

The fractured surface of the leaving end was battered in a few places, all of which were secondary effects. The flanges of the wheels bruised the metal at the fillet under the head after the rail was overturned. The radiant, fan like, appearance of the fractured surface indicated its point of origin. In the fracture of steel the plane of rupture has its origin and extends from the center of radiation. This simple and reliable method of judging of the incipient point of rupture should be familiar to all. Its observance would obviate many erroneous conjectures concerning the cause of rail failures. In the present instance the cause of fracture had erroneously been attributed to flaws and defects in the steel where none existed, in three different places none of which had a relation to the incipient point of rupture.

Figure 2 represents a sulphur print of the cross section of the rail, near the fractured end. The uniformity of the metal is almost phenomenal. No adverse criticism attaches to the rail respecting its composition or structure.

Flange wear was shown incident to its position as a high rail on a curve but not of unusual amount. All parts of the periphery of the head, exposed to contact with the treads and flanges of wheels are modified in structure, strength, and ductility. Different effects, however, are experienced at different parts of the running surface. At the outer part of the head the metal is crowded outward, laterally. Median metal is flattened. Lateral flow occurs on the gauge side half of the head, arrested somewhat by the fillets of the wheels. The flanges of the wheels cause flow and shearing of the metal down the gauge side.

A profound disturbance of the metal in the top of the head of the rail results from the action of the wheels. It is important that this fact be recognized, since it constitutes the crux of the rail problem. The manner of failure of rails leads to this conclusion.

Photomicrograph, Figure 3, shows the distorted shape of the grain of the metal at the lower corner of the head, gauge side, at the place indicated by the star on Figure 1. The original toughness of the steel was destroyed by the action of the flanges of the wheels. The brittleness displayed by the rail at the time of derailment, as well as the subsequent tests, testify to this feature.

Photomicrograph, Figure 4, represents the metal on the gauge side of the head, at mid-depth. The metal in this vicinity was sheared off by the wheel flanges, with slight disturbance below the abraded surface.

Photomicrograph, Figure 5, shows the flattened structure and downward flow of the metal at the upper corner of the head, gauge side The normal structure of the metal, in unaffected parts of the cross section, is shown by Figure 6 Each of these photomicrographs represent transverse sections at a magnification of 100 diameters

Since the origin of rupture was on the gauge side of the head it signifies that that part of the rail was exposed to a strain of tension at the time of rupture The gauge side of the head is not ordinarily put into a high state of tension Under vertical loads it is in compression The presence of a horizontal force is needed to account for such a rupture as witnessed on this occasion The nosing of engines causes strains of this kind and furnishes the most plausible explanation of the fracture, the section of the rail in front of the engine being the part put into a state of tension

On tangent track irregularities in alignment have been responsible for fractures of this kind The embrittled state of the surface metal and the relatively small section modulus of the rail in lateral direction, each facilitate rupture in a sidewise direction Excess speed was not a factor in this case

The behavior of the derailed engine on this run was satisfactory It had traversed a considerable part of the curve without any untoward circumstance when the derailment took place By the process of elimination responsibility for the fracture of the rail appears to attach to track conditions in that particular locality which would lead to severe nosing of the engine It satisfies all that is known about the derailment to assume that an unusual outward thrust was exerted upon the rail by the engine as the leaving end was being approached Lateral reenforcement was given the rail by the splice bars at its leaving end

Considering the part of the rail embraced by the splice bars as a fixed end and the receiving end of the rail as the long arm of a lever, then the application of a sufficient outward thrust on the long arm would rupture the rail It is believed the present rail was ruptured in substantially the manner just described

The behavior of another rail will be described, which also ruptured by reason of a state of hardness and brittleness acquired from the action of the wheels, wheel burning, in fact, appearing as the chief factor

Figure 7 illustrates the fractured surface of this rail, a rail of 100 pounds weight per yard, which displayed head checks in service Head checks were numerous on the rail—embryonic, and those of advanced stage of development They appeared on the running surface, gauge side of the head The head check here illustrated was one inch long by five-sixteenths inch deep

A series of photomicrographs shows the appearance of the metal next the running surface of the head These photomicrographs, all of 100 diameters magnification, show the hardening of the metal at the immediate surface, with flattening of the grains of the steel in adjacent parts of the cross section and normal structure below the affected metal

Photomicrograph, Figure 8, shows the appearance of the metal at the running surface near the outside corner of the head There was a hardened layer of surface metal with flattened grains next below, showing an outward flow of the metal, that is, toward the outside edge of the head

Figure 9 shows more of the metal with flattened grains, located next below the zone illustrated by Figure 8 The dip of the flattened grains toward the outside edge of the head is conspicuously shown The normal structure of the steel is shown by Figure 10

A rearrangement of the structural state of the metal is accomplished by annealing Figure 11 shows the modified structure after annealing at 1,475° F , its appearance before annealing being shown by Figure 9

Along a median zone the structural condition of the metal is less changed by the wheel pressures Figure 12 shows the metal at the running surface at the middle of the width of the head There was slight hardening of the metal at the surface with a shallow zone of flattened grains Figures 8 to 12, inclusive, represent transverse sections

Figure 13 shows a longitudinal section of the head at the running surface near the upper corner, gauge side Figure 14, also a longitudinal section, represents the metal next below Figure 13 Hardened and cracked surface metal is shown by these two cuts, with outlines of grain structure retained within the hardened zone and with a sharp line of demarcation between hardened metal and that of normal structure

Figures 15 and 16 are transverse sections and represent the metal at the running surface near the upper corner of the head, gauge side They further illustrate the appearance of the hardened surface metal, converted from metal of normal structure

Each of these two rails show the destructive effects of wheel pressures In the first rail there was exhaustion of toughness unaccompanied by thermal effects In the second rail conditions of service involving thermal effects caused hardening of the metal Each showed affected zones of metal of distorted grain structure Track conditions were responsible for these structural changes It will be recognized that manufacturing conditions were not responsible for the fractures of these rails Fractures of these types occur in steel rails of good quality Immunity from these effects of track conditions is not attained through choice of grade of steel employed

In conclusion, the present derailment was caused by the fracture of a rail, the high rail of a curve The origin of fracture was at the lower corner of the head, on the gauge side At that place the metal was embrittled, the result of flange action of the wheels The rail showed moderate flange wear, common to high rails

It was a tension fracture, and since it occurred on the gauge side of the head it represented an outward thrust on the rail at one part of its length while another part was firmly held Occurring as it did abreast the ends of the splice bars, it is inferred that an outward thrust occurred at a short distance from the splice bars

The engine was derailed and apparently passed through the opening in the track made by the broken rail, and without injury to the facing end of the short fragment of the rail Judging from the known circumstances, it is believed that the outward thrust which caused the fracture came from the engine That nosing of the engine broke the rail Furthermore, since the engine had traversed a portion of the curve, that responsibility for its nosing at that particular place was due to a local condition of the track Speed was surely not a factor in the case

Embrittlement of the metal of the rail resulted from the action of the flanges of the wheels The composition of the steel and its structural state, where not affected by service conditions, was good

Fracture occurred, it is believed, a little in front of the engine due to its nosing and that track conditions were mainly responsible for the nosing

The examination of another rail is included in this report, in which wheel burning led to the development of head checks

SUMMARY

The investigation of this accident showed that a broken rail, the high rail of the curve, was responsible for the derailment The circumstances of the case also showed that high speed was not a factor An outward force of some kind was applied of sufficient degree to break the rail

Two principal features are brought out in the investigation made by the engineer-physicist, namely, a state of brittleness in the rail on the gauge side of the head, attributed to the flange action of the wheels, whereby there was loss in strength and ductility in the steel Furthermore, that while nosing of the engine was the proximate cause of rupture that local track conditions were responsible for the excessive nosing required to effect rupture

The metal of the rail was of good quality where not affected by wheel pressures The cause of fracture arrived at appears consistent with the known circumstances of the derailment, and appears the only tenable one which has been advanced

No unsatisfactory behavior of the engine was noticed on this run which would account for unusual nosing While the metal of the rail was embrittled, nevertheless a severe lateral thrust was needed to effect its rupture The condition of the engine and speed as factors being eliminated, local track conditions alone remain as the responsible cause for the derailment

Respectfully,

W P BORLAND,
Director, Bureau of Safety

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ILLUSTRATIONS

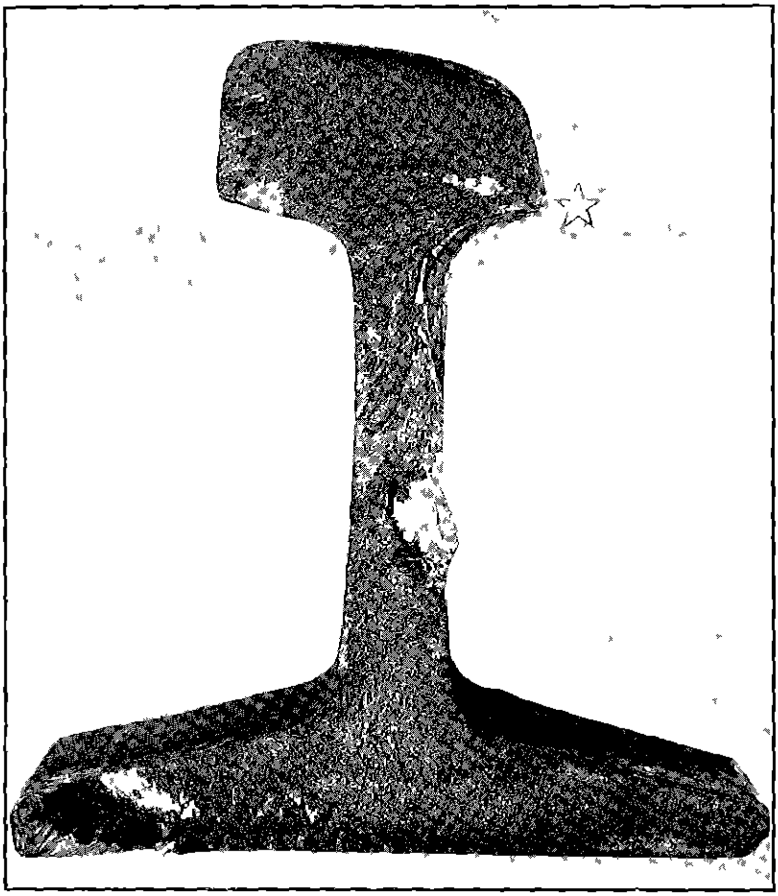

FIG. 1.—Fractured surface of leaving end of long fragment of rail. Origin of fracture at lower corner of the head gauge side at point indicated by a star.

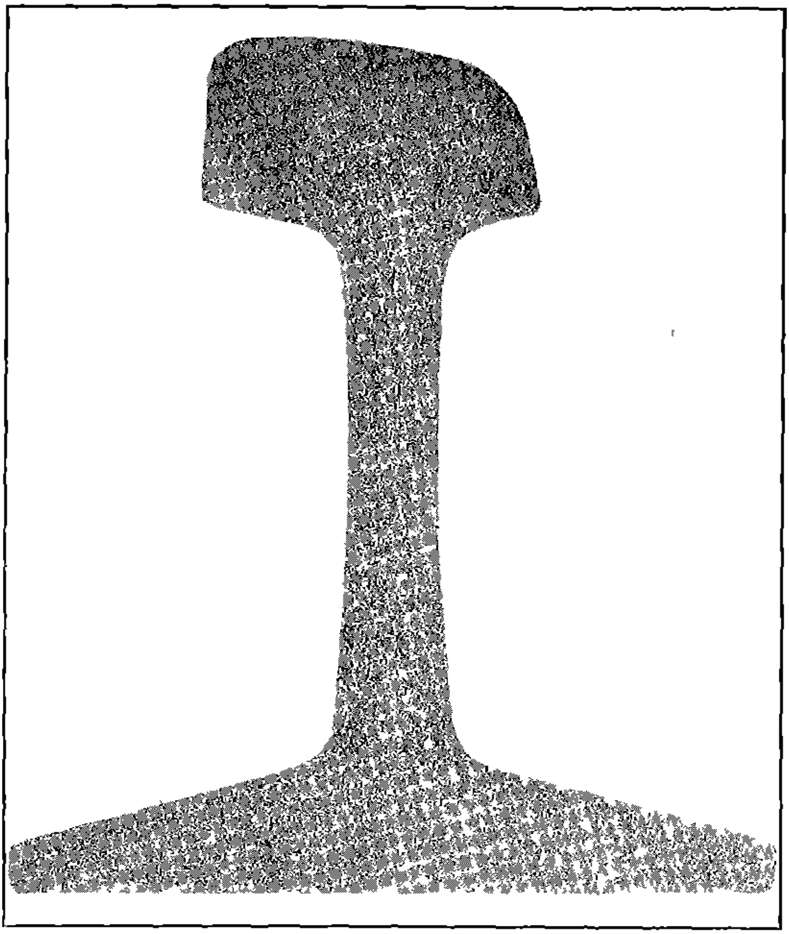

Fig. 2.—Represents a sulphur print of rail, near fractured end.

FIG. 3.—Photomicrograph of metal of rail at lower corner of the head on same element as origin of fracture. Showing flattening of the grains of the steel and flow of the metal. Transverse section, magnification 100 diameters.

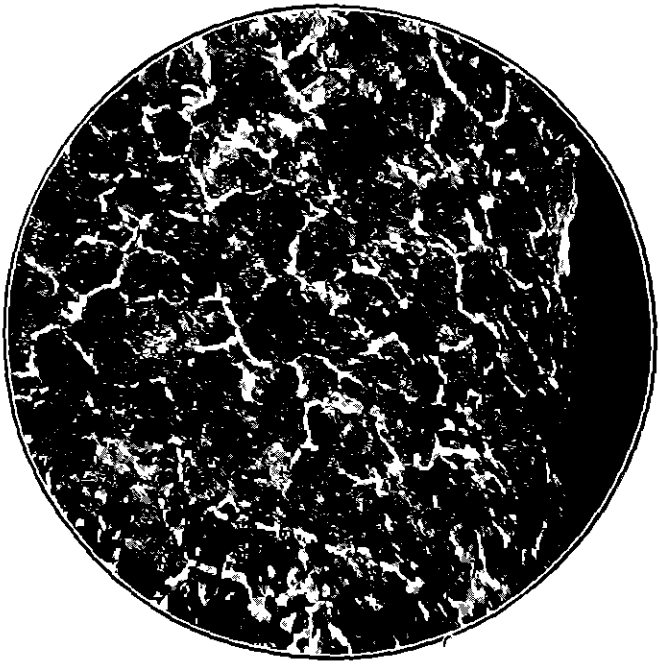

FIG 4.—Photomicrograph of metal, gauge side of head middepth Metal in this vicinity sheared off without distortion of metal below the sheared surface Transverse section Magnification 100 diameters

FIG 5 —Photomicrograph of metal upper corner of head gauge side Flattening of the grains and flow of metal at corner acted upon by the flange of the wheels Transverse section Magnification 100 diameters

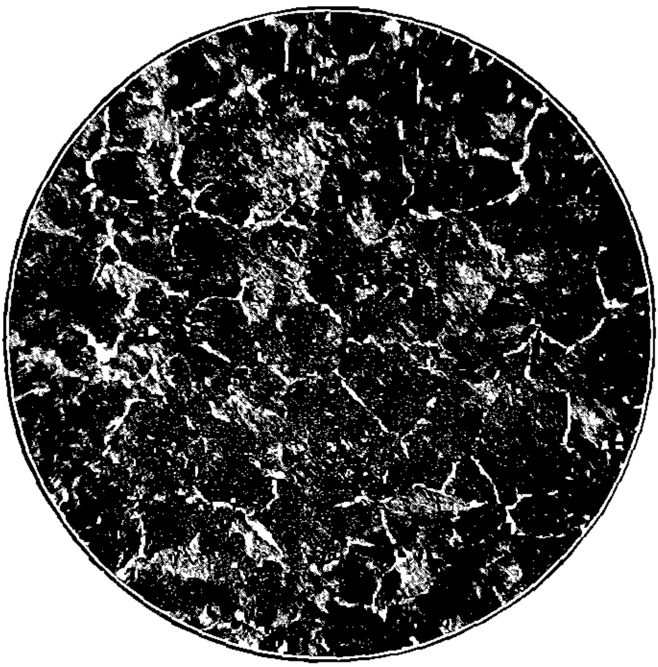

FIG. 6.—Photomicrograph showing normal structure of rail where not affected by wheel pressures. Transverse section. Magnification 100 diameters.

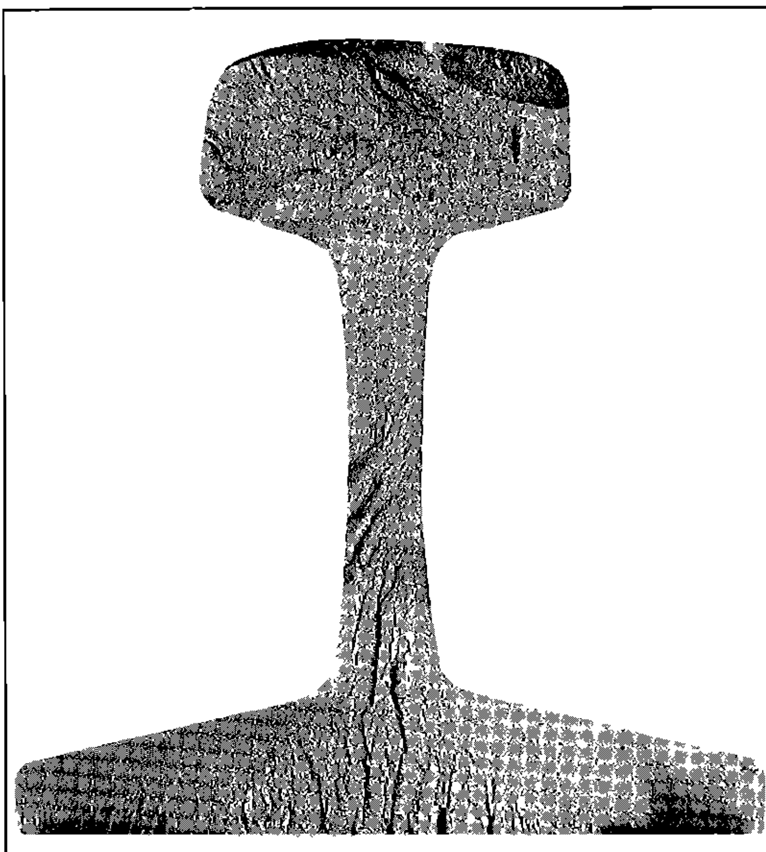

FIG 7.—Head checked rail Progressive fracture on gauge side of head, shown by darkened area Checked surface 1 inch long by five sixteenths inch deep

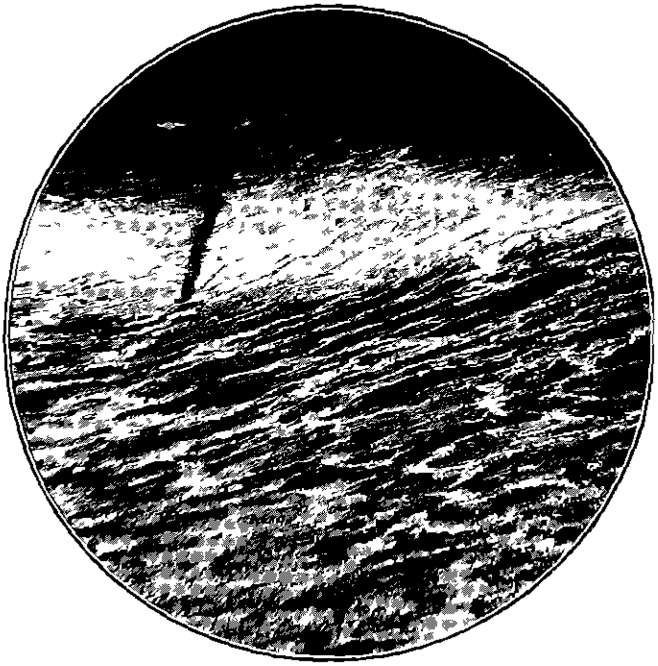

FIG. 8.—Head checked rail. Photomicrograph at running surface near outside corner of the head. Hardened surface with flattened grains below, flow of metal trending toward outside edge of head. Transverse section. Magnification 100 diameters.

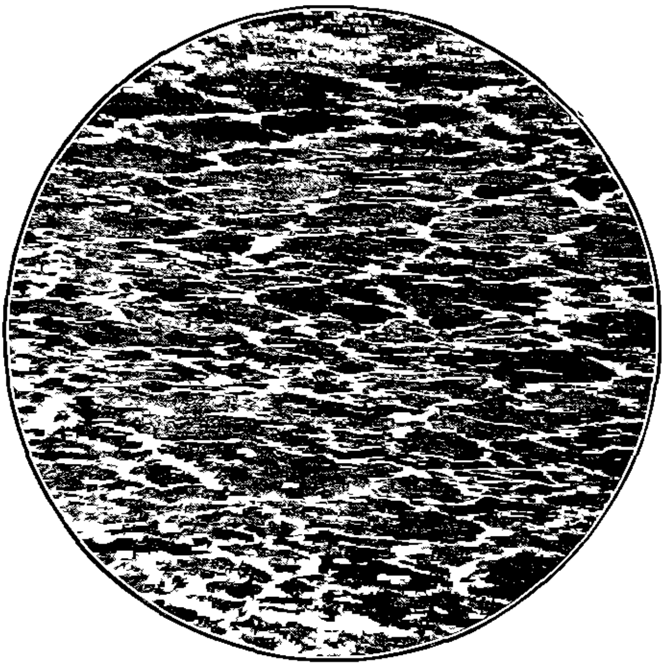

FIG. 9.—Head checked rail. Photomicrograph of metal next below that shown by Figure 8. Showing flattening of the grains and direction of flow outward. Transverse section. Magnification 100 diameters.

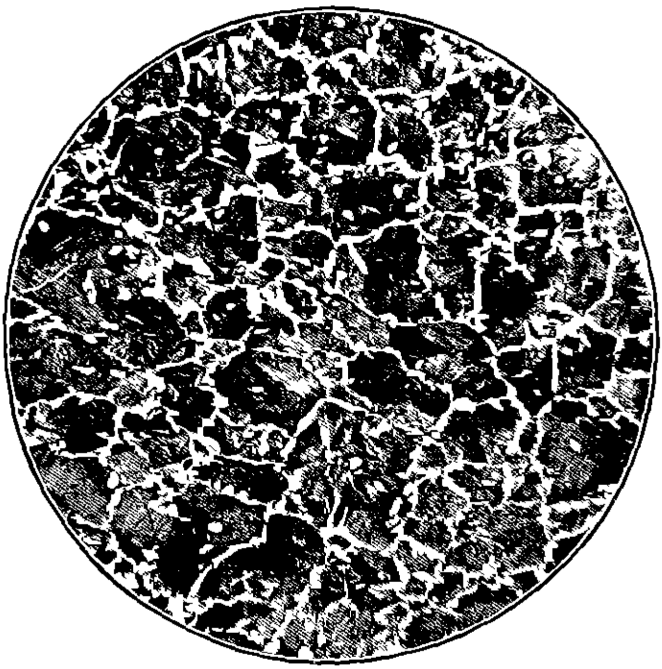

FIG. 10.—Head checked rail. Photomicrograph showing normal structure of the steel where not affected by wheel pressures. Transverse section. Magnification 100 diameters.

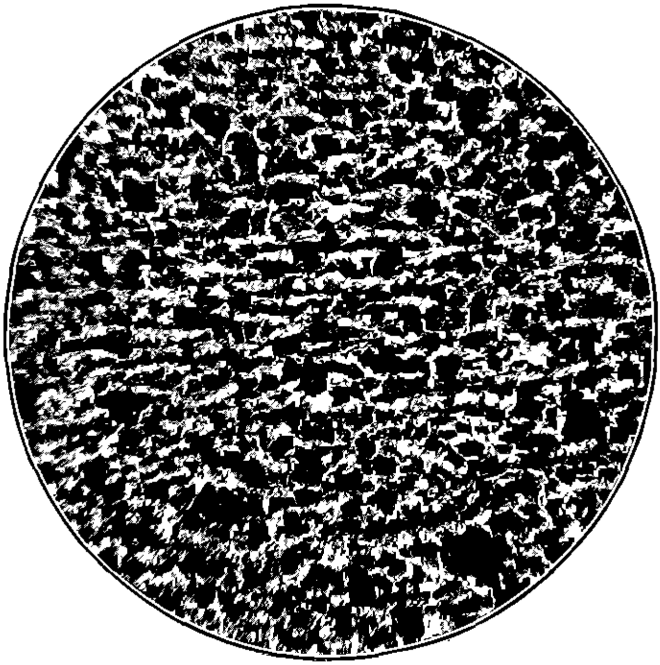

FIG. 11.—Head checked rail. Photomicrograph showing modified structure after annealing at 1,475° F. Appearance before annealing, shown by Figure 9. Transverse section. Magnification 100 diameters.

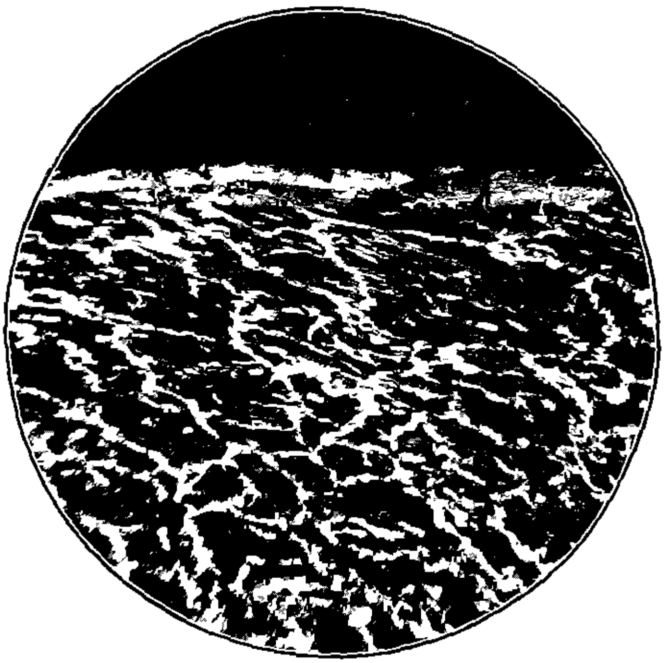

FIG. 12.—Head checked rail. Photomicrograph showing appearance of metal near middle of width of head at running surface. Slight hardening at surface and shallow zone of metal of flattened grains. Transverse section. Magnification 100 diameters.

FIG 13—Head checked rail Photomicrograph at running surface, near upper corner, gauge side of the head Hardened and cracked surface metal hardened metal next below with outlines of grain structure Longitudinal section Magnification 100 diameters

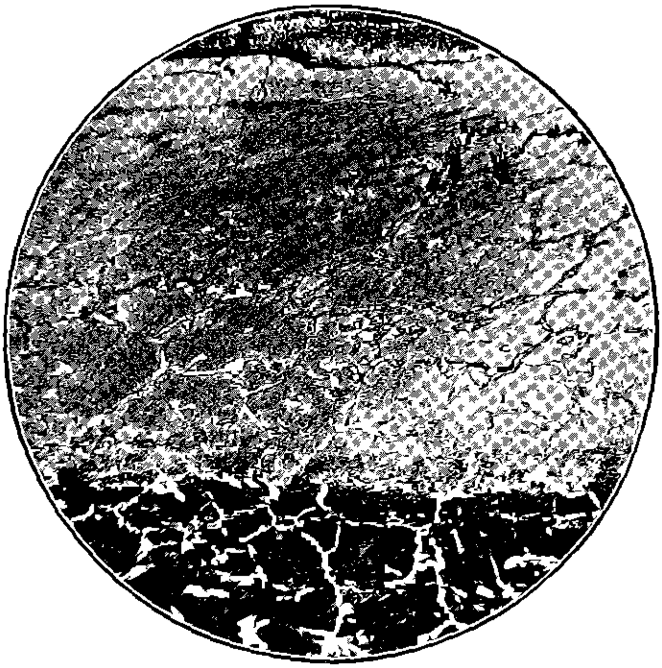

FIG 14.—Head checked rail Photomicrograph near running surface immediately below Figure 13 Hardened zone with metal of normal structure below Sharp line of demarkation of hardened metal Longitudinal section Magnification 100 diameters

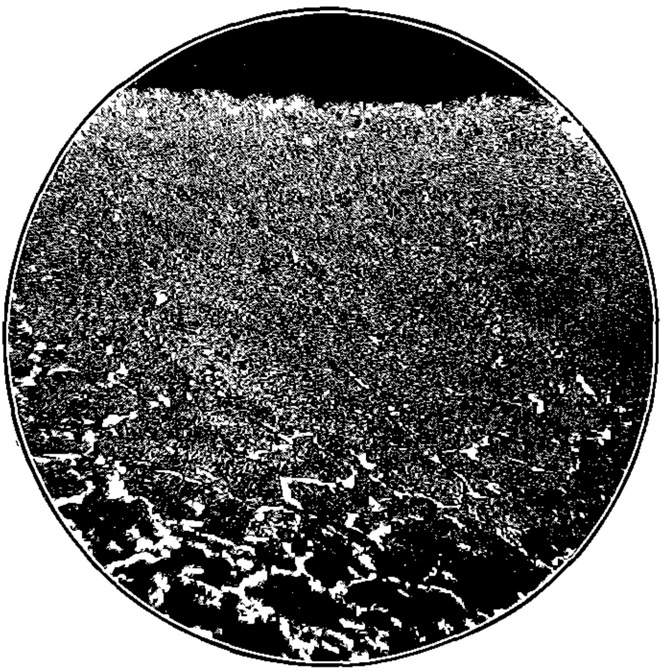

FIG. 13.—Head checked rail. Photomicrograph at running surface near upper corner gauge side of the head. Hardened surface metal. Traces of grain structure within hardened zone. Transverse section. Magnification 100 diameters.

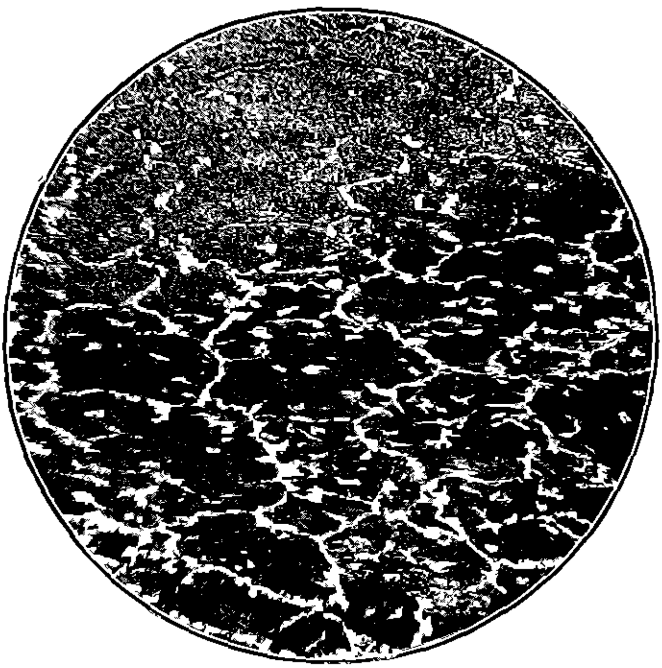

FIG. 16.—Head checked rail. Photomicrograph near running surface immediately below Figure 15. Hardened zone merging into metal of normal grain structure. Transverse section. Magnification 100 diameters.

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