INTERSTATE COMMERCE COMMISSION.

REPORT OF THE CHIEF OF THE BUREAU OF SAFETY COVERING THE INVESTIGATION OF AN ACCIDENT WHICH OCCURRED ON THE CENTRAL OF GEORGIA RAILWAY, NEAR JUNIPER, GA., ON OCTOBER 30, 1917.

MAY 2, 1918.

To the Commission

On October 30, 1917, there was a derailment of a passenger train on the Central of Georgia Railway near Juniper, Ga , which resulted in the injury of 33 passengers and 4 employees After investigation I beg to submit the following report

The Columbus district of the Southwestern Division, on which this accident occurred, is a single-track line extending between Columbus and Fort Valley, Ga , a distance of 72 miles, over which trains are operated by time-table and train orders, no block system being in use By time card rule passenger trains must not exceed 50 miles an hour

The track is laid with 80-pound steel rails, 33 feet in length, with 17 or 18 pine and cypress ties under each rail, ballasted with 12 or 15 inches of rough slag, and well maintained

Eastbound passenger train No 4 consisted of locomotive No 1609 1 combination mail, express, and baggage car, 2 coaches, and 1 Pullman sleeping car, in the order named, and was in charge of Conductor Harrington and Engineman Taylor It left Columbus at 10 52 p m , 42 minutes late, en route to Macon, and was derailed at about 11 35 p. m , at a point about 1 mile east of Juniper, or about 25 miles east of Columbus, while running at a speed estimated to have been about 40 miles an hour

The rear trucks of the tender and the combination car were derailed and ran along close to the rail for a distance of 528 feet. The three rear cars became detached from the remainder of the train, were torn from their trucks and rolled down the embankment to the left of the track, remained coupled together, and lay on their left sides. The forward end of the first coach was 294 feet east of point of derailment and 30 feet from the track, and the rear end of the sleeping car was 30 feet from point of derailment and 35 feet from the track.

On account of the cars being of all-steel construction they were not seriously damaged The track was torn up for a distance of about 200 feet, making it necessary to use 14 new rails and 150 new ties in making repairs Figure No 1 is a general view of the derailed train, looking east

Approaching the point of derailment from the west there is a 1° 45′ curve to the left, 1,000 feet in length, then a tangent about 4 miles in length, the derailment occurring a little over a mile from the west end of the tangent, on an 8-foot fill, and on an ascending grade of 0 85 per cent The weather at the time was clear

Engineman Taylor stated that his train left Columbus at about 10 55 p m , passed Juniper at a speed of about 30 miles an hour, and was proceeding at a speed of about 40 miles an hour when he felt the locomotive jolt as though it had struck something on the rail He immediately shut off steam, applied the air brakes, and upon going back found that the last three cars of his train were completely derailed and the rear trucks of the baggage car and tender were also derailed He said he examined the track and found a broken rail on the north side of the track, which in his opinion caused the derailment He said he had passed over this section of track on several occasions, the last time about 3 25 p m on the day of the accident, but noticed nothing wrong with it

Conductor Harrington stated that he had no warning prior to the derailment, and upon examining the track he found a broken rail on the north side of the track He thought the speed of his train at the time was about 40 miles an hour

Supervisor Watson stated that he was riding on train No 4 at the time it was derailed, examined the track after the accident, and found a broken rail He said the rail was laid in the track in 1905 and had remained there until it broke He stated that the foreman in charge of the section where the derailment occurred had 10 miles of track to maintain, assisted by six to nine section men, and he considered the track at that point in first-class condition

Investigation definitely developed the fact that a broken rail was the cause of the accident, and an investigation to discover the cause of its failure was conducted by Mr James E Howard, engineer-physicist

Acknowledgment is made of the cooperation of Mr A P Wells, engineer of tests, and other officials of the Central of Georgia Railway, Dr J R Harris, chief chemist of the Tennessee Coal, Iron & Railroad Co , Mr W R Shimer, metallurgist of the Bethlehem Steel Co , and Mr J T Wallis, general superintendent of motive power, Pennsylvania Railroad Co , in the investigation of this material

FIG 1 —General view of the derailment

REPORT OF THE ENGINEER-PHYSICIST

The rail which caused the derailment of train No 4 was an 80-pound rail, A S C E section, upon which there was no brand mark, but which from evidence acquired is believed to have been rolled about the year 1905 and placed in the track soon thereafter It was located on the north side of the track At the time of derailment it broke into a number of fragments, of which 15 were recovered There were nine principal fragments, the longest 9 feet 6¼ inches at the receiving end, the shortest a few inches long at an intermediate part of its length The derailed cars passed through the opening which was made in the track by the displacement of these fragments

The failure of the rail was due to the presence of transverse fissures, eight being displayed in the different fragments of the head The fissures were in different stages of development, ranging in size from one-eighth inch diameter to 1⅝ inches diameter They progressively increased in size from the easterly end to the westerly end of the rail Two of the fissures had enlarged from their interior nuclei and reached the side of the head on the gauge side of the rail The surfaces of these fissures were dark colored The other fissures had not reached the periphery of the rail and therefore presented bright surfaces, having a silvery luster, when exposed to view following the derailment All were located on the gauge side of the head or over the web

In the examination of the rail which followed, the several fragments were inspected noting the directions in which the lines of rupture traversed the rail, the location and size of each transverse fissure, photographing four of them, and sketching the places of the ties which were located in the vicinity of the transverse fissures Subsequently, the metal of each of three fragments was planed off on one side of the head, and the top of another fragment, in quest of additional fissures which had not been revealed at the time of the derailment There were none of sufficient size present to admit of being discovered by this somewhat cursory examination The internal strains were measured in sections taken from fragment No 1 from the receiving end of the rail, the results showing strains of compression next the running surface, and strains of tension in the interior of the head Strains in the flanges of the base were measured on sections of the rail over and between ties

Chemical analyses were made of the metal of the head, in close proximity to the largest and to the smallest transverse fissure Microscopic examinations were also made of the metal in the vicinity of and at the edge of one of the fissures, on both longitudinal and cross sections Photomicrographs were made of the metal which included those showing the distortion of the grain of the steel next the running surface of the head where it had been affected by the wheel pressures The general appearance of the rail, natural size, reduced for reproduction herein, was shown on a cross section which was polished and etched with tincture of iodine Tensile tests were made of the metal taken from the gauge side of the head, near the center of the head and on the outside, completing the examination

To these results some notes are appended upon the development of a number of shearing fractures witnessed in other rails, not involved in the present derailment Confusion has existed concerning the classification of transverse fissures, in differentiating them from certain other types of rupture which are at times associated with them The examples of shearing fractures presented herewith represent a class of fractures which accompany some transverse fissures, and at other times appear alone

Referring to the present rail, figure No 2 is a diagram of the rail viewed from the gauge side, showing the lines of rupture developed at the time of the derailment, the direction in which they traversed the rail, the places at which transverse fissures were displayed and their dimensions, also the location of ties which were adjacent to the transverse fissures

Photographs of the leaving ends of fragments Nos 1, 2, 3, and 4, showing the transverse fissures which were displayed on each, appear in figure No 3 These represent the largest two fissures, and two of intermediate size

Figure No 4 represents the cross section of the rail near the leaving end of fragment No 3, after having been polished and etched with tincture of iodine A group consisting of a large number of dark colored dots and short lines appears in the lower middle part of the head, which extend down the web into the base Markings of this kind appear on sections iodine etched and on sulphur prints, those on the present rail being somewhat less pronounced than frequently displayed by rails when inspected in this manner

The group of four photomicrographs shown on figure No 5 represent, in cross section, the structure of the rail in the vicinity of the transverse fissure which was developed at the leaving end of fragment No 3 Figure A of this group shows the distortion of the microstructure next the running surface of the head Lateral flow of the surface metal took place toward the gauge side Figure B represents the microstructure at the upper corner of the head on the gauge side of the rail The flattening of the structure here was very pronounced Figure C shows the structure at the periphery on the guage side of the head, near the lower corner, where no abrasive action nor contact with the wheels had taken place An undisturbed grain structure is here exhibited Figure D represents the microstructure at the middle and lower part of the head There was no

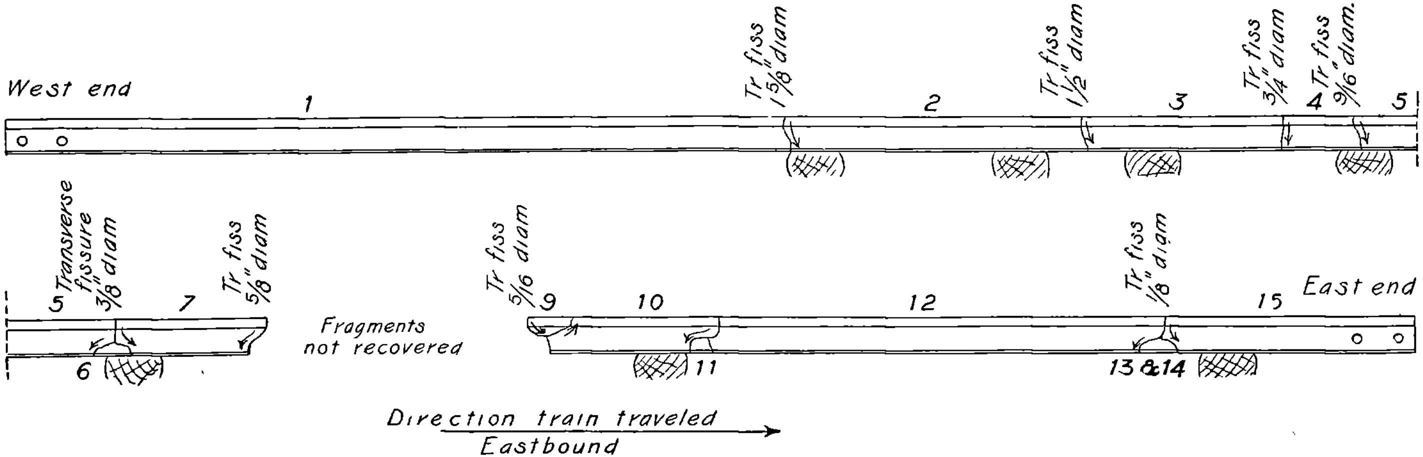


FIG 2 —Diagram of the fractured rail, showing lines of rupture, and directions in which they traversed the rail, indicated by arrows Eight transverse fissures displayed Positions of ties in the vicinity of the transvers fissures sketched in characteristic difference in the microstructure of the head in the vicinity of the nucleus of the transverse fissure and other parts of the middle of the head.

The microstructures shown on figure No. 6 represent the rail in vertical, longitudinal section, at the center of the head and at the edge of the transverse fissure which was on the leaving end of fragment No. 3. Figure E shows the structure at the center of the head; figure F, at the edge of the transverse fissure. The structure at the nucleus of the fissure and elsewhere in that vicinity was not unlike that of other parts of the interior of the head, in which respect the micrographs on both the longitudinal section and the cross section furnished identical results.

The results of measurements of the internal strains in the rail, on two sections taken from fragment No. 1, are shown on diagrams Nos. 7 and 8. The stresses corresponding to the internal strains in the metal next the running surface of the head and in the flanges are shown on figure No. 7. Two sets of values are given for the stresses in the strips from the head. These strips assumed curved shapes when detached, convex on the running surface. This behavior indicated that the internal strains were of different intensities at different depths of metal below the surface, varying within the limits of the depths of the strips. The higher values entered on the diagram are believed to more nearly represent the stresses as they existed in the intact rail than the lower ones. The former values are based upon chord measurements; the latter upon measurements taken upon the strips when forcibly held straight.

The internal strains in the head represent cooling strains of fabrication, augmented or superseded by the cold rolling strains from the wheels, acquired in the track. The internal strains due to the wheel pressures commonly exceed those of fabrication. The stresses in the flanges are chiefly the cooling strains of fabrication, which under ordinary conditions of service remain in the rail substantially unchanged. The cold rolling action of the wheels, however, is an important factor in modifying the primitive state of strain in the head of the rail.

The internal stresses in the interior of the head are shown on the diagram, figure No. 8. Those on the gauge side, and in that half of the head, were strains of tension, attaining a maximum of 6,300 pounds per square inch. This section of rail furnished a pronounced example of interior strains of tension reaching a maximum along those elements of the head in which so many of the nuclei of transverse fissures are located. The range of internal stresses in these two sections, which were located end to end in the rail, amount to 21,900 pounds per square inch, referring to the metal of the inside half of the head.

The relations between the internal stresses of compression next the running surface, and those of tension in the interior of the head, explain the cause of the interior origin of transverse fissures, as it has been stated in previous accident reports The line of contact between the tread of the wheel and the head of the rail is usually on the gauge side of the head This accounts for the greater number of transverse fissures being found on the gauge side or over the web, and less frequently in the outer half of the head

The internal strains in the flanges of the base of the present rail were measured on sections between ties and over them No substantial difference was found among the several determinations. The surface of the base was slightly worn where it rested upon the ties, but without distortion of shape The removal of metal by abrasion and wear does not result necessarily in the introduction of internal strains, but depends probably upon the intensity of the abrasive forces

Figure No 9 shows the appearance of some planer chips taken from the interior of the head of fragment No 3 A heavy cut and feed were taken in removing these blue chips for the purpose of showing the quality of the steel

The results of chemical analyses of the rail appear in table No 1. The analyses represent the metal from opposite ends of the rail, chips being taken from the head in the vicinity of the largest and the smallest transverse fissures respectively.

TABLE No 1 —*Chemical analyses of rail, gauge side of head, in vicinity of transverse fissures*

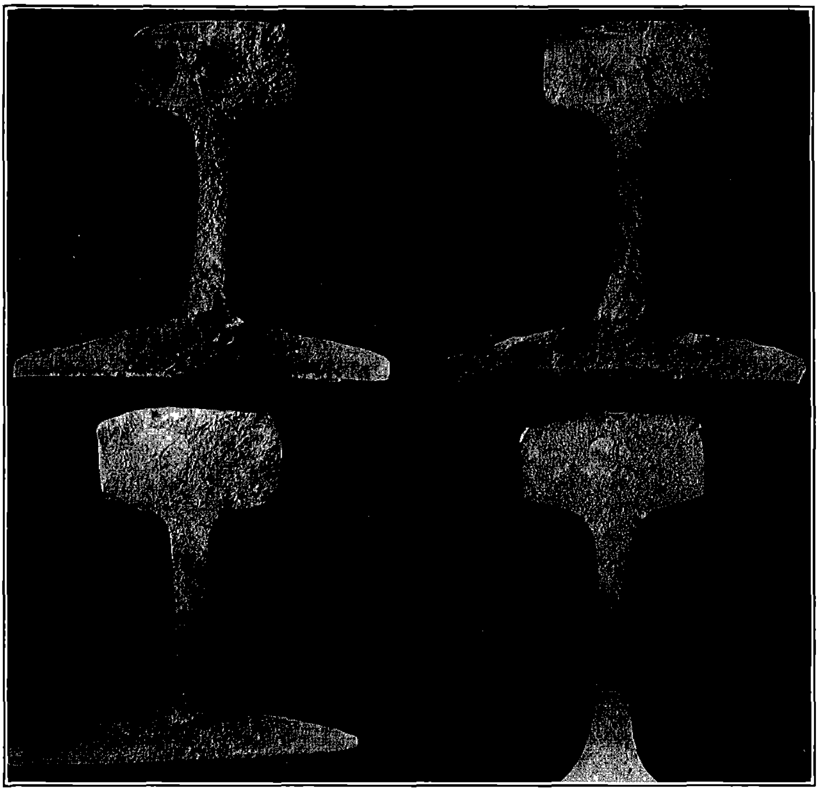
Description	Carbon	Manganese	Phosphorus	Sulphur	Silicon
Fragment No 1, vicinity of largest transverse fissure	0 70	0 98	0 058	0 026	0 007
Fragment No 12, vicinity of smallest fissure	71	97	061	025	008

Tensile test pieces were taken from fragment No 3, from the gauge side, from the middle, and from the outside of the head, the results of which appear in Table No 2

TABLE No 2 —*Tensile tests of rail, longitudinal specimens from head, stems 0 505 inch diameter by 2 inches long*

Description	Elastic limit per square inch	Tensile strength per square inch	Elongation	Contraction of area
	Pounds	*Pounds*	*Per cent*	*Per cent*
Gauge side of head	80,380	110,100	2 00	2 00
Middle of head	67,400	80,140	50	40
Outside of head	71,400	124,800	13 75	16 33

1 2



3 4

FIG. 3.—Transverse fissures displayed on the leaving ends of fragments Nos. 1, 2, 3, and 4, respectively.

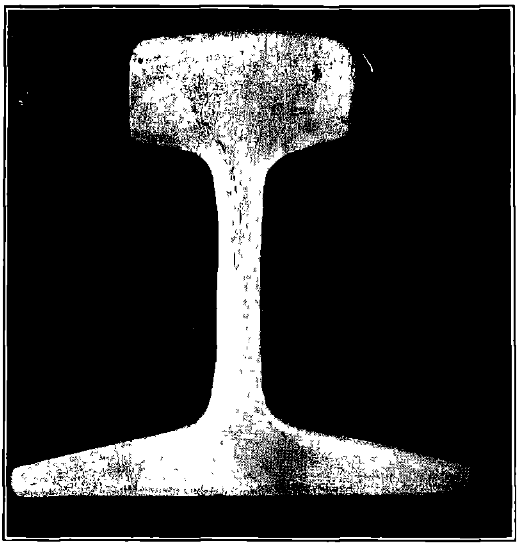


FIG 4 —Cross section of rail, near leaving end of fragment No 3, polished and etched with tincture of iodine

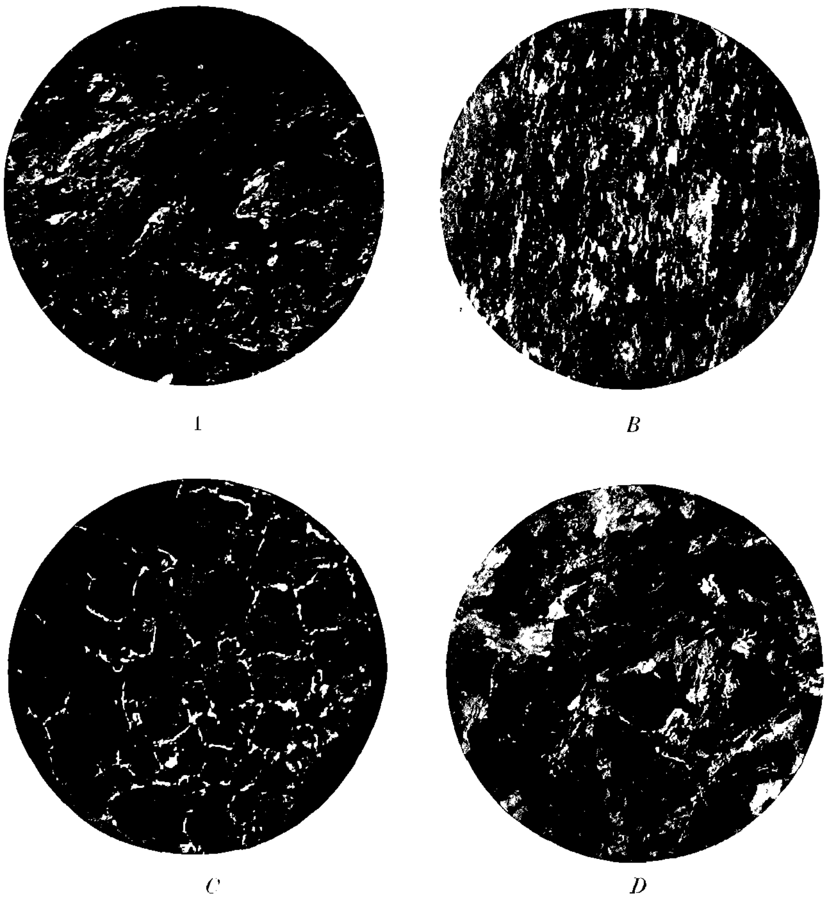
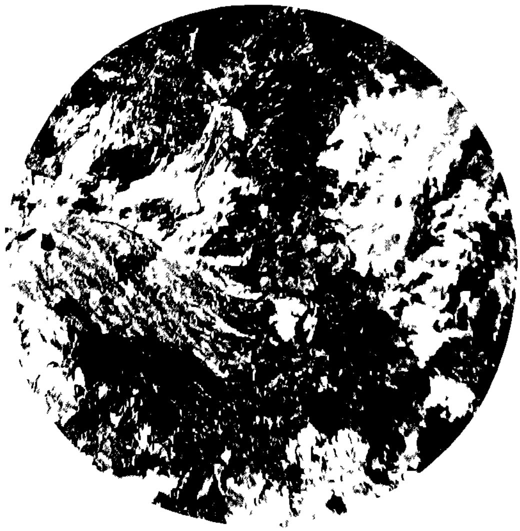


FIG. 5.—Microstructure of the head of the rail, near the leaving end of fragment No. 3, cross section, magnification 100 diameters. A. At running surface near middle of top of head, showing lateral flow of surface metal toward gauge side of head. B. At upper corner of the head gauge side. Most pronounced effect of wheels in distorting the grain of the steel. C. Near lower corner of the head gauge side. Slightly decarburized edge. Beyond the reach of the wheels and no distortion to the grain of the steel. D. Structure of the rail near the center of the head.



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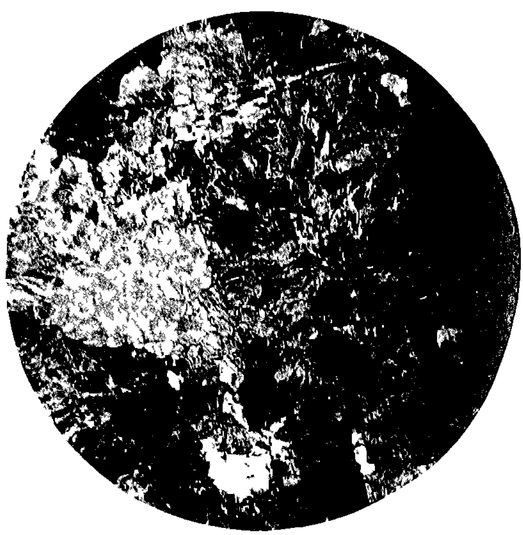

F

FIG 6 Microstructure of the head of the rail, near the leaving end of fragment No 3, vertical, longitudinal section, magnification 100 diameters E Structure of the rail near the center of the head F Structure at the edge of the transverse fissure on the leaving end of the fragment

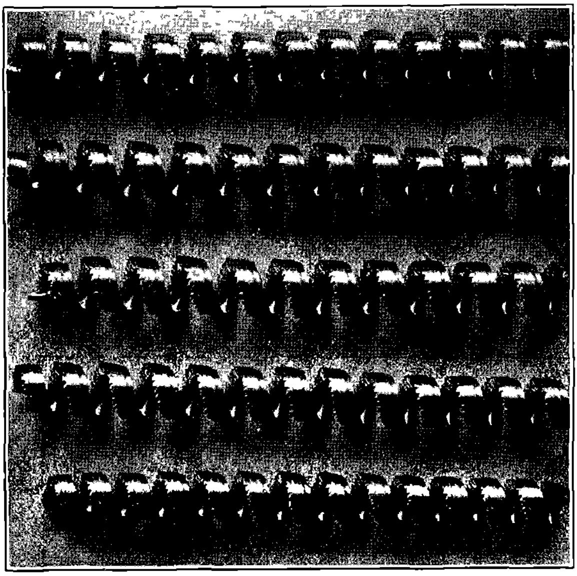

FIG 9 —Appearance of planer chips taken from the middle of the head, fragment No 3

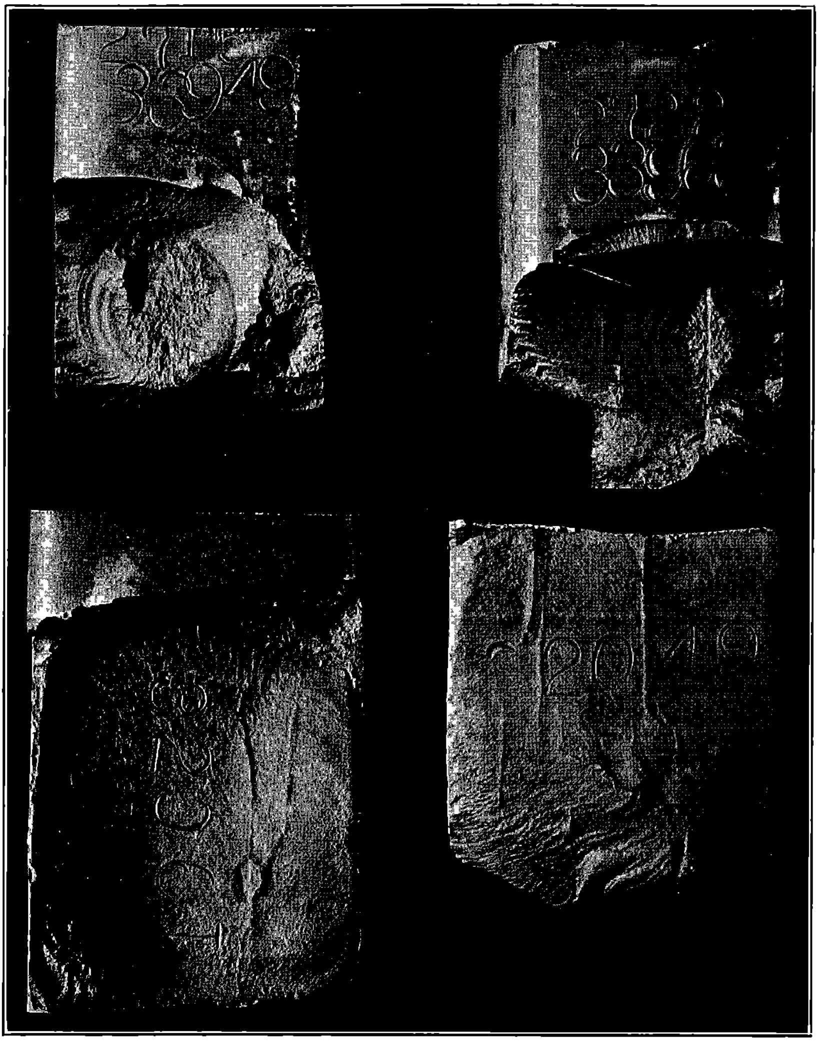

FIG 10 —Group of shearing fractures in heads of other rails not involved in present derailment Progressive shearing fractures in horizontal longitudinal planes, origins at longitudinal streaks in the steel

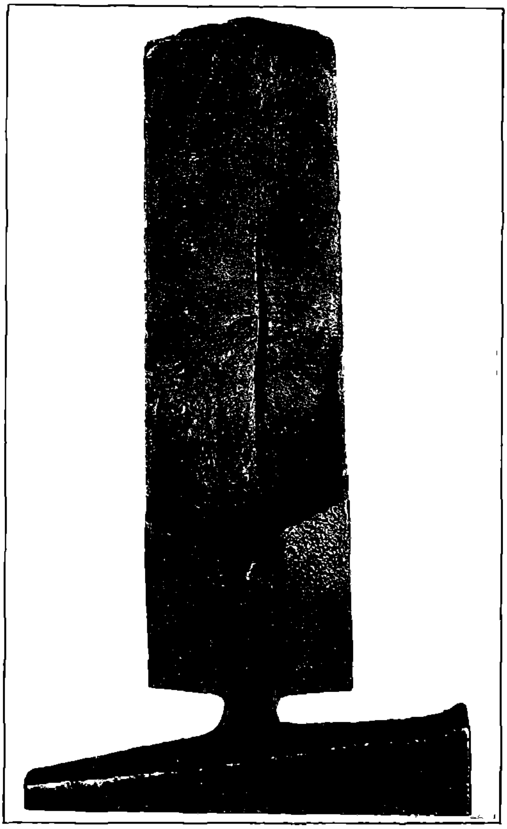

FIG 11 —Shearing fracture in head of rail, progressive fracture starting at split in head View from the under side

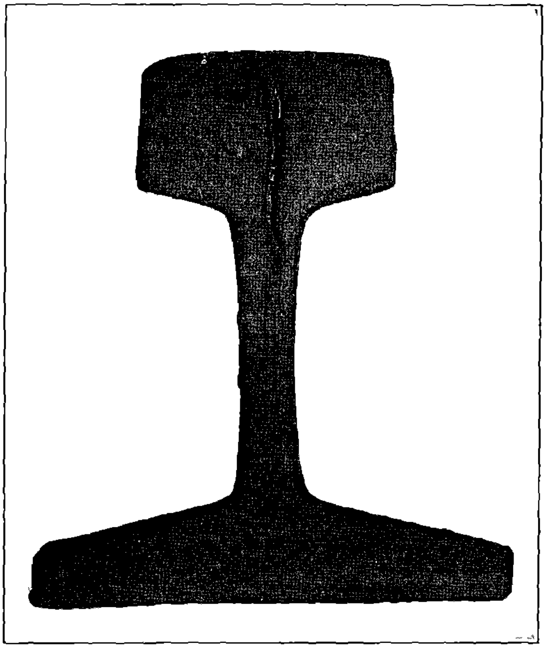

FIG 12—Cross section of rail shown in Fig No 11 Split head from which a horizontal shearing fracture started detaching the upper portion of the head

It will be noted that the test piece from the outside of the head displayed the greatest elongation, that from the middle the least, while that from the gauge side had an intermediate value In the display of elongation, the test pieces stood in the same order as in tensile strength, the usual result since the development of elongation goes on at an accelerating rate as higher stresses of tension are reached. While some uncertainty may attach to the definition of the elastic limits in different laboratories, nevertheless, the minimum values in these test pieces were far above any expected fiber stresses resulting from direct bending loads which the rails should receive in the track The ductility of the steel was practically eliminated in the test piece from the middle of the head, much reduced in that from the gauge side, but apparently unimpaired in the metal next the outside of the head The results of the tensile tests and the strain measurements are in harmony, each pointing to the influence of the wheel pressures in their modifying effects upon the physical properties of the steel

Transverse fissures have well defined nuclei, from which they progressively extend Neither chemical analyses nor microscopic examinations have revealed any common cause attaching responsibility to the composition or structural state of the rail for the incipient formation of transverse fissures This type of fracture has the traits of a fatigue fracture, that is, one resulting from the application of a sufficient number of repeated stresses of the required magnitude, but none necessarily reaching the elastic limit of the metal Service conditions undoubtedly cause the progressive development of transverse fissures They have been known to reach such a size that practically the entire head was ruptured before the rail was removed from the track Interest centers upon the state of the metal at the nuclei of the fissures when in search of a cause for their formation, but as above stated no definite cause has been found, although the search has been a diligent one There is a limit of endurance for all steels and rupture ensues when that limit has been reached. The primitive tests of rails, under current specifications governing their acceptance, do not furnish this class of information It will be acquired when rails in full cross section are subjected to repeated stresses of known magnitude

Transverse fissures may be associated with other types of rupture, the origins of which have well recognized causes Slag inclusions and streaks in the steel from blowholes are among the causes which lead to certain fractures The process of manufacture orients these inclusions and disposes them in longitudinal directions in the finished rail Wheel pressures set up shearing stresses, the effects of which encounter these longitudinal streaks and lead to split heads, as the vertical seams are designated, or may result in shearing fractures being developed in horizontal or oblique planes Some confusion has existed in respect to recognizing the characteristic features by which different types of rupture are identified, and fractures which are found associated with transverse fissures have been grouped with them To aid in the better discrimination between different types of rupture some photographic prints are inserted, illustrating some shearing fractures in the heads of a number of rails

Figure No 10 shows a group of four rail heads in each of which progressive shearing fractures developed, the origins of which were at longitudinal streaks in the steel Fractures of this kind in the head, and similar ones in the base, follow the longitudinal streaks for a distance, then turn in their course and terminate at the surface or edge of the rail section In the base they form crescent-shaped fractures Those in the head, as here witnessed, generally change their courses in opposite directions, at one end curving upward and terminating at the running surface of the head, at the other end taking a downward course into the web and thence through the base. The difference in the manner of their development is attributed to the influence of the combined longitudinal bending and shearing stresses in the head on the one hand, and to the crosswise bending stresses received by the base on the other hand The resemblance of these fractures to the ruptured surfaces of transverse fissures has led to their being mistaken for a modified form of transverse fissure

Figure No 11 shows a combined split head and horizontal shearing fracture Each were progressive fractures The split-head fracture had its origin in the upper part of the head, extending downward into the web The split-head fracture was doubtless the primary one, the shearing fracture secondary, the latter having its origin at the edges of the former Eventually the shearing fracture changed its course, at one extremity curving upward and completing the rupture in the head, at the other end curving downward and separating the web and the base An end view of the rail is shown on figure No 12, where the fracture appears as a split head only

SUMMARY

The results of this investigation show the failure of the rail involved in the present derailment was due to the presence of transverse fissures Eight were displayed in the fragments of the head, all of which were located on the gauge side of the head or over the web. A number of years have now elapsed since this type of rupture was brought to notice in these accident reports They constitute a menace to the integrity of rails, and continue to develop in rails of different ages and weights It is believed to have been established in what manner they progressively develop, since they are found in different stages of development in the same and in different rails. Many features connected with their occurrence have been assented to by common concurrence of opinion But notwithstanding this remedial efforts have not been inaugurated and no adequate protection has been provided against the recurrence of this serious type of fracture This is a disquieting condition which should be ameliorated There is urgent need of the compilation of all relevant data upon the numerous instances of failures of this kind and prompt and energetic efforts made to suppress this insidious type of fracture

H W BELNAP,
Chief, Bureau of Safety

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