INTERSTATE COMMERCE COMMISSION.

REPORT OF THE DIRECTOR OF THE BUREAU OF SAFETY IN RE INVESTIGATION OF AN ACCIDENT WHICH OCCURRED ON THE PHILADELPHIA & READING RAILWAY NEAR ANNVILLE, PA., ON NOVEMBER 21, 1923.

February 18, 1924.

To the Commission:

On November 21, 1923, there was a derailment of a freight train on the Philadelphia & Reading Railway near Annville, Pa., the wreckage of which was struck by a passenger train moving in the opposite direction on an adjoining track, which resulted in the death of 1 passenger and 2 employees and the injury of 47 passengers, 1 news agent, and 2 employees.

LOCATION AND METHOD OF OPERATION.

This accident occurred on the Lebanon Valley branch of the Harrisburg division, extending between Harrisburg and Reading, Pa., a distance of 53.4 miles; in the vicinity of the point of accident this is a double-track line over which trains are operated by time-table, train orders, and an automatic block signal system. The accident occurred at a point approximately 1.5 miles west of Annville station; approaching this point from either direction the track is tangent for a considerable distance. The grade for westbound trains is 0.52 per cent descending to within 900 feet of the point of accident, from which point it is 0.51 per cent ascending for some distance beyond the point of accident. The track in the vicinity of the point of accident is laid in a cut, the sides of which are about 8 or 10 feet high, with 100-pound rails, 33 feet in length, with 18 treated ties to the rail length, tie-plated, triple-spiked, ballasted with stone about 8 inches in depth, and well maintained.

The weather was clear at the time of the accident, which occurred at about 5.03 p. m.

DESCRIPTION.

Westbound freight train extra 1745 consisted of 48 cars and a caboose, hauled by engine 1745, and was in charge of Conductor Haws and Engineman Alleman. This train passed Wyomissing Junction, its initial reporting station on the Harrisburg division, at 2.50 p. m., passed Annville, according to the train sheet, at 5 p. m., and at a point approximately 1.5 miles west of Annville, while

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traveling at a speed of about 25 or 30 miles an hour, the thirty-first car from the engine became derailed, swerved to the left across the eastbound main track, and was struck by eastbound passenger train No. 194, which was passing at the time.

Eastbound passenger train No. 194 consisted of one combination baggage and smoking car, two coaches, one dining car, and one Pullman chair car, in the order named, all of all-steel construction, hauled by engine 316, and was in charge of Conductor Heiges and Engineman Landis. This train left Harrisburg, its initial terminal, at 4.30 p. m., on time, passed Palmyra, the last open office and approximately 3.75 miles west of the point of accident, at 4.58 p. m., six minutes late, and collided with the derailed car or cars of extra 1745 while traveling at a speed estimated to have been about 55 or 60 miles an hour.

Fifteen cars of extra 1745, cars 25 to 39, inclusive, were derailed; the first six cars being derailed to the right, while the seventh car, a steel coal car, loaded, swerved to the left, fouling the eastbound main track, and was practically cut in two by engine 316, which climbed over the derailed equipment, cleared the embankment, which was about 10 feet high at this point, and came to rest about 30 feet from the main track. The first three cars of train No. 194 mounted the derailed freight equipment and came to rest in an upright position only slightly damaged. The employees killed were the fireman and baggageman of train No. 194.

SUMMARY OF EVIDENCE.

Engineman Alleman, of extra 1745, stated that his train left Reading at 2.30 p. m. and that the airbrakes worked properly in making several stops en route. Approaching the point of accident, at which time the speed of his train was about 18 or 20 miles an hour, the signal indications were all clear and he did not notice anything unusual such as a jar or lurching of the engine when passing over the portion of track where the train was derailed. Immediately after train No. 194 had passed his engine there was a severe jerk, the air gauge indicated that the brakes had been applied in emergency, and he shut off steam and stopped.

Engineman Landis, of train No. 194, was interviewed at the hospital, but on account of injuries he was unable to give a detailed statement of the accident. He did state, however, that the signals approaching the point of accident all displayed clear indications and that just as the two engines were passing each other he saw fire flying from the wheels of the freight cars ahead and applied the air brakes in emergency, the collision occurring at about the same time.

Conductor Haws, of extra 1745, stated that he did not look at his watch until about 5 minutes after the occurrence of the accident and at that time it was 5.08 p. m.; he later found the watch of the fireman of train No. 194 which had stopped at 5.03 p. m. The statements of the other members of the train and engine crews of the trains involved added nothing of importance to the evidence.

Division Superintendent Chamberlin and Division Engineer Miller, who were passengers on train No. 194, with Conductor Heiges, of that train, made a thorough examination of the track very shortly after the accident. A broken rail was found on the south side of the westbound track immediately in front of the heel of a No. 10 frog of a crossover connecting the two main tracks. A portion of a rail about 4½ feet in length was intact and spiked to the ties; there was then a portion of rail about 14 inches long where the top was entirely off and the base shattered. Close inspection of this rail disclosed spots thought by them to have been due to manufacture and resulted in segregation taking place. Beyond this point pieces of the rail were missing and could not be found; another section of this rail, about 16½ feet in length, was found which had been battered down on the receiving end and it was thought that a number of cars had passed over it without derailing before it finally gave way and resulted in the general derailment. Division Engineer Miller stated that in August, 1920, signal failure reports showed a broken rail in the vicinity of this point and that in the early part of 1921 this track had been relaid.

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 accident which occurred November 21, 1923, on the Philadelphia & Reading Railway, near Annville, Pa., was due to the fracture of a rail which displayed a split head type of rupture. This rail, rolled by the Bethlehem Steel Co., at its Steelton works, weighed 100 pounds per yard, and was branded, "100 R. G. B. S. Co. Steelton, IIIIIIIIIII 1920 O. H." Its heat number was "11200 A 12." It was laid in the track January, 1921.

At the time of the accident 12 feet in length of the rail, an intermediate section, was broken into short fragments. There were pieces of the head, separated into halves, and detached fragments of the web and base. Not all of the smaller fragments were recovered. At the receiving end there was a partially split section, 4½ feet long; at the leaving end an intact section 16½ feet long.

The recovered fragments, from the intermediate part of the length of the rail, showed the presence of a longitudinal seam at the center of the head. This seam constituted the cause of its failure. Some of the fragments showed the plane of rupture had traveled easterly, on others it had traveled in the opposite direction. The incipient point of rupture, longitudinally, was not shown by the recovered fragments, but was located, of course, at the place whence the plane of rupture changed directions. Split head fractures have definite origins from which they extend longitudinally. Vertically they develop upward and downward from the seams at which they originate.

The longer fragment of the leaving end showed no trace of the split head fracture. The head of the shorter fragment was partially split. The plane of rupture had deflected and was approaching the gauge side of the head in this fragment. It terminated in the section covered by the splice bars, at a distance of three-eighths inch from the side of the head, here nearly separating it vertically.

After the plane of rupture had deflected from its course at the middle of the head it passed through metal macroscopically sound. Whether the rail first failed abreast the incipient point of the split head fracture or elsewhere along its length the recovered fragments were insufficient to indicate. It does not follow necessarily that final rupture of the rail occurs at the origin of the split head itself.

Describing the photographs and micrographs reproduced herewith illustrating this rail and one other, each of which displayed a fracture of this kind, Figure 1 shows a cross section of the halves of the head of the rail involved in the present accident as they appeared after polishing and etching with tincture of iodine. The web and base of the rail are shown in outline.

The place of rupture, in vertical direction, had its origin at a longitudinal seam at the center of the head. A star is placed on the cut at the side of the seam, for identification.

Figure 2 shows the appearance of the ruptured surfaces of these two fragments, a star being placed on the cut opposite the seam for identification. The radiant appearance of the ripples on the fractured surface indicate the plane of rupture traversed the head of the rail in lengthwise direction, as well as separating it vertically.

Just below the fillet of the head the plane of rupture bifurcated separating the halves of the head from the web. At this particular place in the rail the half of the head on the gauge side was the first to be detached, followed by the outer half. A number of small fragments were successively detached from the intermediate part of the length. These are without significance respecting the origin of rupture.

Figures 3 and 4 are photomicrographs showing the appearance of the metal adjacent to the longitudinal seam in the head. There were minute slag inclusions in this vicinity, but not in segregated areas. The contiguous metal, judged by its appearance, would not be expected to display a streak of the character of the one which precipitated the accident.

Figure 5 shows a cross section of the rail near the receiving end, as it appeared after polishing and etching with tincture of iodine. At this place the plane of rupture has approached within three-eighths inch of the gauge side of the head.

Pronounced markings appeared on this iodine etched cross section; darkened areas, dots, and dashes. Each mark has some significance but for the most part they would hardly exert an appreciable influence in promoting rupture of a rail, the gravity of their presence depending upon their position and size. In the earlier stages of the attack of the staining liquid the dots and dashes are more sharply defined. They acquire an exaggerated appearance when the etching is continued, and the surface darkened sufficiently for photographic purposes.

The dark zones bordering upon the edges of the split head plane of rupture are without significance in respect to the development of the fracture. The illustration shows how an erroneous aspect may be given a portion of the etched surface through the presence of some foreign substance. The metal in the opposite halves of the head was substantially alike in structural appearance. In general, rails are remarkable for their symmetry of appearance on opposite sides of a vertical center line.

Figure 5a shows the appearance of the metal on the side of the split head after washing the section with alcohol. When repolished and reetched the darkened borders did not reappear.

The markings on the cross section of the rail shown by Figure 5 were microscopically examined in three places. Near the center of the head a darkened spot was displayed, occupying a place near the element on which the seam causing the split head was located. This spot, toward which an arrow points on the cut, was photographed oversize and enlarged to 8 diameters appearing as shown by Figure 6.

The metal was repolished and again etched with tincture of iodine, developing a cloudy zone when lightly etched. A spot on this zone was marked with a needle for identification, photographed, and shown by photomicrograph Figure 7. Polishing off the iodine etched surface a group of minute inclusions appeared, shown by Figure 8. The surface was etched with picric acid, displaying the structure shown by Figure 9, on which also appear dots representing the slag inclusions. These inclusions would be expected to impair the strength of the metal in its resistance of lateral strains, and lead to the formation of a split head fracture.

The examination was next directed to some dark lines near the upper surface of one of the flanges, marked for identification with an arrow, on Figure 5. The appearance of these lines is shown by photomicrograph Figure 10. An interrupted line of minute slag inclusions was the characteristic feature of this streak in the metal.

Still another darkened spot was examined, located in the base near the junction with the web, also marked with an arrow on Figure 5 for identification. This darkened spot occupied a position in the ingot, but on its opposite side, corresponding to the slag streak in the head which was responsible for the present accident. The examination of this spot furnished an illustration believed to represent a structural condition adequate to cause the development of a split head, provided it was located in the critical zone in the head. In the base it was not situated in a danger zone and its presence there can be ignored.

The last remark brings to notice the feature that structural conditions to be menacing must occupy certain definite danger zones in the cross section of the rail, and that vulnerability is found in certain localities with which the intensity of wheel pressures bear a definite relation.

Figure 11 represents the darkened spot, near the junction of the web and the base, after etching five seconds in picric acid. The picric acid etch was next polished off. Slag streaks continuous and interrupted forming unwelded seams were found in this locality. Figures 12 and 13 represent these seams. They constituted the edge of a zone containing groups of minute inclusions outside of which the metal was quite free from them.

It is believed that seams, such as these, if present in the head, critically located and oriented, would lead to the development of a split head fracture. Split head fractures indicate the effects of wheel pressures penetrate to the centers of the heads of rails. Evidence of such penetration is also furnished from other sources. It is not believed a chance occurrence that a seam in the center of the head is situated in a plane of rupture originating elsewhere; the seam is held to be the cause, rupture originating at its locus.

Without taking up the question of eliminating streaks, or entering upon a discussion whether they can be eliminated, it may be remarked that it is important to ascribe the formation of split head fractures, as well as all other types of fractures, to their proper causes. Erroneous explanations or those inadvertently ascribed to irrelevant conditions stand in the way of reaching corrective measures, if they are attainable.

Possibly the matter of segregation has been given greater prominence with respect to certain types of fracture than justifiable. A rail of unusual degree of segregation was examined in connection with the present accident. Its carbon content in the head was 0.85; in the web, 1.33. This rail, 130 pounds weight per yard, displayed a split head fracture. The cause of the fracture was a longitudinal seam located near the center of the head. The fractured surface presented an appearance common to split head fractures, and identical to that of the 100-pound rail involved in the present accident.

Figure 14 shows a cross section of the 130-pound rail after polishing and etching with tincture of iodine. An arrow on the cut points to the position of the seam, located a little above the limits of the segregated area.

Figure 15 is a side view of the head showing the seam as it appeared on the fractured surface. A star is put on the cut abreast the seam for identification. The segregated zone was clearly an incidental feature and not a contributory cause in the fracture of the rail.

Objections to segregated metal would be valid if segregation was proven to present an unfavorable relation to the type of fracture under consideration. In this 130-pound rail, segregation was apparently beneficial in its results rather than detrimental. Its presence probably saved the outer half of the head from being detached from the web; possibly averting a derailment.

Segregated metal occupies the same place in the cross section of the rail as a pipe. A pipe results from a cooling cavity in the ingot from which the rail is rolled. Seams result from slag inclusions. There is no necessary relation between these two phenomena. It has not come to notice that either piping or segregation has been a contributory cause in split head fractures. Each is a distinct type of rupture resulting from different antecedent conditions. Split head rails are of frequent occurrence. Failures from piping are seldom witnessed, notwithstanding which split head rails in many quarters continue to be called piped rails, a misleading misnomer.

There is a tendency to underestimate the gravity of split head rails, due to the circumstance that detection is possible at certain stages in their development. The ratio between width and depth of fracture is so unfavorable, however, that difficulty is presented in the early detection of split head rails. The minor and not the major dimension of rupture only afford the means of detection.

It is conceivable that cooling strains may play a part in the formation of split head fractures. They appear the dominating if not the sole cause of the formation of shattered zones in the heads and bases of rails. Cooling strains may concentrate upon planes of structural weakness, such as slag inclusions and originate incipient nuclei of subsequent fractures. Accelerated rate of cooling has such an influence, and possibly size of head of rail modifies thermal effects.

As to corrective measures, a certain degree of control is probably at the command of the steel maker, in respect to the amount of entrained slag. The aggregation and location of acicular groups do not appear controllable features. Flattened inclusions of extreme width occupy certain parts in the cross section of the rail, incident to the contour of its outline, notably in the web and upper side of the flanges. Roll design must be adapted to meet the demand for rails of given shapes, and such influence on the disposition of the inclusions is unavoidable. Flattened inclusions in the central part of the head, vertically oriented, are without doubt menacing. It is not apparent how to control the shape of inclusions in this part of the rail. The elimination of all inclusions would remove those from the danger zone as well as other parts of the cross section. Greater freedom from inclusions would mitigate the situation in respect to split head fractures.

It does not follow that escape from one type of fracture will not involve an accentuation of troubles in some other direction. One fact is conspicuous: rails are overstrained members. Such has been the case in some degree from the very start of carrying loads on wheels. A railroad track is not a permanent structure, in an engineering sense. Local overstraining of the metal adjacent to the running surface has always been the case. It can best be endured when the volume of affected metal is of moderate extent.

In conclusion, the failure of the rail involved in the present accident was due to a split head fracture. The origin and cause of the fracture was a longitudinal seam located near the center of the head. The fracture developed vertically, splitting the head into halves and extended lengthwise the rail nearly half its length. In its course it followed the seam in the head for the greater part of its length, but deflected toward the gauge side as it approached the receiving end. In the latter part of its course the plane of rupture passed through metal macrospically sound.

A polished and etched cross section of the rail displayed darkened areas with dots and dashes signifying the presence of inclusions, oxides, silicates, sulphides, all of which may be included in the general term slag.

Slag inclusions located in the central part of the head lead to the development of split heads, when in flattened shapes, and probably when in closely associated acicular groups.

Split head rails, at times, admit of detection. A dark streak along the middle of the running surface is an accepted manifestation of a split head. Lateral expansion of the head is slight in amount compared with the vertical depth of the fracture and therefore affords a somewhat precarious warning of the extent of the fracture. Its inadequacy as a reliable index of the gravity of the case is probably the reason for the occurrence of accidents arising from this cause rather than disregard or neglect of the indications.

SUMMARY.

This report deals with a type of rail failure which is of frequent occurrence, but fortunately impending rupture is often discovered and the rails are removed from service before rupture is complete. Nevertheless derailments occur from split head rails attended with serious consequences. In the present case loss of life occurred on a passing train on the track adjacent to the broken rail. The presence of this rail was a menace to both tracks of the double-track road.

The engineer physicist has presented data which appear to describe an inherent cause for this type of fracture. A structural condition existed in the metal due to the presence of certain inclusions which formed planes of weakness in the head of the rail.

Rolling loads tend to expand the width of the head. When the lateral effects of wheel pressures encounter an interior seam a split head fracture may result. The danger zone is in the central part of the head. The surface metal is crowded in lateral directions under wheel pressures. Interior metal can not respond in the same manner as the surface metal, and rupture from within ensues without display of ductility, when sufficiently strained.

Realizing that split head fractures originate at seamy streaks in the metal, the elimination of the seams or restriction of wheel loads, whereby the presence of seams would not be felt, are the obvious remedies. Immunity from rupture through either of these exigencies does not receive encouragement from the producers or users of rails. In the avoidance of accidents from this cause reliance, such as it is, is placed upon track inspection and the removal of rails which are in process of rupture.

Respectfully submitted,

W. P. Borland,
Director, Bureau of Safety.

ILLUSTRATIONS.

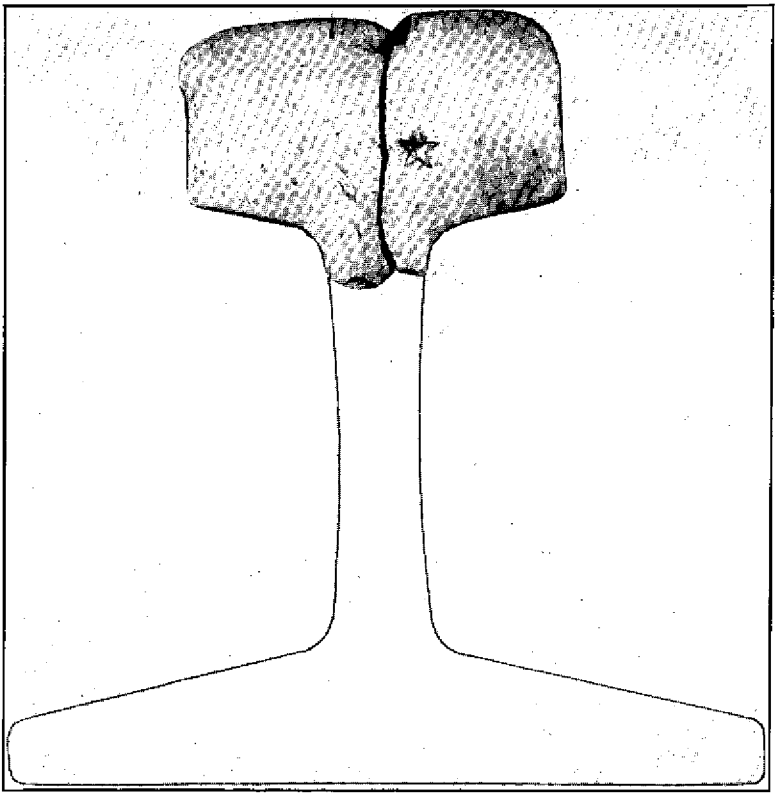

FIG. 1. Cross section of head of rail with outlines of web and base, surface polished and etched with tincture of iodine. Fracture began at seam at the center of the head, abreast star placed on the cut for identification.

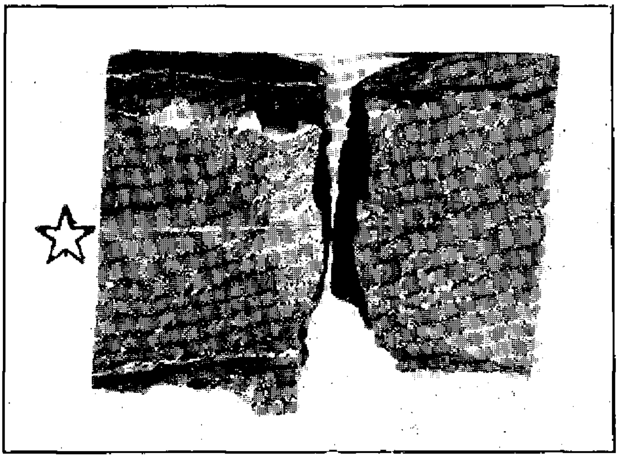

FIG. 2.—Pieces of the head of the rail, showing the longitudinal seam responsible for the split head fracture. A star is placed opposite the seam for identification.

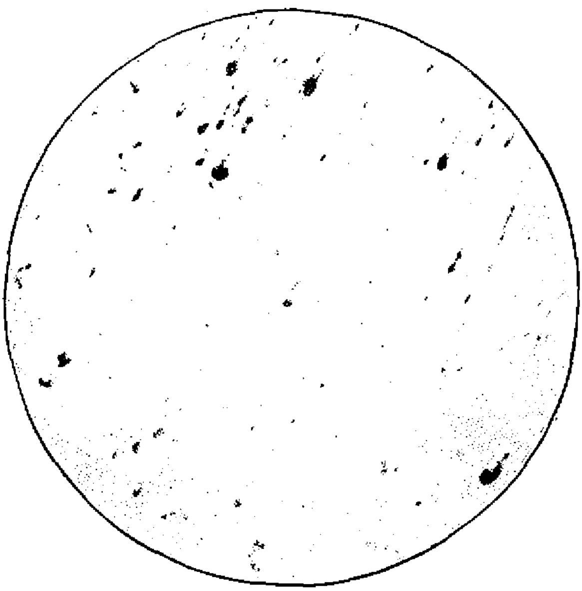

FIG. 3.—Photomicrograph of head of rail adjacent to the longitudinal seam at center of head. Surface polished but not etched, minute slag inclusions shown. Transverse section. 100 diameters magnification.

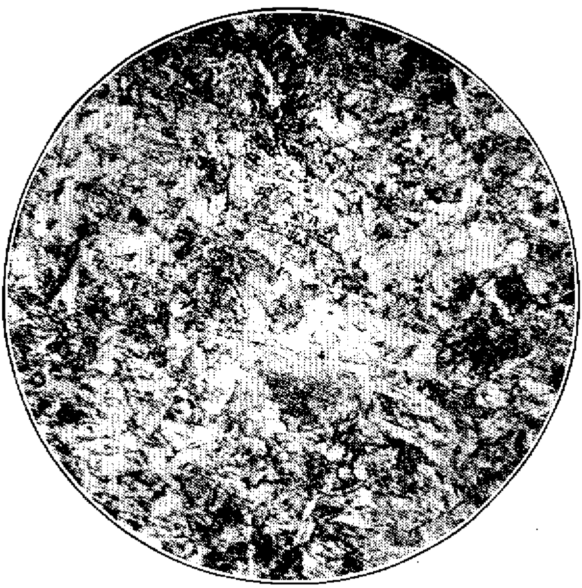

FIG. 4.—Photomicrograph of head immediate vicinity of fig. 3. Surface polished and etched with picric acid. Transverse section, 100 diameters magnification.

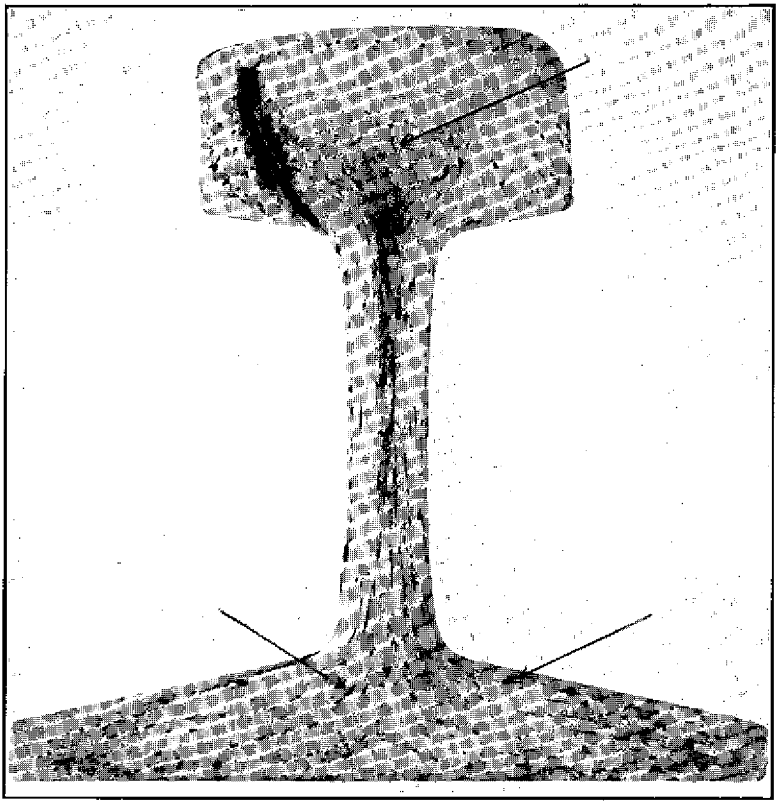

FIG. 5.—Cross section of rail near receiving end. Split head fracture had approached within three-eighths inch of gauge side of the head. Surface polished and etched with tincture of iodine. Dark borders of fracture not significant.

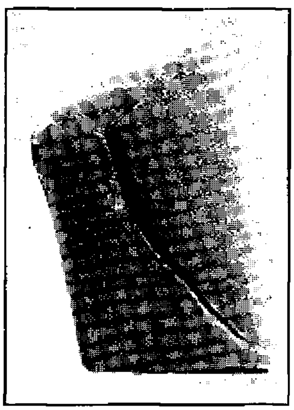

FIG. 5a.—Cross section of part of head, part of section shown by fig. 5. Repolished and etched with tincture of iodine, darkened borders of fracture not reappearing.

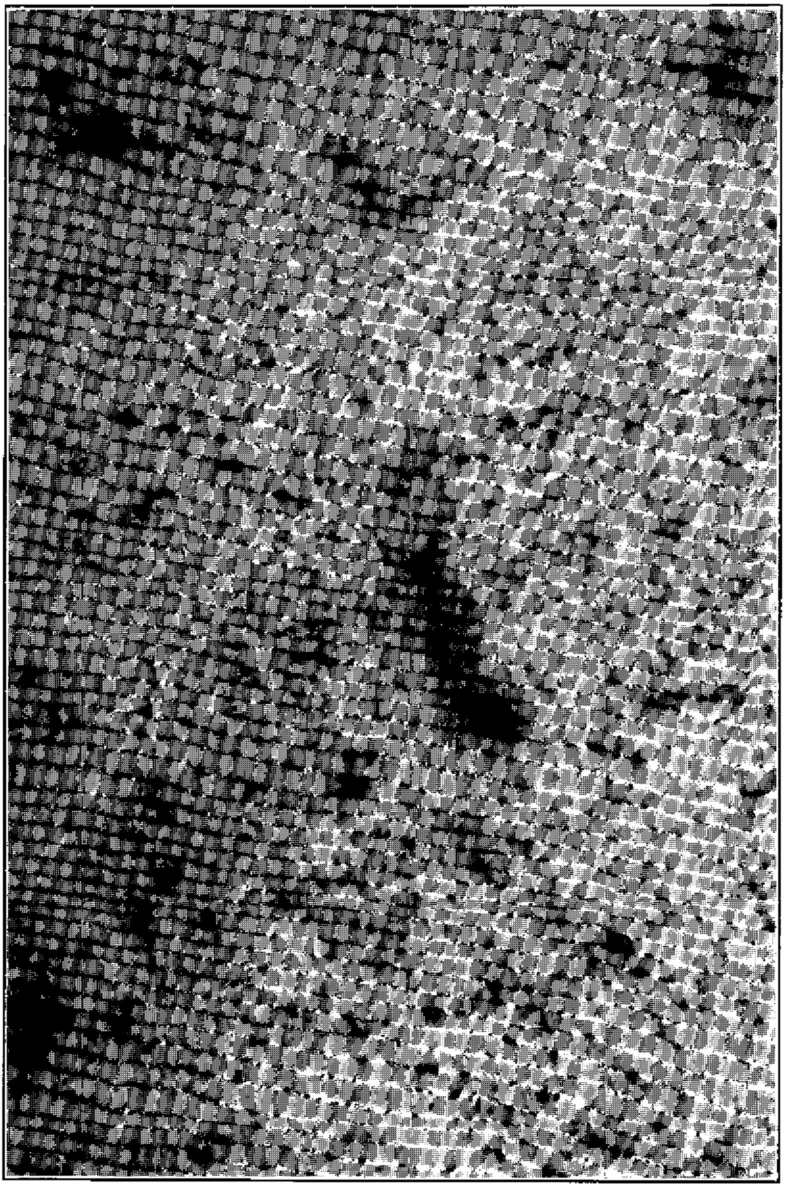

FIG. 6.—Appearance of a darkened spot near center of head of rail enlarged 8 diameters. See arrow on fig. 5 pointing to this spot.

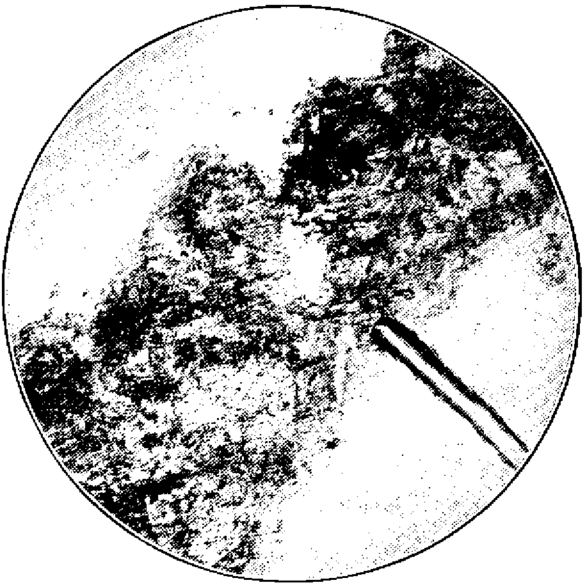

FIG. 7.—Photomicrograph of darkened spot near center of head of rail, same spot shown by fig. 6. Transverse section, 100 diameters magnification.

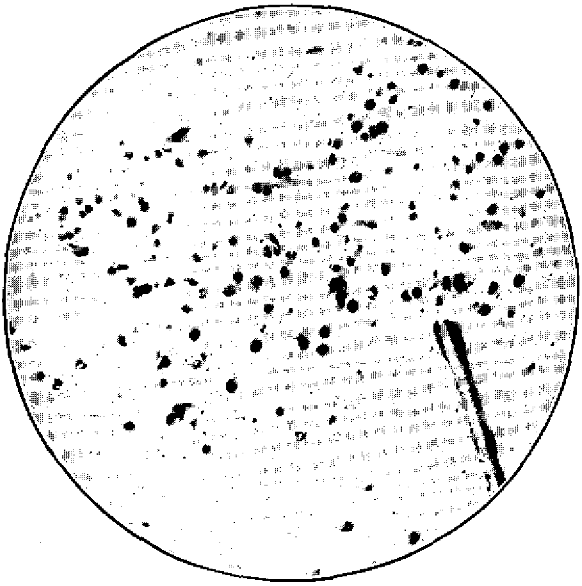

FIG. 8.—Photomicrograph of darkened spot near center of head of rail, shown by fig. 7. Appearance of surface after iodine staining was polished off. Transverse section, 100 diameters magnification.

FIG. 9.—Photomicrograph of darkened spot near center of head, etched with picric acid. Transverse section, 100 diameters magnification.

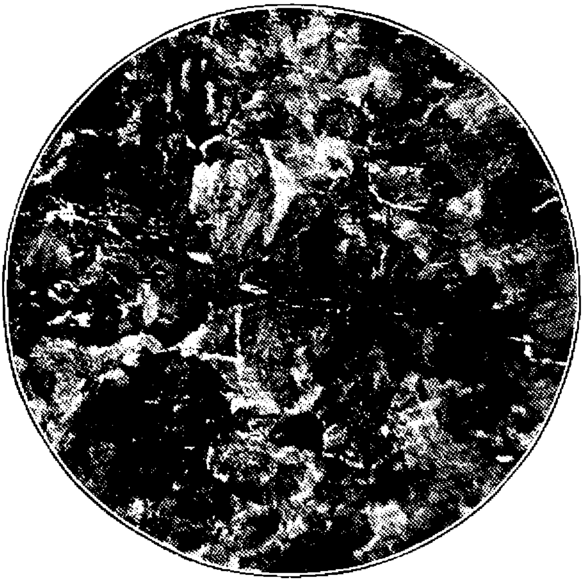

FIG. 10.—Photomicrograph picric acid etching of darkened streak near upper surface of flanges of rail, marked with an arrow on fig. 5 for identification, showing an interrupted line of slag inclusions, which appeared macroscopically as a continuous line on iodine-etched surface. Transverse section, 100 diameters magnification.

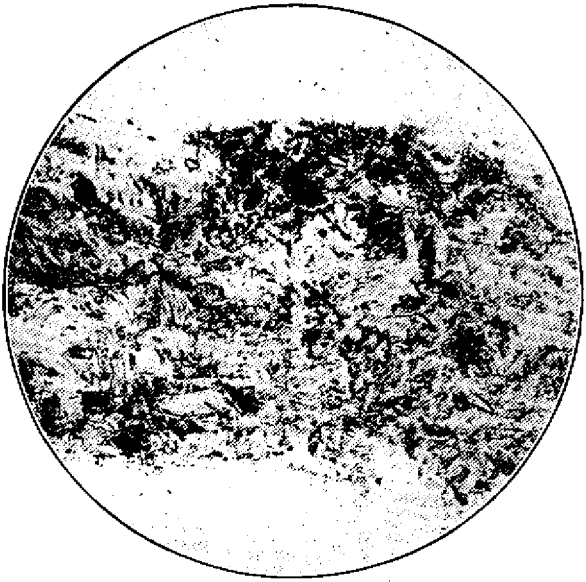

FIG. 11.—Photomicrograph of spot in base of rail darkened by tincture of iodine, marked by an arrow for identification on fig. 5. Appearance after etching five seconds with picric acid. Transverse section, 100 diameters magnification.

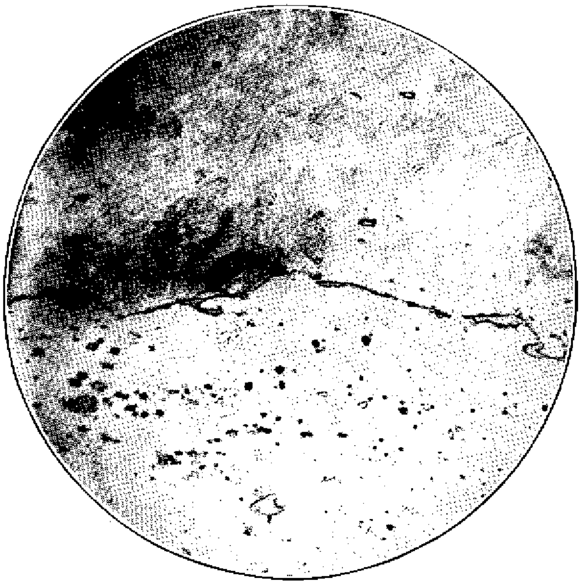

FIG. 12.—Photomicrograph of spot in base of rail darkened by iodine (see fig. 5) appearing on fig. 11, shown to be a slag streak when picric-acid etching was polished off. Seam located at edge of a group of minute slag inclusions. Transverse section, 166 diameters magnification.

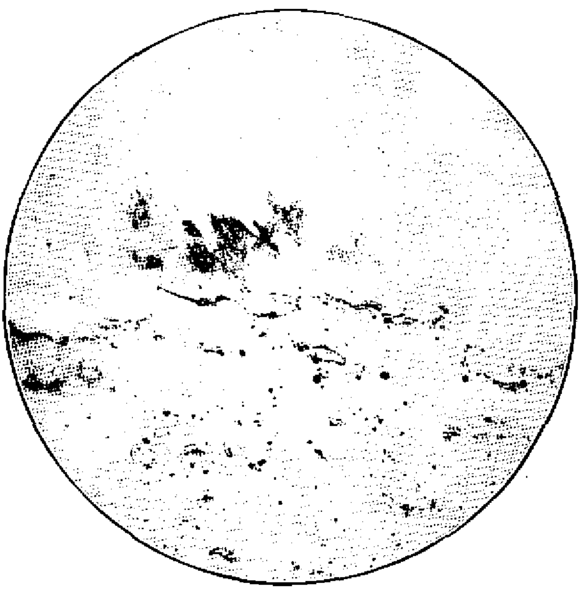

FIG. 13.—Photomicrograph of same streaked metal shown by fig. 12. Transverse section, 166 diameters magnification.

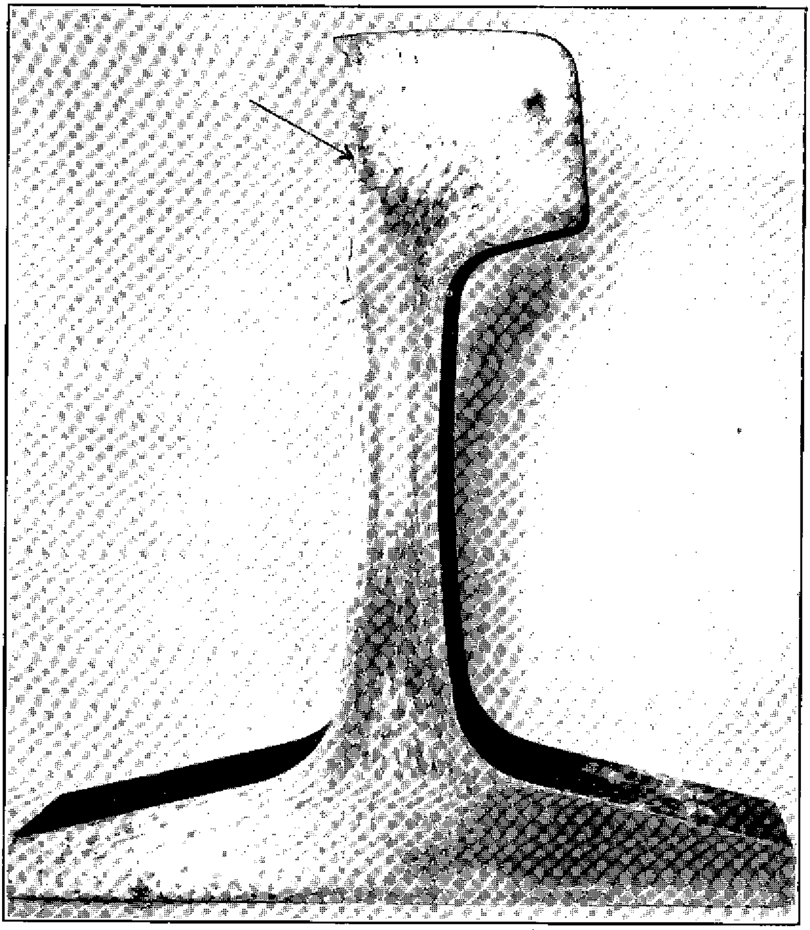

FIG. 14.—Cross section of a 130-pound rail, which displayed a split head fracture caused by the presence of a longitudinal seam. An arrow marked on the cut shows location of seam. This was a segregated rail, the segregation not being the cause of its fracture.

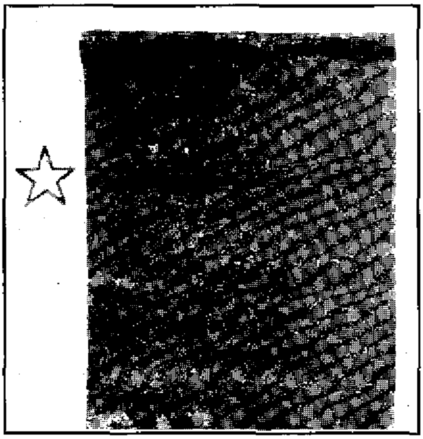

FIG. 15.—Side view of the head of the 130-pound rail, fractured surface showing longitudinal seam which caused its rupture. Star put on cut abreast the seam for identification.

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