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INTERSTATE COMMERCE COMMISSION

REPORT OF ACCIDENT ON THE GREAT NORTHERN RAILWAY NEAR SHARON, N. DAK., DECEMBER 30, 1911

BY THE CHIEF INSPECTOR OF
SAFETY APPLIANCES

ACCOMPANIED BY

REPORT OF THE ENGINEER PHYSICIST OF THE
BUREAU OF STANDARDS

PRINTED BY ORDER OF THE COMMISSION
MAY 2, 1912

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REPORT OF THE CHIEF INSPECTOR OF SAFETY APPLIANCES COVERING HIS INVESTIGATION OF AN ACCIDENT WHICH OCCURRED ON THE GREAT NORTHERN RAILWAY NEAR SHARON, N DAK , DECEMBER 30, 1911, ACCOMPANIED BY REPORT OF THE ENGINEER-PHYSICIST OF THE BUREAU OF STANDARDS COVERING HIS INVESTIGATION OF THE BROKEN RAIL CAUSING THIS ACCIDENT

May 4, 1912

To the Commission

On December 30, 1911, there was a derailment on the Great Northern Railway near Sharon, N Dak This derailment caused the death of 2 passengers, 1 employee not on duty, and 2 dining-car employees Injuries were received by 15 passengers the train conductor, news agent, and 1 porter This accident was reported by telegraph on the date of its occurrence, and after investigation I beg leave to submit the following report

Train No 3, known as "The Oregonian,' runs from St Paul Minn to Spokane, Wash This train left St Paul at 10 45 p m on December 29 and at the time of derailment consisted of one mail car one baggage car, two coaches, one tourist sleeping car, one dining car, one standard sleeping car, and Great Northern business car No A-25 This train was hauled by engine No 1439 and was in charge of Conductor Crowder and Engineman Vogel It passed Finley N Dak the last station previous to the point of derailment at 9 18 a m December 30, and had reached a point about 2 miles west of Finley when the accident occurred, at about 9 23 a m The speed of the train at the time of derailment was estimated to be about 25 miles per hour

The entire train was derailed with the exception of the engine and tender The mail car remained partly on the rails, while the baggage car was derailed and leaning to one side The two coaches tourist sleeping car, and dining car were resting on their sides at the bottom of a 20-foot fill The couplings held between the first three of these cars while the dining car broke loose and was a few feet away from the tourist car The standard sleeping car remained upright at the top of the embankment. The forward trucks of the business car were derailed, the rear trucks remaining on the rails. The tourist and dining cars caught fire from the cooking ranges carried by them and were totally destroyed, together with the coach next to the tourist car. The destruction of the remaining cars was prevented by the use of snow and fire extinguishers.

The accident occurred at the beginning of a 2° curve leading to the right on an ascending grade of one-half per cent. Approaching this curve the track is straight for some distance. It is laid with 85-pound rails, 33 feet in length, double spiked on both sides. Tamarack ties are used, with steel tie-plates. About 20 ties are used under each rail, with about 2 feet of gravel ballast.

The weather at the time of the accident was cold and stormy, the temperature being 18° below zero, with a light snow falling and a strong wind.

This accident was caused by a broken rail. Arrangements were therefore made with the Bureau of Standards, Department of Commerce and Labor, for the purpose of having this rail examined and the causes of its failure ascertained. This examination was conducted by Mr. James E. Howard, engineer-physicist of the Bureau of Standards, and the results of his examination, with accompanying explanatory illustrations, are attached to and made a part of this report.

The broken rail causing this accident was an 85-pound Bessemer steel rail, made by the Illinois Steel Co., South Works, heat No. 66825. This rail was rolled in 1906 and laid in the track on August 30 of that year. After the accident the receiving end was found to be intact for a distance of 18 feet 7½ inches, while the leaving end was intact for a distance of 8 feet 11½ inches. The intervening section, 5 feet 5 inches in length, was broken into many pieces, 18 of which were recovered. The entire rail was sent to the Bureau of Standards for examination and test.

Examination of this rail showed that although the head was split for a length of nearly 8 feet, the initial rupture at the time of derailment was the crescent base fracture between fragments Nos. 8 and 8a, as shown in figure 8. The rail was necessarily in a weakened condition by reason of the split head, but it had undoubtedly been in that condition, to some extent, for some time preceding the time of the derailment. The accident is believed to have been precipitated at this particular time by the development of the base fracture above mentioned. Between fragments 8 and 8a was found a longitudinal streak or laminated seam, 6½ inches in length, with a depth of about 0.1 inch. This line of rupture appears to have preceded all others with respect to the time of development. This initial fracture was followed by the fracture of the web and head between fragments Nos 6 and 7 and fragment No 9, shown in figure 3 Other lines of rupture followed in succession The lines of rupture at the westerly end of piece No 2, shown in figure 3, and the easterly, or receiving end of piece No 18 shown in figure 4 represent the limits between which all the fractures in this rail were developed The fissure in the head extended from a point near the easterly end of piece No 1 along the length of the rail into fragment No 11 Etching of fragment No 12 showed the split head, or fissure, to extend into that fragment, but it could be traced no farther Figures 5 and 6 clearly show the black line on the running surface of the head of the rail, indicative of interior defects

Attention is called to that part of the report of Mr Howard stating that it is characteristic of the crescent-shaped flange breaks shown in figures 8 and 9, that there is practically no display of extension of the steel across the laminations Rails display ample extension when the metal is strained in the direction of the length of the rail parallel to the length of the lamination, but in a crosswise direction they show great brittleness Wherever there is a lack of structural continuity in the steel, brittleness may prevail when it is overstrained at right angles to that lack of continuity Stresses may more readily reach the necessary maximum in the base than in the head, probably accounting for the fact that flange breaks are more numerous than split heads The manner of accomplishing overstraining is quite different in the head than in the base and from the examination of this rail it may be inferred that defects in the base are of a more grave character relatively and lead to more rail fractures than defects located in the head of the rail The split head had been in this rail for some time and the rail had been passed over by many trains while in that condition but the base fracture was probably fully developed by the derailed train Laminated seams are regarded as a common cause for many of the base fractures and for many of the split heads

Mr Howard's report further shows that there was no slag along the line of the fissure, or split head, and that its probable origin was at a point where the steel was much higher in carbon content than in other portions of the rail It also appears that there was a segregation of phosphorus and sulphur This split head was undoubtedly caused by the combination of high carbon steel at the center of the head with laminated seams interposed between that and the medium carbon steel at the outside of the rail After starting the split head was gradually developed by many trains with their heavy wheel loads until at the time of the failure it had reached the length of about 8 feet previously mentioned Attention is also called to figure 13 showing the carbon content of the steel at different points varying from 0 37 per cent to 0 77 per cent The analysis of the test ingot showed 53 per cent carbon This analysis is supposed to represent the heat, but if the heat does not represent the rails produced therefrom, the analysis would seem to be of no particular value as it would be useless to refer to the composition of a rail as being of a certain per cent carbon when one part contains 100 per cent more carbon than another part

Since Mr Howard's report shows that crosswise stresses are held to be directly accountable for flange breaks in the bases of rails in service, it is apparent that tests should be required for the purpose of determining the brittleness of the metal when subjected to such stresses

The results obtained by bending a piece of the rail under examination in a crosswise direction are shown in figures 14 to 17, inclusive Figure 17 shows that when bent in the direction in which rails are usually tested satisfactory results can be obtained It thus appears that there is practically no extension of the metal in a crosswise direction, and that laminated and streaky metal, such as was responsible for the failure of this rail can not be detected by the usual lengthwise tests

When subjected to the drop test the rail fractured on the first blow, but fulfilled current rail specifications in respect to elongation and interior soundness Two other drop tests were also made, neither of which revealed any interior defects The fragments tested were then subjected to crosswise bending, and it was found that laminated seams were present The drop test, therefore in this instance failed to detect these interior defects

Mr Howard further calls attention to the fact that the subject of laminated streaks is not a new one that it has been dealt with in various congressional documents issued in 1908 and 1909, and that the presence of such streaks and seams in the finished rail can be attributed to the condition of the metal in the ingot

The examination of the broken rail causing this accident clearly shows that its failure was due primarily to the presence of laminated seams thus weakening the base of the rail to such an extent that in all probability it was broken by the engine drawing train No 3 These laminated seams are defects of manufacture, and current specifications, as well as tests made before acceptance, are not sufficient to insure the discovery of such defects Careful track inspection should have disclosed the fact that this rail was defective, in so far as the split head or fissure was concerned, as the dark streak on the running surface of the head of the rail was very pronounced

The number of rail failures which occur on the railways of the United States is constantly increasing On the Great Northern Railway during the months of November and December 1911, and January 1912, there were 2 760 rail failures Of this number 936 were defective One interesting feature in this connection is the fact that of these 936 defective rails 605 were 90-pound rails made in the years 1908 1909, 1910 and 1911 Of approximately 600 rails which failed on the Minot division of this railway during 1910 and 1911, 80 per cent were caused by fractures starting from seams in the bases of the rails while only 7 per cent showed no signs of defects

Present specifications and tests, in so far as the detection of longitudinal seams is concerned, appear to be inadequate In view of the fact that the existence of rails with defects of the character herein discussed has been recognized for several years it would seem to be time that some definite action be taken toward eliminating this source of danger and securing structurally sound rails

Respectfully submitted

H W Belnap,
Chief Inspector of Safety Appliances

REPORT OF THE ENGINEER-PHYSICIST

I have the honor to report upon a steel rail received from the Great Northern Railway, which fractured in the track and appeared to have caused the derailment and wreck of train No. 3 on the morning of December 30, 1911, at a place near Sharon, N. Dak.

This train left St. Paul December 29 and was running in a westerly direction when upon approaching the easterly end of a 2° curve it was in part derailed, the north rail of the track fractured, the derailed cars leaving the track in a northerly direction, toward the inside of the curve. At the time of the accident, 9.23 a. m., the temperature was about 18° F. below zero, with a strong northwest wind blowing and a little snow in the air.

The train was made up as follows: Engine and tender No. 1439, mail car No. 52, baggage car No. 1668, smoker No. 3512, first-class coach No. 4314, tourist sleeper No. 6572, dining car No. 7105, Pullman sleeper, and business car No. A–25.

The engine, tender, and part of the mail car remained on the track and the rear trucks of the business car. The other cars of the train were derailed, four of which fell over on their sides at the foot of an embankment, and three of the four, namely, the day coach, tourist sleeper, and dining car, were destroyed by fire.

The casualties numbered—5 killed, 4 of whom were in the dining car, and 18 injured.

The rail which fractured was of Bessemer steel made by the Illinois Steel Co., weighing 85 pounds per yard, heat No. 66825, and branded "8509 Illinois Steel Co. South Wks. VIII–1906." It was laid on tamarack ties, 20 to the rail, with tie plates, the rails being 33 feet long.

The order under which the rails were bought called for the following chemical composition:

	Per cent
Carbon	0.48 to 0.50
Phosphorus	Not over 0.10
Silicon	Not over 0.20
Manganese	0.80 to 1.10

The average composition of rails inspected on August 4, 1906, the month in which the rail was laid, was reported:

	Per cent
Carbon	0.53
Phosphorus	.086
Silicon	.088
Manganese	.95

The dimensions of the rail were:

	Inches
Height	5
Width of base	5
Thickness of web	$\frac{11}{16}$

An intermediate part of the length of the rail was fractured at the time of the accident. The easterly end remained intact for a length of 18 feet 7½ inches, and the westerly end for a length of 8 feet 11½ inches, between which two parts a section 5 feet 5 inches long was fractured. From the ruptured section there were 18 fragments recovered.

FIG. 1.—General view of wreck.

These fragments and three short sections which were cut off by the railway company were forwarded to the Interstate Commerce Commission, Washington, D. C., and by the commission sent to the Bureau of Standards. Subsequently the remaining parts of the rail were shipped to the Bureau of Standards, the entire rail then becoming available for examination and test.

The scene at the derailment is shown by photographs, figures 1 and 2, which were taken soon after the occurrence and while the cars were still burning

The examination of the fragments of the rail and the intact portions showed that it was defective in two respects, the steel was laminated and streaky in both the head and the base, while the rail also had developed a split head

The longest seamy lamination developed at the time of the fracture of the rail in the track was 6½ inches in length, which occasioned a crescent-shaped base fracture, while the fissure of the split head was a little less than 8 feet in length

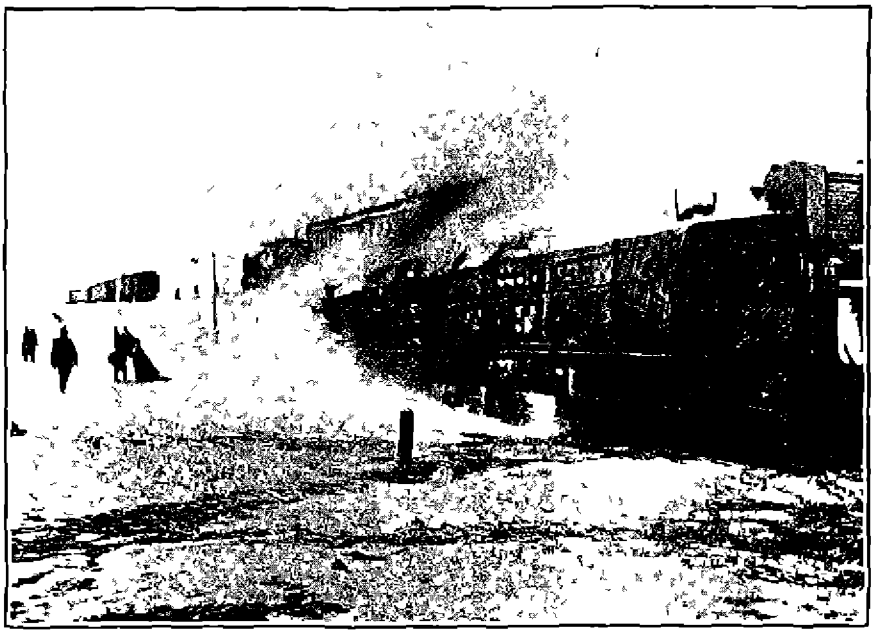

FIG 2 —Dining car burning at foot of embankment

It is believed that the initial rupture at the time of derailment was the crescent base fracture, notwithstanding the greater length of the fissure in the split head The rail necessarily was in a weakened condition by reason of the presence of the split head, but it had undoubtedly been in that condition to some extent for a time preceding the accident The wreck, however, is believed to have been precipitated at this particular time by the development of the base fracture along the line of a laminated seam, which initial fracture was immediately followed by a complete failure at the head, while other lines of rupture followed in rapid succession The opening in the rail eventually reached a length of 5 feet 5 inches

A series of photographs was taken of the fragments of the rail, showing the lines of rupture, viewing the rail in elevation from the gauge side, from the top and from the bottom in plan and certain end views The fragments were so placed that the right sides of the photographic prints or groups represent the east ends of the fragments

Figure 3 shows fragments Nos 2 to 11, inclusive, as they were marked for identification No 1 was a short piece cut off at St Paul, into which the fissure of the split head extended, but which it was not necessary to represent in a photograph

Figure 4 shows the balance of the fragments included within the 5 foot 5 inch section The direction of the movement of train No 3 was from right to left over the rail, as photographed The lines of rupture at the westerly end of piece No 2 and the easterly end of piece No 18 represent the limits between which the track fractures were developed The fissure of the split head extended from a place near the easterly end of piece No 1, along the length of the rail into fragment No 11, an open fissure nearly 8 feet long, while upon etching fragment No 12 the split seemed to be present in that fragment, but could be traced no farther

Concerning the order of events, as they are believed to have occurred during the brief interval of time in which these several fragments were detached, evidence fixes the initial line of rupture at a base fracture between the flange fragments marked 8 and 8a Fragment 8a is abreast that marked 8 and located on the outside of the base of the rail Between these two fragments there was found a longitudinal streak or laminated seam 6½ inches in length and having a depth of about 0 1 inch This line of rupture appeared to have preceded all others in respect to time of development It was followed by the fracture of the web and head between fragments 6 and 7 and that of 9 The fracture at this place extended in an upward direction from the base through the web and head The diverging lines of the fractured surface furnish this indication, while the metal at the running surface of the head between fragments 6 and 9 flaked off that part of the rail having been momentarily in a state of longitudinal compression

The line of rupture between fragments 9 and 10 took a downward course, starting from the top of the head Fragment No 9 was driven downward so suddenly as to cause blue-black heating on the wedge-shaped surface of the web About the time this was happening fragments of the head, 3 and 3a, were detached from the web The fissure of the split head had prior to this however, nearly separated fragments 3 and 3a, longitudinally The next fragment to be detached appeared to be No 6 which was easily knocked off its web by a comparatively light wheel blow then followed 7, 4 and 5

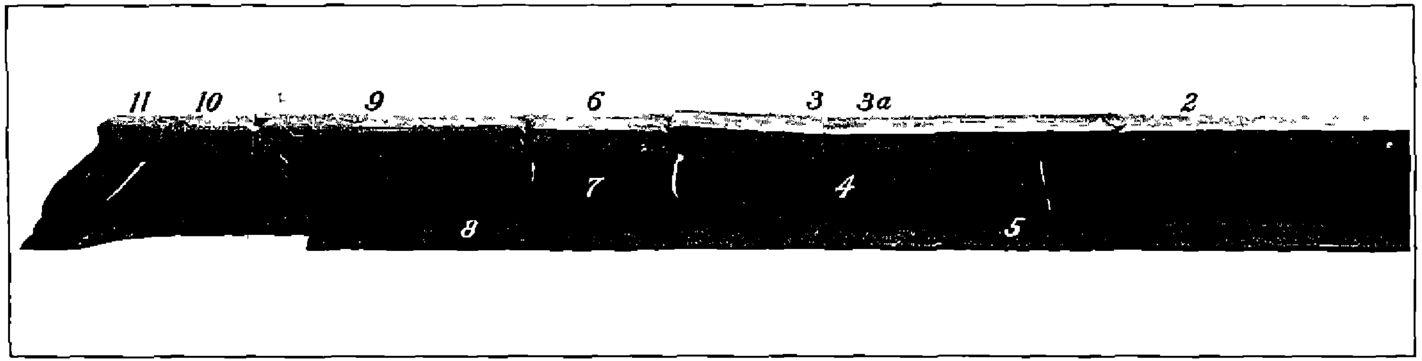

Fig. 3.—Fragments of broken rail, viewed from gauge side. Easterly portion of fragments.

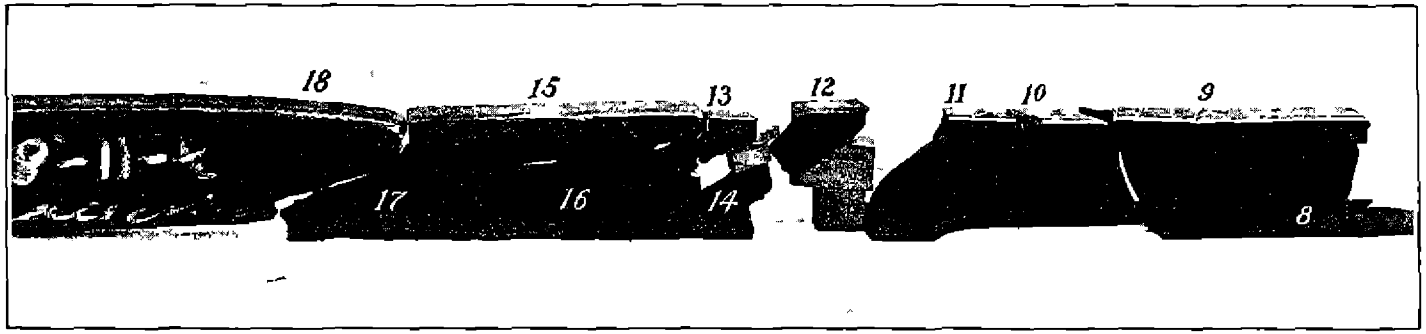

Fig. 4.—Fragments of broken rail viewed from gauge side. Westerly portion of fragments.

In a westerly direction from the initial line of rupture, the several fragments were apparently detached in substantially the order in which they were encountered by the movement of the train one after another in succession being broken off until No 18 was reached The receiving end of this piece was bent downward about an inch below the track level

Figures 5, 6, and 7 show the running surface of the rail The usual dark band along the middle of the head, indicative of a split head, was visible for the greater part of the length which was fissured There was a measurable increase in the width of the head over a considerable part of the length of the fissure No further remarks need be made concerning the appearance of the running surface since the familiarity of track inspectors with such examples is very complete The flaked surface of the head immediately on each side of the fracture between fragments 6 and 9 will be noted on figure 6 The receiving ends of all other fragments were battered by the blows of the wheels as they were in succession detached from the main part of the rail, excepting the halves of the split head Nos 3 and 3a, that were forced off the web

Figure 8 shows the line of rupture between fragments 8 and 8a of the base regarded as the initial line of rupture of the rail at the time of the wreck Evidence concerning this feature of the case seems complete and consistent throughout There were other secondary flange fractures, which also followed seams in the steel, the same as the initial line of rupture Figure 9 shows the appearance of the fractured surface of flange 8 and two other similar fractures In different parts of the length of the rail there were five such flange breaks, two being located in the intact ends of the rail on either side of the part destroyed at the time of the accident

It is characteristic of these crescent-shaped flange breaks that there is little or practically no display of extension prior to rupture of the steel across the laminations Rails may and do display ample extension when the metal is strained in the direction of the length of the rail, that is parallel to the lengths of the laminations, but in a crosswise direction they fracture with great brittleness, when, for example, the flanges are bent crosswise

So far as known, there is no material difference between the streaks and laminated seams of the head and those of the base, excluding those of the base which chance to have their origin in laps during rolling Wherever there is a lack of structural continuity in the steel brittleness may prevail when the steel is overstrained at right angles to that discontinuity Overstraining more readily occurs in the base or in the flanges of the base than in the head of the rail that is, the stresses may more readily reach the necessary maximum in the base For this reason probably flange breaks are more numerous than split heads, and not from any substantial difference in the relative degree of lamination of the steel in those two parts of the rail The manner of accomplishing overstraining is quite different in the head than in the base, and it may be inferred from the example of

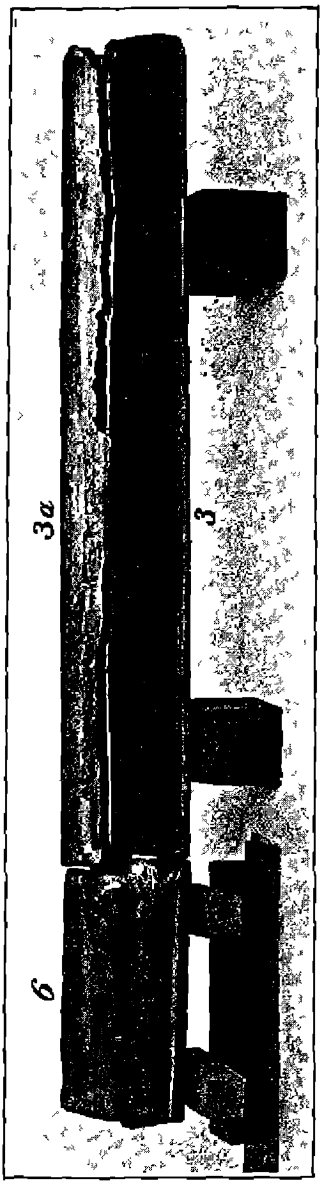

Fig 5 —Fragments of broken rail, viewed from top Easterly portion of fragments Showing battered receiving end of fragment No 6

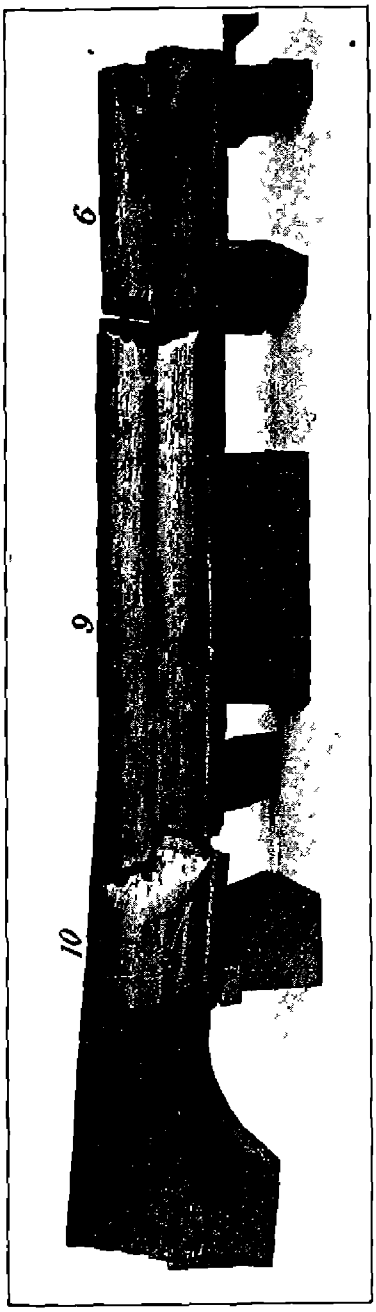

Fig 6 —Fragments of broken rail, viewed from top Middle portion of fragments Showing battered receiving ends of fragments Nos 6 and 10, and where metal flaked off between Nos 6 and 9 this rail that, relatively defects in the base are of a more grave character and lead to more rail fractures than defects which are in the head.

The fissure in the split head of the present rail reached a length of nearly 8 feet, and during the period of its development doubtless many trains passed over the rail, whereas the base fracture was of a less progressive character and not unlikely was wholly developed by the wrecked train. Laminated seams are regarded as a common cause for many of the base fractures and for many of the split heads.

Figure 10 shows end views of several fragments, illustrating the size attained by the fissure of the split head. Such a fissure could not reasonably have been formed by the passage of a few trains but was one of progressive development and since its incipient stage had been in existence for a considerable length of time. It is less disquieting than certain other fractures, any of which may lead to ultimate disaster, in that it admits of being discovered in the track in time to avert an accident; nevertheless it is undesirable, as all defects are which may cause injury and loss of life.

Figure 11 shows the two fragments of the head, one on either side of the fissure which constituted the split. These pieces were each about 18½ inches long. While the evidence presented in the fragments was not sufficient to definitely establish the place along the length of the rail where the fissure in the head had its origin, still there was

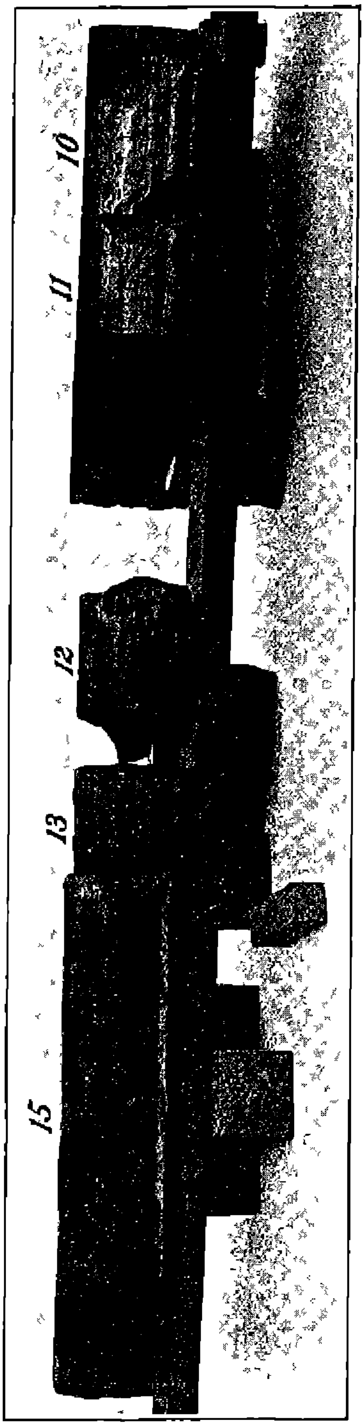

FIG 7.—Fragments of broken rail viewed from top. Westerly portion of fragments. Showing battered receiving ends of each fragment.

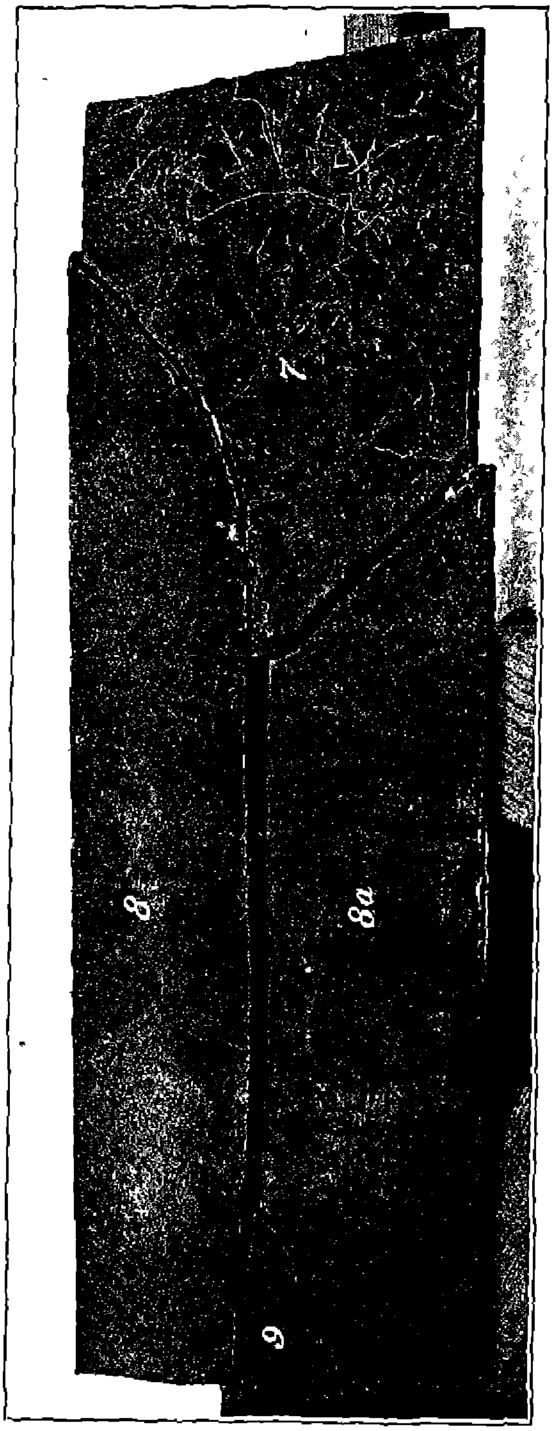

Fig 8—Base fracture of rail between flanges 8 and 8a Believed to have been the initial line of rupture at time of wreck

a suggestion that the place was located near the westerly end of these fragments and extended in each direction therefrom There was no evidence of slag along the line of the fissure, that is, no more than that which may have been present in the laminated streaks No slag pocket or inclusion of size was present

If the fissure had its origin at the place suggested, then it occurred in the immediate vicinity of metal high in carbon content compared with other parts of the rail Analysis showed the carbon to be 0 73 per cent in the lower part of the center of the head, against 0 53 per cent near the running surface There was also segregation of phosphorus and sulphur in the vicinity The segregated metal was found near the junction of the head with the web

It does not follow that the proximate cause of the split head was segregation, but it may have been the combination of high carbon steel at the center of the head with laminated seams interposed between that and a medium carbon steel at the running surface Such a combination seems adequate to induce the formation of a *longitudinal fissure*, which would constitute a split head when extended and developed This is a statement of the case why the laminated state of the metal is regarded as a common cause for certain of the fissures of this type, and for certain of the crescent-shaped base fractures

The combination is regarded as an unfavorable one, since a seam in hard steel is a greater menace than one in soft, ductile metal

And further, the soft surface metal of the rail, readily responding to the cold rolling action of the wheel pressures, introduces internal strains which, taken together with the direct wheel loads, may cause excessive lateral stress in the head of

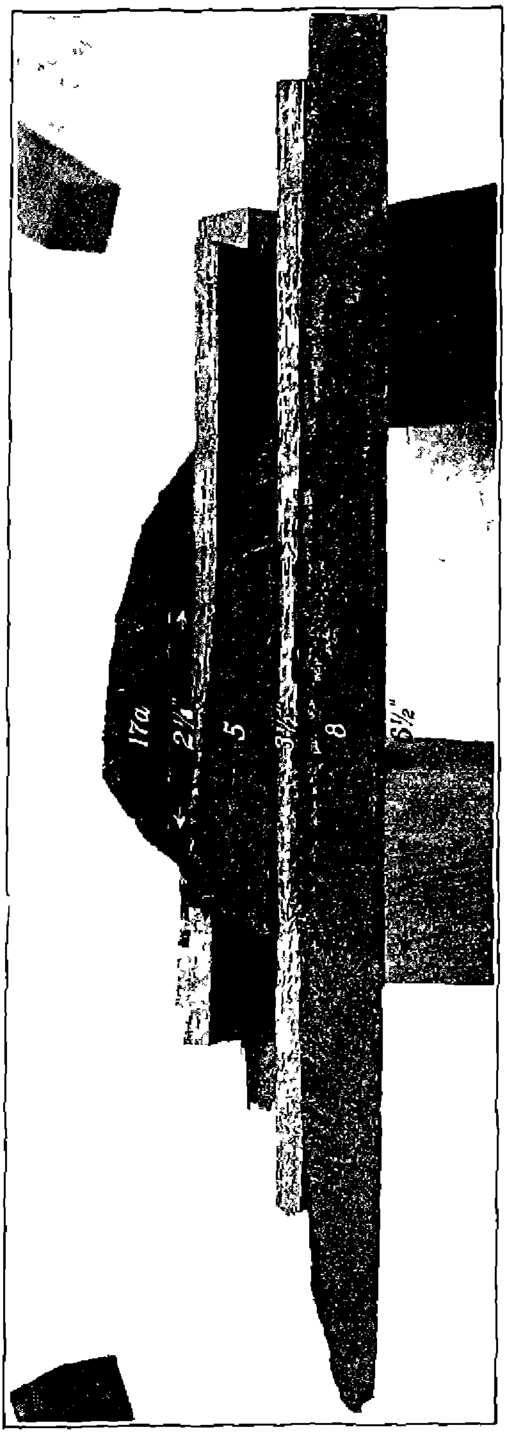

FIG 9 —Appearance of fractured surface of flange 8 and two others Each *fractured surface displayed one or more laminated seams*

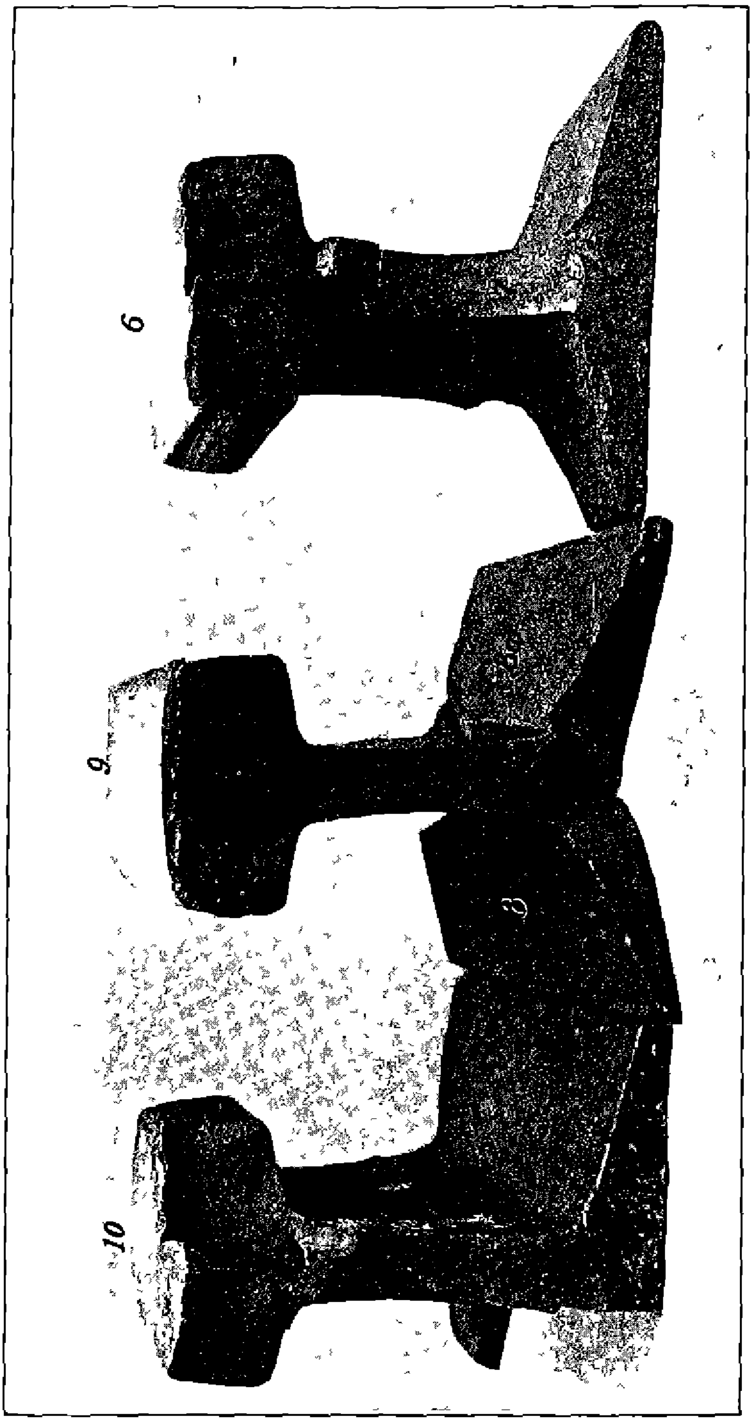

FIG. 10.—End views of fragments showing size of fissure of the split head

the rail The great strength of the head against crosswise stresses generally prevents the formation of fissures which would occasion split heads, otherwise their more common occurrence would be expected

It has been shown on earlier occasions that internal strains of great intensity may be introduced in steel by means of cold rolling or hammering An experiment of this kind was repeated on the metal from the head of the present rail Strains of tension were introduced by means of a small hand hammer reaching an intensity of 25,000 pounds per square inch The surface metal, which was disturbed by the hammer blows, was put into a state of initial compression sufficient to strain the metal in other parts of the bar, in tension in the amount above mentioned

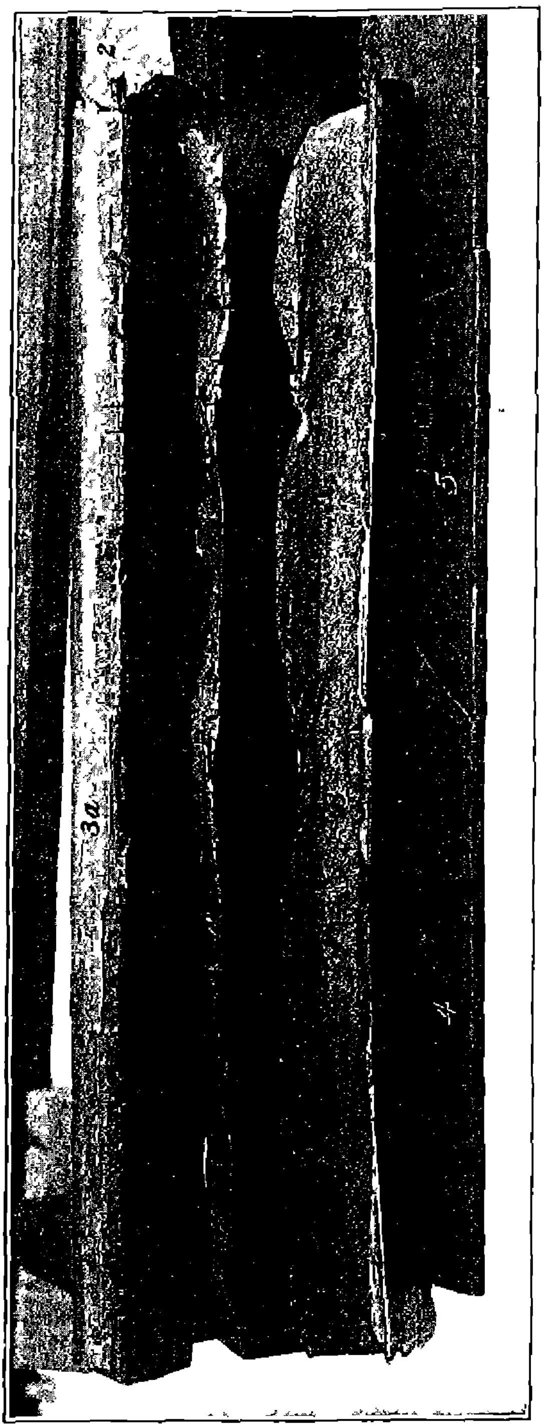

Fig 11 —Showing two parts of split head fragments 3 and 3a, believed to have been detached from rail next succeeding the base fracture, between flanges marked 5 and 5a

The cold flow of the metal at the running surface of a rail is witnessed in the fin which frequently forms on the outside of the head Incipient longitudinal cracks have been found in the heads of rails, and those incipient cracks have been on the lines of streaks

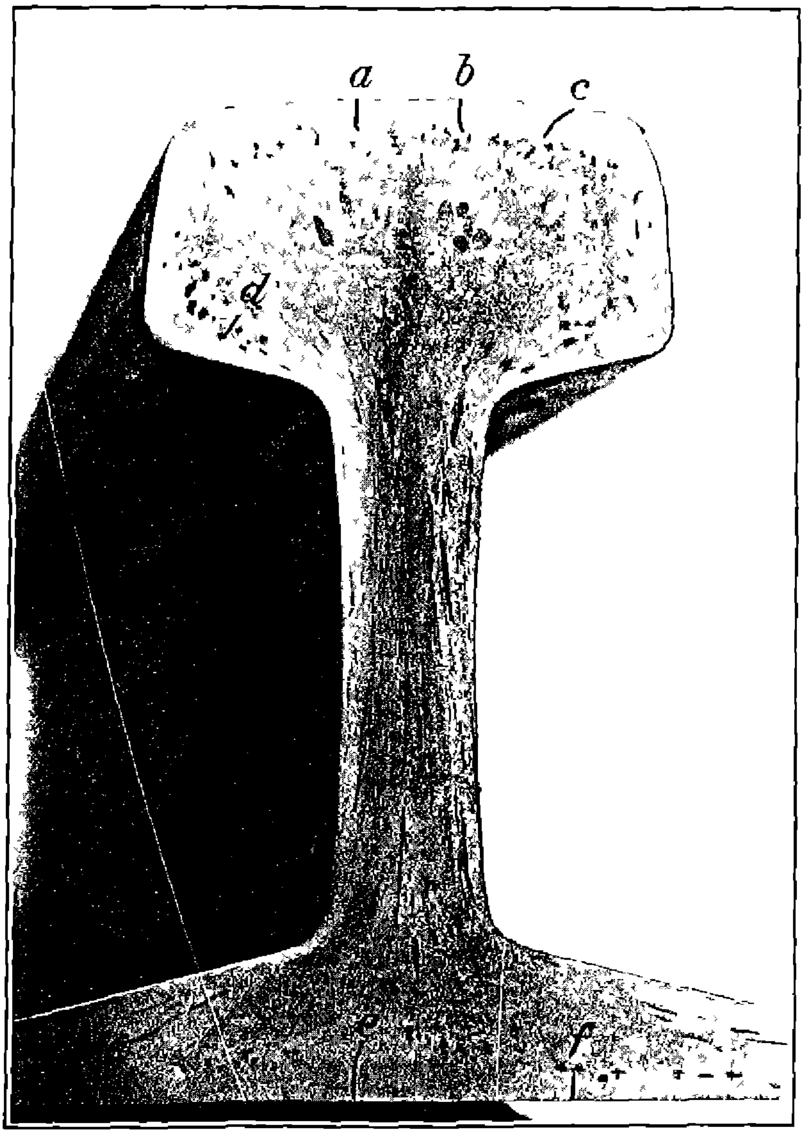

FIG 12 —Cross section of rail piece marked No 1 beyond limits of split head Laminated seams at places marked *a* *b* *c*, *d*, *e* and *f*, revealed by bending a thin section of the rail

Figure 12 represents a polished and etched cross section of the rail just beyond the end of the fissure of the split head A thin section was taken and ruptured in six places four in the head and two in the base, by transverse bending Each fracture displayed a laminated seam, one of which was attributed to the lateral cold flow of the surface metal of the head from the wheel pressures, the others to the initial structural condition of the steel

Figure 13 shows a cross section of the rail at the westerly end of piece No 1, in which the fissure of the split head appears Carbon determinations were made from chips taken at the places

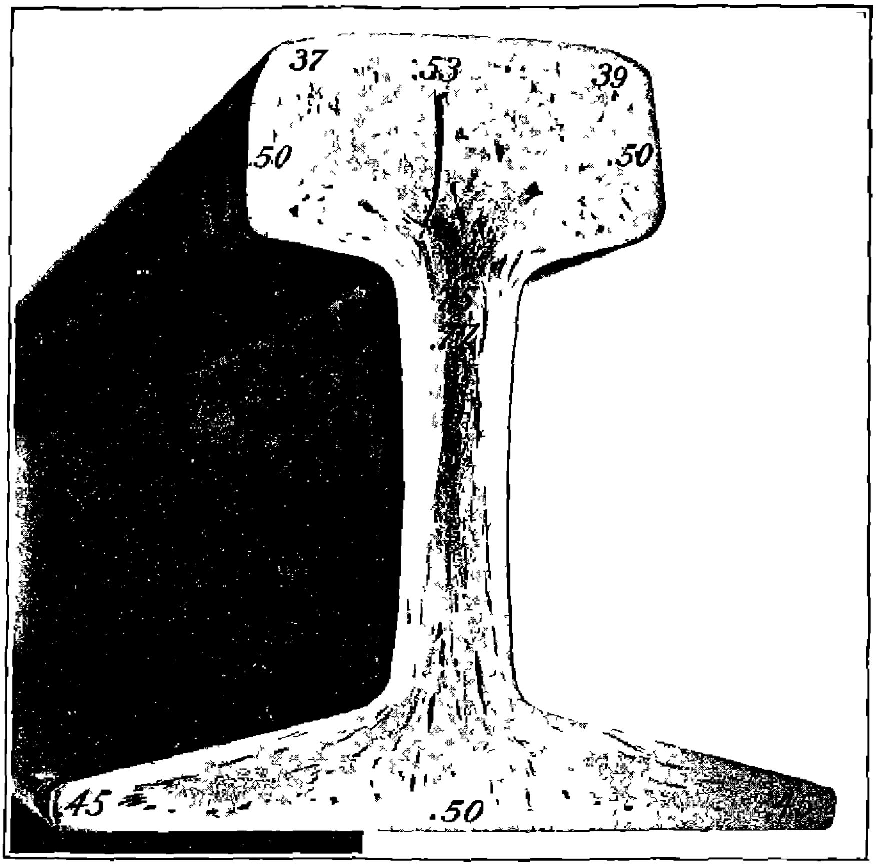

Fig 13 —Cross section of rail, piece marked No 1, showing fissure of the split head Figures on illustration show percentage of carbon found at different parts of the head web and base

indicated on the figure It will be noted that the range in carbon was from 0 45 per cent to 0 77 per cent the lower carbon metal being found near the surface of the rail Subsequently other determinations were made, using chips taken nearer the top surface of the head and the minimum carbon content there found was 0 37 per cent

It is customary in current specifications to accept a chemical analysis from a test ingot as representative of the heat of steel but unless the heat represents the rails there would seem to be no particular advantage in having the analysis

The carbon determination of 0 53 per cent reported on August 4, 1906, was apparently considered as representing the metal in the rails delivered at that time, but it certainly did not apply to the cross section of this rail, which shows a range in carbon from 0 37 per cent to 0 77 per cent Questions of decarburization as well as of segregation are involved in a discussion of this aspect of the case, but results are quite meaningless which fail to indicate the composition of the rails regardless of the composition of the test ingot It seems inconsiderate to appeal to seriously refer to the composition of the rail in which one part contains 100 per cent more carbon than another part

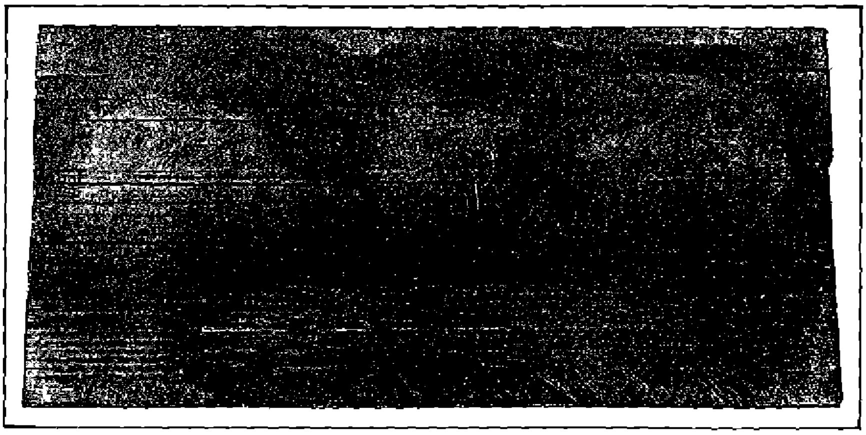

FIG 14 —Base of rail, from piece marked No 1 rough polished and etched to show location of seams Appearance before crosswise bending

FIG 15 —Base of rail from piece marked No 1, showing brittle fractures developed along lines of seams by crosswise bending

Further considering the influence of lamellar streaks on the extension of the metal, specimens were prepared from both the base and the head of the rail, and bending tests were made with them, illustrating the brittleness of the metal when subjected to crosswise stresses The results are of interest, since crosswise stresses are held to be directly accountable for the flange breaks in the bases of rails in service Tests should certainly be made in the direction in which numerous fractures occur in order to demonstrate the useful properties of the rail in the track Such tests should be made and not ignored in any earnest effort to secure structurally sound rails

FIG 16 —Base of rail, from piece marked No 1 Brittle fractures completed, separating base into three strips

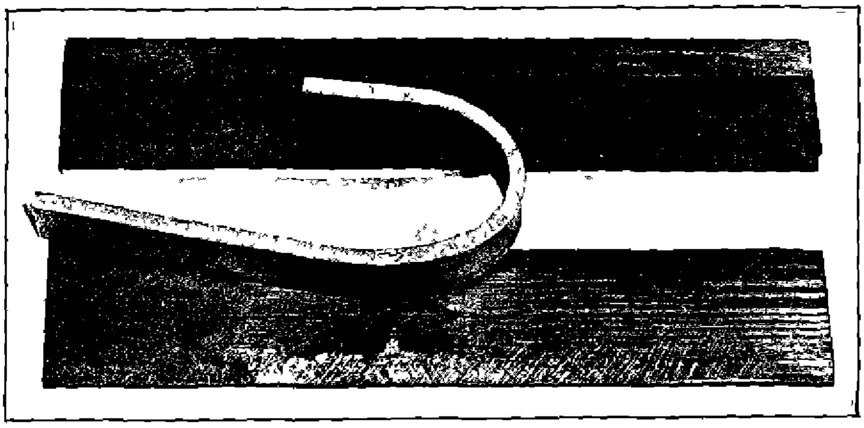

FIG 17 —Base of rail, from piece marked No 1 Appearance of middle strip which after having been detached by brittle crosswise fracture displayed good bending qualities when bent in lengthwise direction of the rail

Figures 14 to 17, inclusive, form a group illustrating the result of bending a piece of this rail in a crosswise direction In preparing this specimen the base was planed off from the web side to a thickness of one-fourth of an inch It was then rough polished and etched, to show the location of the streaks which appeared, as shown by figure 14 at the middle of the width of the piece The specimen was then bent in a crosswise direction, starting two fractures, practically without the display of any extension of the metal, as shown by figure 15

The fractures were completed, separating the base into three strips, shown by figure 16 Thus it was shown that the metal of the base was devoid of the ability to display permanent extension without fracture when bent in this direction but the result merely conformed with experience in the track, where brittle base fractures of this class are of common occurrence

The middle strip of the fractured base was next bent in a lengthwise direction, with the result shown by figure 17 It bent through an angle of 180 degrees without rupture This bend was made in the direction in which rails are currently tested for acceptance When the metal is bent in a lengthwise direction or parallel to the direction of the longitudinal seams and laminations, the presence of such seaminess, which causes brittle crescent-shaped base fractures in the rails in the track passes undetected

A similar test was made with a specimen from the head of the rail This was planed down from the under side, to a thickness of three-

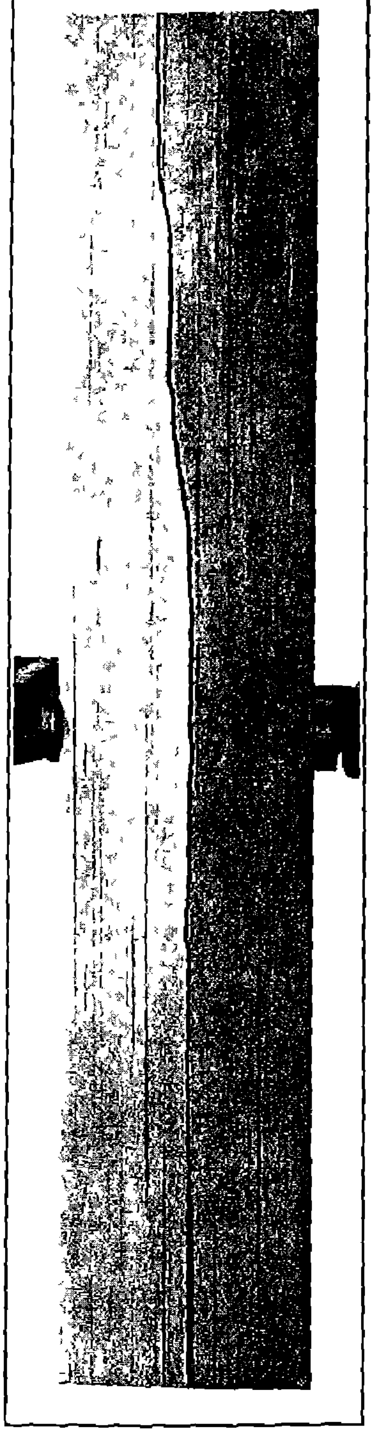

Fig 18 —Head of rail, from piece marked No 18 Showing brittle fracture developed along line of seam by crosswise bending eighths of an inch It was bent in a crosswise direction, after having been polished and etched to locate the streaks Fracture occurred along the line of a streak, in a brittle manner Figure 18 shows the appearance of the specimen after fracture

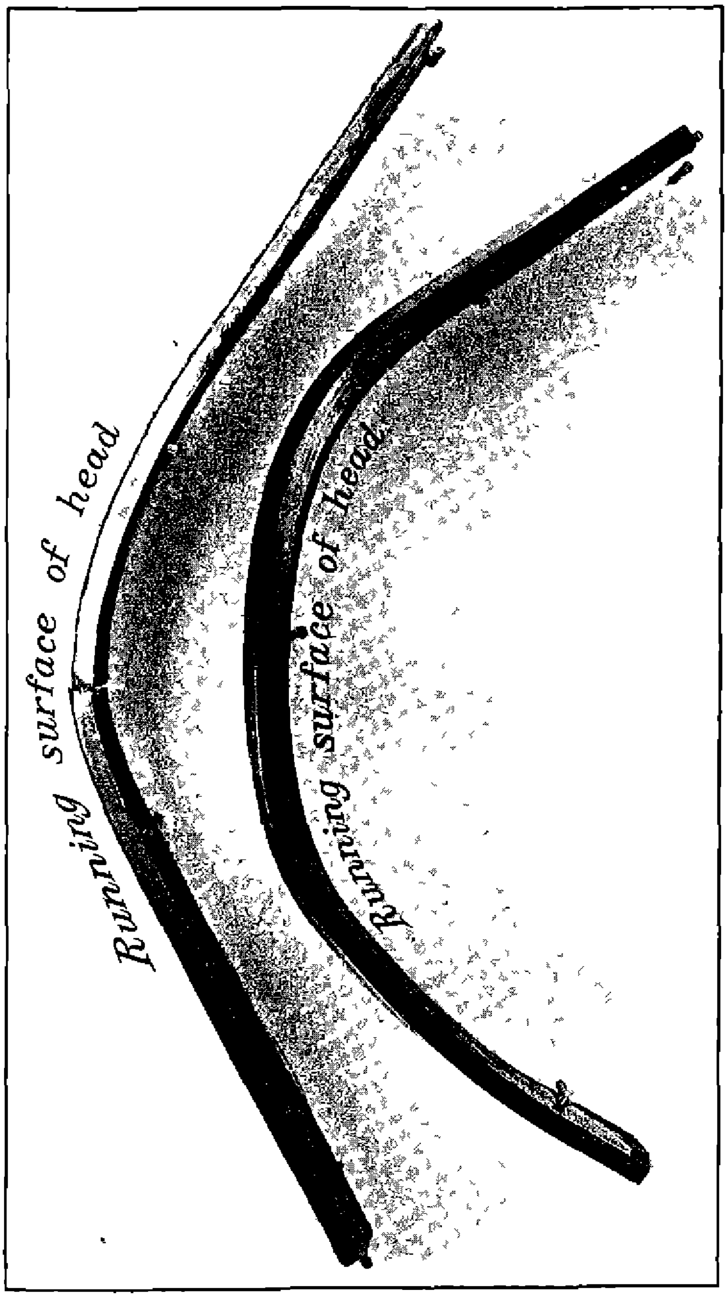

FIG 19 —Head of rail, from piece marked No 18 Appearance of strips which after having been detached by brittle crosswise fracture displayed good bending qualities when bent in lengthwise direction of the rail

The two strips were subsequently bent in a lengthwise direction with the result shown by figure 19 The upper strip of the figure was bent with the running surface of the head on the tension side of the bend the lower strip with the running surface on the compression side

The fissure of the split head terminated at a place near the end of the piece which was marked No 1, for identification A short section of the head was cut off where the fissure ended Two views of this section are shown by figure 20, an end view and an interior one after wedging off the outside portion of the head The fissure in its course had deflected, leaving the center line of the head and approaching the outside edge

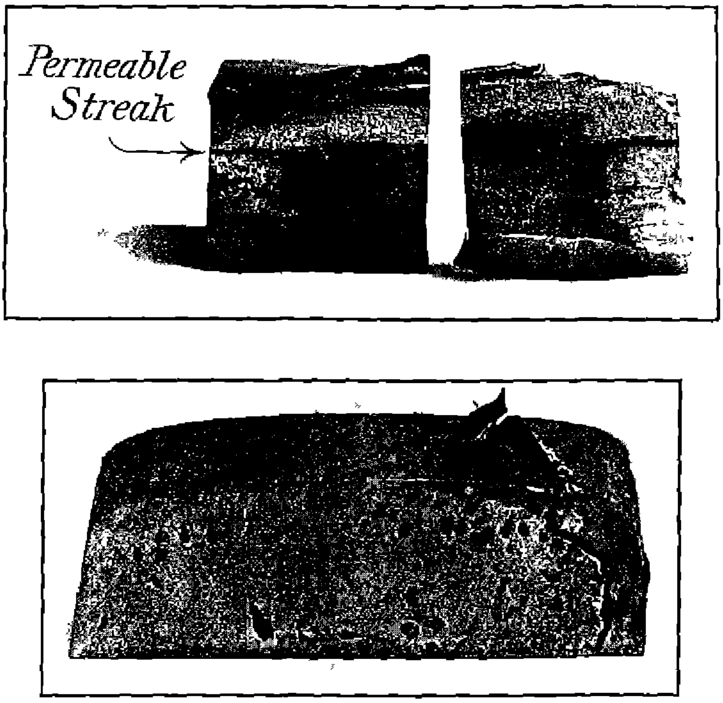

Fig 20—Head of rail at end of fissure of split head Showing surface of fissure with permeable acicular streak and etched end view

Tincture of iodine had been used on the section, which darkened the surface of the fissure It also darkened an acicular streak, which seems to indicate that a permeable streak had existed in the head since rolling or had been made permeable in the track In either case it furnishes an additional example of defective metal in the head

The appearance of two additional etched surfaces is shown by figure 21 These surfaces represent the metal within 1$\frac{5}{8}$ inches from either end of the full length 33-foot rail The section on the left displays a crack penetrating the inside flange from the upper

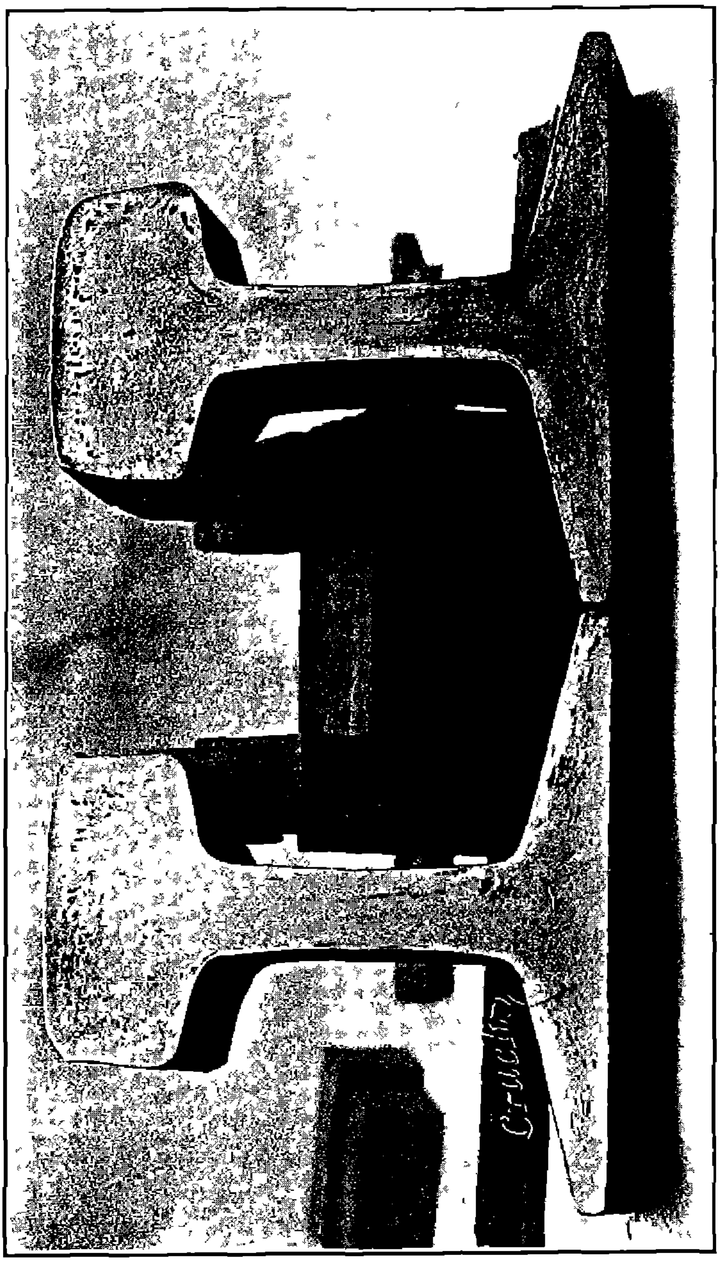

FIG. 21.—Etched cross sections, near opposite ends of rail Showing crack in flange entering from upper side, which started at a seam in the steel

surface This crack had its origin at the extreme end of the rail and started at a well-defined seam in the metal in the fillet at the junction of the web and base It would seem that the rail had been used with splice bars of the Wolhaupter type and that the fracture of the flange from the upper side had been occasioned by a strain of tension at the fillet The selective character of the stress in locating an incipient fracture at a seamy streak will be noted

Streaks and lamellar seams are known to be frequent occurrences and are recognized as detrimental to the integrity of the rails It is important to review the question of their origin It seems consonant with evidence acquired to attribute a considerable part of the responsibility for the presence of such streaks and seaminess in the finished rails to the condition of the metal in the ingot A series of illustrations on this feature could be furnished, following the metal through the successive passes of the mill in the reduction of the ingot to the finished rail

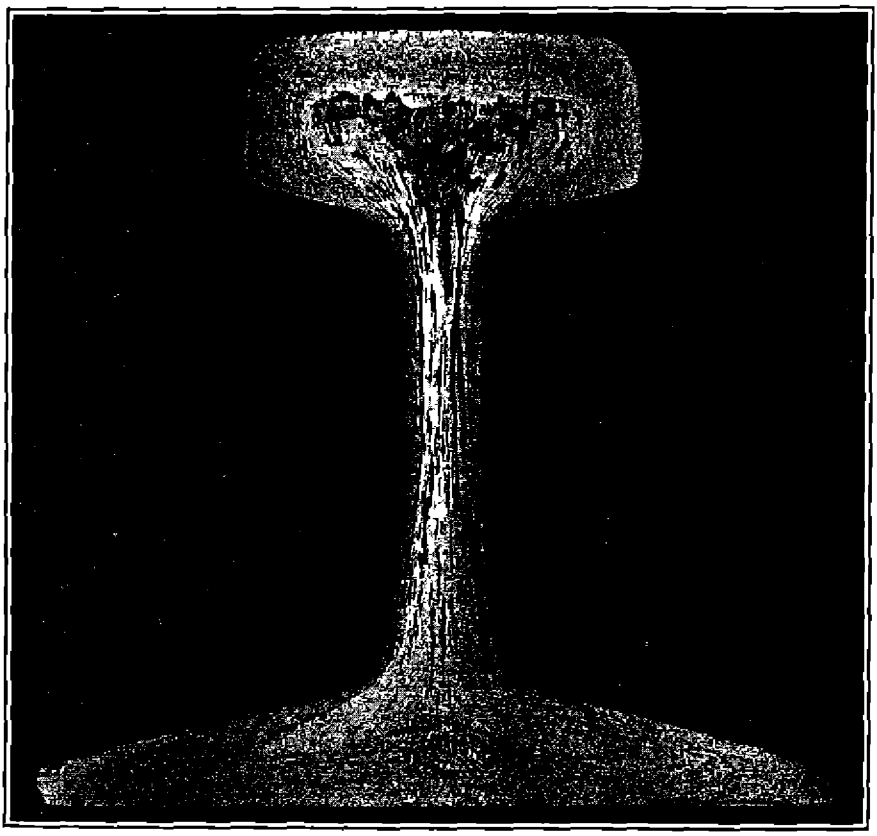

FIG 22 —Etched cross section of a rail, rolled from an ingot which was laid on its side to cool, head side of rail up Reproduced cut from earlier rail tests

However, such illustrations have already been published in congressional documents, which are accessible to all Next following, however, two cuts will be reproduced which show that a certain degree of control of the markings, which are brought out upon etching, can be exercised by the handling of the ingot and one other cut will be reproduced which shows the presence of markings near the periphery of a section after an early pass through the rolls of the rail mill

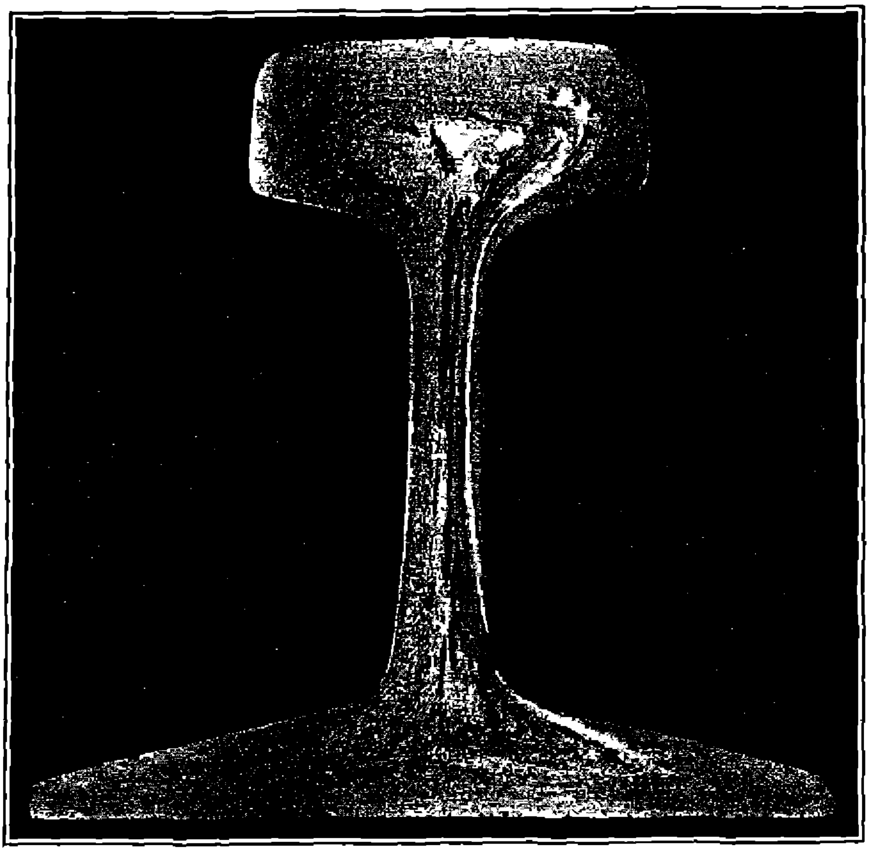

FIG 23—Etched cross section of a rail rolled from an ingot which was laid on its side to cool web side of rail up Reproduced cut from earlier rail tests

The ingot from which the rail, shown by figure 22, was rolled, was laid upon its side to cool after stripping, with the side up which formed the head of the finished rail, while the ingot from which the section shown by figure 23 was rolled was laid down with the side up which formed the web of the rail The orientation of the markings was accordingly modified as witnessed in the cuts

Figure 24 shows the section of an open-hearth steel rail ingot after the seventh roughing pass This section was taken near the middle of the height of the ingot, or 52 per cent from the top The markings are in kind not unlike those which are witnessed on the cross sections of finished rails

Blowholes and slag inclusions found in ingots seem adequate to account for the presence of certain streaks and laminations in the subsequent shapes down to the finished rail The following table states the number of blowholes and slag inclusions which were counted on the surfaces of slices from different parts of an ingot These figures state the counts made upon one-quarter of the cross section of the ingot, and should be multiplied by four to represent the probable total number on the full cross section

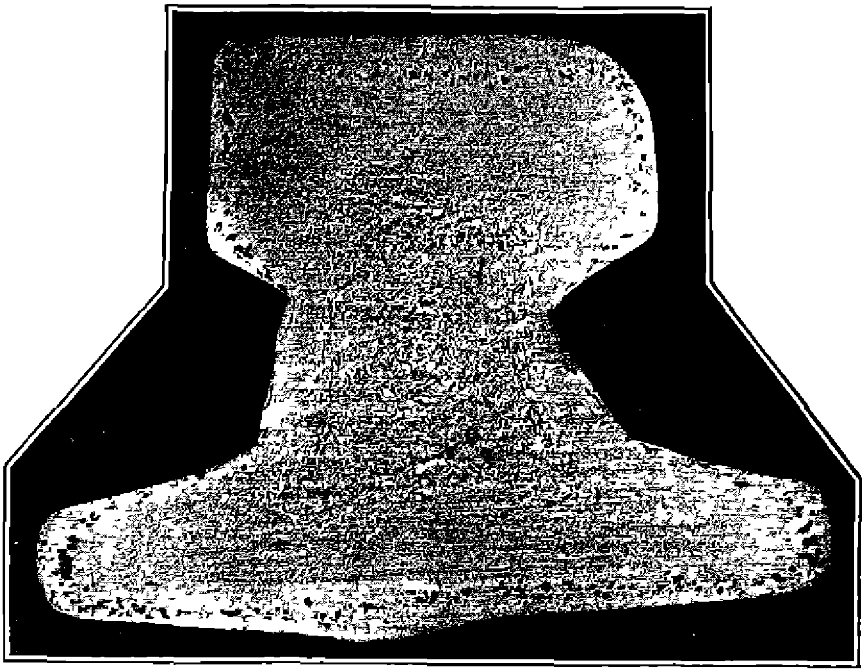

FIG 24 —Etched cross section of shape after the seventh roughing pass Open hearth rail steel Reproduced cut from earlier rail tests

Blowholes and slag inclusions in the surfaces of slices from one-quarter of a rail steel ingot

No of slice	Distance from top of ingot (by volume)	In surface of slice: Approximate number of blowholes	In surface of slice: Approximate number of slag globules	Maximum diameter of slag globules
	Per cent			
1	3 7	410		
2	4 6	229	7 slag buttons	
3	7 5	128	2 slag buttons	
4	10 4	78	3 slag buttons	
5	13 3	66	3 slag buttons	
6	16 3	60		
7	19 2	71		
8	22 2	79	8 slag buttons	
9	25 2	92		
10	28 2	93	12 slag buttons	
11	31 3	70	6 slag buttons	
12	34 3	56	9 slag buttons	
				Inches
13	37 4	27	250	0285
14	40 1	20	206	0204
15	43 5		228	0277
16	46 7		268	0249
17	49 8		263	0091
18	52 9		401	0161
19	56 1		355	0139
20	59 3		343	0156
21	62 5		449	0211
22	65 7		560	0146
23	69 0		741	0214
24	72 2		1,085	0089
25	75 5		1,053	0280
26	78 8		968	0105
27	82 1		899	0203
28	85 4		1 116	0248
29	88 7		1,648	0229
30	92 1		1,703	

Slag buttons lodged on the lower surfaces of a number of the blowholes The table gives the number which were found on the quarter ingot slices The slag inclusions were in globular form and located near the edges of the ingot along the middle part of its height In the lower slices the inclusions were found in the central part of the ingot

Drop tests were made upon three pieces of the rail The details of the tests were conducted in conformity with current specifications, that is the distance between supports was 3 feet, weight of tup 2,000 pounds, and height of drop 17 feet The first piece, tested with the head up, fractured on the first blow, displaying an elongation of 5 per cent and 7 per cent, respectively, for 2 consecutive inches, the fracture showing no interior defect, that is, the structural defects known to exist in the rail were not revealed by the drop test, the fracture being reported as having no interior defect

The rail thus fulfilled current specifications in respect to elongation of the metal and interior soundness

In the two succeeding drop tests the elongation ranged from 3 per cent to 5 per cent, the fractures as before revealing no interior defect. There was a fourth test made on the full section, a transverse test under static conditions in the testing machine. The distance between supports was 5 feet. This test permitted of the determination of the elastic limit of the rail, an important factor in the strength of materials but not ascertained in the prescribed drop test. The elastic limit was 57,000 pounds per square inch. The rail was bent through an angle of 30 degrees without rupture, the base elongating 15 per cent and 16 per cent, respectively, for 2 consecutive inches.

The difference in the display of elongation in the two kinds of tests will be noted, as well as in the angle through which the rail was bent, which, in the drop test, was but a few degrees, against 30 in the testing machine.

In order to determine whether the particular pieces of rail which fulfilled the requirements of the drop test in respect to extension and soundness were in reality free from laminated streaks and seaminess two of the fractured ends were subjected to crosswise bending of the metal of the bases. The results showed the metal of these pieces seamy as other parts of the rail had been found. Lamellar base fractures of these two pieces are shown by figure 25, in which the brittleness displayed by the steel will be noted.

Prominence is given the subject of laminated streaks in this report since there can hardly be a reasonable doubt concerning the important part which they play in causing rail fractures in service. The gravity of the case requires emphatic mention of this feature. The subject is not a new one, but has in the past been placed before engineering and technical societies and associations having to do with specifications. From 4 to 6 years have elapsed since it has been recognized that laminated streaks were prevalent in steel rails and a prolific cause of fractures. Not less than 15 years have elapsed since the presence of streaks in steel forgings has been a source of anxiety.

Congressional documents under date of 1908 and 1909 have dealt with tests and examination of steel rails along the lines of this report and these documents have been furnished 475 libraries located in different parts of the country, while copies of these documents have been available for public distribution.

Tension tests were made on the metal of the rail, taking out specimens in both longitudinal and transverse directions.

A longitudinal specimen from fragment No. 3a gave the following results:

Elastic limit	pounds per square inch	54,500
Tensile strength	do	106,500
Elongation in 3 inches	per cent	17.3
Contraction of area	do	29.0

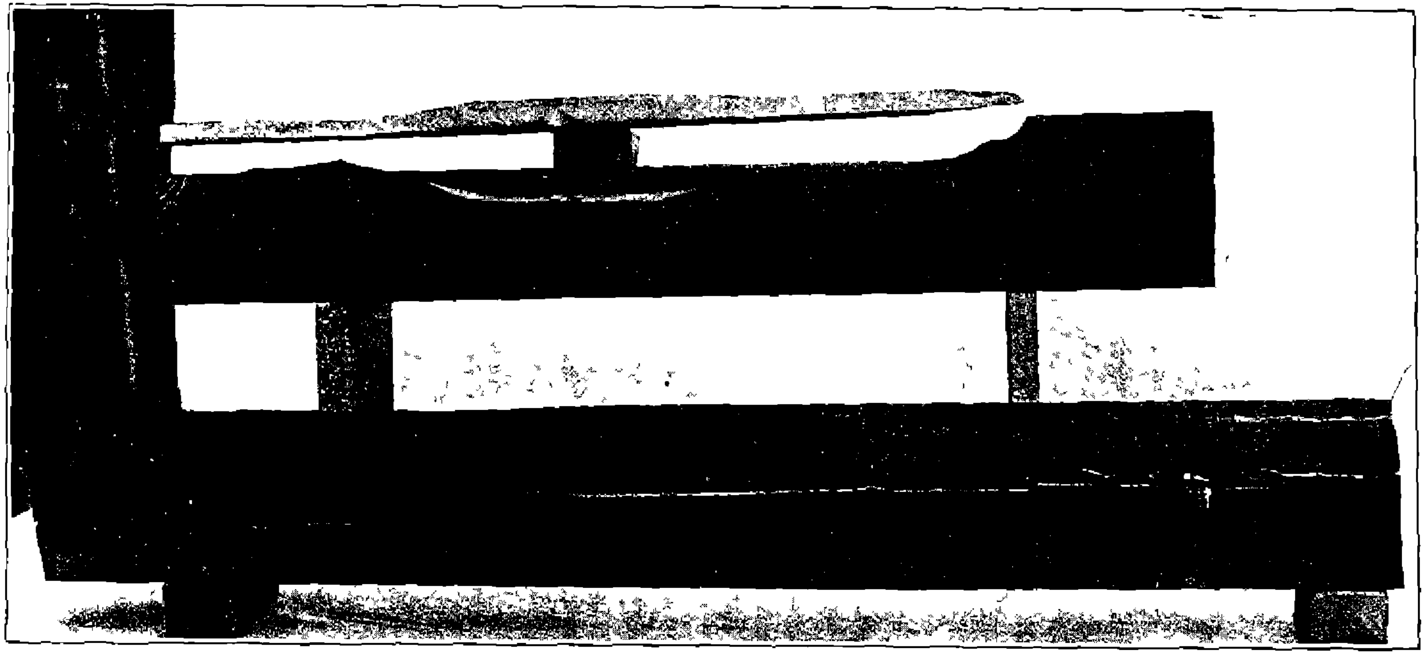

Fig. 25.—Ends of rail after drop test, showing brittle seamy fractures developed by crosswise bending. Pieces in which these interior defects were not revealed by the drop test.

At the segregated part of the head the tensile strength rose to 124,000 pounds per square inch In a crosswise direction the metal was brittle and displayed lamellar streaks in specimens, both from the head and from the base The tensile strength dropped to 83,600 pounds per square inch, with only 2 per cent elongation and 2 per cent contraction of area

It is important to consider whether an improvement in the structural condition of rail steel is attainable Such seems to be the case, since experimental rollings have furnished rails which, so far as could be ascertained, were free from streaks A critical examination and test failed to reveal any streaks or laminations in the bases of those rails It is inferred from data at hand that the output of individual mills fluctuates, at times approaching nearer the desired state of excellence than at other times It is believed to be metallurgically feasible to produce better rail steel than has at times been offered and accepted

In conclusion, it appears that the immediate cause of the wreck of train No 3 was a defective rail

That two defects were present in the rail, laminated seams which weakened the base and a split head

That the proximate cause of the fracture of the rail was the weakness of the flanges of the base by reason of laminated and streaky metal

That laminated and streaky metal is present, without a reasonable doubt, in many rails now in service

That such metal has been the direct cause of the fracture of many rails in the track for a term of years past

That it is metallurgically feasible to manufacture and furnish rails less defective than have found their way into the track

That such defective rails are a menace to safe travel

That specifications governing the acceptance of rails are inadequately drawn to exclude from acceptance defective rails

That one of the most common types of rail fractures is not guarded against by current specifications, referring to the base fractures of the crescent-shaped type

That the defects, in part, have their origin in the metal while in the state of the ingot

That streaked and laminated metal in both the head and the base is probably a common cause for certain of the split heads and generally the cause for the flange breaks of the base, the magnitude of the wheel loads being understood as sufficient to apply the necessary overstraining force

That the chemical analysis of the usual test ingot does not furnish assurance of the chemical condition of the finished rail

That the presence of interior defects of a serious character, which have caused a great number of rail fractures, is not revealed by the drop test.

It is believed that when seaminess and lamination of the metal shall have been eliminated, a very important advance will have been made in steel-rail manufacture. Until that result is assured one of the vital features of the rail problem will remain unaccomplished. Assurance of the structural soundness of the ingot and subsequent shapes down to the finished rail will be furnished when a careful and critical examination of the metal at the different stages shall have been made. It is entirely inadequate for the purpose to make a cursory examination of the ingot. There is reason for believing that disasters of the kind caused by the breaking of the present rail will be of less frequent occurrence when structurally sound rails are put into service.

Respectfully submitted,

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Engineer-Physicist.

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