INTERSTATE COMMERCE COMMISSION

REPORT OF THE CHIEF OF THE DIVISION OF SAFETY, COVERING THE INVESTIGATION OF AN ACCIDENT WHICH OCCURRED ON THE PENNSYLVANIA RAILROAD NEAR NEWARK, N Y, ON FEBRUARY 16, 1917

MAY 19, 1917

To the Commission

On February 16 1917, there was a derailment of a passenger train on the Pennsylvania Railroad near Newark N Y, which resulted in the injury of two passengers and two employees After investigation as to the nature and cause of this accident, I beg to submit the following report

The train involved in this accident was northbound passenger train No 8425 consisting of one combination baggage and smoking car and one coach, hauled by locomotive 4160, and was in charge of Conductor Marriman and Engineman Maloney It departed from Stanley, N Y according to the train sheet, at 3 32 p m, on time, left Fairville N Y the last stopping point previous to being derailed, at 4 36 p m one minute late, and at about 4 40 p m was derailed at a point nearly 1½ miles beyond Fairville or 5 miles north of Newark, while traveling at a speed of 35 or 40 miles an hour

The engine remained upright on the roadway with some of its wheels derailed, and was not materially damaged The tender turned over on its side while both of the cars in the train were derailed, but remained practically upright no serious damage being sustained by any of the equipment

This part of the Pennsylvania Railroad is a single-track branch line, 34 miles in length, on which train movements are governed by a manual block signal system The point of derailment was on a long curve of 1 degree, leading to the right, on a slightly ascending grade The track is laid with 60-pound steel rails, 30 feet in length on an average of 17 oak and pine ties ballasted with cinders Tie-plates were used on the pine ties The weather was clear

Engineman Maloney stated that his train was traveling at a speed of 35 or 40 miles an hour when he felt the locomotive derail and he at once made an emergency application of the brakes the train being brought to a stop within a distance of 367 feet Careful examination of the wheels and flanges of the derailed equipment failed to show anything which could have contributed to the accident Examination of the track showed that there was a broken rail on the inside of the curve, the first marks of derailed wheels on the ties being 18 feet beyond the first break in the rail which was broken into a large number of pieces Trackwalker Day stated that he had passed over this part of the track about five hours previous to the derailment, and at that time he found everything to be in good condition According to the train sheet one northbound and three southbound trains had passed over the track between the time it was inspected by Trackwalker Day and the time of the derailment, the crews of none of these trains noticing anything wrong with the track

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

Acknowledgment is made of the cooperation in this inquiry of the officials of the Pennsylvania Railroad Co and of the Cambria Steel Co

REPORT OF THE ENGINEER-PHYSICIST

The rail which broke and caused the derailment of train No 8425, February 16, 1917 on the Sodus Bay Branch of the Pennsylvania Railroad, was a 60-pound rail rolled by the Cambria Steel Co in March, 1887 and laid in the track in the following June It bore the brand marks Cambria Steel 87 III

The type of fracture was split head Failure took place in the receiving half of its length About 3 feet of the rail, at its immediate receiving end remained intact Beyond this part there was a broken section, 8 feet 4 inches long followed by an unbroken section 18 feet 8 inches long, completing the length of the rail 30 feet The unbroken section was locally bent at the time of the derailment Forty-eight fragments of the broken section were recovered

The appearance of the recovered fragments is shown by figure No 1 some of the fragments being assembled in their relative places, while others were laid in a row, their places in the intact rail not having been established

The top of the rail showed an increase in width of 0 18 inch, as nearly as could be judged when the fragments were put together This increased width corresponded substantially with the width of opening of the seam in the head, a relation generally found in split-head rails

Lateral flow of the metal occurred in the shallow zone between the running surface of the head and the upper edge of the seam. The formation of a split head is attributed to the wedge action of the steel in this affected zone, reaching streaked metal, starting an incipient seam where the metal of the head in a crosswise direction is deficient in strength or in ductility or both. The incipient seam gradually develops in length and in depth until there is complete separation of the head.

Longitudinal seams or lines of rupture with serrated surfaces were shown on the fragments of this rail. The head was split along the greater part of the 8-foot 4-inch broken section.

Figure No. 2 is a view of the top of the head, the fragments comprising this part of the rail being placed approximately in their relative positions. Figure No. 3 is a view of the under side of the head showing a serrated portion below the running surface of the outside half of the head. This part of the ruptured surface had been hammered comparatively smooth by the passage of trains over the rail, evidence of the progressive character of its failure.

A macroscopic examination was made of a full cross section of the rail near the broken portion, followed by a microscopic examination of the steel in that vicinity. The macroscopic appearance of the rail is shown by figure No. 4, representing a cross section after it had been polished and etched with tincture of iodine. There were zones of dark-colored dots near the periphery of the head and adjacent to the under surface of the base. At the junction of the head and web, in the web, and near the upper surfaces of the flanges these markings appeared as lines. The changed appearance of the markings at different parts of the cross section is attributed to changes in shape which the metal undergoes in its reduction from the rectangular form of the bloom to that of the finished rail. In the earlier shapes from the ingot the markings are dots which are changed into dashes by the draft of the rolls in forming the rail. The unsymmetrical dark zone at the junction of the head and web is taken to indicate that the ingot from which this rail was rolled was laid on its side to cool.

Figures Nos. 5 and 6 represent longitudinal sections from the lower part of the head and base respectively. Tincture of iodine was used in etching these sections, which are here reproduced in nearly natural size.

Figures Nos. 7 and 8 show magnified images of a portion of the head and of one of the flanges, each in cross section.

A series of photomicrographs are presented illustrating the microstructure in different parts of the rail. Picric acid was used in etching the steel for microscopic examination. Figure No. 9 shows the average structure at the middle of the head, in which coarse-grained pearlite appears with thick irregular ferrite network. Figure

No 10 represents low carbon metal found in a zone about one-eighth inch below the running surface This figure also substantially represents low carbon areas in other parts of the head

Figure No 11 shows the structure of a streak in the web which appeared as a dark-colored band when etched with iodine It is higher in carbon and finer grained than the average structure Figure No 12 shows a low carbon streak, having a fine-grained structure in which coarser grains are present Figures Nos 13 and 14 are sections of low carbon metal with fine-grained ferrite and ferrite streaks

The effect of wheel pressures in causing a distortion of the grain of the steel immediately below the running surface of the head of the rail is shown by figures Nos 15 and 16 Figure No 15 is a view of the structure in cross section The lateral flow of the surface metal is shown in this figure In a crosswise direction the metal yields and flows toward the side of the head taking the path of least resistance Longitudinally, the tendency of the surface metal to flow is effectively resisted The grains are flattened but do not show longitudinal drift Figure No 16 shows the flattening of the grains viewed on a longitudinal section Whereas the lateral flow of the metal tends to develop split heads, in a longitudinal direction the inability of the metal to flow, except at the extreme ends of the rail, results in the introduction of internal strains of compression, the presence of which promotes the formation of transverse fissures in the interior of the head where the opposite strains of tension prevail

The longitudinal streaks in the metal of this rail are believed to have had a direct influence on the formation of the split head Examples of split heads have been witnessed in different stages of development, and incipient seams have been found to coincide with and follow the paths of interior streaks The quest for the primary cause of the presence of streaked metal leads back to the ingot Efforts to introduce streaks by heat or mechanical means have been unsuccessful Conversely their removal by heat or mechanical means has not been accomplished Sudden quenching of hot steel will cause the formation of thermal cracks but such cracks are of a different order to the streaks and seams under consideration These are present in steel which has cooled slowly

Mass segregation occurs in the cooling of ingots shown in the chemical analysis of the metal There are slag or other nonmetallic inclusions in different parts of the ingot and blowholes are also found The primitive condition of the ingot exercises its influence over the structural state of the finished rail The large reduction in sectional area given the metal of the ingot orients these structural conditions and leads to the formation of longitudinal streaks in the rail Lengthwise the rail this structural arrangement seldom affects its serviceability. In a crosswise direction, however, the character of the streak becomes an important factor, especially when service stresses approach the limit of endurance of the steel.

The streaks brought to view upon etching with tincture of iodine differ in their characteristics, each variety assuming greater or less importance, depending upon the severity of the service stresses. There are streaks which represent metal enriched in carbon, others in which ferrite predominates. In these streaks the continuity of the metal is not lost. The welding of blowholes may be partial, the efficiency of which in a degree depends upon the composition of the steel. The presence of slag is a barrier against welding and at such inclusions the continuity of the steel is interrupted.

Wheel pressures which cause lateral flow of the metal in the head of the rail differentiate the properties of these streaks. Whenever evidence is presented of permanent flow having taken place, the rail problem has evidently passed beyond the stage in which the elastic limit of the steel is a controlling factor. The rail is practically certain to fail in course of time under a repetition of these overloads. The life of the rail may be prolonged or its type of failure changed by the elimination of streaks. It is highly desirable that structural soundness be attained as nearly as the art of steel making permits. A margin in strength should be maintained between working loads and the ultimate resistance of the rail in which structural soundness is an essential factor.

A number of rails of different weights and of more recent fabrication were examined in conjunction with the 60-pound rail which caused the present derailment. Figure No. 17 shows the cross section of a 70-pound rail rolled in 1900. Markings of the same general character were displayed as those exhibited by the 60-pound rail. Figure No. 18 shows the markings on a 100-pound rail rolled in 1912. This rail developed a transverse fissure in service. There was also an incipient longitudinal seam located near the middle of the head, having a depth of one-half an inch. An incipient crack of this character, which was attributed to service conditions, would lead to the development of a split head.

Figure No. 19 represents a 125-pound rail, rolled in 1914. The markings caused by the iodine are exaggerated in size. The dark spots had minute nuclei which represented the real structural state of the metal. Tincture of iodine attacks the steel with different degrees of vigor, according to the strength of the solution, the composition of the steel, and the character of the polished surface. A fresh tincture gives better results than one in which the iodine flakes have been for a time in solution. The markings on this 125-pound rail gave a less favorable impression on the photographic print than the structural state of the steel warranted. The most truthful markings are those which present sharply defined outlines, easily recognized on the rail itself but not clearly distinguishable on photographic prints.

Figure No. 20 is a view of the top of the head of the 125-pound rail, shown in cross section by figure No. 19. A heavy fin had been formed along the gauge side of the head, the lateral flow of which amounted to about one-half an inch. The running surface on the gauge side was smooth. On the outer half of the head the metal was laminated, the edges of which had a rippled appearance.

Figure No. 21 represents an etched section of an early wrought-iron rail, of about 40 pounds weight per yard. The heterogeneous character of wrought or puddled iron is illustrated in this rail. Notwithstanding the appearance of etched sections, this metal is known to possess properties which make it peculiarly well adapted for certain purposes where a combination of strength and toughness is required.

The prevalence of streaks in steel rails, in those of different weights and different years' rolling was shown by the markings witnessed on each of the sections examined. The general results of the examination of rails of recent fabrication show an improvement over the earlier rails in respect to a diminution in the number of streaks.

The investigation of the 60-pound rail included measurements of the internal strains in the steel with corresponding measurements on the companion sections of the heavier rails which have been shown in the etched cross sections. Figure No. 22 shows the strains and corresponding stresses measured at places indicated by the shaded sections, when strips were detached from the body of the rail. This section was taken from the leaving end of the rail just beyond the portion covered by the splice bars. The immediate surface at the top of the head was shown to have acquired very great hardness. It was difficult to file. Surface metal had to be removed with an emery wheel to permit drilling the reference holes which defined the limits of the 10-inch gauged length located on the running surface. The initial compression at the top of the head, 18,000 pounds per square inch, is attributed chiefly to the cold-rolling action of the wheels.

The internal strains in the flanges of this section were lower than usual, less than the normal rate of cooling in fabrication would be expected to leave in the steel. It is believed that service conditions, or those attending the derailment, were responsible for these low values. Results more nearly normal were found in a section taken from the middle of the length of the rail, selecting a place where the rail had retained its straightness. Figure No. 23 shows the results on this section. Two strips were taken from the top of the head. The strip from the gauge side showed 11,700 pounds per square inch compression that from the outside showing 20,400 pounds per square inch

The relations between the internal strains acquired by the strips from opposite sides of the head are apparently influenced by the rigidity of the steel In cases where the head maintains its shape substantially unchanged the internal strains show less variation than in those rails where a decided lateral flow takes place along one edge Lower values are commonly shown by the strips taken from the side on which lateral flow is most pronounced

Figure No 24 shows the internal stresses in the 70-pound rail the etched section of which was shown by Figure No 17

Figure No 25 shows the stresses which were present in an 85-pound rail A high state of internal strain was found in each half of the top of the head Concerning the strains in the flanges it is inferred that the flange on the gauge side had been locally deformed, by reason of which it was left in a final state of tension, instead of compression, the normal strain due to cooling

Figure No 26 illustrates the stresses in a 100-pound rail, one in which a transverse fissure had developed in service The shape of the head was not materially distorted The internal stress was higher on the gauge side than on the outside of the head

Figure No 27 represents a 125-pound rail, the etched cross-section of which was shown by figure No 19 and a view of the running surface by figure No 20 The internal stress in the strip from the gauge side is seen to have only one-third the value of that from the outside of the head The influence of lateral flow is believed to be a factor in the difference in stresses here displayed

Figure No 28 shows the internal stresses in a 125-pound rail taken from a curve The low values in the strips from the top and the gauge side of the head will be noted At an intermediate stage in the measurements there was a strain at the top of the head corresponding to 6,600 pounds per square inch tension In cutting up these sections, the removal of strips from one part of the cross-section disturbs the relations of the strains in the remaining parts, increasing the primitive strains in some cases or, as here shown, reversing the state of strain

In rails which are exposed to considerable wear there is necessarily a gradual change in the relations of the internal strains accompanying the changes in cross section The strains of tension in the interior of the head must undergo changes in location corresponding to those parts of the head which are in compression This feature may be expected to have an influence on the life of the rail, in the development of fatigue fractures The reduction in area of the rail would also change its section modulus and increase the magnitude of the fibre stresses due to bending loads

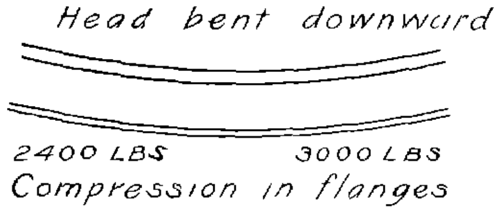
Figure No 29 shows the internal stresses in a new 125-pound rail This rail cooled normally on the hot bed As here shown, the cooling stresses in new rails are normally less in the head than in the flanges The stresses in the head attain a state of ascendency, after the rail reaches the track due to the cold rolling of the wheels Longitudinal shearing strains are necessarily set up in the metal of the base where opposing strains of tension and compression are present in juxtaposition The same must also be true in respect to the head where the reaction of the exterior strains of compression is taken up by interior strains of tension It follows that an increase in compressive strains at the running surface of the head facilities the formation of transverse fissures and tends also to cause longitudinal seams, both being directly augmented by the wheel pressures

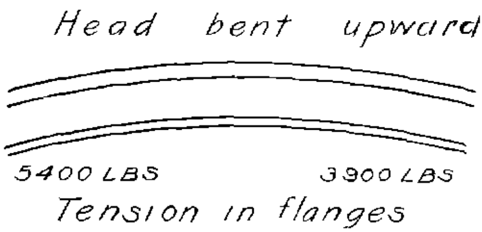
Figure No 30 illustrates the state of internal strain which was found in an old wrought-iron rail Along the top of the head, stresses of compression were present which reached the value of 24,920 pounds per square inch One flange was in a state of compression, the other in a state of tension The strains exhibited by the strip from the top of the head were the highest observed in the present series of measurements The strains at the immediate top were even higher than the figures representing the average value for the strip This was made apparent by the strip assuming a curved shape when detached convex on the side of the running surface, the deflection of which was 0 22 inch measured on a chord of 12 inches

The permanent character of internal strains is well exemplified in this early rail Several decades have doubtless elapsed since these strains were introduced

The shape of the head of the wrought-iron rail is favorable for acquiring and retaining a high state of internal strain The wheel loads, which it received were no doubt very low in comparison with those of the present time Experimental tests on a new steel rail, previously reported, have shown the acquisition of higher surface strains by the lower wheel loads The depth of penetration, however, depended upon the magnitude of the loads, a greater volume of metal being affected as the wheel loads are increased The volume of metal affected by the wheel loads must be taken into consideration, as well as the intensity of the internal strains introduced, in judging of the effect of wheel pressures in promoting rupture of the rail

Supplementary tests were made on two sections of the 60-pound rail, for the purpose of illustrating the changes in the internal strains which may be accomplished by bending loads, independent of the cold rolling action of the wheels. One section was bent downward, that is, with the head on the concave side, straining the flanges in a tensile direction. The flanges were left in a state of initial compression. The result of giving the rail a slight permanent set in this direction was uncertain, on account of doubts attaching to the magnitude of the primitive strains. The second section was bent upward, that is, with the head on the convex side, straining the flanges in a compressive direction. This bending resulted in a reversal of the primitive strains, the flanges being changed to a final state of tension. It was thus shown that the normal strains of compression in the flanges may be reversed and tensile strains introduced by cold bending, although the permanent set given the rail is of slight amount. The sketches herewith, in which the curvature appears very much exaggerated, show the stresses which were present in the opposite flanges of each section after the bending loads were applied and released.





A tabular statement of the results of the measurements of the internal strains and stresses follows.

TABLE No 1—*Initial stresses in steel rails*

[Stresses pounds per square inch corresponding to measured strains Compressive stresses in ordinary faced type Tensile stresses in heavy faced type]

No of section	Description	Head			Web	Base		
		Side	Top	Side		Flange	Middle of width	Flange
	60 pound Cambria rail, rolled March, 1887							
1	Section taken near leaving end	3 000	18 900	**900**		900	300	**1,200**
2	Section taken near middle of length		11 700 20,400			6,600	900	8,400
3	70 pound rail "Cambria 70 lbs No 539 1900 III		13 200			6,900	**4 800**	7 800
4	85 pound rail "P S 8030 Illinois"		18 600 21,000			**4 800**	**3,300**	8,100
5	100 pound rail "OH 10031 I S Co Gary IIIIIIIIII 1912"		1[illegible] 900 12 600			5 700	**6 300**	8,400
6	125-pound rail "P S 1914 IX		[illegible] 700 17 700			14 100	**2,700**	12,000
	125 pound rail High rail on curve	4 200	3 000	11,400	2,700	11 400		14,400
	125 pound rail New rail	1 800	2 100	1 200	3,600	7,200	**3 600**	7 200
7	40 pound rail Early wrought iron rail		24 920			4,760		**1 080**
	60 pound Cambria rail bent downward					2 400		3 000
	60-pound Cambria rail bent upward					**5 100**		**3,900**

The results of chemical analyses and tensile tests upon three of these rail sections appear in tables Nos 2 and 3

TABLE No 2—*Chemical analyses of rails*

No of section	Description	C	Mn	P	S	Si
1	60-pound Cambria rail rolled March 1887					
	Head	0 421	0 85	0 132	0 088	0 083
	Web	472	89	168	112	083
	Base	431	87	137	086	083
3	70-pound rail "Cambria 70 lbs No 539 1900 III"					
	Head	48	98	088	037	095
	Web	59	1 02	129	019	115
	Base	49	98	088	036	098
6	125 pound rail "P S 1914 IX					
	Head	80	58	026	021	110
	Web	92	62	030	026	114
	Base	80	58	024	021	110

TABLE No. 3.—*Tensile tests and hardness determinations on longitudinal specimens from heads of rails.*

No. of section	Description	Elastic limit per square inch	Tensile strength per square inch	Elongation	Contraction of area	Appearance of fracture	Brinell hardness
		Pounds	*Pounds*	*Per cent*	*Per cent*		
1	60-pound Cambria rail, rolled March, 1887	50,200	102,000	8	8.2	Granular	209
		51,140	101,300	8	8	do	
3	70-pound rail, "Cambria 70 lbs. No. 539 1900 III"	65,570	102,050	3	2.2	do	242
6	125-pound rail, "P S 1914 IX"	59,400	130,000	11	13	do	271

Rail failures are usually traceable to definite causes upon which the rails themselves furnish reliable evidence. The fractured surfaces are the written pages upon which the data are recorded. The incipient point of rupture, whether located in the head, in the web, or in the base; the progressive development of fatigue fractures, referring to the type of transverse fissures; the direction in which the fracture traversed the cross section of the rail; distinctive marks differentiating primary and secondary lines of rupture; all of these features are commonly shown by the fractured surfaces.

In the examination of a fractured rail, interest primarily centers upon the metal at the immediate point of origin. At this place the structural state or physical properties of the steel or the conditions of service reach a maximum and become responsible for its failure. The failure of the present rail was undoubtedly precipitated by the seamy state of the metal in the head. The steel was of medium hardness in respect to its chemical composition. Wheel loads had not distorted the general shape of the head except at the broken section.

Repeated impulses along different elements of the head, their paths varying according to the lines of contact made by wheels of different contours of threads, had effected a hardening of the surface metal covering a width of 2 inches.

Internal strains were introduced, amounting to many thousand pounds compression, measured in the direction of the length of the rail. Lateral flow had taken place in the metal next the top of the head, shown at the surface by a flattening of the grains, and necessarily exerting an effect on the interior metal. Under the influence of lateral flow, it is believed that an incipient crack was started in the interior of the head, this effect reaching some line of structural weakness, or place where the continuity was interrupted by a slag or other seam.

A measurable increase in the width of the head in rails which have otherwise maintained their primitive shape, commonly signifies that a seam is in progress in the interior. Very soft rails may show increase in width without a split head necessarily being in process of development. The deformation may be confined to the formation of a fin along the side of the head. The detection of a split head in the very earliest stage of its development does not appear feasible. In its more advanced stage the general increase in width of the head, or droop at the under side, or a discolored line along the running surface, are the recognized indications of the presence of a split head. By reason of the difficulties attending the detection of a split head before it has reached an advanced stage, and the possibility of error in judgment in interpreting the significance of the first visible indications, every effort should be made to eliminate the presence of streaks from the steel.

The sequence of the passes in the rail mill, in the reduction of the bloom, is shown to be favorable in respect to the modification of the form of the streaks which are located in the different parts of the cross section of the finished rail. The streaks have an acicular formation in the more critical parts of the head and the base, one which probably minimizes their influence in leading to split heads and some kinds of base fractures. The draft of the rolls converts these acicular lines into seams of considerable width in the metal of the web and at the junction of the web with the head and the base. Structurally, these seams are more detrimental than the acicular lines, but they are located, fortuitously though it may be, where their presence is seldom felt.

A careful examination of the metal at different stages from the ingot to the finished rail is essential for a thorough exposition of the subject of streaks. Blowholes and shrinkage cavities disappear from view in the early passes of the blooming mill. Slag or other nonmetallic inclusions, found in globular form in the ingot, are drawn into acicular lines in the finished rail, modified in shape at the web, as above stated. Regions differing in chemical composition from the surrounding metal appear as bands of varying width and thickness. These structural variations are frequently of such an order that the results of chemical analysis do not adequately indicate the state of the metal. Drillings for chemical analysis taken at a streak are so diluted by the surrounding metal that the characteristics of the streak are obscured. If the seaminess is due to an incompletely welded blowhole, structural rather than chemical manifestations should be looked for. Microscopic examination offers a promising method of test in this connection.

All rails are subjected to internal strains, which are not negligible factors, as the magnitude of their values indicates. If it were feasible to furnish rails initially free from internal strains they would not remain so. The cold rolling of the wheels in the track promptly introduces strains at the running surface of the head. No grade of steel has been examined which has resisted this action of the wheels.

Another feature may be mentioned in connection with the introduction of internal strains and which results from the application of overstraining loads. It has reference to the impairment of the primitive values of the elastic limit both in tension and in compression, and has an influence upon what might be termed the state of saturation of the steel for internal strains. An overstraining load in either tension or compression has been found to lower the elastic limit of the steel in the opposite direction. In acquiring further information upon the phases through which the metal passes in reaching rupture this feature will require consideration.

There was a notable difference in the behavior of the strips which were detached from the head of 125-pound rail No. 6. The strip from the gauge side of the top of the head assumed a concave shape while that from the outside sprung into a convex shape, each with reference to the running surface. Both strips showed a mean state of compression as previously stated. The springing of a strip into a curved shape is evidence that the intensity of the internal strains is variable, changing at different depths from the surface. It further appears, in the case of these two strips, that the changes in one were in reverse order to those of the other, this reversal occurring in passing from the gauge side to the outside of the head, a distance less than three inches. These and other variations witnessed in rails, after a term in service, stand as records of what has occurred in the track, and furnish a partial answer to the query sometimes made, why all rails do not fail when some do. The permanent record found in the rails themselves shows that they have not all been strained alike.

In conclusion it appears: That the failure of the rail which led to the present derailment was caused by a split head;

That the split head resulted from a condition of streaked and seamy metal;

That ingot conditions were responsible for this streaky state;

That warning was given of the development of the fracture by a decided increase in the width of the head prior to the time of derailment, and that such warning called for the removal of the rail from the track.

SUMMARY

This rail failed by developing a split head, which it displayed after a term of service of about 30 years. Seaminess of the metal led to the failure, a condition which had undoubtedly prevailed during this long interval of time, since seaminess of this kind originates in a condition of the ingot from which the rail is rolled. It can not be stated when separation of the metal first occurred, nor the rate of progress of the seam which finally separated the head into halves. The rate of extension of the seam was probably an accelerating one during a certain stage of its formation, although this accelerating rate of extension may not necessarily have continued up to the time of final fracture. The smooth, battered surfaces of the split head indicate that the rail had existed substantially in the state of its final condition for some little time before the fracture was completed.

Wheel pressures tend to increase the width of the head of the rail, and when the effects of such pressures penetrate a sufficient depth and encounter a streak or seam in the steel, an opportunity is offered for the commencement of a split head.

Wheel pressures caused a hardening of the steel in this rail at the running surface; it was superficial but very hard at the immediate surface of the head. The flattening of the grains just below the running surface is shown by the photomicrographs. There was evidence of lateral flow but no drift in a longitudinal direction.

The seaminess of the steel was shown on polished and etched sections. Cross-sections of the rail showed these markings as dots and short lines; on a longitudinal section they appeared as streaks. The report calls attention to the difference in the formation of these streaks in different parts of the rail. In the upper part of the head and the lower part of the base they are needle shaped, or acicular. In the web and at the junction of the web with the head and the base these needlelike streaks are converted into seams of considerable width. This change in formation is due to the draft of the rolls in the rail mill. Structurally the seams are more menacing to the integrity of the steel than are the acicular lines. Fortunately, however, the wider seams are located in such parts of the rail that their presence is seldom felt or disclosed. In cutting up rail sections for examination the machine tools are frequently broken when a seam is reached which dips away from the tool cut, showing the tendency of steel to split along the plane of a seam.

The examination of rails of different weights and of different years' output shows the prevalence of streakedness in some degree in most rails. A comparison of rails of early fabrication with those of current manufacture is favorable for those which are being made at the present time.

Measurements were made of the internal strains in the rail which caused the present derailment, also those which were in other rails taken from the track. Service conditions introduce strains into all grades of steel and of all weights and types of rails. The values of these strains amount to many thousand pounds per square inch, and they are permanently retained in the metal, in wrought iron as well as in steel. An old wrought-iron rail which was examined, displayed the presence of strains which had probably been locked up in the metal upward of 40 years. These internal strains may be modified by track conditions, and the state of internal strain of a rail, when properly interpreted, is a reliable index of what occurred in the track preceding the time of the examination.

The range in values of the internal strains witnessed in rails from the track is significant. They stand as permanent records for what has taken place, the summation of fabrication and track conditions.

In the light of present knowledge it is impracticable to detect a split head in its earliest stage of development. Incipient seams are found in rails in which the metal is separated hardly the thickness of a sheet of paper, yet the seam may have extended one-half inch or more in depth. It is not until the width of the head has increased a noticeable amount that the presence of the split head admits of being detected in the track. Perceptible increase in the width, a droop at the under side of the head, and a dark streak along the running surface constitute the visible evidence of a split head, all of which indications manifest themselves late in the development of the fracture. Under these circumstances it is necessary to exercise the utmost vigilance in track inspection. The difficulties of detecting an incipient crack emphasize the importance of eliminating streakedness from the steel as far as the art of steel making renders it possible.

Respectfully submitted.

H. W. BELNAP,
Chief, Division of Safety.