INTERSTATE COMMERCE COMMISSION

REPORT OF THE CHIEF INSPECTOR OF SAFETY APPLIANCES COVERING HIS INVESTIGATION OF AN ACCIDENT WHICH OCCURRED ON THE LOUISVILLE & NASHVILLE RAILROAD NEAR HAYS MILL, ALA, OCTOBER 1, 1912, ACCOMPANIED BY REPORT OF THE ENGINEER-PHYSICIST OF THE BUREAU OF STANDARDS COVERING HIS INVESTIGATION OF THE BROKEN RAIL CAUSING THIS ACCIDENT

AUGUST 15, 1913

To the Commission

On October 1, 1912, there was a derailment on the Louisville & Nashville Railroad near Hays Mill Ala , which resulted in the death of 1 express messenger and the injury of 15 passengers, 3 postal clerks, 2 Pullman employees, 1 express messenger, and 1 employee of the railroad After investigation as to the nature and cause of this accident and the circumstances connected therewith, I beg to submit the following report

Southbound passenger train No 7 runs from Cincinnati, Ohio, to Montgomery, Ala , via Louisville, Ky This train was hauled by engine No 188, and consisted of 1 baggage and mail car, 1 express car, 1 baggage car 1 second-class coach, 1 day coach, 2 Pullman cars, and 2 deadhead coaches, in the order named, and all of wooden construction It was in charge of Conductor Arnold and Engineman Thompson This train left Nashville, Tenn at 9 15 p m , 10 minutes late, passed Elkmont, the last open telegraph office, at 12 18 a m , 11 minutes late, and was derailed approximately 1 mile south of Hays Mill at about 12 25 a m

The speed of the train at the time of the derailment was 50 miles per hour The entire train, with the exception of the engine and tender and the rear coach was derailed The derailed cars, still coupled together, came to rest on their sides at the east side of the track Fire broke out immediately, evidently starting from the oil lamps with which the baggage mail, and express cars and the second-class coach were lighted, and the entire train, with the exception of the rear coach, was consumed by the flames The express messenger was cremated before he could be extricated from the wreckage At the time of the accident the weather was clear and cool

This division of the Louisville & Nashville Railroad is a single-track line The track is laid with 80-pound steel rails, 33 feet in length, about 18 oak ties to each rail, single spiked, no tie plates being used The track is ballasted with furnace slag and crushed rock and is well maintained

The derailment occurred on a slight grade ascending toward the south The track at this place is on a fill of about 6 feet and is straight for more than a mile in either direction The damage to track was slight only 4 new rails on the east side of the track and 83 new ties being required to repair the damage caused by this accident

Engine No 188 was of the Pacific type, built by the Louisville & Nashville Railroad in 1910 Its total weight was 94 tons and the weight on drivers was 126,000 pounds The capacity of tank was 7 000 gallons of water and 14 tons of coal An examination of the wheels and flanges on both engine and tender showed that they were in good condition

Both Engineman Thompson and Fireman Manners stated that as the train was running along at a speed of from 45 to 50 miles per hour they felt a sudden jerk and the air brakes applied, looking back they saw the cars turning over on their sides

Neither of them noticed any jar as the engine passed over the rail that was found broken after the accident The first car derailed was the baggage car, it was immediately followed by all the other cars in the train except the rear coach

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

The broken rail causing this accident was manufactured by the Tennessee Coal & Iron Co by the open-hearth process, it weighed 80 pounds to the yard, was rolled in June, 1906, and was laid in the track that fall It was marked "T C I Co 80 A S Open Hearth 111111 06" This rail had been in service at the time of the accident about six years, and other rails laid at the same time were in good condition and showed little wear After the accident the north or receiving end of the rail was intact for a distance of 13 feet and 4 inches, at which point the first break occurred At this point was found a transverse fissure in the ball of the rail on the gauge side about 1.85 inches in diameter, as shown in illustration No. 3. The remaining part of nearly 20 feet of the rail was broken into a number of pieces, all but 3 of which showed defects and flaws in the ball of the rail ranging from $1\frac{15}{16}$ of an inch in diameter to $\frac{3}{32}$ of an inch in diameter; at 11 of these breaks the metal at the head of the rail displayed transverse fissures. The manner in which the rail broke and the location of the transverse fissures found in the rail are clearly shown in illustrations Nos. 1 and 2. Illustrations Nos. 3 to 8 show the end view of the transverse fissures in their regular order, and illustration No. 9 shows a transverse fissure found in a test piece taken from the head of the rail, while it was being turned down to be used in testing the tensile strength of the metal in the rail.

It is noted that these flaws or fissures were all located on the gauge side of the head of the rail or directly over the web. These fissures were similar to the fissures found in the broken rail that caused the accident on the Lehigh Valley Railroad at Manchester, N. Y., on August 25, 1911, previously reported upon.

In that case, in addition to the transverse fissures mentioned, the rail was piped and there were longitudinal seams in the head of the rail. In the rail under investigation in this case no such additional defects are apparent. The cause of this rail failure was the formation and development of transverse fissures which finally caused it to break under the heavy wheel pressures to which it was subjected. The defects existing in the rail were of such a nature that careful and diligent inspection would fail to disclose them.

The analysis of the metal in this rail showed a practically uniform carbon content, and structurally the metal appeared sound. The etched surface of the cross section was uniform in appearance and free from the dark markings frequently noted in rail sections, as is shown by illustration No. 10. Microscopic investigation failed to detect unsound metal or foreign substance at or in the vicinity of the nuclei of the transverse fissures. In his report Mr. Howard calls attention to the fact that this type of fracture seems confined and peculiar to steel rails, and that so far as known no internal progressive transverse fissures have been found in other structural steel nor in steel rails which have not been in service.

The combined bending stresses and intense wheel contact stresses which attend the service conditions of a steel rail appear, therefore, to be the cause of the formation of these fissures. The insidious character of these fissures and their menace to safe travel by rail fully justify the conclusion reached in previous reports upon steel rails that there is an absolute necessity of making a complete investigation of track and rail conditions for the purpose of determining the effect thereon of the recent types of locomotives and cars with their greatly increased wheel loads This condition is extremely grave Mr Howard further states

> No method has been found capable of locating incipient interior fissures and which, it should be remarked, do not present oxidized surfaces But so grave a matter as this should not be left in its present state of uncertainty, and data upon contributory causes, track conditions, wheel loads, and grades of steel in which these fissures appear should all be acquired Primarily the formation of a transverse fissure is the result of an overload, for that particular rail from whatever point the subject is viewed It is regarded as an imperative duty which should at once be performed to ascertain and define the actual stresses to which the rails are daily subjected

The accident reports of the commission show that in the year ending June 30, 1902, 78 derailments were caused by broken rails, while in the year ending June 30, 1912, there were 363 derailments due to the same cause In 11 years 2,422 derailments have been caused by broken rails and have resulted in the death of 158 persons and the injury of 5,177 persons

The facts disclosed by the investigation of this derailment emphasizes the statements made in a number of other reports dealing with this subject, and, as stated in the report dealing with a similar accident on the Lehigh Valley Railroad, show that—

> a most complete and searching examination should be made of the whole question This examination should deal with steel rails from the furnace to the time they are laid in the track, it should determine whether the tests now used in the steel mills are adequate to detect imperfect rails, it should ascertain whether the use of high carbon steel is not attended with dangers not recognized in the drawing up of current specifications, it should be extensive enough to inquire into the causes which contribute toward such a destruction of the structural integrity of the steel as was the case with this rail, it should take up the securing of measurements in the track of the actual fiber stresses which are caused by the new types and weights of locomotives and under the different wheels of these locomotives, in order to obtain information from which to judge of the severity of the strains to which the track is daily subjected, in fact track conditions as they exist at the present time should be dealt with even to the most minute detail

From the report of Mr Howard it would appear that the danger zone in the use of steel rails as at present manufactured has been reached, and since it is supposed that transverse fissures are the direct result of high wheel pressure acting on hard steel, a complete investigation should be made for the purpose of scientifically determining the matter and ascertaining a remedy Until such an investigation has been made the danger of similar accidents will exist

Respectfully submitted

H W BELNAP,
Chief Inspector of Safety Appliances

REPORT OF THE ENGINEER-PHYSICIST

I have the honor to submit the following report upon a fractured rail from the Louisville & Nashville Railroad, the circumstances attending which were as follows

Fast passenger train No 7, southbound, from Cincinnati, Ohio, to Montgomery, Ala , was derailed October 1, 1912, at a place near Hays Mill, Ala , by reason of the fracture of a rail, resulting in the death of the express messenger and the injury of 21 passengers

The train was made up as follows Engine No 188, baggage and mail car No 118, express car No 205, baggage car No 244, second-class coach No 557, day coach No 959, Pullmans Galway and Granatan and coaches Nos 826 and 827

The engine and tender passed over the fractured rail and remained on the track The 9 cars of the train were derailed, leaving the track to the left Fire broke out immediately, cremating the express messenger and consuming all the train excepting the rear car This occurred at 12 25 a m

The fractured rail was an 80-pound rail, 33 feet long, rolled by the Tennessee Coal & Iron Co , June, 1906, and laid that fall It was branded "T C I Co 80 A S Open Hearth 111111 06" The receiving end of the rail remained intact for a length of 13 feet 4 inches The leaving end was broken into a number of fragments, 18 of which were recovered, the principal ones ranging from a length of 36 inches down to a length of 7¼ inches

The rail was fractured across its entire section, head, web, and base at 14 places At 11 of these places the metal of the head displayed transverse fissures, which ranged in diameter from 0 37 to 2 inches At only 3 of the fractures, which extended across the head, was the metal exempt from the presence of transverse fissures

The diameters of the fissures, taken in succession from north to south along the length of the head, were as follows 1 85, 1 25, 1 50, 1 50, 0 60, 0 85, 0 37, 0 85, 2, 0 85, and 1 55 inches

These fissures were located either on the gauge side of the head or directly over the web, as heretofore found, none being present in the outer half of the head The minimum distance apart of adjacent fissures was 7¼ inches, the maximum distance 36 inches

In addition to the transverse fissures which were displayed at the time of the wreck, 2 others were subsequently found, making 13 in all One, which had a diameter of 1 12 inches, was found in a section of the head while it was being turned down for a tensile specimen The section fell apart in the lathe when the outer metal had been turned away for a distance The appearance of the fissure was the same as those which were displayed at the time of the derailment

The thirteenth transverse fissure was found in the head of the 13 feet 4 inches section of the rail Its presence was made known by bending the head of the rail, which had been detached from the web and base by means of a machine tool cut This fissure had a diameter of 0 37 inch Its presence reduced the ultimate strength of the head 36 per cent over the strength of a corresponding bending test made where no internal transverse fissure existed

The specification under which this rail was furnished required the following chemical composition

	Per cent
Carbon	0 55–0 68
Phosphorus (not over)	06
Silicon (not over)	20
Manganese	80–1 10

It was stated that the following composition was attained

	Per cent
Carbon	0 57
Phosphorus	057
Silicon	008
Manganese	88
Sulphur	040

Analyses of the metal of this rail, however, showed a different content in respect to carbon than specified and reported as having been furnished Analyses of chips taken out near the running surface of the head from the center of the head and from the upper part of the web gave the following results

	Top of head	Center of head	Upper part of web
	Per cent	*Per cent*	*Per cent*
Carbon	0 88	0 85	0 84
Phosphorus	051	052	048
Silicon	014	014	019
Manganese	68	67	67
Sulphur	035	032	031

An additional carbon determination was made of metal from the nucleus of a transverse fissure, drilling into the head of the rail at that part of the surface which was the first to separate in the formation of the fissure. The carbon content here was 0.85, showing metal of normal composition according to the previous determinations.

Tensile test of longitudinal specimen from head of receiving end of rail

Length of stem	inches	10
Diameter of stem	do	1.005
Sectional area	square inch	.7933
Elastic limit per square inch (approximate)	pounds	45,000
Tensile strength per square inch (approximate)	do	86,850
Elongation in 10 feet	per cent	8
Contraction of area	do	1.1
Appearance of fracture		Granular

Structurally the metal of this rail appeared uniform. It was a sound rail, referring to the quality of the metal. Cross sections were polished and etched with tincture of iodine at 6 places along its length. The etched surfaces were uniform in appearance and substantially free from the dark markings which are frequently displayed by rail sections. Microscopically, also, the metal appeared sound and no defects were detected at or in the vicinity of the nuclei of the transverse fissures. So far as could be judged the formation and extension of these 13 transverse fissures was the result of service conditions to which the rail had been exposed in the track, not materially influenced by structural inequality of the steel.

A series of photographic prints, reproduced by the half-tone process, shows the appearance of the fractured rail in side elevation and on which are seen the directions taken by the several lines of rupture, two polished and etched cross sections, also the fractured ends on most of which appear transverse fissures, and the fissure which was found in the specimen intended for tensile test. In all 11 of the transverse fissures which were in the head of this rail are represented in these illustrations.

Transverse fissures have been described in earlier reports of rail fractures and the causes described which are believed to lead to their development. The insidious character of these fissures and their menace to safe travel by rail justifies further remarks upon the probable manner of their formation.

This type of fracture seems confined and peculiar to those conditions which affect steel rails. So far as known, internal, progressive transverse fissures have not been found in other examples of structural steel, nor have they been found in steel rails which have not been in service. The combined bending stresses and intense wheel-contact stresses which attend service conditions of a steel rail appear to constitute the features which lead to the formation and development of interior transverse fissures. No other contributory causes have been recognized as being present and active in this connection. Regardless of the grade or quality of the steel there must be present longitudinal strains which cause the separation of the metal of the rail in a longitudinal direction But the magnitude of those strains necessary to cause rupture will be greater or less according to the grade of the metal

In earlier periods of railway practice rails of lower physical properties were used and failures of another kind were then prevalent Cold flow of the metal occurred With increase of wheel loads harder steels were introduced to check this tendency While disturbance of the metal at the running surface of the head still continues to a certain extent, notwithstanding the greater hardness of rails of current manufacture, nevertheless the effect on surfacing, causing a rough track, has not been found objectionable from an operating point of view But the formation of interior transverse fissures has made its appearance as a consequence, apparently, of these changed conditions

The effect of repeated alternate stresses in causing rupture in all grades of steel, without the display of ductility and under the action of fiber stresses somewhat below the elastic limit of the metal, is known Repeated alternate bending of a steel rail, and all rails are exposed to repeated alternate bending stresses, has a tendency to cause ultimate rupture in a brittle manner under fiber stresses below the primitive elastic limit of the steel

But exposure to bending stresses alone—that is, unaccompanied by intense wheel pressures on the running surface of the head—would lead to fractures which would have their origins at the fibers most remote from the neutral axis of the rail, where the stresses would be the greatest Under such circumstances rails would be expected to fracture, starting either at the running surface of the head or at the underside of the base

Since transverse fissures have their origins at the interior of the head and are longitudinal tensile fractures of the metal, it is necessary to look for a cause for the transference of the incipient place of rupture from the outside fibers to interior ones The cold rolling of the running surface of the head by the wheels doubtless occasions this transference The gauge side of the head is most affected by the wheel loads, and that should be the side of the head to develop interior fissures, as examples of fractured rail have shown it to be

The effect of the wheels is to put the metal at the running surface of the head into a state of internal compression The springing of the head into convex shape on the running side, when detached from the web, is evidence of the release of internal compression The present rail sprung in that manner when the head was detached from the web Herein is found a cause which has a tendency to transfer the incipient place of rupture from the surface to the interior of the head The metal in compression at the running surface must perforce put the metal next below it in a state of tension and augment the tensile strains of the bending loads In a way the rail is an example of unsymmetrical loading, or rather presents an unsymmetrical result of loading, with bending stresses alone affecting the base, while the head is affected by the combined bending stresses and internal strains of compression

It is not a question of grade of steel whether or not this action takes place, but in specific cases a question of what constitutes an overload for the particular steel being used Rails which develop this type of fracture have certainly been overloaded The close proximity of transverse fissures to each other precludes the explanation that they are the result of bending stresses taken alone The results call for the presence of an independent force, the influence of which is felt along the entire length of the head, and such in fact is the manner in which the compression metal acts

Since these fissures occur in planes at right angles to the direction in which the rails were rolled their formation would not be looked for as a result of mill practice Certainly the presence of fissures approaching 2 inches diameter would not be attributed to the action of the rolls of the rail mill, ignoring the fact, for the time being, that such fissures are located on one side only of the head There is lack of continuity in steel in the ingot at places where slag inclusions exist, yet such globules, of one one-hundredth of an inch diameter, more or less, are drawn out in the finished rail into longitudinal filaments parallel to the length of the rail The examination of rail steel through the successive reductions from the ingot to the rail has failed to furnish examples of incipient fissures developed at right angles to the direction of rolling

No method has been found capable of locating incipient interior fissures and which, it should be remarked, do not present oxidized surfaces But so grave a matter as this should not be left in its present state of uncertainty, and data upon contributory causes, track conditions, wheel loads, and grades of steel in which these fissures appear should all be acquired Primarily the formation of a transverse fissure is the result of an overload, for that particular rail, from whatever point the subject is viewed It is regarded as an imperative duty, which should at once be performed, to ascertain and define the actual stresses to which the rails are daily subjected

Structural materials admit of being used with safety, but fundamentally the stresses to which they are exposed must be known It is difficult to refer to a more flagrant example than that of steel rails where definite knowledge of the actual fiber stresses made use of in service is lacking The loads which are placed upon the columns of buildings are known with reasonable certainty Strain sheets show the stresses with which the members of bridges are loaded and the details of such structures are carefully designed to keep within what are believed to be safe loads

The strength of elevator ropes, on which we trust our lives is known and a careful margin maintained between the breaking load and the allowable working load These illustrations of the use of structural materials are relatively simple examples when compared with the complex conditions which attend the use of steel rails, emphasizing therefore the necessity for ascertaining so far as may be working stresses in steel rails

Experiments which were made nearly two decades ago showed the necessity for conducting observations in the track for ascertaining and defining the fiber stresses in rails due to given wheel loads The moment of resistance of the rail and the tie spacing not being sufficient data on which to base computations for the reliable determination of the actual fiber stresses under given wheel loads owing to the yielding character of the roadbed, hence requiring an experimental determination of the fiber stresses in the track itself Since those early tests were made wheel loads have been greatly increased and, also bearing on the case, wheel spacing has been changed It can doubtless be said that definite information is practically lacking in respect to the fiber stresses in rails which are developed by modern equipment, even under static conditions of loading where no obstacle exists for the acquisition of such data Commendable efforts have been made at different times in the laboratory to acquire reliable information upon the primitive physical properties of the materials made use of in track equipment, but years should not be allowed to pass without corresponding efforts being directed to the material after it reaches the track Such a dearth of important information as pertains to service stresses in steel rails is probably without a parallel in the history of the materials of construction

In conclusion it appears

That the presence of interior transverse fissures in the rail under consideration was the cause of the derailment and wrecking of train No 7

That 11 such fissures were displayed on fractured surfaces developed at the time of the derailment, and 2 additional fissures found in this rail

That the sizes of the fissures ranged from 0 37 to 2 inches diameter

That they were located in the head of the rail on the gauge side or directly over the web, none being found on the outside of the head

That the metal of the rail in other respects was structurally sound and of satisfactory quality and normal to steel of its chemical composition

That the formation and successive development of these transverse fissures as a matter of opinion, was the direct result of overstraining loads, combined alternate repeated bending stresses, and intense wheel-contact stresses

It appears furthermore that the carbon content of this rail was 23 per cent higher than the upper limit of the specifications and 47 per cent higher than the steel was reported, thus nullifying the value which might attach to the reported composition of the steel and giving such report a perfunctory character

That the margin of strength and safety in rails can not be known in the absence of information concerning the stresses to which they are subjected and that there is immediate and urgent need of instituting an inquiry into the magnitude of the stresses to which steel rails are subjected in the track

That the prevention of derailments and the safety of railway travel will be aided and benefited by the careful determination and definition of the conditions which prevail in the track

Respectfully submitted

JAMES E HOWARD,
Engineer-Physicist