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INTERSTATE COMMERCE COMMISSION

REPORT OF THE DIRECTOR OF THE BUREAU OF SAFETY IN RE INVESTIGATION OF AN ACCIDENT WHICH OCCURRED ON THE ATCHISON, TOPEKA & SANTA FE RAILWAY NEAR YAMPAI, ARIZ., ON MARCH 13, 1928[1]

MARCH 25, 1929

To the Commission

On March 13, 1928, there was a derailment of a passenger train on the Atchison, Topeka & Santa Fe Railway near Yampai, Ariz., resulting in the death of 1 mail clerk and 2 employees and the injury of 27 passengers, 2 mail clerks, and 2 employees. The investigation of this accident was made in conjunction with a representative of the Arizona Corporation Commission.

LOCATION AND METHOD OF OPERATION

This accident occurred on the first district of the Arizona division, extending between Needles, Calif., and Seligman, Ariz., a distance of 149.2 miles; in the vicinity of the point of accident this is a double-track line over which trains are operated by time-table, train orders, and an automatic block-signal system. The accident occurred at a point about 1.1 miles east of Yampai; approaching this point from the west there is a short tangent, followed by a compound curve to the left about 2,438 feet in length, with a maximum curvature of 8° 10′, the accident occurring on this curve at a point approximately 2,047 feet from its western end, where the curvature is at its maximum. The grade for eastbound trains is descending, being 1.01 per cent at the point of accident.

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[1] The delay in issuing this report was due to the fact that the investigation involved laboratory and research work on a number of rails which displayed base seaminess.

The track was laid with 90-pound rails, 33 feet in length, with about 22 hardwood ties to the rail length, tie-plated, fully spiked, and ballasted with from 10 to 12 inches of cinders, rail anchors are also used The rails at this point were rolled in 1920, and had been used elsewhere prior to being laid on this curve in May, 1925 At the point of accident the track was on a fill about 12 feet in height Slow boards are located in advance of certain curves and at other points where the speed of trains is permanently restricted, and resume-speed boards are located at the end of the restricted territory, at a point 3,063 feet west of the point of accident there is a slow board, which limits the speed of trains to 24 miles per hour around this particular curve

The weather was cloudy at the time of the accident, which occurred at about 11 06 p m

DESCRIPTION

Eastbound passenger train No 10 consisted of 2 baggage cars, 1 combination baggage and mail car, 1 baggage car, 1 coach, 1 chair car, 2 tourist cars, and 1 standard Pullman car, in the order named, hauled by engine 3744, and was in charge of Conductor Bland and Engineman Cole The first, second, and fourth cars were of steel-underframe construction, while the remainder were of all-steel construction This train left Peach Springs, the last open office, 13 7 miles west of Yampai, at 10 33 p m , three minutes late, passed Yampai at 11 04 p m , on time, and was derailed while rounding the curve at a speed estimated by the crew to have been between 20 and 30 miles per hour

Engine 3744, together with its tender, the first six cars, and the forward truck of the seventh car were derailed to the south, the engine was badly damaged and the first car was practically demolished, while the remaining derailed cars were more or less damaged The employees killed were the engineman and the fireman

SUMMARY OF EVIDENCE

Starting at the western end of the curve and proceeding eastward, there are 1,383 8 feet of 2° 15′ curve, including the spiral, then 341 72 feet of 3° 30′ curve, 100 feet of 4° curve, and 100 feet of 6° curve, followed by 331 86 feet of 8° 10′ curve, and then 180 feet of easement spiral, the initial point of accident occurring on the 8° 10′ portion of the compound curve at a point 121 3 feet from its western end Inspection of the track after the accident disclosed that six of the outside rails of the curve had been torn out of the track

The initial point of derailment occurred at the receiving end of rail 4, these six rails being numbered from west to east, in the direction in which the train was moving Four feet of rail 4 at its receiving end had been broken into several pieces, two or three of which could not be located, and the leaving portion of the rail, 29 feet in length, caught in the brake rigging under the engine and was still there when the engine came to rest, this piece of rail 4 was bent almost double and had carried with it the west half of rail 5 The east half of rail 5 remained bolted to rail 6, which was diagonally across the roadbed, from northwest to southeast, and which in turn remained bolted to rail 7, rails 6 and 7 remained intact Rails 1, 2, and 3 were torn out of the track apparently by the buckling of the equipment as a result of the accident The break in rail 4 occurred within the limits of the rail joint connecting rail 3 to rail 4, the ties east of and including the second tie east of the rail joint were not disturbed, however, the two rail-joint ties and the tie immediately east thereof were slightly marked, while 66 ties west of these rail-joint ties, under rails 1, 2, and 3, were torn up

Conductor Bland said that he was riding in the chair car and that the first he knew of anything wrong was on feeling a slight jar, followed by the running-in of the slack and then the occurrence of the accident He also said that the speed of the train was about 30 miles per hour when it was approaching the slow board, that the air brakes were applied and the speed was reduced to about 20 miles per hour, and that then the air brakes were released After the accident he saw a broken rail, which, in his opinion, was the cause of the derailment

Head Brakeman Rothlisberger was riding in the rear car, acting in the capacity of flagman, he estimated the speed of the train to have been between 30 and 40 miles per hour when it was approaching the slow board and said that it was then reduced to between 20 and 30 miles per hour, after which the derailment occurred After the accident he saw marks on the ties on the gauge side of the south or outside rail under the head end of the seventh car, apparently wheel-flange marks, and he thought the accident was the result of spread rails, he did not see a broken rail

Flagman Wood, who had been relieved by the head brakeman of the duty of flagging and was riding in the fifth car at the time of the accident, said he felt an air-brake application made in the vicinity of the slow board and then paid no more attention to the manner in which the air brakes were operated until they were applied in emergency at the time of the accident In his opinion the emergency application was made by the engineman and was not a result of the accident, as he said he had time to brace himself before the crash occurred Flagman Wood immediately went back to flag and on his way back noticed nothing irregular with track conditions

General Foreman of Bridges and Buildings Combs was riding in the fifth car at the time of the accident and he estimated the speed of the train to have been about 20 or 25 miles per hour at that time An air-brake application was made in the vicinity of the slow board and then the brakes were released, the accident occurring shortly afterwards He was of the opinion the accident was caused by a broken rail, as was Brakeman Devaney, who was also deadheading on train No 10

Road Foreman of Engines Richards arrived at the scene of the accident a few hours after its occurrence and found the throttle of the engine closed, the brake valve in full-release position, and the handle of the independent brake valve in application position, there was considerable débris and broken parts lying against the brake valve, however, and in his opinion it was this material that forced the brake valve to the release position His inspection of the engine failed to disclose any defect that would have caused the accident, there was a scar on the flange of the right front engine-truck wheel, apparently caused by striking metal, and he thought that the accident might have been caused by a small part of the head of the rail having broken off

Division Engineer West stated that the maximum gauge of the curve was 4 feet 8⅞ inches, while the maximum superelevation of the outside rail was 4⅜ inches, sufficient for the rate of speed allowed The division engineer also stated that he had not reached any conclusion as to the cause of the accident

The evidence seemed to indicate that this accident was the result of a broken rail An examination as to the reason for the failure of this rail was made by Mr James E Howard, engineer-physicist, whose report immediately follows

REPORT OF THE ENGINEER-PHYSICIST

The derailment of train No 10, March 13, 1928, near Yampai, Ariz, was apparently caused by the fracture of rail designated in the testimony as No 4 From the evidence presented by the fragments, the primary cause of the derailment was the fracture of this rail in the joint at its receiving end The type of fracture was a modified half-moon or crescent-shaped break, occurring at the immediate receiving end of the rail The circumstances attending the derailment lead to the inference that the track was in a weakened condition when train No 10 entered upon it Rail 4, on the high side of

FIGURE 1A.—View of derailed train

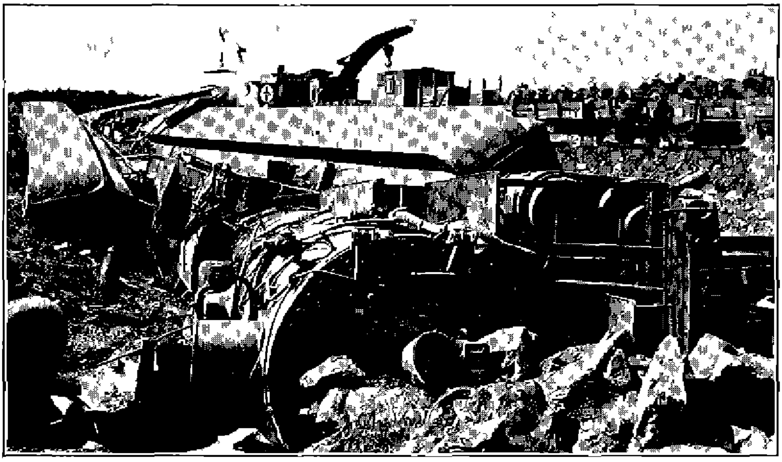

FIGURE 1B.—Closer view of engine

an 8° 10′ curve, was broken in the joint, between the splice bars, the speed of the train was slow, fragmentation of the splice bars and receiving end of the rail occurred under the engine, the engine took a tangent course, carrying with it 29 feet of the forward part of rail 4, making with it a loop which included a part of rail 5, rails 1, 2, and 3, over which the engine had passed, were dragged from the roadbed out on the high side of the curve by the equipment

This outline of what occurred at the time of the derailment is supported by the evidence presented by the fragments of rail 4 The receiving end of a fragment of the base of rail 4, matched in its position between the splice bars, showed one portion of a crescent-shaped break The distance from this fragment to the end of the rail was 3 inches, representing a section of the rail which was not recovered The missing pieces can be reconstructed, since the recovered fragment is typical of this type of fracture and this type only

Figure 2 represents the base of the rail, the shaded portion indicating the missing parts Base fractures are commonly progressive, not immediately forming in new rails but with an interval of time elapsing between their incipient formation and final rupture They originate at a longitudinal seam in the lower surface of the base, thence gradually extending upward A crescent-shaped piece of the base is eventually detached The final stage of complete rupture is reached by the upward extension of the fracture from the base of the rail, traversing upward through the web and the head This review presents the reasons for thinking the derailment followed a pre-existing state of weakness in the track

FIGURE 2—Sketch showing typical lines of rupture of crescent shaped base fractures Shaded portion missing in this derailment

On tangent track, and with higher speeds, the engine which completes the rupture of the rail commonly passes on without derailment There is no force present adequate to suddenly change the direction in which the engine is moving, therefore it continues on the rails in front of it In the present case the impulse of the engine and equipment was to take a tangential course A weakened joint in the track on the high side of the curve did not offer sufficient centrifugal resistance to continue the engine in its circular course, hence the train was derailed

The fragmentation at the receiving end of rail 4 naturally continued the first break at the joint and when the engine left the track and its driving wheels had spanned the high rail, 29 feet of its length was picked up and carried forward, forming a large loop

Figure 3 shows an end view of the fracture of the base of rail 4 the receiving end of the first recovered fragment This was photographed in its relative position to the fractured splice bars The splice bars were broken at the middle of their lengths The line of rupture of the inner splice bar changed its vertical course, and terminated at the spike notch in its flange

It will be noted that the lower surface of the base, as the rail appeared when in the track, gave no evidence of longitudinal seaminess The mill scale, a magnetic oxide, extended across and hid from view the surface manifestations An " X " is placed on this cut and on the following figure to indicate the same spot on the rail

Figure 4 shows the base of the same fragment illustrated in the preceding figure The fragment was cut in two and one part pickled in hot hydrochloric acid This treatment brought into view the presence of surface seams

It has been the experience in the examination of crescent-shaped base fractures that such fractures invariably started at a longitudinal seam In some cases the seam was several hundredths of an inch in depth and displayed blue-black walls Such a seam or lap was made without doubt during the fabrication of the rail Other explanations have been offered for the presence of some of these manifestations Short, intermittent lines have been attributed to the breaking through of small blowholes which had formed near the surface when the ingot was cast

The presence of surface seams covering a portion of the periphery of the head and a portion of the base led to the introduction of a deseaming process which at least removed the seaminess at the particular pass at which it was done Diagonal rolling has been given consideration in the fabrication of rails

Structural shapes display similar seaminess, often much exaggerated, and in which there is a relation between the location of the seams and the roll designs in which the shapes were formed Seams are found at definite places in rolled angles, channels, and beams, especially in the latter in pronounced degree

The effects of seams would be minimized if those of the base could be restricted to the edges of the flanges Little danger to a rail attends the detachment of a small crescent-shaped fragment from the edge of the flange Such fractures do not extend inward laterally to the web Reductions from the ingot must be made at plastic temperatures, which vary in different parts of the cross section of the shapes, particularly so as the final passes are reached

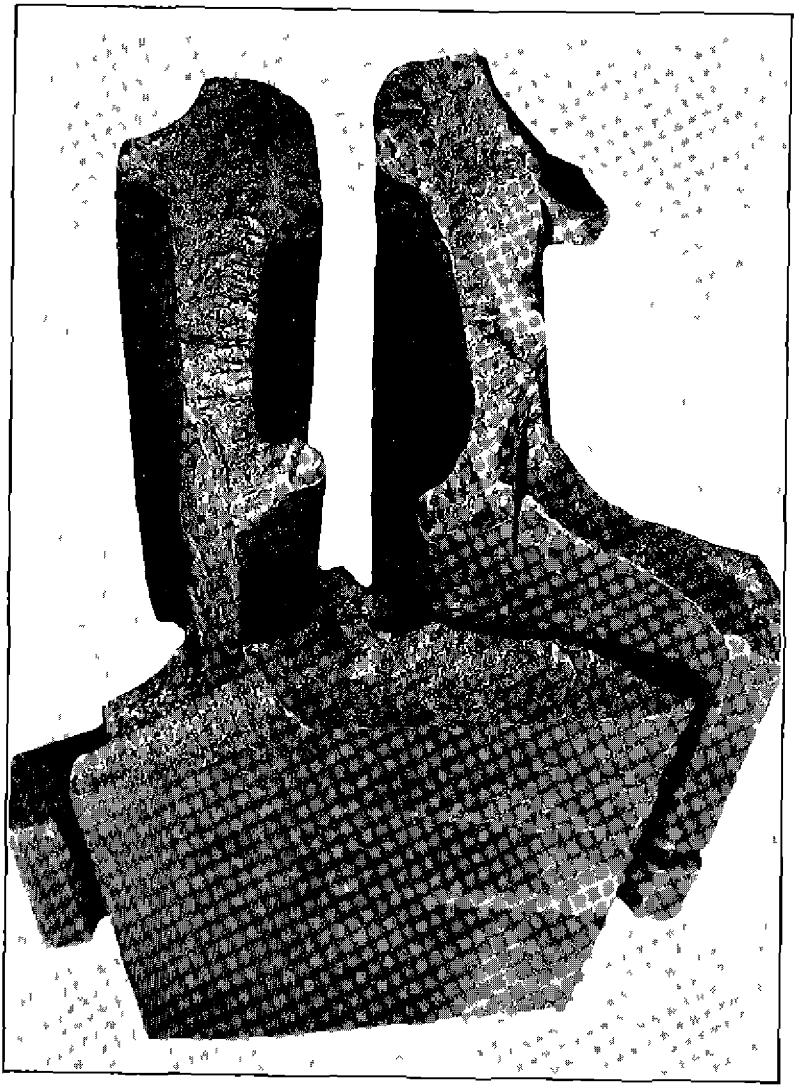

FIGURE 3.—Fractured splice bars and base of rail No. 4 near receiving end

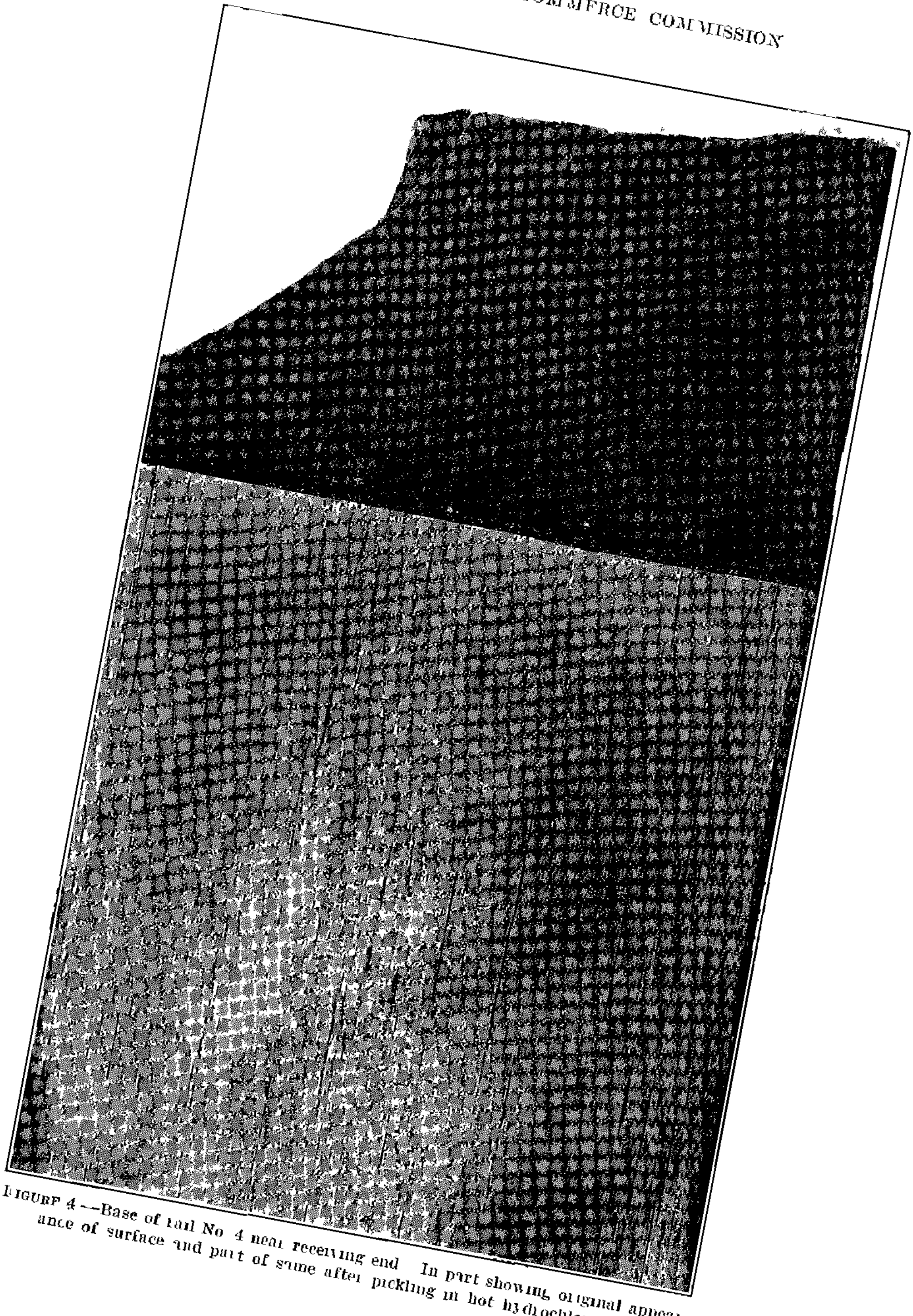

FIGURE 4.—Base of rail No. 4 near receiving end. In part showing original appearance of surface and part of same after pickling in hot hydrochloric acid.

The principal change in the dimensions of the ingots and derivative shapes is that of length. This feature causes no concern to the users of rolled shapes. The final shapes, however, must conform to template in order to pass specification. Lateral changes in the rolled shapes must in the end bring about the cross section of the finished rail, the exactness of which is generally insisted upon by the users of the rails.

Influences which lead to the formation of surface seaminess appear to cause different results on different occasions. Some rails are nearly free from seaminess whereas others are very much affected too seamy to justify putting them into the track.

Tests of bases of rails by crosswise bending the flanges, display a high degree of strength apparently in excess of service requirements. Such results, however, furnish additional examples of the remote relations between primitive static tests and the endurance of repeated strains of service. Variations in the state of seaminess of the bases of different rails from those nearly immune and those extremely charged with numerous and deep seams, would appear to indicate that some control of conditions at the mill was possible during fabrication which would restrain their formation.

Cases have been presented in which base seaminess was so pronounced that fragments could be knocked off with a sledge at will, almost anywhere. On the other hand, crescent breaks have been started by seaminess in the base directly under the web of such limited extent that only complete and absolute elimination of the seams would seem effectual against ultimate rupture from that cause.

Heavy bases are obviously stronger than light ones. Internal strains of cooling are less in thick than in thin flanges. Rails can be strengthened in the base, still leaving the matter of surface seaminess uncorrected.

Another example of a crescent-shaped break is presented by Figures 5 and 6, showing the end of a broken rail, corresponding to that of the recovered fragment of the rail involved in the present derailment. These two cuts represent a 110-pound rail which fractured in service. A crescent-shaped fragment which originated at a longitudinal surface seam was detached from the base. At one end the line of rupture was diverted from its course parallel to the axis of the rail, extending obliquely to the edge of one flange. At the other end, after a slight change in direction, the rupture bifurcated and extended each way to the edges of the flanges. From the middle of the base it took an upward course and separated the metal of the web and the head, thus completing the fracture of the rail. The shape of the base at the fractured end was the same in each of these two rails. This being common to all fractures of this type, it is not necessary to be in possession of each end of the rail to identify the type of fracture

Figure 5 shows the base of this 110-pound rail as it appeared when removed from the track No seaminess is shown, nor suggestion of that which existed below the mill scale

Figure 6 shows its appearance after pickling in hot hydrochloric acid, displaying very pronounced seams The other end of this rail, not necessary to reproduce here showed a continuation of the seams and the origin of the crescent-shaped fracture at one of them

The question is raised from time to time concerning the output of the different rail mills as to the prevalence of surface seaminess in their products, whether the rails from the different mills were different or substantially the same, whether different weights of rails differed, whether those of different ingot position showed any modification traceable to that cause

For this purpose sections of rails from each of the several rail mills excepting the mill which rolled the rail responsible for the present accident, were examined Short sections were pickled in hot acid and their bases photographed The results were not all the same in degree, but from no source were rails presented of complete exemption from base seaminess General experience leads to the belief that fluctuations would be found if the tests were repeated but substantially the same results would be reached

A number of cuts are presented which illustrate pickled sections of bases of rails from the different mills

Figure 7 represents a 90-pound rail, ingot letter B Surface seaminess is most pronounced near the edges of the flanges, although the middle of the width of the base showed a number of sharply defined seams

Figure 8 represents a 100-pound rail ingot letter C Surface seams and light colored streaks are present but not sharply defined Duration of exposure in the bath has an effect on the result of the pickling

Figure 9 represents a 105-pound rail ingot letter unknown Surface seams sharply defined, some, apparently of considerable depth are shown

Figure 10 represents the base of a 110-pound rail, one-half of which was pickled, with one-half showing the surface as it came from the rolls The pickled surface displayed sharply defined seams of which, on the untreated surface there were no indications

Figure 11 represents the base of a medium manganese steel rail, 127-pound weight, ingot letter A This rail exhibited a marked state of seaminess It was an A rail Rails from different parts of the ingot are expected to show differences in segregation of the

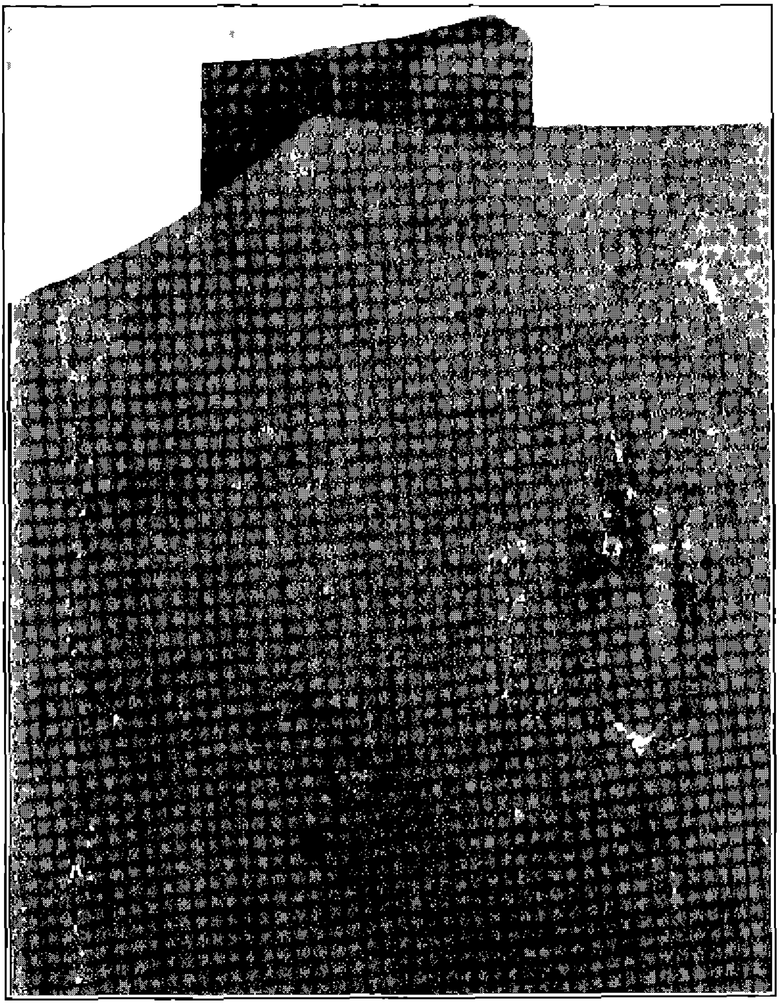

FIGURE 5 —Base of a 110 pound rail Appearance before pickling

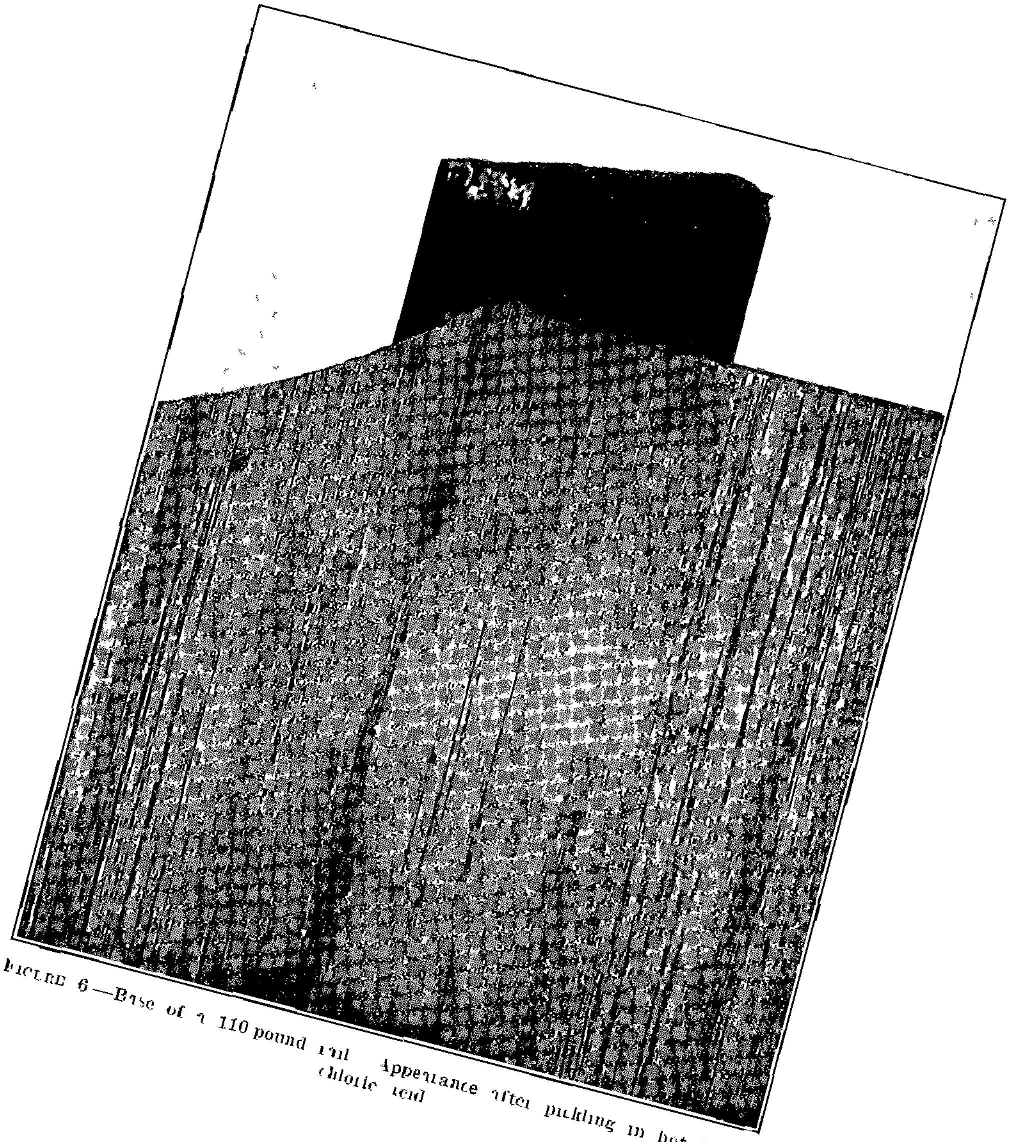

FIGURE 6.—Base of a 110-pound rail. Appearance after pickling in hot hydrochloric acid.

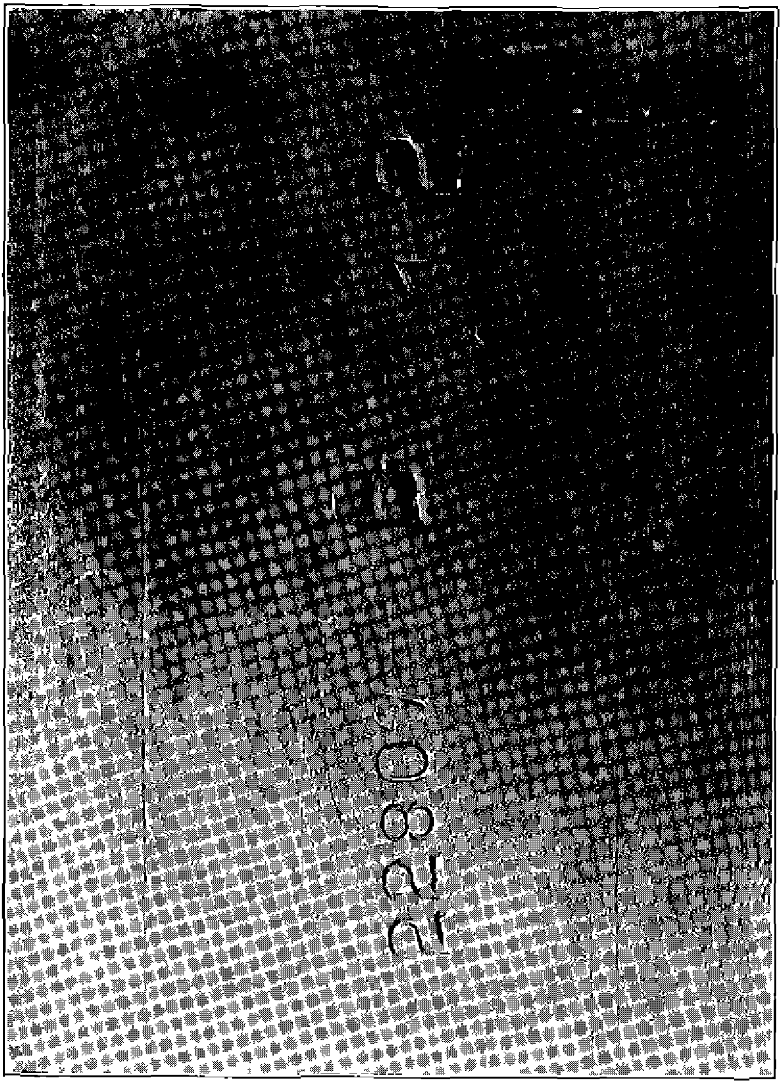

FIGURE 7—Base of a 90 pound rail Appearance after pickling in hot hydrochloric acid One of a series from different rail mills

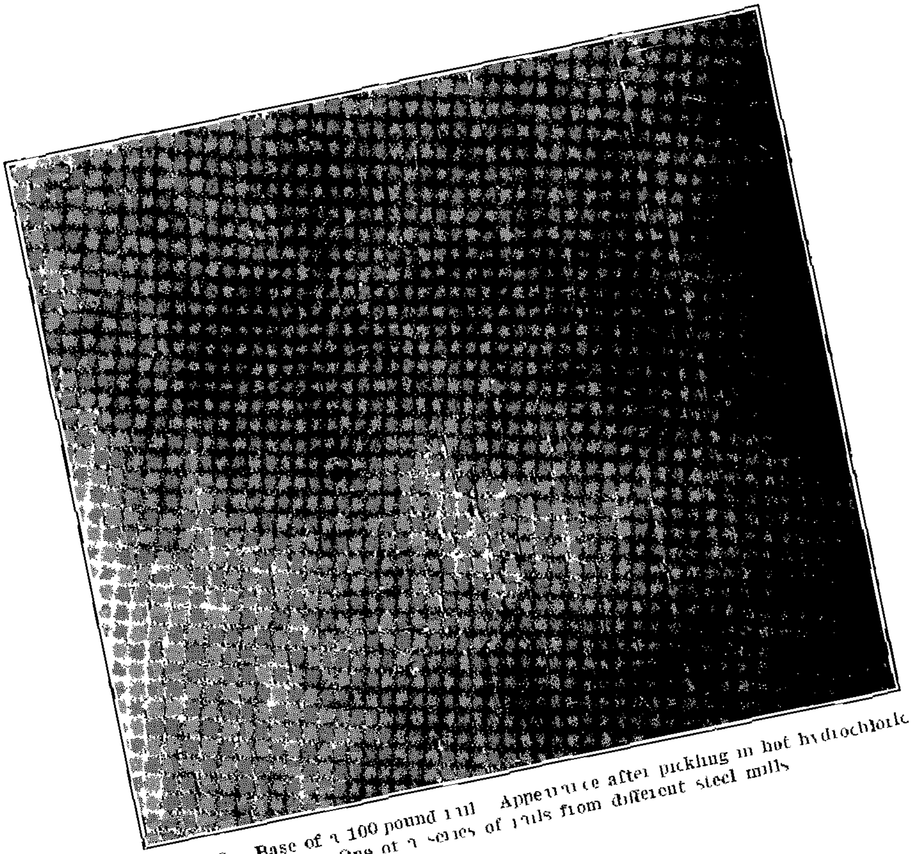

FIGURE 8.—Base of a 100-pound rail. Appearance after pickling in hot hydrochloric acid. One of a series of rails from different steel mills.

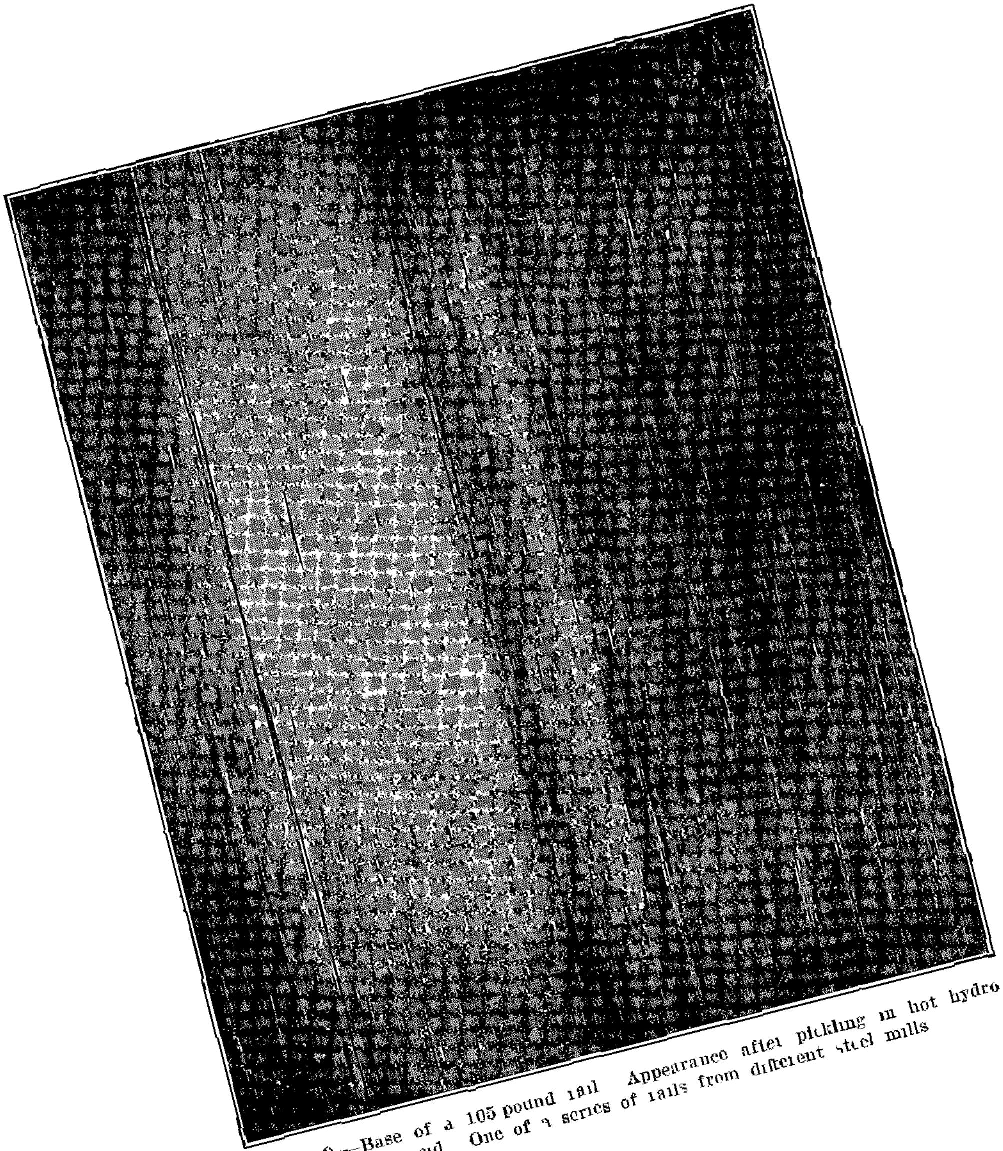

FIGURE 9 —Base of a 105 pound rail Appearance after pickling in hot hydrochloric acid One of a series of rails from different steel mills

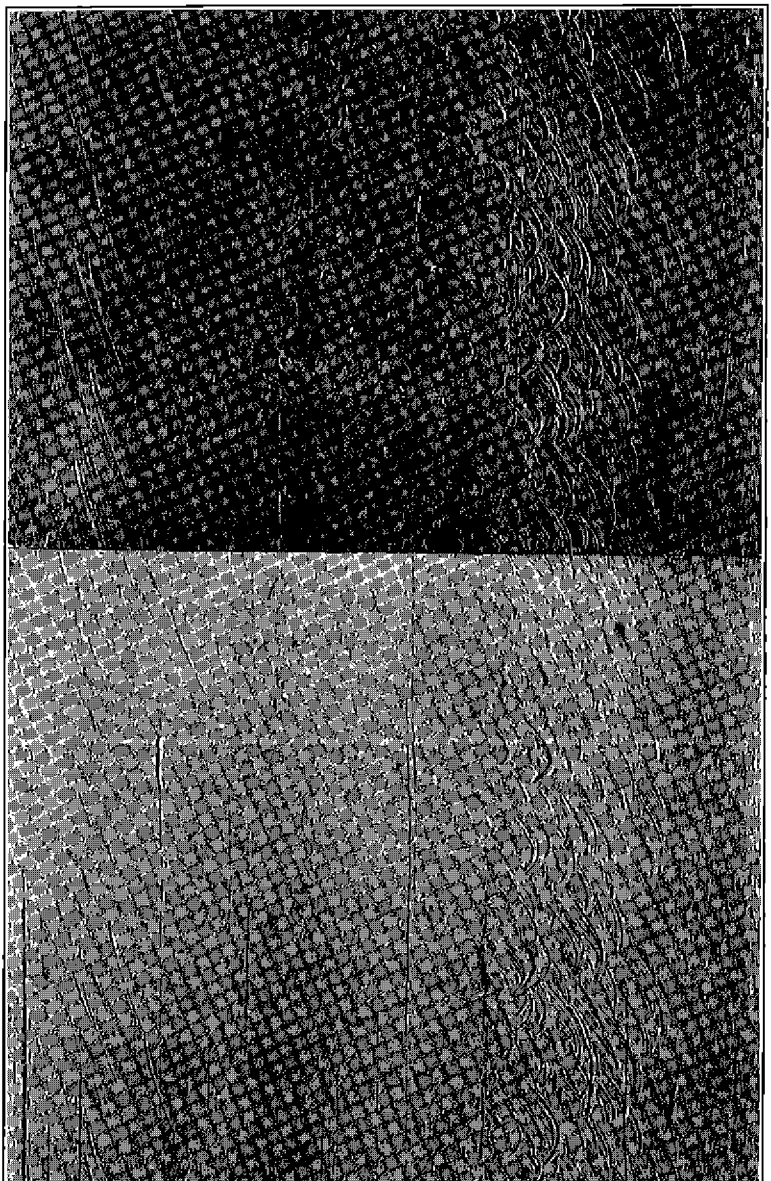

FIGURE 10—Base of a 110 pound rail Appearance of base upper part of cut, before pickling, lower part of cut after pickling in hot hydrochloric acid One of a series of rails from different steel mills

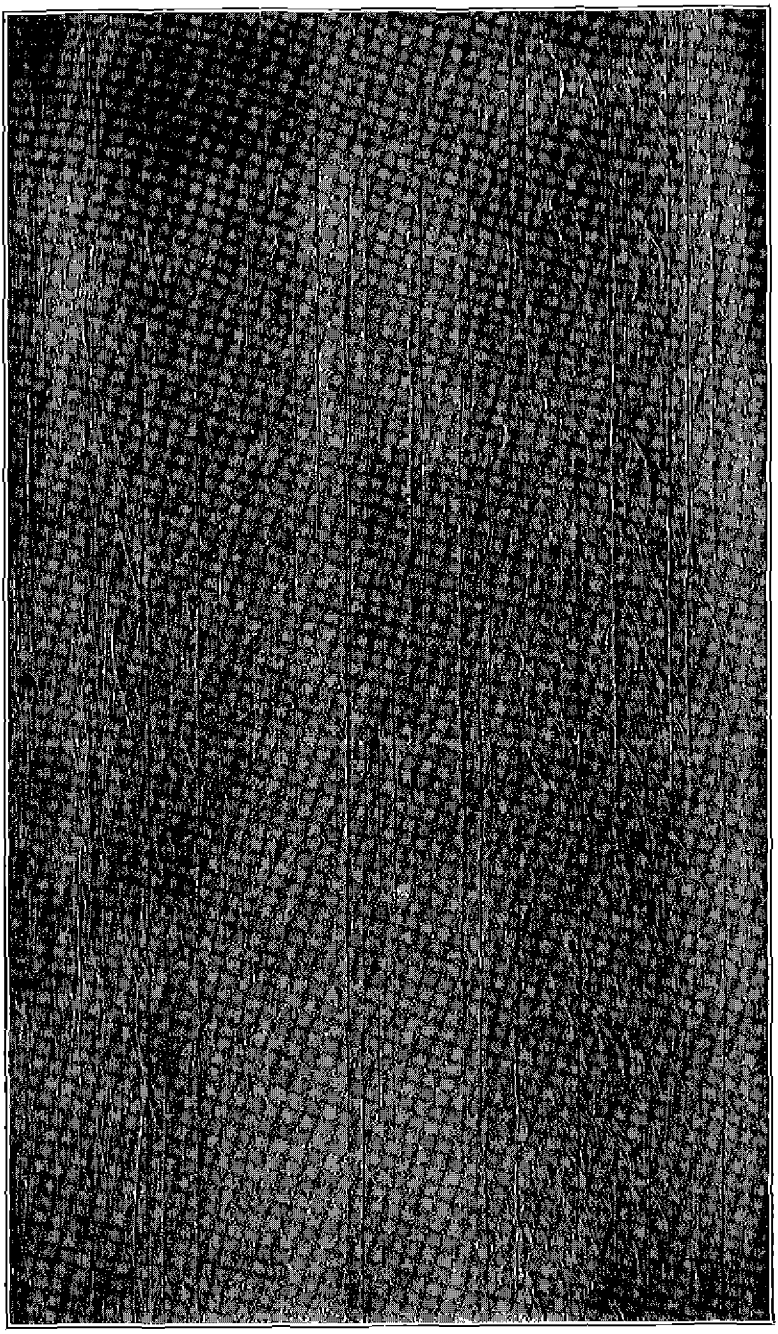

FIGURE 11 —Base of a 127-pound rail medium manganese steel Appearance after pickling in hot hydrochloric acid One of a series of rails from different steel mills

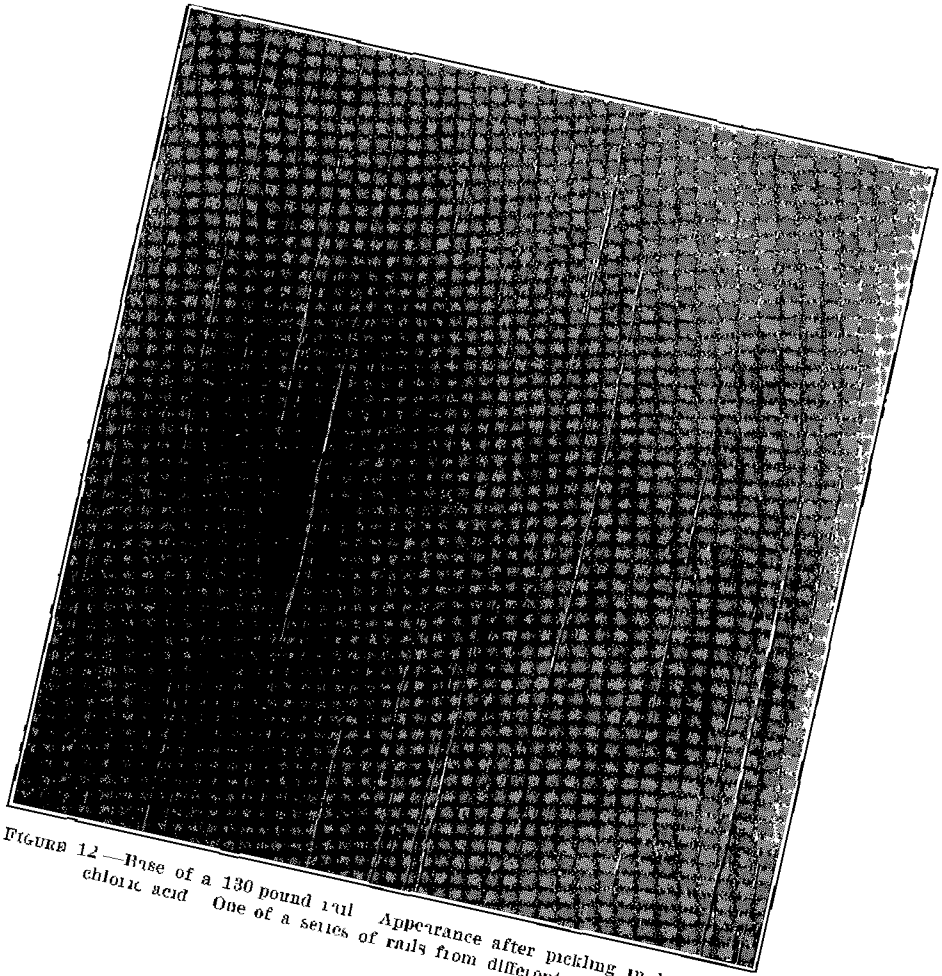

FIGURE 12.—Base of a 130-pound rail. Appearance after pickling in hot hydrochloric acid. One of a series of rails from different steel mills.

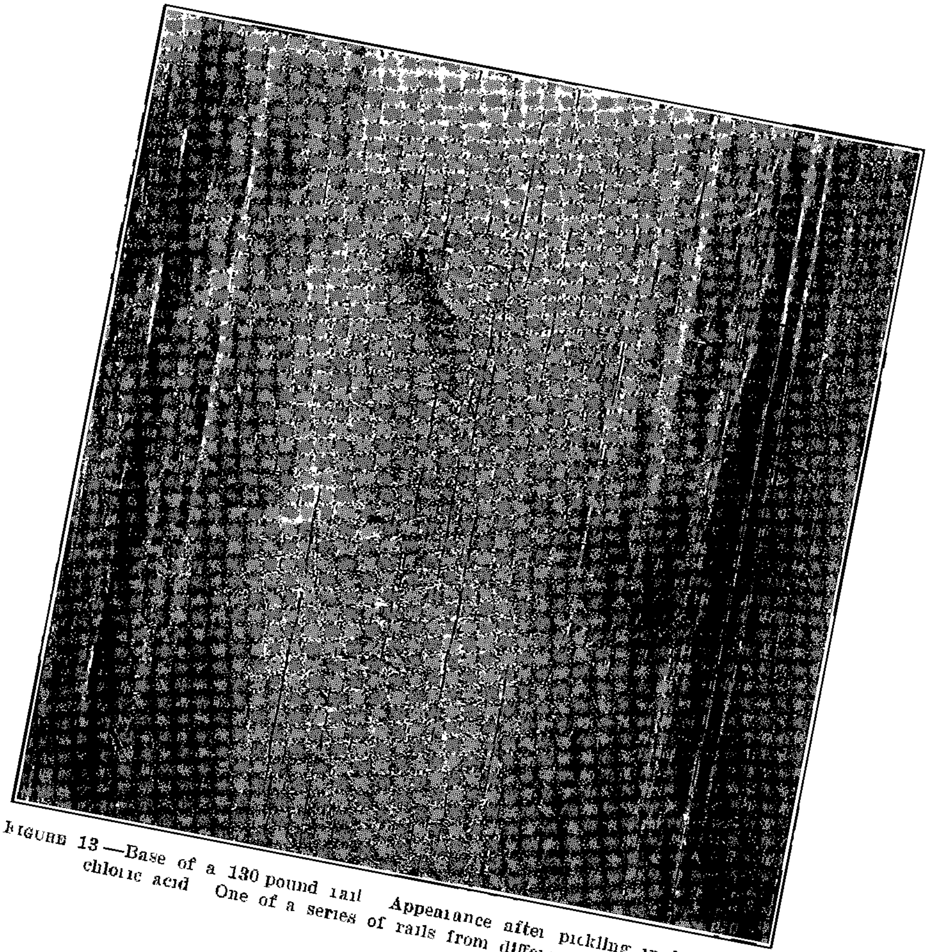

FIGURE 13 —Base of a 130 pound rail Appearance after pickling in hot hydrochloric acid One of a series of rails from different steel mills

chemical elements, positive or negative, foreign inclusions, and blowholes. It is not clear, however, that surfaces should differ according to ingot position.

Figure 12 represents the base of a 130-pound rail, ingot letter C. Surface seams are distributed here and there over the surface.

Figure 13 represents the base of a 130-pound rail, ingot letter unknown. The seams are sharply defined. They are distributed quite generally but most pronounced along the middle of the surface of the base.

Weights per yard, ingot letter, and chemical composition of rails from different steel mills

No	Weight pounds per yard	Ingot letter	Chemical composition ladle analyses				
			Carbon	Manganese	Phosphorus	Sulphur	Silicon
7	90	B	65	78	026	034	156
8	100	C	76	65	025	061	20
9	105		71	83	029	035	18
10	110	C	80	70	026	028	19
11	127	A	57	1 35	025	025	10
12	130	C	77	85	029	040	21
13	130						

These examples represent rails of recent rolling taken at random. Rails come to notice in which the surface seaminess is more conspicuous than those here presented, also there are those which display a lesser number of seams. The degree of prominence of the seams in individual cases may depend upon the length of exposure in the pickling bath. The mill scale is removed by the acid and some of the metal put into solution. The longer the period of pickling the more of the steel goes into solution, and the wider the seams appear.

A sharp reentering angle, as well known, is a menace to all grades of carbon steels which are exposed to repeated stresses, and especially alternating stresses. It is probably safe to say also menacing to steels exposed to shocks and vibratory stress. The metal may not be weaker inherently at the root of a sharp seam, it may even be stronger by reason of attached reenforcement of adjacent metal, but vibratory strains are interrupted and intensified at such places. Shocks, wave motions, and vibratory strains are common to railway track and equipment, and these factors lead to certain kinds of fractures.

Knowledge of how to read fractures, to identify their points of inception and determine the direction in which they traverse the member is so easily acquired that a correct diagnosis of most fractures should be made. But such a method of procedure is seldom followed. Ordinarily fractured material is submitted for test to determine whether its physical properties meet the specifications under which it was purchased, no attention being paid to the features responsible for its rupture; an open book but not read. A great waste of effort constantly goes on in these retests of material. Tensile tests, Brinell hardness, chemical composition and examination of microstructure comprise the usual range of laboratory tests for fractured material. They have no specific relation to the cause of rupture when for example the reason for rupture was the presence of a seam in the steel. Equally untrustworthy is attributing the primitive fracture to a location in the rail where only secondary results could take place.

SUMMARY

The cause of the present derailment is attributed to a base fracture at the receiving end of rail designated as No. 4. It was a fracture of the crescent-shaped type. Occurring at the immediate end of the rail, some of the material which goes to make up an ordinary fracture of this kind was not included in the portion of the rail broken. The primitive portion of the fracture was covered by the splice bars, and therefore hidden from view.

Engineers who have to do with the metallurgy of rails should take up the study of fractured surfaces. The examination of such surfaces supplies reliable data upon which causes of fracture can reliably be founded. Correctly interpreted such evidence points to the true cause of rupture. Several fractured surfaces were exhibited by rail 4, but they were secondary to the break at the immediate receiving end. This derailment again brings to notice a danger zone in the length of the rail not shown by electric track circuits and hidden from view against track inspection, namely, the short section between bond wires and covered by the splice plates.

Respectfully submitted.

W. P. Borland, *Director.*

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