INTERSTATE COMMERCE COMMISSION.

REPORT OF THE CHIEF OF THE BUREAU OF SAFETY COVERING THE INVESTIGATION OF AN ACCIDENT WHICH OCCURRED ON THE CHICAGO GREAT WESTERN RAILWAY NEAR WYETH, MO, ON JANUARY 3, 1920

April 29, 1921

To the Commission

On January 3, 1920, there was a derailment of a passenger train on the Chicago Great Western Railway near Wyeth, Mo, which resulted in the death of 1 passenger, and the injury of 79 passengers and 3 Pullman employees As a result of the investigation of this accident I submit the following report

The accident occurred on the seventh district of the southern division, a single-track line extending between Leavenworth and Conception, Mo, a distance of 74 2 miles, over which trains are operated by time-table and train orders Proceeding westward from the station at Wyeth there is 912 feet of tangent, followed by a 3-degree curve to the left 846 feet in length, 1,678 feet of tangent, and a 2-degree curve to the left, 679 feet in length The accident occurred on this latter curve at a point 427 feet west of its eastern end The grade from Wyeth is practically level for 1,750 feet, followed by a descending grade to the point of accident, varying from 0 29 per cent to 0 83 per cent The track is laid with 85-pound rails, 33 feet in length, single spiked to an average of 18 oak ties to the rail, ballasted with stone and cinders to a depth of from 8 to 12 inches Tie-plates are used on curves The rails were laid in the track in October, 1904 The general condition of the track was fairly good, although many of the rails were not in good condition At the time of the accident the weather was cold and partly cloudy

The train involved in this accident was westbound passenger train No 3, en route from Minneapolis, Minn, to Kansas City, Mo It consisted of 1 mail car, 1 baggage car, 1 smoking car, 1 day coach, and 8 Pullman sleeping cars, in the order given, hauled by engines 923 and 286, and was in charge of Conductor Cavanaugh and Enginemen Venn and Peavy It passed Rea, 3 3 miles east of Wyeth and the last open telegraph office, at 7 17 a m, 3 hours and 8 minutes late, and at about 7 26 a m was derailed at a point about three-quarters of a mile west of Wyeth while traveling at a speed estimated to have been about 40 or 45 miles an hour

The two engines and the first three cars came to a stop about 2,100 feet beyond the point of derailment, with only the forward pair of wheels of the rear truck of the baggage car derailed All of the remaining cars in the train were derailed to the left side of the track The day coach was derailed just before passing over bridge F–460, a 96-foot plate-girder structure, located 630 feet beyond the initial point of derailment, and after passing over the bridge went down a 20-foot embankment, coming to rest about 50 feet from the track The first and second sleeping cars went down the embankment just before reaching the bridge, coming to rest on their sides at a point about 50 feet from the track The third sleeping car came to rest in an upright position with its forward end down the embankment and the rear end resting on the roadbed, being almost at right angles to the track The fourth sleeping car remained upright with its forward end close to the rails and its rear end down the embankment, 10 or 12 feet from the track This car remained coupled to the fifth sleeping car, which was also entirely derailed, with its forward end down the embankment, while the rear end remained on the roadbed close to the left rail, with the body of the car inclined at an angle of about 45 degrees The remaining three sleeping cars came to rest in an upright position close to the rails

Examination of the track showed that the first marks of derailment were at a broken rail on the inside or left of the curve, at a point about 150 feet back of the last car in the train The receiving end of this rail was intact for a distance of 23 feet 6 inches, and remained upright and spiked in its proper position The running surface was slightly beveled at the break, indicating that a few wheels had passed over it The remainder of the rail was broken into many pieces, 32 of which were recovered, these 32 pieces constituted only a small portion of the leaving end The receiving end of the next rail on the west remained in place, with the rail joints and the end badly battered by wheels passing over them This rail was intact for a distance of 30 feet 6 inches The balance of the leaving end, together with the seven adjoining rails, was torn out of the track by the derailed equipment None of the rails on the outside of the curve was disturbed in any way The first flange marks on the ties were on the left sides of both rails, and were first visible opposite the first broken rail at the end of the receiving portion of 23 feet 6 inches Careful examination failed to disclose any marks indicating that any portion of the train had been derailed before reaching this point

Engineman Venn, of engine 923, stated that he shut off steam a short distance beyond Rea, at which time the speed of the train was about 45 miles an hour, and that he reduced this speed to about 35 miles an hour on the curve just east of Wyeth The speed then increased slightly on the descending grade and was about 40 miles an hour at the time of the derailment He did not notice any jar or unusual motion of the engine when passing over the point of derailment, and had started to work steam when the brakes were applied from the rear, at this time his engine was at the eastern end of the bridge He at once placed his brake valve in the lap position, and then changed it to the emergency position He stated that he did not make any detailed examination of the track, but from his observations concluded that a broken rail was responsible He considered the track to be in fair condition and safe for the speed at which his train was running

Fireman Hutchings, of engine 923, said that he did not notice any unusual motion of the engine His first knowledge of the derailment was when he felt the brakes applied At this time he was riding on his seat and on looking back he saw the day coach going down the embankment He thought the speed of the train at the time was about 35 or 40 miles an hour

Engineman Peavy, of engine 286, stated that he shut off steam about 4 miles east of the point of derailment The speed was reduced between Rea and Wyeth by an application of the air brakes, and again when passing Wyeth The balance of his statements corroborated those of Engineman Venn The statements of Fireman Wilcox, of engine 286, added nothing to those of Engineman Peavy

Conductor Cavanaugh stated that he was riding in the forward end of the smoking car when he felt a severe jar, as though the car had been derailed, and he at once pulled the emergency cord for the purpose of stopping the train He estimated the speed to have been from 40 to 45 miles an hour Shortly after the accident he went back to the rear of the train, but did not make a detailed examination of the track, concluding that a broken rail was responsible for the accident

P A Nolden, employed in the engineering department of the railway, was a passenger on the train Shortly after it was derailed he went back to examine the track, and about 100 or 150 feet beyond the rear of the train he found a broken rail, the leaving end of which was broken into a number of pieces, while the receiving end was intact The next rail on the west was also broken on the leaving end

Track Supervisor Millett stated that he reached the scene of the accident at about 10 30 a m Examination of the first broken rail disclosed a flaw in the head He saw nothing on the running surface of the rail to indicate that it was defective He also found a crack in the head of the receiving portion of this rail which extended back into the rail In his opinion the defect in this rail was such that it could not have been detected without lying down on the ground He thought that the break at the leaving end of the adjoining rail was due to the derailed equipment He also said that he had passed over the track on the preceding day, and at that time did not notice any indication of anything wrong The superelevation on the curve was 2 inches, and he considered it safe for a speed of 50 miles an hour

The investigation clearly developed that the accident was due to a broken rail, which apparently had been in a defective condition for a considerable length of time The examination to determine the reason for the failure of this rail was conducted by Mr James E Howard, engineer-physicist, whose report immediately follows

REPORT OF THE ENGINEER-PHYSICIST

The derailment of train No 3 was due to the failure of a rail, the leaving end of which was broken into a number of small fragments The receiving end, for a length of 23 feet 6 inches, remained intact The type of rupture displayed was a split-head fracture A vertical plane of rupture was developed which nearly separated the head into halves, which extended along the length of the rail for a distance of 13 feet Of this section, 9 feet 6 inches was broken into small fragments, 32 being recovered

The rail was 85 pounds weight, A S C E section, rolled in September, 1904, and laid in the track in October of that year Its age was therefore 15 years 3 months It was made of Bessemer steel, heat number 46664, and branded "Illinois Steel Co So Wks IX 1904 8504"

This rail presented a common type of rupture, the characteristics of which are illustrated in the several cuts herewith, reproduced from photographs and sulphur prints In rails with split heads a longitudinal, vertical plane of rupture is developed, located along the middle of the width of the head The origin of the plane of rupture is an interior one, located about one-quarter of an inch, more or less, below the running surface of the head The shallow zone above the origin of the rupture remains unbroken until the last stages of failure are reached In the development of the split head the plane of rupture extends downward until abreast the junction of the head and the web Here it commonly bifurcates, the branches extending right and left toward the fillets under the head Final rupture occurs by the complete separation of the halves of the head and their detachment from the web At the upper initial edge of the plane of rupture a small v-shaped ridge of metal, attached to the upper zone of metal, is frequently found This acts as a wedge to separate the walls of the fracture

The incipient point of rupture, in respect to the length of the rail, was somewhere in the 9-foot 6-inch section, which was broken into small fragments The characteristics of the metal of the rail were similar along this portion of its length and in the unbroken part adjacent thereto The photographic cuts and sulphur prints represent the adjacent metal

Figure No 1 shows the appearance of the rail, in cross section, near the fractured portion, after polishing and etching with tincture of iodine The upper edge of the plane of rupture is characterized by the presence of markings on the end surface revealed by the tincture of iodine These markings, here viewed on end, represent longitudinal streaks in the steel They are lines of structural weakness, affecting the metal under crosswise strains

The split in the head, shown at this stage of development, is much wider at its upper edge than elsewhere The wedge-shaped rib of metal at its upper edge is forced by the successive wheel pressures between the faces of rupture, thereby increasing the width of the head

The plane of rupture separated into two branches One branch extended and reached the periphery of the section at the fillet under the head on the outside of the rail The other branch extended toward the gauge side of the rail and appears in a partially developed stage

Figure No 2 is a side view of the rail showing the line of rupture under the head which had reached the peripheral surface Figure No 3 is an endwise view farther along the length of the rail, where the split in the head was less developed Fractures of this kind do not always continue in an unbroken course, but deviate under the influence of contiguous streaks in the metal The end surface shown in this cut was polished and then etched with tincture of iodine

Figure No 4 is a sulphur print of the end surface shown by figure No 3 The markings are substantially the same as those revealed by the use of iodine Figures Nos 5 and 6 are sulphur prints of longitudinal surfaces of the head and base, respectively, each about one-fourth inch below the peripheral surfaces Other sulphur prints at different depths showed similar longitudinal streaks, but not coinciding with those on surfaces near by

Figure No 7 represents the rail in cross section at a place where the head was intact The iodine markings show the continuance of the structural conditions which prevailed in other parts of the rail Figure No 8 represents another part of the rail where the head was intact This section was pickled in hot hydrochloric acid The same characteristic markings appear on the cross sections, whether revealed by polishing and etching with tincture of iodine, by means of sulphur prints, or upon pickling in hot acid

Photomicrographs of this rail will be presented and discussed in a later part of the report Illustrations are herewith presented of other rails which have failed and caused derailments—failures which were influenced by the structural state of the metal

Figures Nos 9 to 13, inclusive, represent a rail which failed on March 30, 1920, causing the derailment of train No 111, near Savan, Pa , on the Indiana Branch of the Buffalo, Rochester & Pittsburgh Railway Co This was an 80-pound rail rolled by the Carnegie Steel Co It failed by the development of a fracture under the head, at the junction of the web Its development was progressive, having its origin at a zone of streaked metal The head was detached from the web, followed by the fracture of the web and the base

Two views of the principal surfaces of rupture are shown by figures Nos 9 and 10 Figure No 9 is looking up, at the under side of the head Figure No 10 is looking down, on the upper edge of the web The surfaces of progressive fractures wherever found are similar in appearance, leaving no doubt concerning their identity The characteristics of fractured surfaces commonly furnish reliable evidence upon the manner of failure of steel members

Opportunity was taken to further examine the Savan rail in quest of surface seaminess—a condition of the metal of the base which has led to many fractured rails The results are shown by figures Nos 11 and 12 Figure No 11 represents the appearance of the base of the rail, two fragments, as it appeared when removed from the track Spike-maul marks are shown on the left-hand figure of the cut Figure No 12 shows the appearance of the surface of the base after pickling in hot hydrochloric acid Surface seaminess, not in evidence on the rail as it came from the track, was revealed upon pickling

Two end surfaces of the Savan rail as they appeared after pickling are shown by figure No 13

Figures Nos 14 to 18, inclusive, represent a rail which failed on January 19, 1921, causing the derailment of train No 9, of the Erie Railroad, near Friendship, N Y This was a 90-pound rail rolled by the Carnegie Steel Co , and was branded " Carnegie 1909 E T IIIIIIII 90 A " It illustrates a piped rail, in connection with which a split-head fracture developed

Split-head rails are often erroneously reported as piped rails The primary causes which lead to the failure of these two types are distinctly different, and their origins are located in different parts of the cross section of the rail A split-head fracture has its origin in the upper part of the head A piped rail has a plane of separation in the web and lower part of the head Split-head rails are of frequent occurrence, while piped rails are not A split-head fracture *may occur in conjunction with a piped rail as the present rail* shows—a matter not affecting their separate origins

Figure No 14 shows the hot sawed end of the Friendship rail The vertical line of separation in the web shows the characteristic feature of a piped rail This rail displayed a composite fracture in which its piped condition was probably the leading cause Associated with the plane of rupture in the web, there was a horizontal shearing fracture in the head and also a split-head fracture The piped state of the rail was embraced in part and reenforced by the splice bars The support given the rail by the splice bars doubtless accounts for the display of the several types of rupture in immediate association with each other

Figure No 15 is a side view of this rail showing the fractured surface of the web between the bolt holes and partially exposed a short distance beyond Above this portion of its length the head of the rail was broken in a crosswise direction in addition to a vertical plane of rupture which nearly separated it into halves Both the pipe and the split-head fracture continued beyond the limits of this photograph

Figure No 16 is a view in cross section of the Friendship rail farther along its length, photographed after polishing and etching with tincture of iodine The pipe extended into this section The opposite faces were in close proximity to each other, hence the pipe does not show in this cut The split in the head had separated and is clearly visible

Figure No 17 is a sulphur print of the Friendship rail at a place where the pipe was clearly visible, and also where the split in the head was in an advanced stage A lateral branch of the split-head fracture had nearly reached the peripheral surface of the rail at the fillet under the head on the gauge side The fracture of the rail at this point is of interest in showing the dominating influence of the wheel pressures in relation to fractures in the head The formation of a lateral branch of the split-head fracture doubtless resulted from the wheel pressures exerting a spreading effect on the metal at the top of the head In the order of development the formation of this lateral branch probably was the last part of the fracture to occur The walls of the split-head fracture were separated by the wedge action of the cold-rolled metal of the top of the head When the medial line of pressure between the wheel and the rail occurs near either the gauge side or the outside edge of the head there is an overturning moment applied to the head Such eccentric loading leads to the bifurcation of the line of rupture in the case of a split head The different contours of the treads of wheels are responsible for different elements along the running surface receiving the maximum impinging pressures and causing the alternate loading of one side and then the other of the head of the rail This alternate eccentric loading of the head accounts for the bifurcation of the vertical plane of rupture in a split-head rail abreast the junction of the head and the web where bending stresses in crosswise direction under such circumstances attain high limits It will be inferred from the present exhibit and the remarks which are submitted that relatively there is a greater tendency, under the influence of track conditions, for a rail to fail by the development of a split head than by reason of the presence of a pipe

Figure No 18 shows the appearance of the Friendship rail after pickling in hot acid at the cross section upon which the preceding sulphur print was taken Greater solubility of the metal takes place at those places which are stained by the iodine, or marked on the sulphur print, than on other parts of the cross section, resulting in the close similarity of the illustrations furnished by these three methods

In the study of the failure of steel, attention centers upon one principal feature and the relations of subordinate features to the principal one The principal feature relates to the stress or strain, mutually related factors, which the metal is capable of enduring and the manner in which limiting values in terms of stress or strain are reached In plainer language, it is desired to know what loads the steel will carry, what relations the properties of the metal which are shown under test bear to the endurance of service conditions, whether any part of the elongation displayed in the tensile test or the contraction of area then displayed will be realized in service, whether the ultimate tensile strength of the steel represents a particular value to the rail when in service, whether the ductility clause of the drop test has any real significance, whether the drop test itself has any definite relation to the serviceability of the rail These and other queries suggest themselves Chemical composition and finishing temperatures are factors which influence and control physical properties in rolled shapes—established by the laws of nature and not by specifications

Opportunity occasionally offers to acquire data touching upon some of the above queries On the present occasion microscopic observations were made upon the structural appearance of the metal of the Wyeth rail adjacent to the running surface of the head, at the upper terminal of the split-head fracture, and at the lower terminals of the bifurcated fracture The observations were directed to the distortion of the grain of the steel adjacent to the running surface, where flattening and flow occur immediately, due to the wheel pressures, and noting the undistorted shape of the grains at the split-head fracture

The metal of this rail was capable of displaying ductile flow The distorted shape of the grain next the running surface and the formation of a fin along each edge of the head is evidence thereof At the terminals of the split-head fracture and the apex of the wedge-shaped rib at the upper edge of the split-head fracture there was, however, no appreciable distortion of the grain At these places, microscopically, there was absent any evidence of an appreciable permanent set of the steel having taken place Ductile flow and brittleness in the same rail are here shown, the result of the manner in which the stresses were received The same is true of other carbon steel rails Whether any part of the elongation or contraction of area of the tensile test is displayed in service depends upon the manner in which those features are developed

A series of four photomicrographs was taken along the upper zone of the head of the Wyeth rail, showing the shape of the grain of the steel within the zone directly affected by the wheel pressures Each represents the metal of the rail in cross section, and each at a magnification of 100 diameters Fig No 19 represents the shape of the grain near the running surface of the head about in line with the gauge side of the web, that is, not far from the middle of the width of the head The grains were slightly flattened along this element, the distortion not being very pronounced This element appeared to be within the neutral axis with respect to distortion and direction of flow of surface metal

Figure No 20 shows the distortion of the grain at a place nearer the gauge side of the head The flattening of the grain here is very pronounced, with a drift toward the gauge side Figure No 21 shows the distortion of the grain on the opposite side of the center line of the head The flattening of the grain and drift toward the outside edge of the head is here also very pronounced A fin was formed along each edge of the head, the metal to form which necessarily came from the upper part of the head Under such circumstances it is quite evident there would be a neutral element on either side of which the surface flow would take place in opposite directions, as these photomicrographs indicate The flow of metal at the extreme outside edge of the head showed a laminated state, as illustrated by Figure No 22 The laminations were separated and individually broken The dark Z-shaped lines on the cut represent lines of fracture

The depth of the zone of distorted grain was about five-hundredths of an inch Below this depth normal shape of grain prevailed A feature of interest is raised in this connection—namely, that microscopic evidence is not presented showing a disturbance of the structural state of the metal so far down as the origins of split-head fractures are located Evidence of a state of internal compression in the upper part of the head does not rest upon microscopic indications, but upon the results of strain gauge measurements In comparing the results of strain gauge measurements with the indications of the microscope it has not been made clear that the presence of internal strains of either tension or compression may be recognized with the aid of the microscope If such was the case the most far-reaching results would come from the use of the microscope in ascertaining the existing states of strain in all kinds of engineering structures

Figure No 23 represents the apex of the wedge-shaped rib at the upper terminal of the split-head fracture shown by figure No 1 There was no distortion of the grain at the apex of this wedge This illustration touches upon another feature in the behavior of metals—namely, that cubic compression, however great, and it has been observed up to a pressure of 117,000 pounds per square inch, has no permanent effect upon the structural state of the steel The wedging apart of the split-head fracture, therefore, does not demand there should be of necessity a distortion of the grain of the wedging member

Figure No 24 shows the termination of the shorter branch of the bifurcated split head fracture illustrated in figure No 1 The crack in the steel is indicated by the oblique irregular line which appears in the cut, darker than the ferrite boundaries of the grains and lighter than the pearlite grains This appearance of the crack is due to its being filled with iron rust

Figure No 25 shows the termination of the split-head fracture illustrated in figure No 3 The plane of the fracture at this place had deflected and approached nearer the fillet under the head than shown by figure No 1 The irregular black line extending obliquely downward in this cut represents the termination of the crack The surfaces of the fracture were not oxidized in this case

The last two photomicrographs illustrate this feature That a plane of rupture may pass into or through a steel member without change in shape of the grain, and therefore without display of appreciable ductility This has been found true in different grades of steel The behavior of rails in service furnishes the basis for the query concerning the value in itself of the ductility clause of specifications A greater or less display of elongation will take place in steels, depending upon their composition, when tested in such a manner as to permit of the display of ductility, that is, certain steels inherently possess such ability by reason of their chemical composition Specifications can enumerate these numerical values, but without changing the results These remarks are made because the failures of materials are often attributed to lack in meeting specifications, when as a matter of fact the relation between the specified properties and the ability of the material to endure service stresses has not been given consideration This is a plea for a better understanding of the specific causes which lead to failures, in which those of rails present notable opportunities

In summation, the failure of the rail which caused the present derailment was due to the presence of a split-head fracture Wheel loads cause distortion of the grain of the steel and induce lateral flow of the metal at the running surface of the rail the tendency of such loads being to spread the railheads The successful resistance of such lateral forces depends upon the structural soundness of the metal in the railhead Longitudinal streaks are lines of weakness which influence the formation of split-head fractures and locate their incipient points of origin Longitudinal streaks are due to casting and mill conditions Their elimination, or reduction in numbers and gravity of development, are matters for the steel makers to consider The ages at which split-head rails manifest themselves indicate such fractures are of slow and progressive development It is a matter of conjecture, although having the appearance of probability, that split-head rails would be unknown if strictly seamless steel was available for rails The rail problem is intensified by reason of the employment of high wheel pressures Soft rails display mashed heads Hard rails furnish a large number of transverse fissures

There is a popular fallacy entertained that split-head rails do not constitute a dangerous type of fracture, since at certain stages in their progress of rupture they may be detected in the track This evidence, however, is presented at a late stage, after the necessary margin in strength in the rail has been practically exhausted, and not prior thereto An element of danger has arisen when split-head rails are detectable in the track An economic question is involved in the elimination of the causes of split-head failures, since many rails are removed for this cause which are not otherwise unserviceable Finally, split-head failures should not be reported as piped rails

SUMMARY

The cause of this accident is shown to have been due to the failure of a rail which displayed a split-head fracture The head of the rail was separated into halves by a vertical plane of rupture, the halves of the head broken into fragments, with lines of rupture separating the web and the base A portion of the length of the rail broke into a number of small fragments

As illustrated and described by the engineer-physicist this type of fracture has its origin in the upper part of the head, the incipient point being located a short distance below the running surface It also appears from the best evidence on the subject that split-head fractures are induced by the presence of certain longitudinal streaks or seams in the metal, and that such seams represent the incipient places from whence planes of rupture extend and destroy the rail in the course of their development

It appears to be well established that split-head fractures begin in the upper part of the head and progressively extend downward in substantially vertical planes When the plane of rupture reaches a depth which brings it abreast or nearly abreast the junction of the head and the web, the plane of rupture commonly changes its course or separates into two branches, one of which eventually reaches the periphery of the rail at the fillet under the head When this stage of rupture has been reached the ultimate failure of the rail soon takes place

The width of the split is narrow in comparison with its depth of penetration—a circumstance which renders the detection of a split-head rail uncertain until the period of final rupture is close at hand This fact should dislodge a popular fallacy concerning split-head rails—namely, that such fractures are easily detected in the track, and therefore should not occasion anxiety, overlooking the fact that when detectable the rail has reached a weakened condition and may be on the verge of rupture

Data in the report are presented on the extension of cracks of interior origin, showing the absence of the display of ductility of the metal in fractures of this class Without the display of ductility, external and visible evidence of impending rupture is evidently wanting Methods of test have been offered for the detection of interior fractures in rails The development of such apparatus does not appear to have reached a state in which its application to rails in the track has been attained As the case now stands, the early detection of split-head rails in the track depends upon the vigilance of the track supervisors and the section men

The engineer-physicist has ventured the remark that split-head rails would be nearly or quite unknown provided seamless steel was found in rails The relation which seaminess of metal bears to split-head rails appears to furnish a basis for this remark It commonly takes years of service to develop split-head fractures, which gives encouragement to the thought that an improvement in the structural state of the steel would measurably prolong the lives of certain rails Elements of safety and economy would be subserved if the primary cause in the formation of split-head failures was removed or the influence of such cause measurably lessened

No comprehensive consideration can be given the subject of rail failures without taking into account the effects of high wheel loads, effects which are destructive in their character Regardless of whether responsibility in the abstract attaches chiefly to the makers or the users of rails, statistics show that a considerable number of rails fail under present conditions of service A reduction in the number is highly desirable In respect to the display of split-head failures, promise of improvement appears to lie in the direction of using steel of less seamy state

Respectfully submitted

W P Borland,
Chief, Bureau of Safety

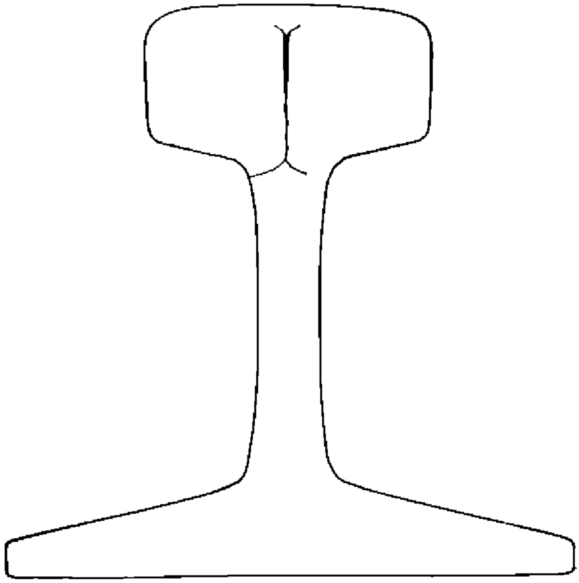

Fig A

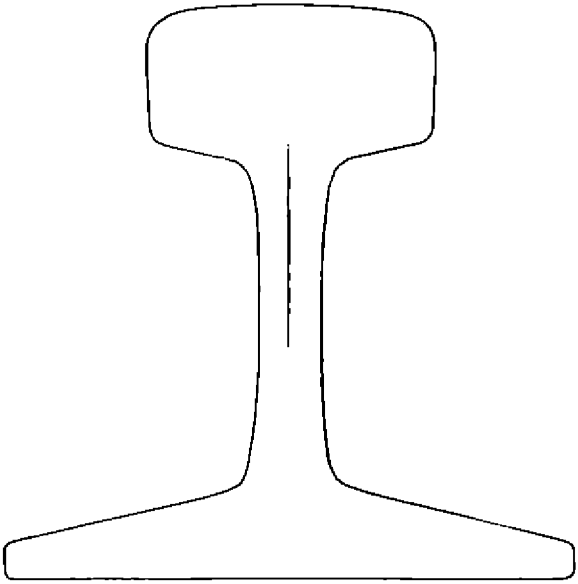

Fig B

Fig A Typical split head fracture
Fig B Typical piped rail

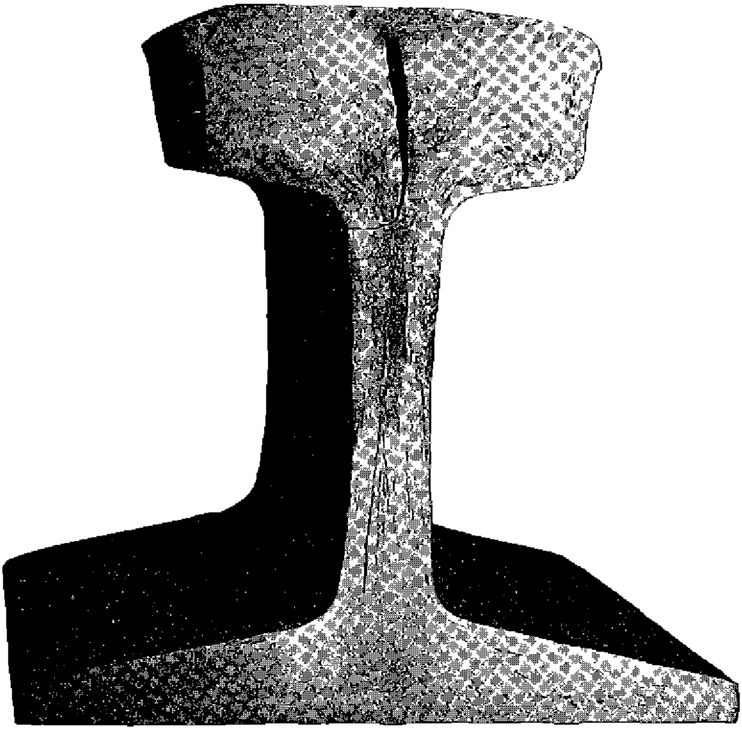

FIG. 1—End view of rail polished and etched with tincture of iodine, showing relations of markings in upper part of head and origin of split head fracture

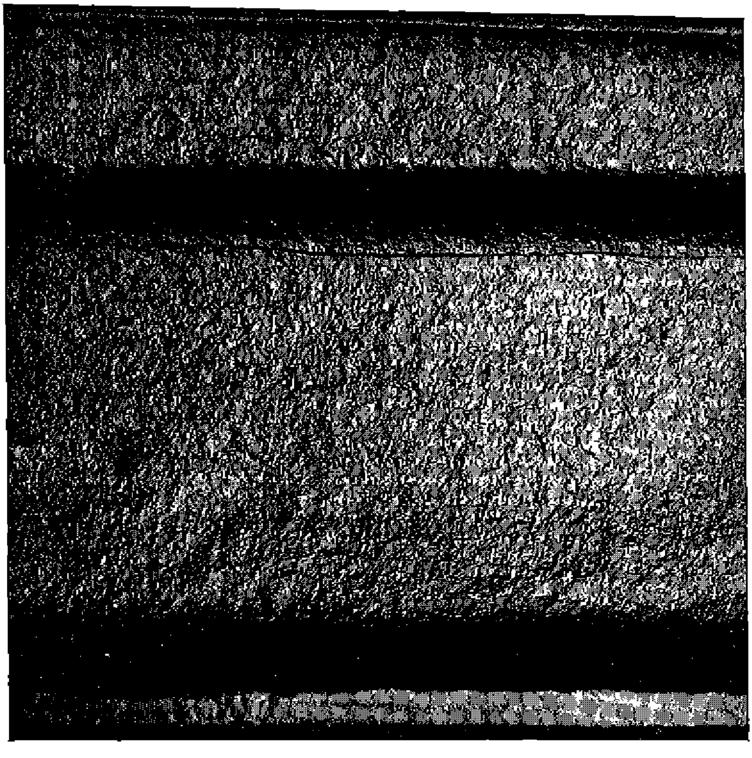

FIG. 2.—Side view of rail, showing longitudinal crack at the fillet under the head, where split head fracture had reached the peripheral surface of the rail

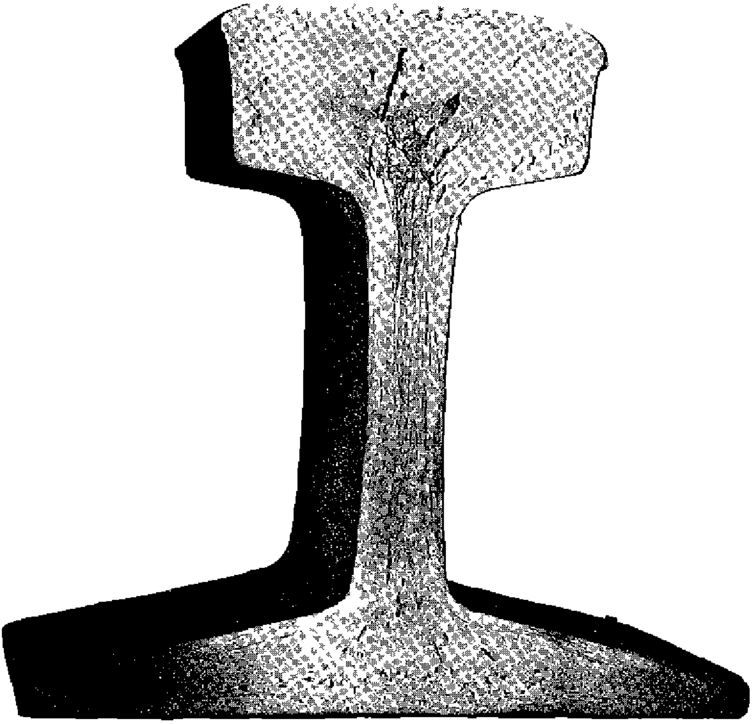

FIG 3—End view of rail, polished and etched with tincture of iodine Cross section of rail where split head fracture was less developed than where shown by figure 1

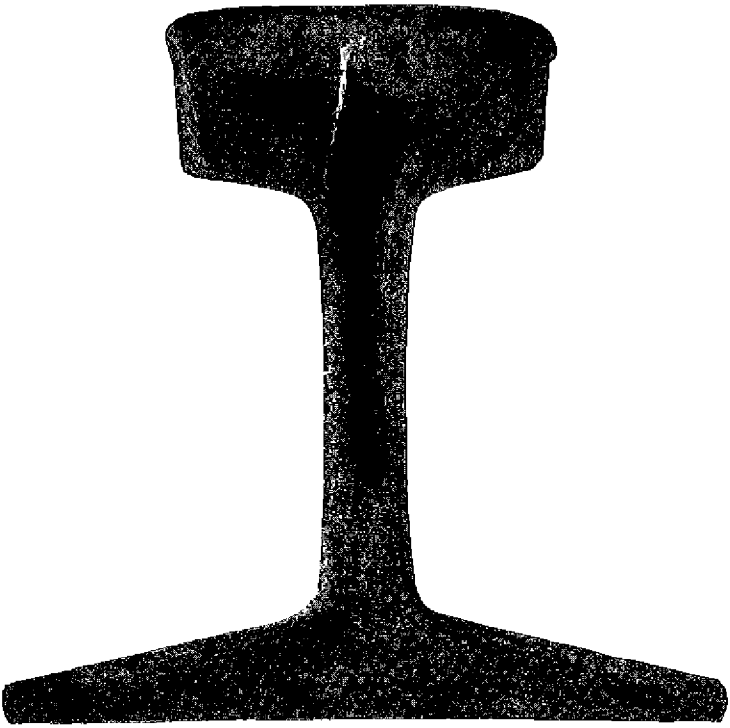

FIG 4—Sulphur print of surface shown by figure 3

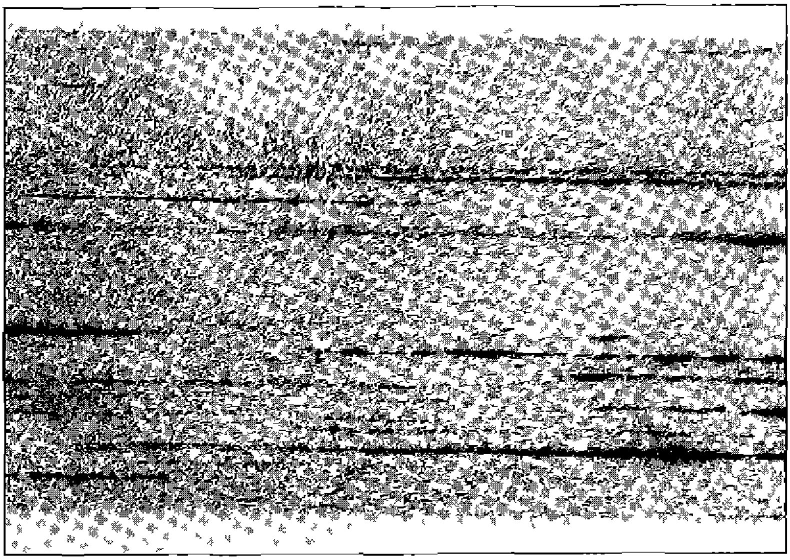

FIG 5—Sulphur print of longitudinal, horizontal surface of head of rail, ¼" planed off the running surface

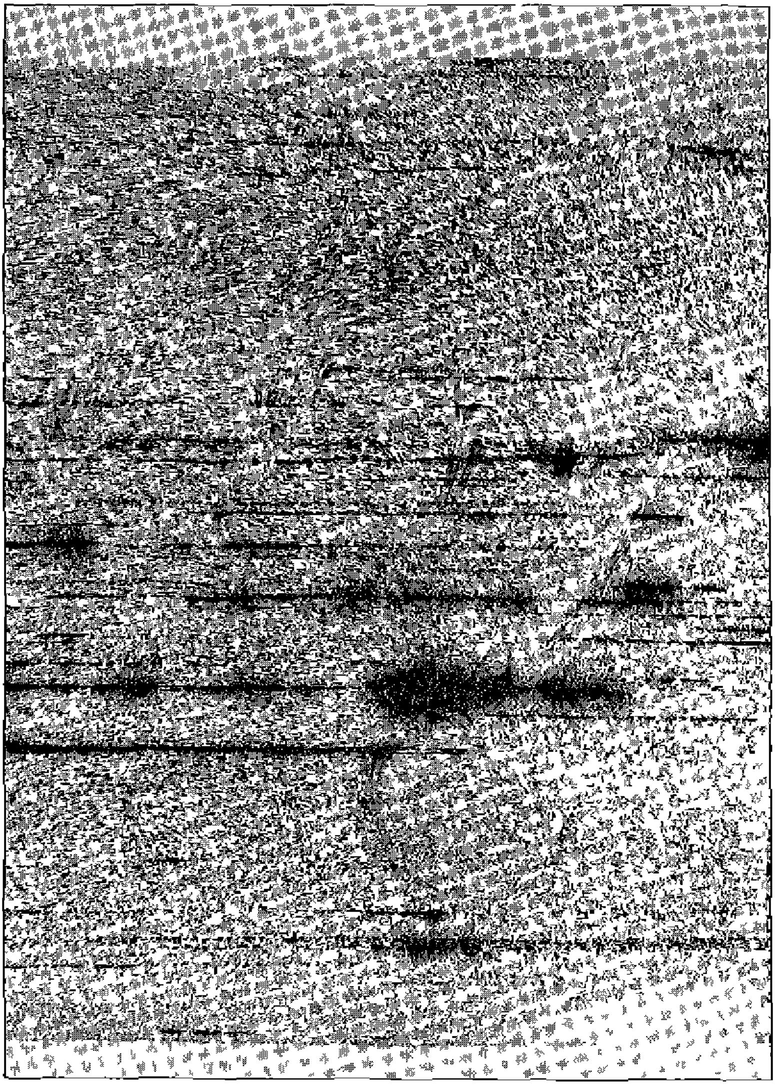

FIG 6 —Sulphur print of longitudinal, horizontal surface of base of rail, ¼" planed off the bottom of the base

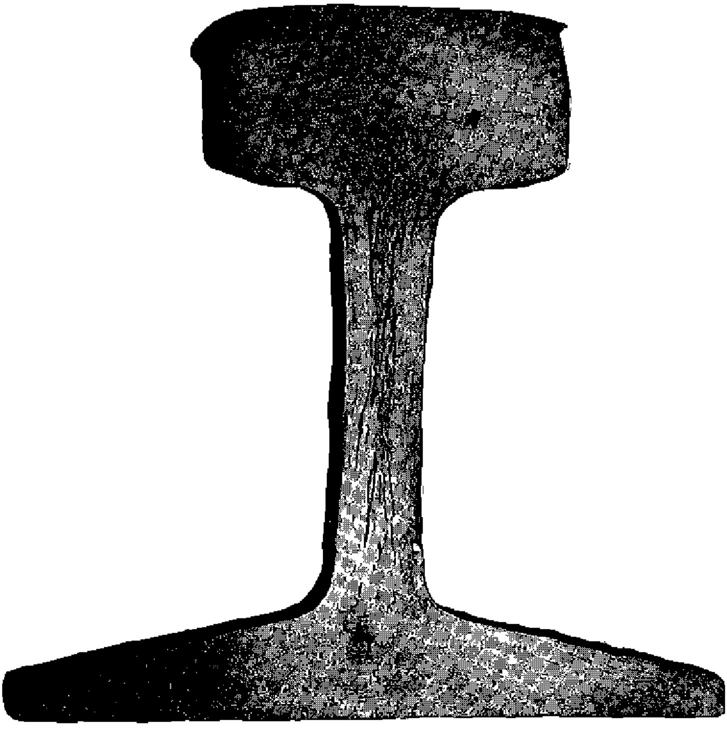

FIG 7 —Appearance of cross section of rail where head was intact, polished and etched with tincture of iodine

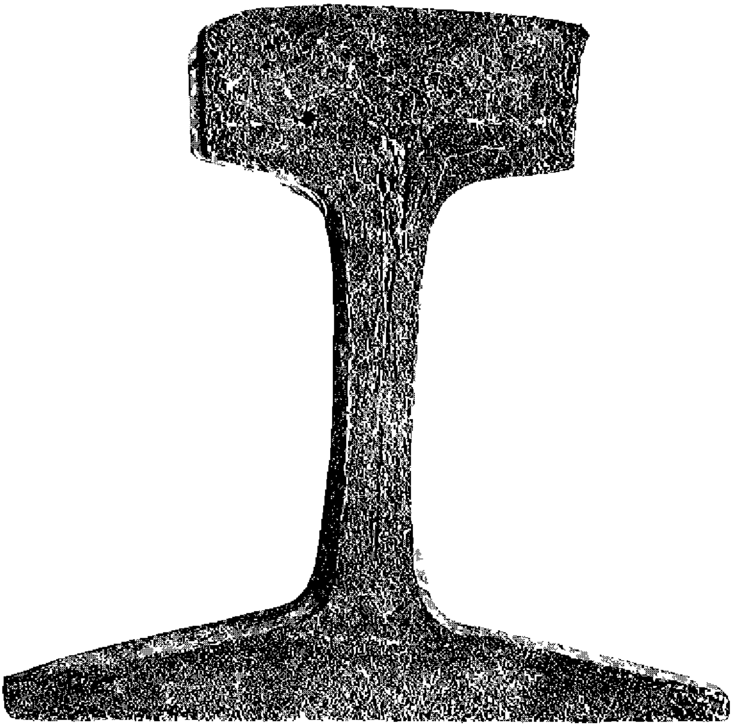

FIG 8 —Appearance of cross section of rail, where head was intact, after pickling in hot hydrochloric acid

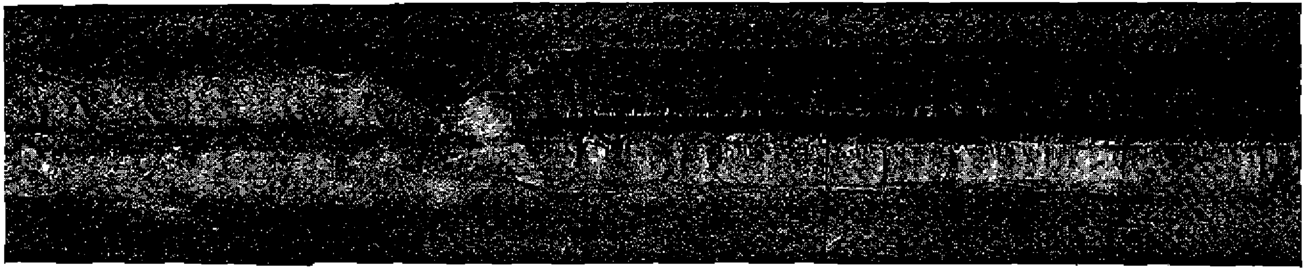

FIG 9 —80 pound rail which failed near Savan, Pa , B R & P Ry Co View of underside of head showing progressive fracture along junction of head and web

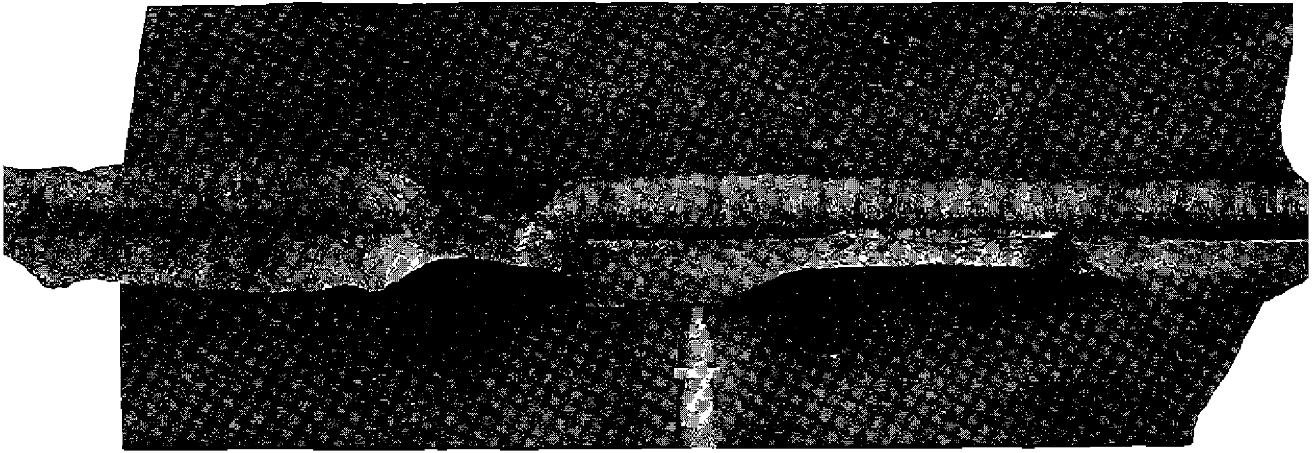

FIG 10 —80 pound rail which failed near Savan, Pa View of upper edge of web the opposite surface of progressive fracture shown by figure 9

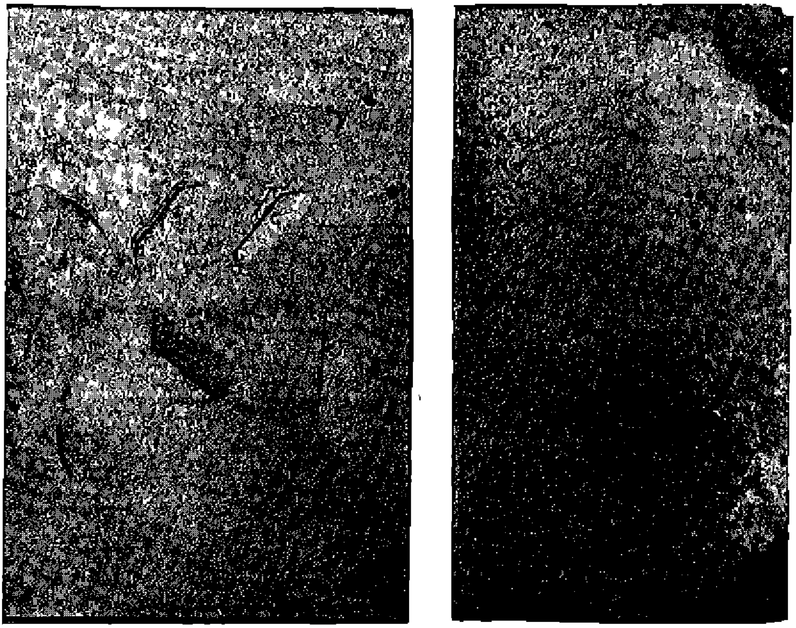

FIG 11—80 pound rail which failed near Savan, Pa Appearance of base before pickling in hot acid

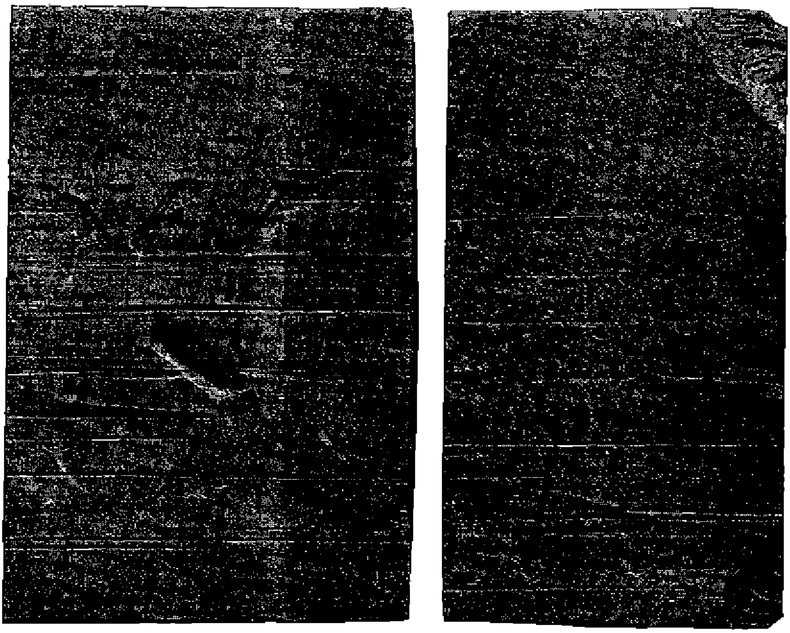

FIG 12—80 pound rail which failed near Savan, Pa Appearance of base after pickling in hot acid

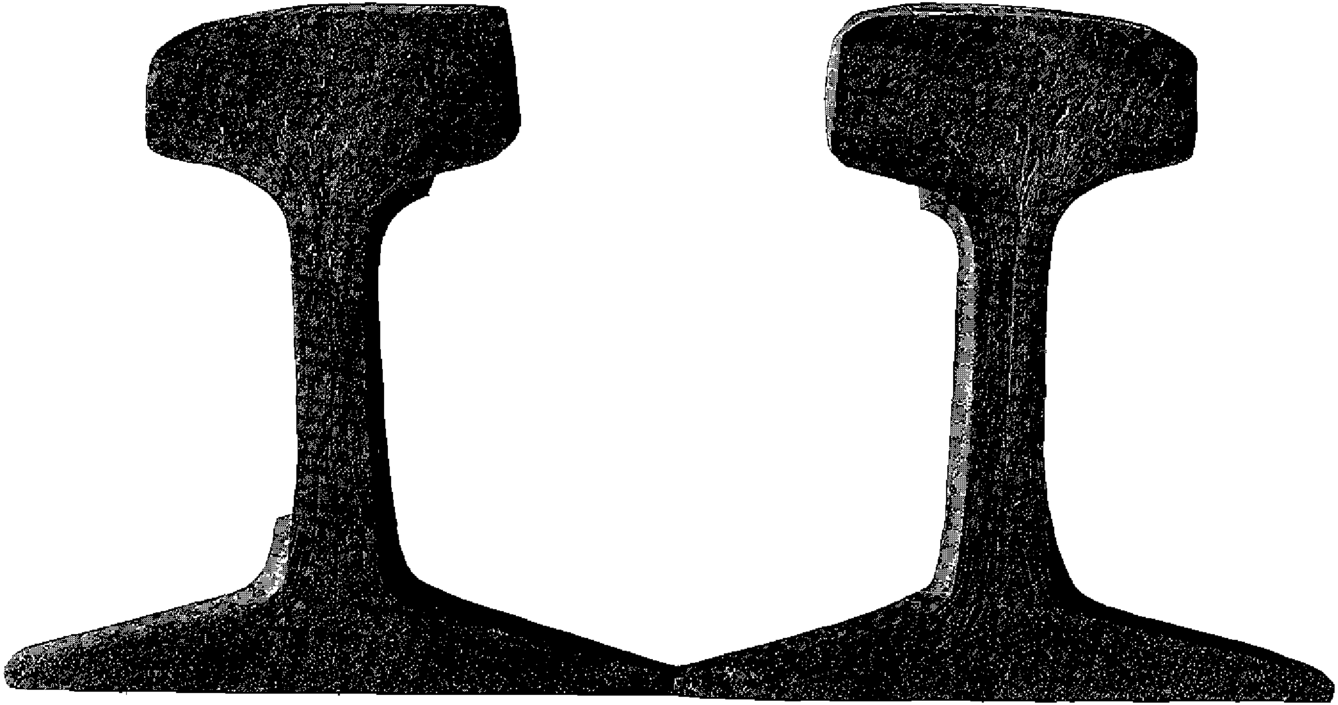

FIG 13 —80 pound rail which failed near Savan, Pa Cross sections near place of fracture, showing appearance after pickling in hot acid

FIG 14 —90 pound rail which failed near Friendship, N Y, Erie Railroad View of hot sawed end showing piped fracture in web, and horizontal shearing fracture in the head

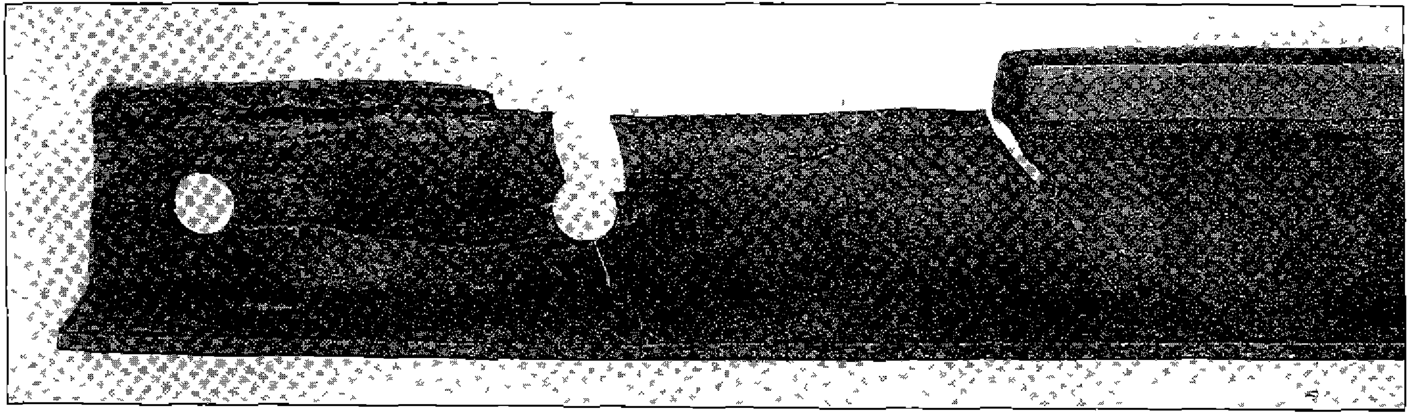

FIG 15 —90 pound rail which failed near Friendship, N Y Side view, showing surface of piped fracture of web Head detached

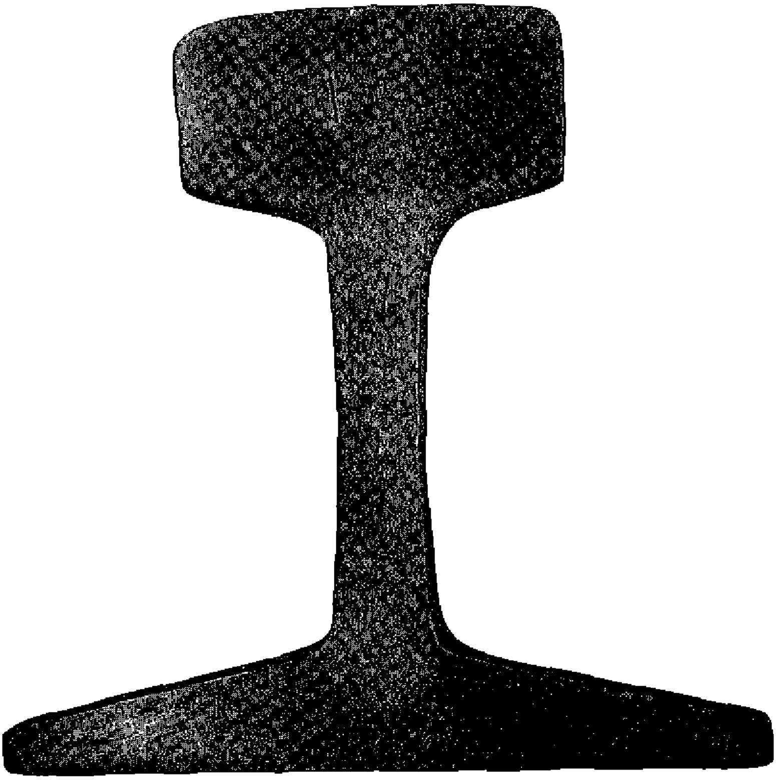

FIG 16—90 pound rail which failed near Friendship N Y Cross section at place beyond the limits of figure 15 Pipe in web obscurely shown, split in head visible

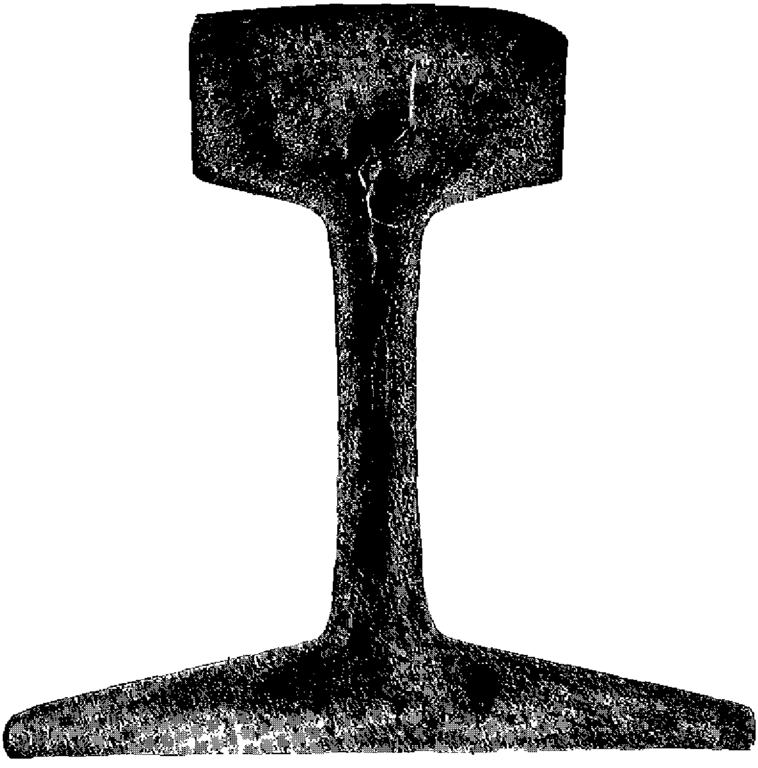

FIG 17—90 pound rail which failed near Friendship, N Y Sulphur print at a place where it exhibited a piped web and a split head fracture a branch extending in the direction of the fillet on the gauge side of the web

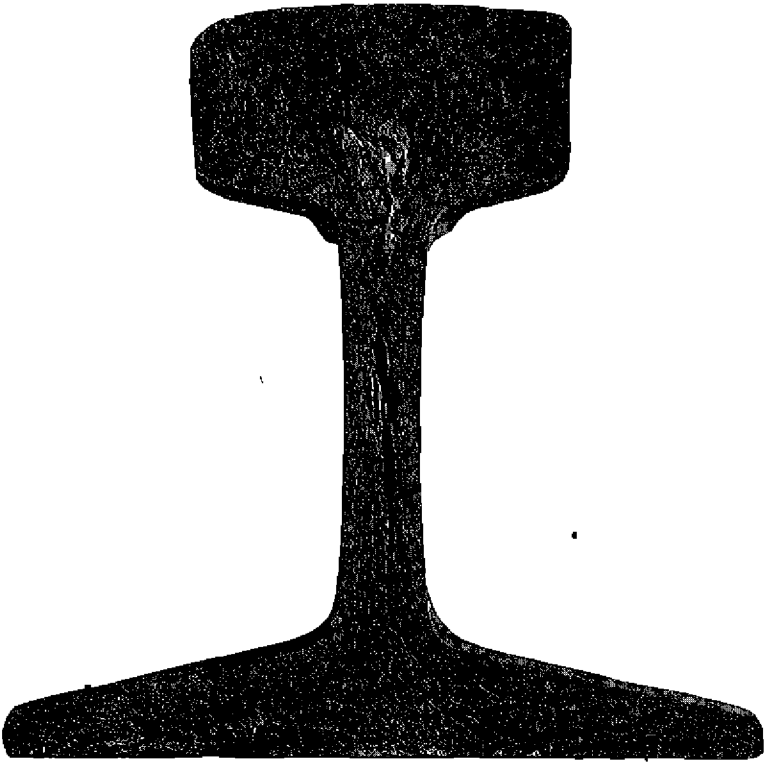

FIG 18.—90 pound rail which failed near Friendship, N Y Appearance after pickling in hot acid, same cross section as shown by figure 17

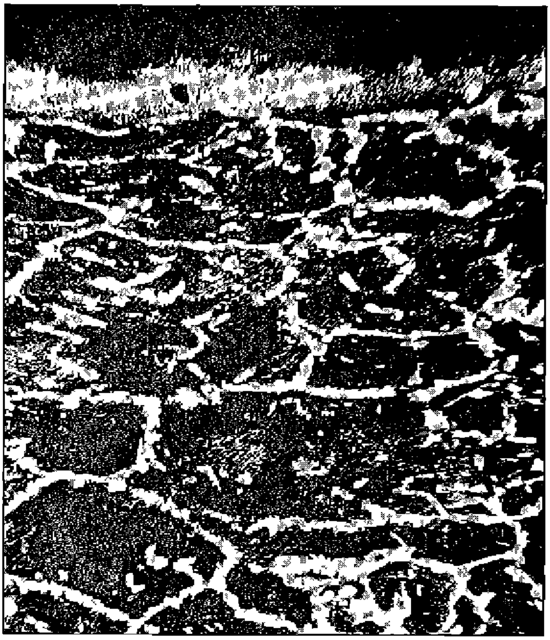

FIG 19—Photomicrograph of Wyeth rail, cross section shown by figure 7, just below running surface about in line with gauge side of web, showing flattening of the grain by wheel pressures Magnification 100 diameters

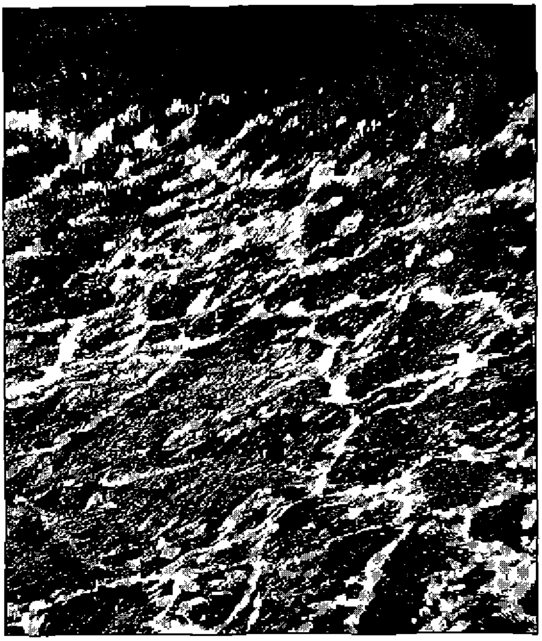

FIG 20—Wyeth rail, same surface as shown by figure 10 Showing flattening of the grain and flow toward gauge side of head at a place between gauge side of head and surface shown by figure 19 Magnification 100 diameters

FIG 21 —Wyeth rail, same surface as shown by figure 19 Showing flattening of the grain and flow toward the outside of the head at a place between the outside of the head and surface shown by figure 19 Magnification 100 diameters

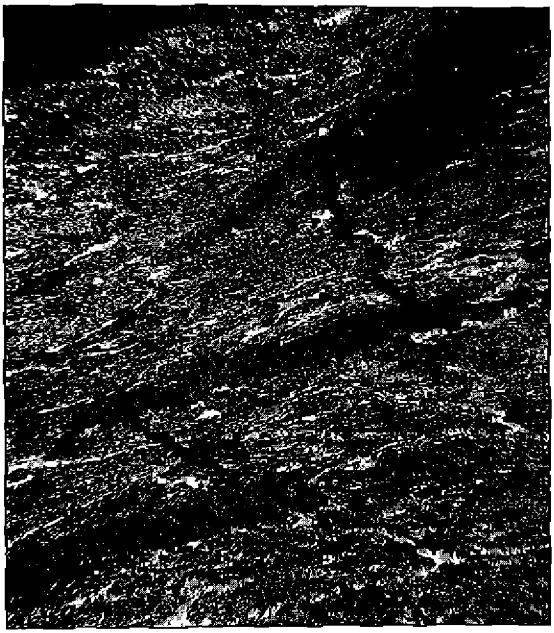

FIG 22 —Wyeth rail same surface as shown by figure 19 Showing laminated structure of the fin formed along the outside edge of the head Laminations separated and individually broken Z shaped dark lines indicate lines of rupture Magnification 100 diameters

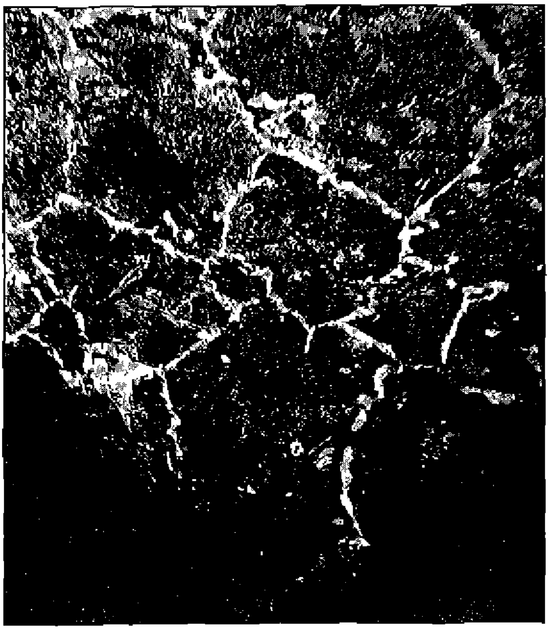

FIG 23 —Yyeth rail Microstructure of apex of wedge shaped rib at upper terminal of split head fracture shown by figure 1 Shapes of grains undisturbed Magnification 100 diameters

FIG 24 —Wyeth rail Microstructure at shorter branch of bifurcated head fracture shown by figure 1 Crack shown by irregular oblique line intermediate in color between the ferrite boundaries and the pearlite grains penetrating steel without distortion of the grain Magnification 300 diameters

FIG. 25.—Wyeth rail. Micro structure at lower terminal of split head fracture shown by figure 3. Crack shown by irregular dark line extending obliquely downward penetrating the steel without distortion of the grain. Magnification 300 diameters.