SOME CHARACTERISTIC SERVICE FAILURES OF RAILS.

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INTRODUCTION

India has about 34,022 miles of rail track and Indian Railways carry on an average about 1260 million passengers a year. The railway traffic is increasing rapidly every year and the Government have a programme of railroad expansion. Most of the rails required by the Indian Railways are manufactured in India by the Tata Iron & Steel Company Limited, Jamshedpur, and the Steel Corporation of Bengal, Burnpur. In the year 1951-52, these concerns supplied 27,198 and 8,552 tons of rails, respectively. The rails manufactured in India are of two varieties usually termed Carbon Steel Rails and Medium Manganese Rails.* All the indigenous rails are inspected and passed by the Government Metallurigcal Inspectorate at Tatanagar, in accordance with I.R.S. Specification T. 12-50 which is equivalent to B.S.S. No 11-36. A very close scrutiny is maintained during their inspection keeping in mind the safety of the travelling public. Even then both indigenous and foreign rails have occasionally failed in service and railway authorities invariably send the failed materials to the Government Metallurgical Inspectorate, Tatanagar, for metallurgical examination.

An attempt has been made in this article to enumerate different causes of service failures of rails in this country. They can be attributed to abnormal segregation, pipe, seam, scrap, discontinuity in the body of the rail due to presence of extraneous metal plate, crater formation in electric traction rail, faulty machining, etc.

TYPES OF FAILURES

Segregation:

Like other metals steel crystallizes during freezing and, in so doing, crystallizes selectively. Segregation is a phenomenon of crystallization depending upon many of factors of which rate of cooling is one of importance. Injurious effects of segregation can be minimised by teeming the metal at proper temperature, and by cropping the top portion of the bloom adequately before rolling into finished product. Fig. 1 illustrates a type of failure due to segregation in 90 lbs. flat foot rails. Two of them marked A and B have vertical split and the other marked C has a horizontal one. The cause of splitting is due to the combined effect of heavy segregation of sulphur and phosphorus, and remnant of pipe in the rail. Chemical composition and the

* I.R.S. No. T. 12-50.

	C%	Mn%	Si% (min.)	S% (Max).	P% (Max).
Carbon Steel Rails	.55/.68	.65/.90	0.05	0.05	0.05
Medium Manganese Rails	.45/.55	1.1/1.4	0.05	0.05	0.05

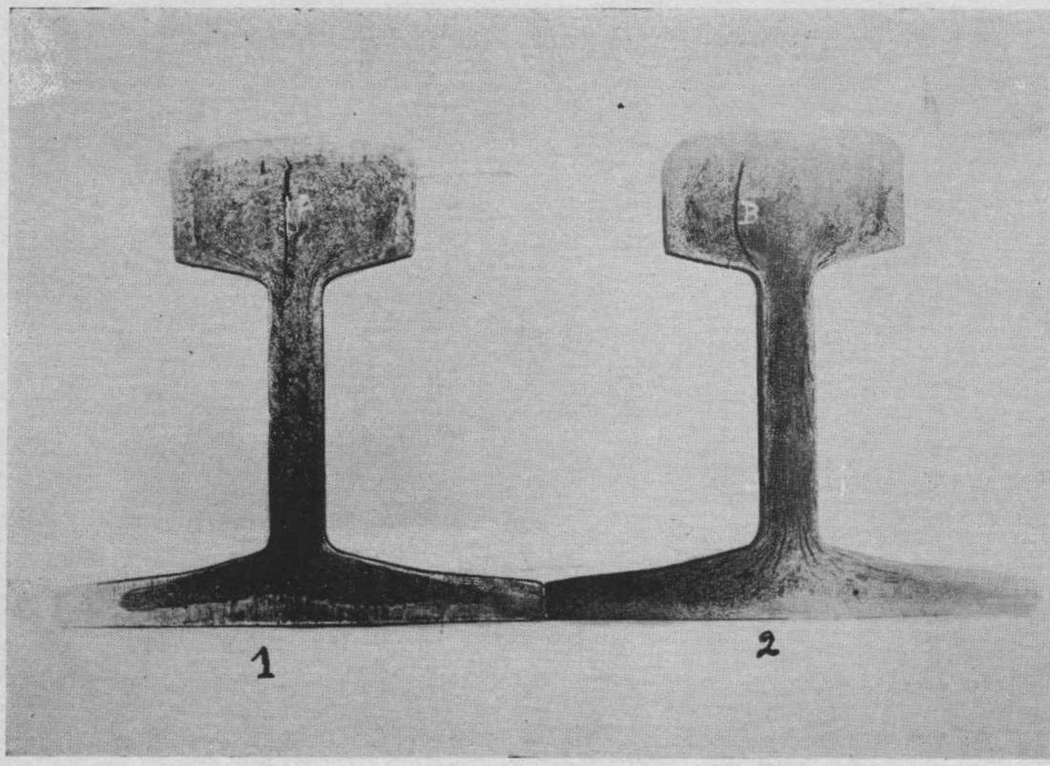
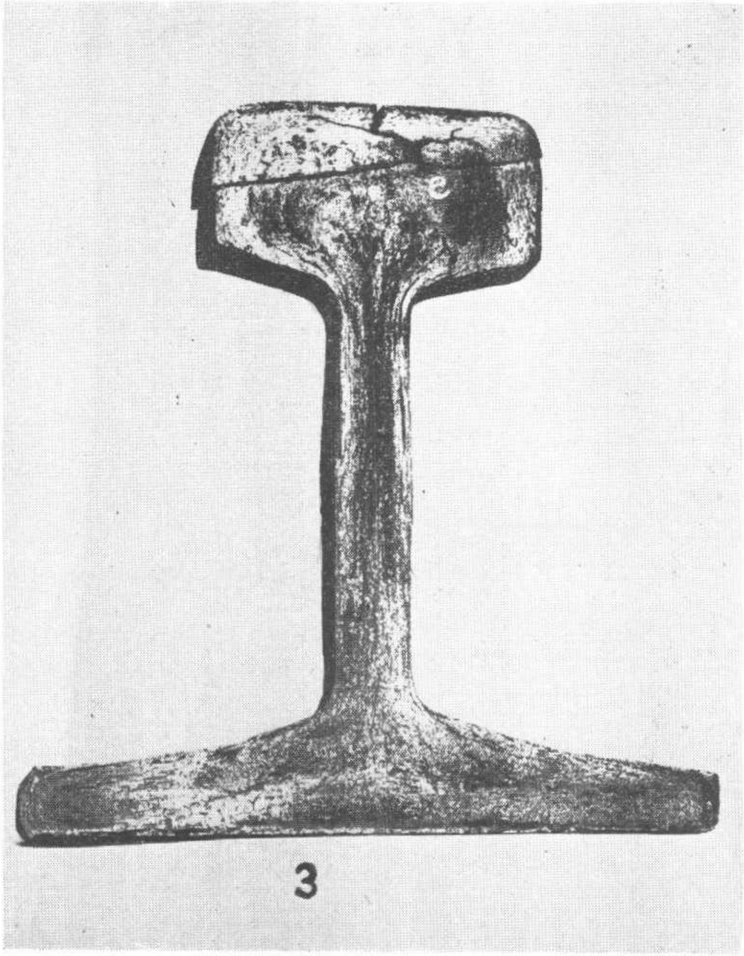


FIG. 1 Failure of three 90 lbs. F. F. rails due to segregation.



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hardness values of the rails shown in Fig. 1 are given below :—

Identification No. (Fig 1)	C.	Si.	Mn.	S.	P.	Hardness on standard position* V.P.H.
	Percent					
Rail—1.	0·31	0·036	0·62	0·124	0·178	178
Rail—2.	0·41	0·031	0·73	0·094	0·145	174
Rail—3.	0·32	0·072	0·70	0·10	0·044	156

270 V.P. H. was recorded on rail table surface near the split.

Mild Steel Inclusion :

A longitudinal crack about 1′-8″ in length was observed in the head of a 90 lbs. flat foot rail in track. The crack had started at a distance of about 5′-10″ from one of the ends of the rail. Macro and microscopic examination on transverse section of the rail showed presence of mild steel inclusion resulting in a discontinuity between the low carbon extraneous material and the high carbon matrix. It is presumed that the sheet metal which is usually placed on the bottom plate got dislocated and floated up with the rising current of molten metal, and got entrapped in the middle of the ingot. It is very likely that the cooling stresses, particularly due to difference in the rate of contraction of the high and low carbon regions were responsible for the initial discontinuity from which fatigue cracks started under service conditions. This is not the first instance where mild steel inclusion was detected in rail. Failure in service, however, due to this type of inclusion is rather rare. Chemical composition and hardness of the material investigated are given below :—

Chemical Analysis, Percent.		V.P.H.
C	— 0·61	
Mn	— 0·86	207 (Standard position in rail)
Si	— 0·072	145 (Mild steel inclusion)
S	— 0·031	
P	— 0·025	

Pipe :

Several cases of failures were reported due to the presence of pipe in rails. They are of two types, viz., (*i*) primary pipe and (*ii*) secondary pipe. Presence of primary pipe is attributed to insufficient cropping of the top bloom of the ingot. Contraction of metal may result in a cavity low down in the ingot known as secondary pipe, and may escape detection of the inspector unless the plane end of rail passes through the pipe.

Figs. 2 and 3 show a 90 lbs. foreign rail with a primary pipe in the web. It was reported that 13½ inch long rail table from one end with a portion of flange was found lying on the ballast when a train was passing (see Fig. 2). A major disaster was averted by a P.W.I. who happened to be in the engine when he heard a loud and unusual knock of the bogie wheels at a rail joint, and stopped all traffic immediately. The fracture of the rail showed pipe and non-

* Standard position in accordance with B.S.S. II—1936.

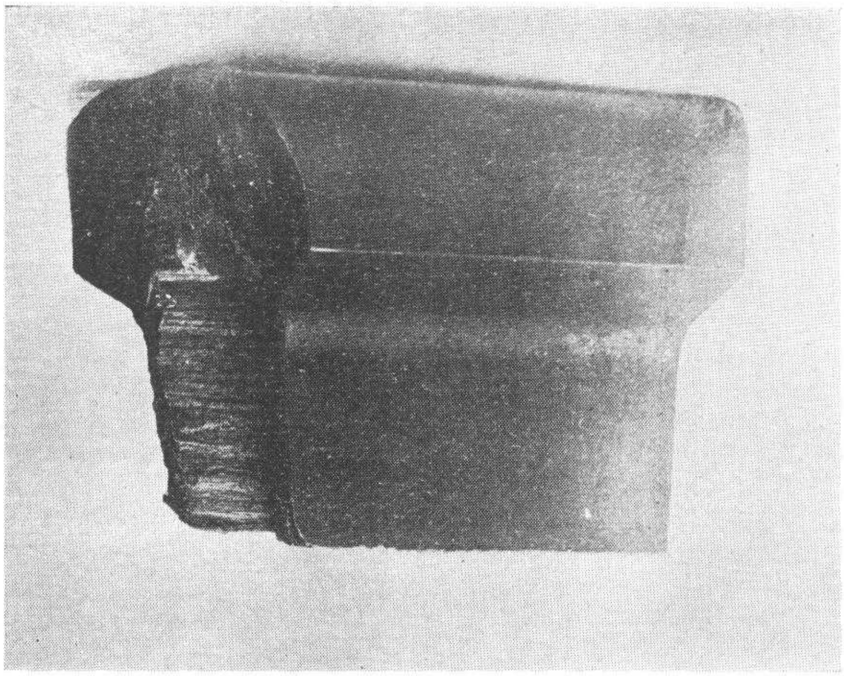

FIG. 2 Primary pipe web of a 90 lbs rail.

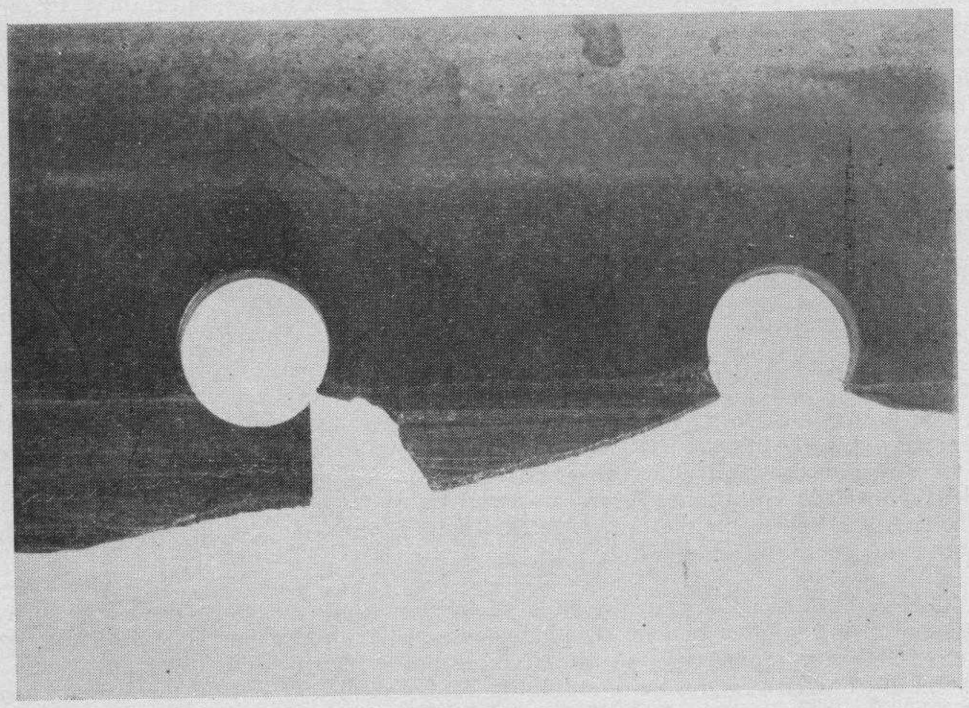

Fig. 3. Primary pipe web of a 90 lbs rail.

metallic inclusion. The rail end was hot sawn, and on enquiry it was found that the rail was laid in track for 1½ months only.

Seams.

During surface inspection of rails seams are one of the principal sources of rejection. Seam is a crack on the surface of a forged or rolled material which has been closed but not welded, usually resulting from blow holes in the original ingot. Fine surface seams do not cause any trouble but deep seams act as stress raisers and may cause fatigue failure in service. If the surface is covered with an adherent coat of mill scale or corrosion product seams may escape detection during inspection.

Lap:

Lap is a rolling defect caused by an overfill, or a fin being formed, and then doubled over by subsequent rolling. If laps are on the rail table they peel off in service, but if they are on the foot or web they may not be detected throughout the life of the rail. During surface inspection laps are difficult to detect. Shallow laps on the rail table may look like serious defects when the first train has passed, but they disappear as soon as there is a slight wear on the rail table. On the other hand deep laps may cause service failures. Laps at the junction of web and flange are highly dangerous. Sometimes pieces of metal get rolled with the rail section resulting in the formation of laps. They got detached during service leaving a crater on the rail table.

Transverse Fissures:

Failure of rails due to transverse fissures is rathar rare in India. Indigenous rails are practically free from this trouble, but a few foreign rails have on occasion failed in track due to this defect. Though this type of failure is rare on Indian Railways, the average failure due to transverse fissures in America for the last five years is 23.9 per 100 track miles. The general American practice is to remove faulty rails from the track by Sperry detector cars. In this arrangement, heavy electrical currents are passed through the rails to detect flaws magnetically. True transverse fissures start on the rail head from a tiny shatter crack or a hair line crack, and gradually spread outward until the unaffected portion becomes so weak that a sudden transverse fracture takes place in the rail under heavy wheel loads. Transverse fissures may cause a serious accident if not detected in time. A typical case of transverse fissure failure is illustrated in Fig. 4. The zone ABCD represents the area of fatigue failure, the rest of the sectional area being fractured due to shock under wheel load.

The origin of hair line cracks in rails has been attributed to several factors such as the presence of dissolved gases in steel, teeming conditions, and particularly the final rate of cooling of the finished rail. Sandberg controlled cooling process has considerably reduced the risk of formation of transverse fissures by retarding the rate of cooling of rails in the temperature range of 400°C to 200°C. Rails made by Tatas and SCOB are control cooled.

Wheel Burns:

90 lbs flat foot rails in a 5 degree curve showed spotted surface after 21 years of service. The rail analysed Carbon—0.59%, manganese—0.34%, silicon—0.046%, sulphur—0.019% and phosphorus—0.027%. The hardness survey gave the following values:—

V.P.H.

Hardness of standard position	212					
Hardness across the table surface at 1/8th	327	327	327	362	358	348
inch intervals starting from one corner	362	344	550	644	564	609
to the other	528	364	344	306	298	275
Hardness on section of the rail 1/16″	275	250	348	331		
below the table surface at 1/4th inch	315	287	295	287		
intervals	256					

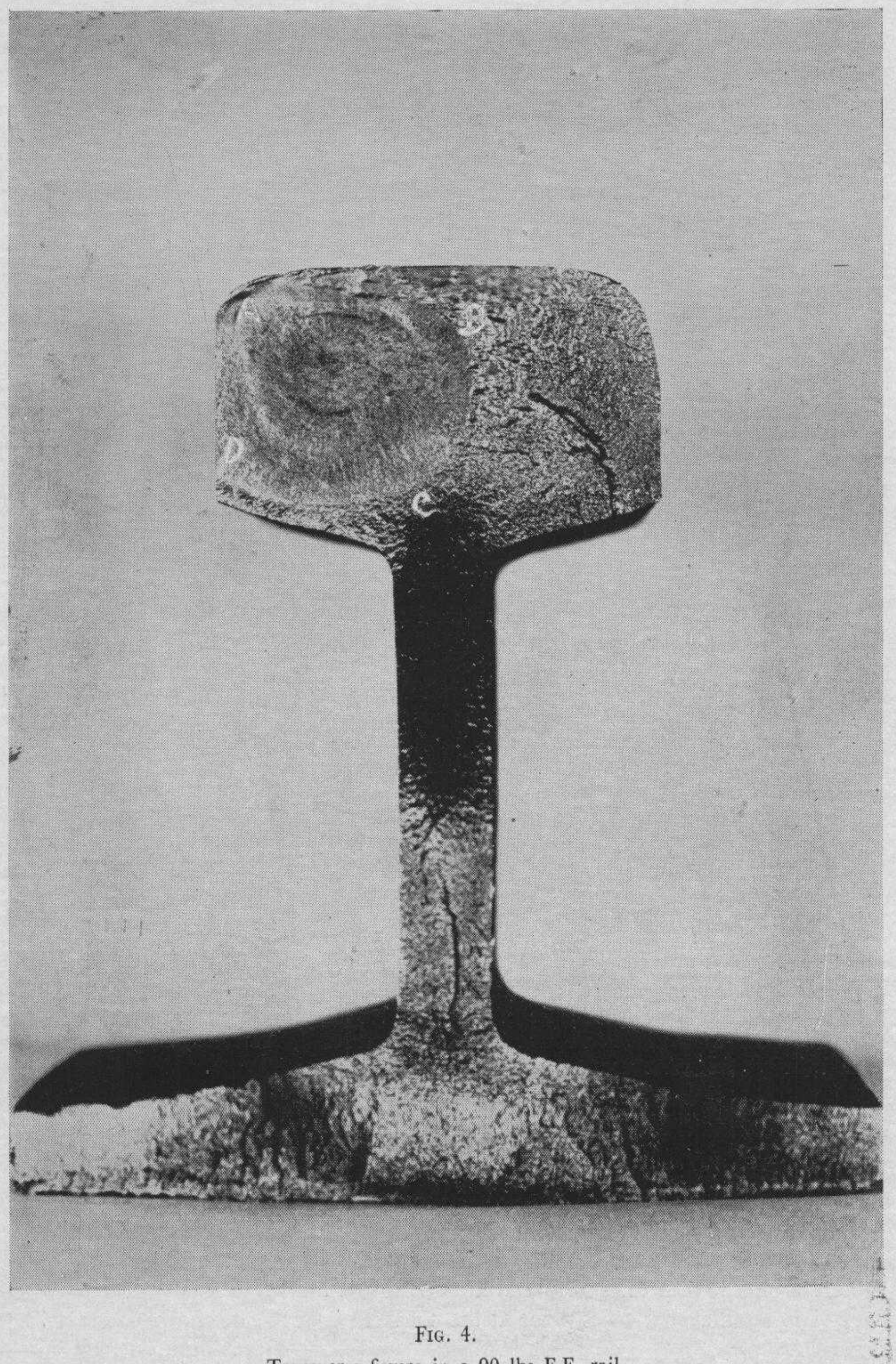

Fig. 4.
Transverse fissure in a 90 lbs F.F. rail.

Macro-examination of the table surface showed presence of two 1/2″ wide shallow hardened streaks of metal, and fine transverse cracks (thermal cracks). Further more, the specimen revealed discontinuous longitudinal cracks and spalling of the surface metal. The cracks and spalling were probably due to severe cold working. The hardening of the surface layer is attributed to excessive frictional heat produced by the slipping of the locomotive wheel followed by instantaneous cooling. This results in the formation of what is commonly known as Wheel Burn.

Short Circuit in Electric Traction Rail:

A failure was reported of a 100 lbs bull head rail which was laid in track two years ago. The condition of cast iron pot sleepers was reported to be good. The track was subjected to electric freight type heavy locomotive. The fracture had taken place at a distance of about 12′-9″ from the joint end of the rail, and 5″ from the nearest structure bond hole. Chemical composition of the rail was:

		Percent.
C	....	0.49
Mn	....	0.98
Si	....	0.121
S	....	0.055
P	....	0.057

One 6 ft. long rail piece cut from the fractured rail stood the falling weight test as per B.S.S. Specification No. 9—1935.

The fracture of the rail revealed characteristic fatigue failure (Fig 5) originating from deep craters on the bottom surface of the rail. Micro examination of the steel near the crater showed three distinct structural changes in the metal, viz., (*a*) thin decarburised area, (*b*) tempered martensite without any free ferrite, and (*c*) medium size grains of sorbopearlite with ferrite at the grain boundaries.

The cause of failure of the rail is attributed to craters which acted as stress raisers, and finally caused failure in the rail. One of the possible reasons for the crater formation is due to rail becoming anode of an electric arc. To verify this an experimental arc was set up on the foot of a 2″ long rail piece cut from the bull head rail with a pressure of 90 volts and current 500 amps.

Micro section taken from the foot of the experimental rail piece showed indentical microstructure as observed in the fracture piece. It would be interesting to know whether similar type of failure in rails takes place in countries like Switzerland, America, England, where electric traction is in considerable use.

Loose Fish Plates.

In order to hold together the adjoining ends of the rails in correct position fishplates are used. Under the passing wheel load the end of one rail is depressed and a blow is given to the end of the adjoining rail when the wheel jumps the gap. The blow or shock loosens the fittings and considerable wear takes place of materials at the joint. A rail joint is considered the weakest part of a track. Due to vibration fishplates are apt to get loose and unless they are tightened immediately considerable wear takes place at the contact surface of the rail and fishplate by the up and down movement of the loose fishplate. Also distortion of the fishbolt holes takes place by the constant hammering action of the fishbolt tending to split the web.

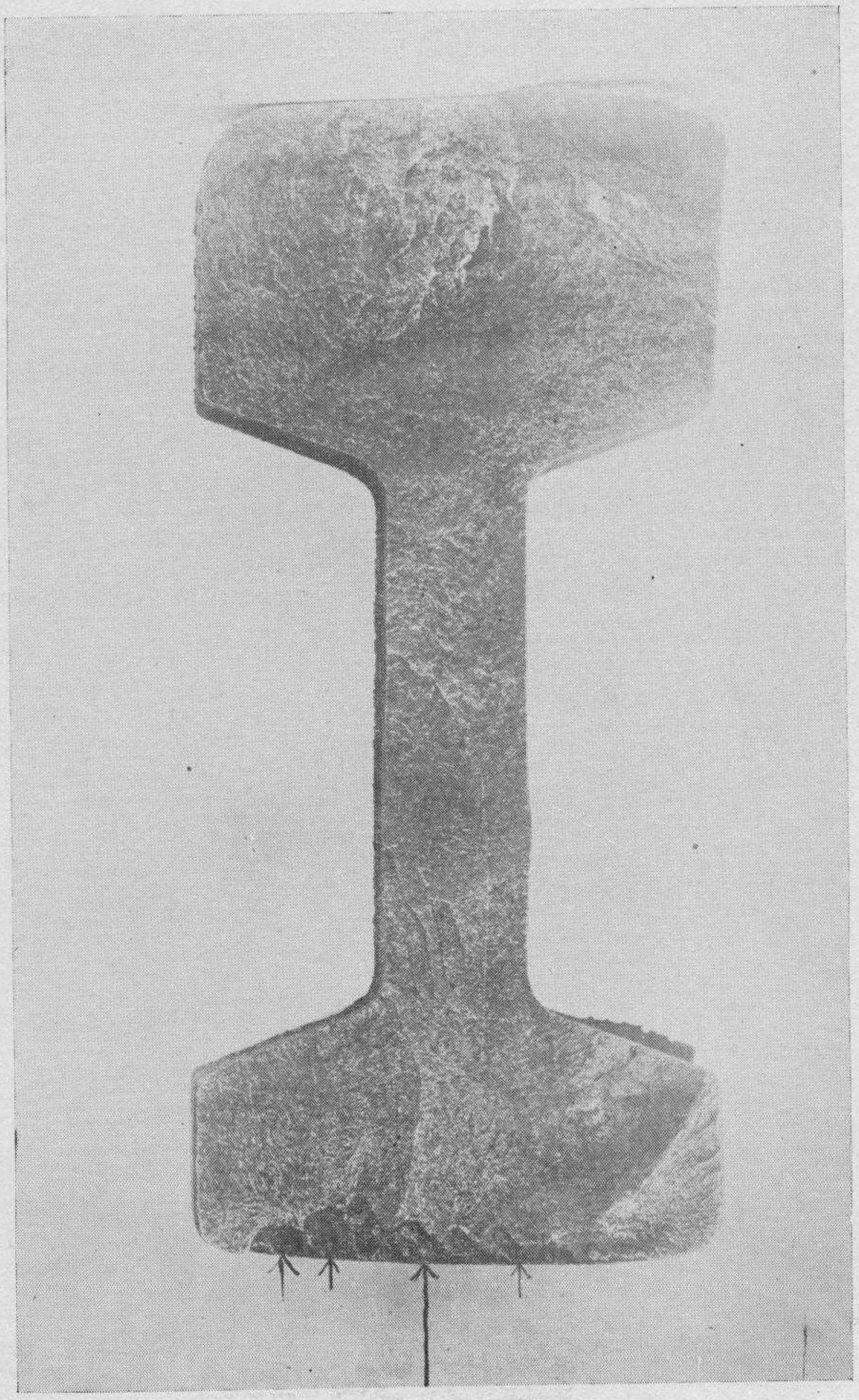

FIG. 5 A broken 100 lbs bull head rail showing craters formed due to electrical short circuit. Failure started from these craters.

Mechanical Defect:

Failure due to mechanical defects or design is rare in rails. Practically every case of mechanical defect that has been referred to the Government Metallurgical Inspectorate has occurred in switches and crossings.

Either the stock rail or the point and splice rail have fractured due to insufficient radius, or as commonly termed due to sharp corners.

On the basis of a number of failures investigated it appeared that not only the strength of the rail was reduced, but also severe local stresses were introduced by sharp corners at the point where the foot had been cut away. They act as loci for the propagation of fatigue failures.

Fig. 6 illustrates a typical case of a failure of Vee joint of splice and point rails. Fracture has started from the sharp angle formed by machining of the flange shown by an arrow. Fig. 7 illustrates a fracture on the foot of stock rail starting from the sharp angle left by machining. The foot of the rail should have been rounded off as shown by the dotted line. Chemical and physical investigations showed that both the rails conformed in every respect the conditions laid down by the I.R.S. specification for steel rails. Falling weight test on these rails were also satisfactory.

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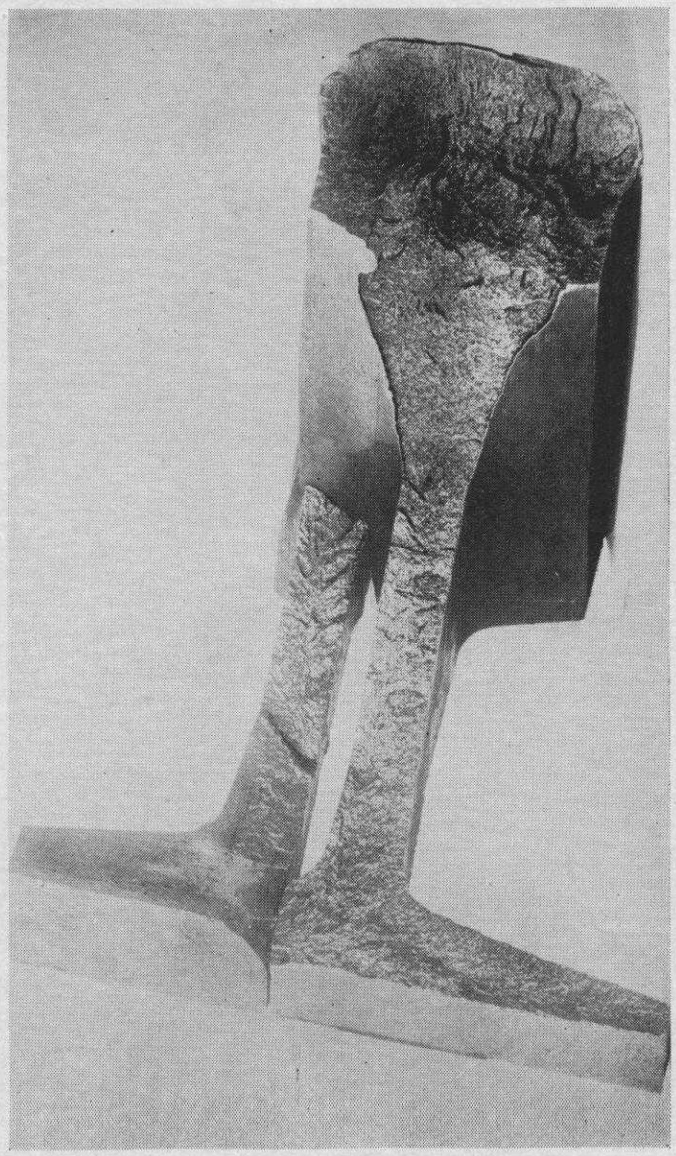

FIG. 6 Failure of a Vee joint due to mechanical defect.

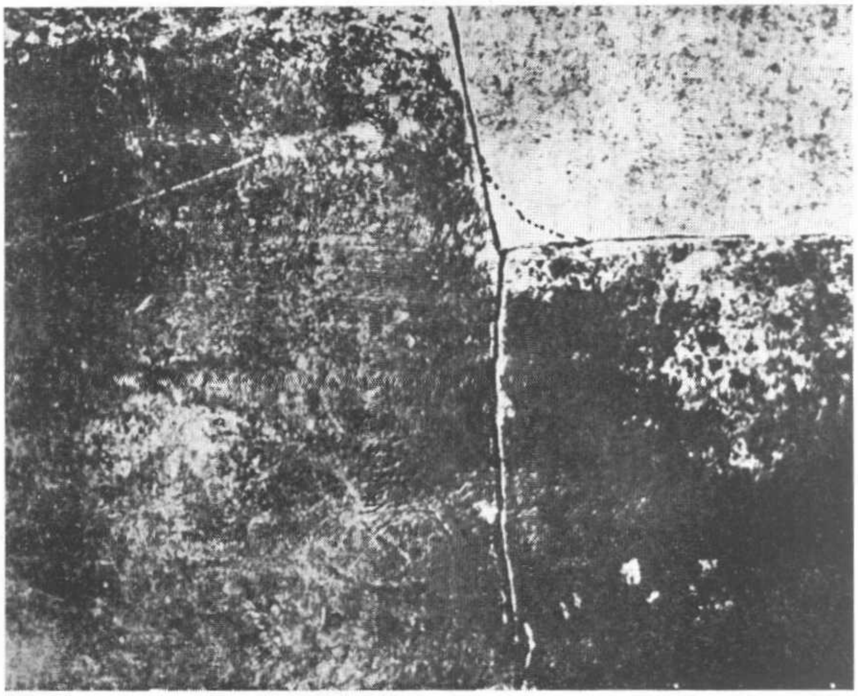

Fig. 7 Failure of a stock rail due to mechanical defect.