SPERRY RAIL SERVICE

Sperry Division of Automation Industries, Inc.
DANBURY, CONN.

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RAIL DEFECT MANUAL

Compiled by

SPERRY RAIL SERVICE

FOR THE USE OF
THE RAILROADS

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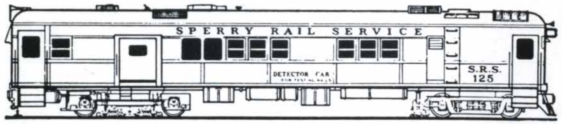

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FOREWORD

Sperry Rail Service has compiled and published this fifth edition of the Rail Defect Manual as a part of the technical service, in addition to actual rail testing, supplied to Sperry customers. It is designed to benefit railroad men concerned with track safety and maintenance of the right-of-way. Since the publication and enthusiastic reception of the last edition of the Rail Defect Manual in 1957 we have received many valuable and helpful suggestions from interested readers for the improvement of the manual. Each of these suggestions has been given careful consideration and many of them have been incorporated in this new edition.

The Sperry Rail Service staff, working with railroad men throughout the country, has spared no effort to make this manual a complete and accurate handbook of rail defects. The material which it contains represents the findings of over 40 years of experience by Sperry Rail Service in the field of rail testing. We realize that our interpretation of certain defects may not be in absolute accord with your own ideas and experience, and we invite your comments and suggestions.

For easy reference this edition has been arranged according to the location of each defect in the rail. The various types of defects have been listed according to the classification system used by Sperry Rail Service.

We thankfully acknowledge the section titled "Making Steel for Railroad Rail" which was contributed by the Bethlehem Steel Co. and consists of excerpts from their Booklet 1822, "The Railroad Rail".

We take this opportunity to thank all the railroad men who assisted us in the compilation of the defect section of the manual.

We also thank the U. S. National Museum, Smithsonian Institution, for help in obtaining the historical data contained in this book.

RAILS AND RAIL TESTING

History of Rails

The earliest record of the use of track for transportation comes from England, where, in 1604, a railway was constructed from nearby coal mines to the river Tyne. The tracks were made of wooden rails, upon which wooden carts with flanged wheels were pushed by men or pulled by horses.

During the eighteenth century, the growth of railways continued in the mining districts of England and Wales. As yet, the steam locomotive was unthought of. Horses or mules pulled the early trains. The tracks were originally made of pine or other soft wood. To improve the wearing quality, a top strip of hard wood was applied. During the middle period of the century, strips of malleable iron replaced the hard wood topping. These iron strips were used only to provide a more durable wearing surface; the timber carried the weight and guided the wheels.

First Metal Rail

In 1776 the first all-iron rail was manufactured near the city of Sheffield, England. These rails, called *plate rail,* (Fig. 1) were made of cast iron in sections 3 feet long. Since flanged-wheel carts were not common in the south of England nor in Wales, these rails were cast in shape of an L, the long leg of which rested on the roadbed while the short leg projected upward. This construction permitted the use of either flanged or common cart wheels upon the track, the upthrust leg taking the place of the wheel flange in the latter case.

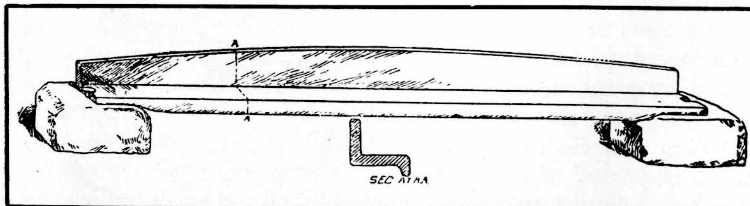


Fig. 1. Plate rail. 3-feet long, made of cast iron, with an upward projecting flange to accommodate either cart or flanged wheels.

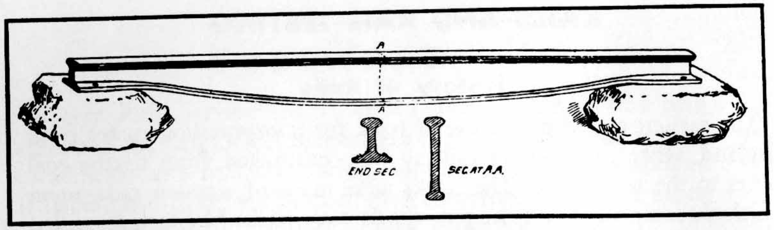


Fig. 2. Edge rail, made of cast iron in 6-foot sections, for use with flanged wheels.

In 1789 William Jessop, who later built the London-Croydon Railway, developed a new type known as *edge rail* (Fig. 2). Due to its vertical section it was many times stronger than either strip or plate rail. In its earliest form, edge rail consisted of a thin web widening out at both head and base while the cross section above the supports closely resembled a modern rail section.

First Public Railway

In 1803 the first railroad intended for public use, the Surrey Iron Railway, was opened for operation between the London docks and Croyden. Intended primarily as a public super-highway, the track was laid with flanged plate rail to accommodate cargo wagons or any other conveyance whose owner was willing to pay for the privilege of a smooth fast ride on a hard road.

The early iron rails were spiked directly to wooden sleepers. As loads on the railroads increased the need for heavier roadbeds became apparent. The most common method of positioning the rails was to set stone blocks along the line to be followed by the track, insert wooden plugs into holes drilled in these blocks and then spike the rail to these plugs. Later, edge rail was supported at each stone block by a cast iron chair (Fig. 3).

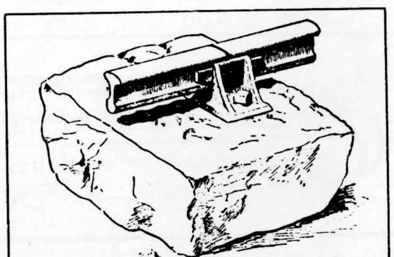


Fig. 3. Cast iron chair, used to support and join early edge rail.

At the beginning of the 19th century the railways, commonly known as tramways, had grown to an impressive size but as yet the carrying capacity and the speed

attainable was limited by the strength of the draft animals used for locomotion. With the growth of manufacturing came a corresponding need of better and faster transportation. The natural result was an effort to improve the railroads.

First Steam Locomotive

Road carriages powered by steam had already been successfully demonstrated. The logical step was to apply steam power to the railroad.

On February 1st, 1804, on the plate rail tracks of the Pennsylvania tramroad in South Wales, a steam locomotive successfully hauled a train of cars. The locomotive was designed by Richard Trevithick. The freight hauled in the cars consisted of several tons of ore for the iron works at Merthyr Tydfil.

In 1825 the Stockton and Darlington Railway in England commenced operation using a steam locomotive designed by George Stephenson. This was the beginning of the commercial use of steam locomotives on regularly scheduled common carriers.

It had originally been planned to lay flanged plate rail on the Stockton and Darlington, but upon Stephenson's repeated recommendation cast iron edge rail was used. This instance marked the adoption of flanged wheels in railway construction.

Origin of Standard Gage

The track of the Stockton and Darlington was laid to a gage of 4 feet 8½ inches—the gage in standard use throughout England and the United States today. The story runs that the width of the Killingworth colliery tramline was 4 feet 8 inches. Since Stephenson, who was the colliery millwright, designed his early experimental locomotives to run on that line, he quite naturally built them to that gage. When he was called upon to design the Stockton and Darlington locomotive he did so to the width to which he was accustomed. The extra half-inch was added to the track width to ease the gage. Stephenson's personal prestige helped to bring about the adoption, after considerable controversy, of the 4-foot 8½-inch gage as the English standard.

The influence of Stephenson's work on American locomotive designs, plus the fact that a number of English locomotives were imported to this country, resulted in the use of the 4-foot 8½-inch gage on the Baltimore & Ohio, several of the New England railroads and on the early Pennsylvania line.

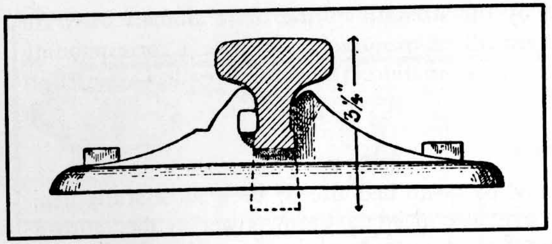


Fig. 4. Rolled iron edge rail, made in 15-foot sections and supported at joint by cast iron chairs.

The South Carolina Railroad, as well as most of the other Southern lines, was built to a gage of 5 feet. The Erie tracks were built to a 6-foot gage, the Missouri Pacific spaced its rails at 5 feet 6 inches, while the early Jersey & Ohio road used a 4-foot 10-inch gage. Not until many years later did the necessities of interchange force the adoption of a standard gage of 4 feet 8½ inches for all American tracks.

First Rolled Rail

A few years prior to the advent of the steam locomotive, John Birkenshaw, owner of the Durham Iron Works, turned out the first *rolled iron rail* (Fig. 4). This rail had a wide rounded head and a thick web designed to be supported by cast iron chairs at the joints. The rail was rolled in sections 13 to 15 feet long as compared to the 3- to 6-foot length of the cast iron plate and edge rail, and weighed 26 lb. per yard.

The first American railway was the Granite Railroad of Massachusetts, built in 1826. This 3-mile stretch of track, from Quincy to Milton, used iron-capped wooden rails, and horses for power.

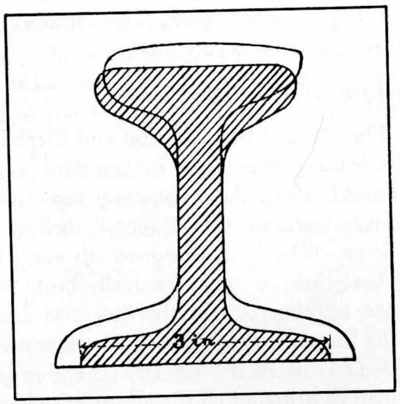
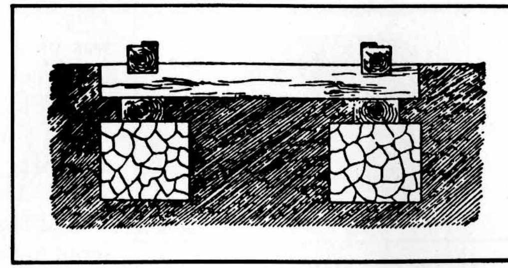


Fig. 5. Stevens T-rail rolled with convex top and base, designed by Robert L. Stevens in 1830. Shaded section shows rail as originally designed. Unshaded section show profile as actually rolled.

First American Locomotive

In 1831 the "Best Friend of Charleston", the first locomotive to successfully pull a train on

Fig. 6. Iron strap rail, spiked to wooden stringers and supported by wooden ties over a gravel and wood sub-foundation.



American tracks, was placed in operation on the South Carolina Railroad. In the spring of the same year construction of the Camden and Amboy Railroad in New Jersey was started, using the rolled *iron T rail* (Fig. 5) designed by Robert Stevens and rolled in England. This rail did away with the need for expensive cast iron chairs since it could be spiked directly to the tie with a hook-headed spike, also designed by Stevens. The roadbed was constructed according to the English idea of securing the rails to stone blocks.

A shortage of stone, however, resulted in the use of wooden ties similar to those in use today. To the surprise of the railroad world it was found that the use of wooden ties made a roadbed that rode better than did track laid on stones.

American Rail Development

Although rolled edge rail rapidly gained favor in English construction, its use in America was necessarily limited by cost. Until the first American rail rolling mill was constructed in Maryland in 1844, the necessity of importing the British product made the use of rolled rail too expensive for widespread use.

As a result, much of the early American track utilized iron strap rail laid on longitudinal wooden stringers (Fig. 6). On the B & O stone stringers were substituted for the wood. Aside from the fact that the the wooden rail had poor wearing qualities, the iron straps that topped it had a pronounced tendency to pull loose from the wooden stringers. This usually happened during the passage of a train, when the iron strip, loosened by vibration, would curl back on itself, causing frequent damage to equipment and injury to passengers. These loose rails were known as "snakeheads" and were a common occurrence.

The first rail rolled at the Maryland mill was a 42-pound *iron U rail*

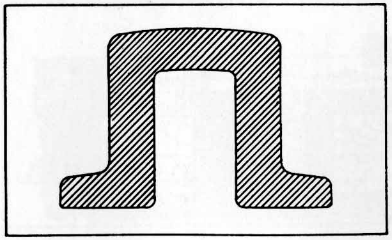


Fig. 7. Iron U-rail. This was the first type of rail rolled in the United States and was used on the Baltimore and Ohio R.R. in Maryland in 1844.

(Fig. 7). A quantity of this rail was used by the Baltimore and Ohio but never achieved much popularity. In 1845, mills in New England and Pennsylvania commenced production of the Stevens T rail. The iron smelted in the United States at this time was inferior to that of England. To provide greater strength the original Stevens rail was modified in such a way that the head was pear shaped in cross section (Fig. 8).

The difficulty of splicing pear shaped rail, led to the development of *compound rails* (Fig. 9). In laying these rails the two sections were staggered so that at no point did a complete gap occur in the rail. At first this type of rail proved highly satisfactory and provided an exceptionally smooth ride. However, the iron wore badly on the inner surfaces and required frequent tightening of the holding nuts or rivets. No new compound rail was laid after 1860.

In 1848 a rolled iron rail weighing 92 pounds per yard, and having

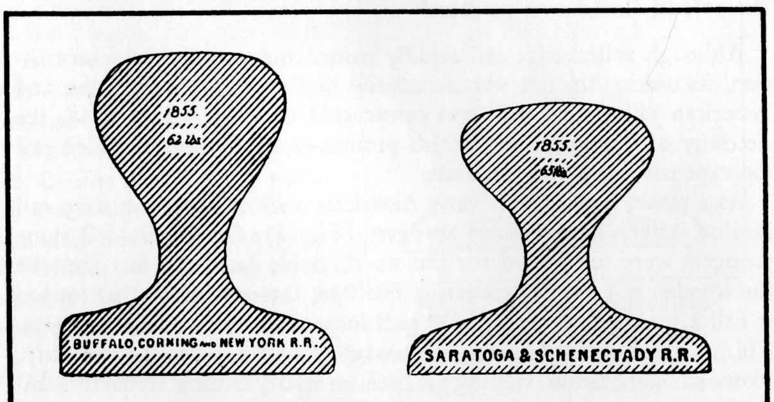


Fig. 8. Pear Shaped rolled iron rail. manufactured in Pennsylvania in 1855.

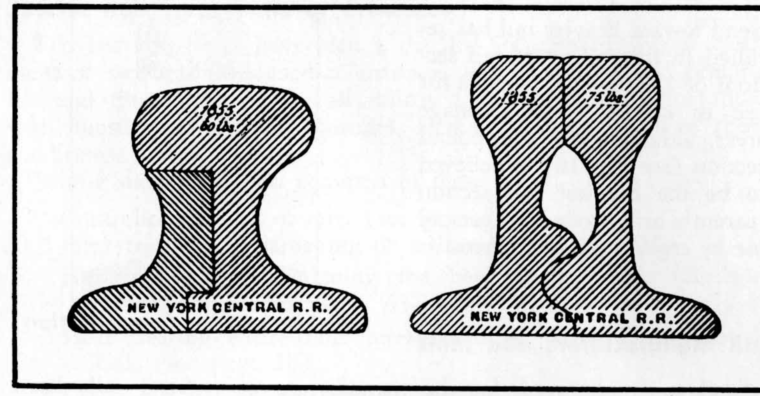


Fig. 9. Compound rail developed in 1855 in an attempt to simplify joint construction. Maintenance difficulties forced its abandonment in 1860.

a cross section very similar to that of modern rail, was tested on the Camden and Amboy Railroad. The iron rail proved to be too rigid to withstand batter by the train and the ends soon hammered out. The rails were removed from the tracks and now form part of the building framework of the U. S. Mint in Philadelphia.

First Steel Rail

The first steel rails are said to have been rolled at the Ebbv-Vale works in Wales in 1855. The difficulty of obtaining good iron on this side of the ocean led the more prosperous American companies to continue to import steel and iron rails from abroad. In 1865 the first Bessemer steel rails made in this country were rolled in the North Chicago Mills. The first steel rails rolled in the United States were produced in Johnston, Pennsylvania in 1867. Between 1870 and 1873 several experiments were made with steel top rail, a type in which web and base were made of iron, and the head of steel. The lessening cost of steel soon made it more practical to make the entire rail of steel.

By 1900, *steel T rail* (Fig. 10) had replaced all other types on the railroads in the United States. From that time until the present, rail development centered about production of heavier rail sections and improved manufacturing processes. Only minor modifications have been made in the shape of the rail. It is interesting to note that the trend toward heavier rail has resulted in the rolling of rail sections of 152 and 155 pounds for use in certain heavy tonnage areas, although the 140 pound section (see Fig. 10) is believed to be the heaviest rail section currently being rolled for general use by any American Railroad.

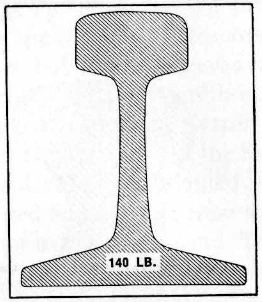


Fig. 10. 140 lb. Cross Section

Rail Manufacturers and Mills

Steel mills equipped for the manufacture of railroad rails have always played an essential part in the development and continual improvement of our railroads. They have developed and tested in cooperation with railroads new manufacturing methods and processes to meet constant needs for better, stronger, longer-lasting rails, rail accessories and other steel products. New sections or types and weights have been made readily available as required and specified. Special treatments (described elsewhere in this booklet) to overcome new problems arising from today's heavy-load, high-speed trains form an increasingly important service which mills render to all railroads seeking the reduced costs and improved performance required for them to stay alive in today's highly competitive transportation market.

Railroads have indeed been fortunate to have their rail needs so ably served by so wide a choice from among the following principal steel manufacturers and their rail mills:

- Algoma Steel Corporation (Canada)—"Algoma" Mill (Sault Ste. Marie, Ont.)
- Bethlehem Steel Company—"Lackawanna" (N.Y.) and "Steelton" (Pa.) Mills
- Colorado Fuel and Iron Corporation—"Colorado" Mill (Pueblo, Colorado)
- Dominion Steel & Coal Corporation (Canada)—"Dominion" Mill (Sidney, N.S.)
- Inland Steel Corporation—"Inland" Mill (Indiana Harbor)
- Tennessee Coal and Iron Company—"Tennessee" Mill (Birmingham, Ala.)
- United States Steel Corporation—"Carnegie" (Pa.) and "Gary" (Ind.) Mills

Special Rail Treatments or Processes

The last few years have seen a decided increase in special treatment of steel rails designed to increase wear resistance and prolong life and thus cut costs for all railroads, but particularly for those with unusual wheel loads, tonnages, terrain (curves) or all of these conditions.

Briefly stated, the most common of these are:

- Controlled cooling of rails (see page 21)
- Heat treating or hardening of rail ends (see page 24)
- Heat treating or hardening the head of the rail. (Railway Track & Structures, Sept. '63—Pages 26-28)
- Heat treating entire rails referred to as "Fully Heat-Treated" Rails (see page 25)
- Changes in manufacturing methods, chemical formulas or content during manufacture to produce tougher steel rails for today's traffic conditions and loads.

Rail ends are usually hardened at the mill by an electrical induction process, gas burners, or other suitable means though this process is sometimes carried out by railroads on rails already on their property or in track.

Heat treating the head of rails or the entire rail may be carried out at the mill or on railroad property with automated equipment (see page 25 for Bethlehem Steel's "Fully Heat-Treated" process). At U. S. Steel's Gary, Indiana plant rail heads are heat treated in pairs by an electrical induction system (A.C.) mounted on a movable carriage. As the latter rides over the rails the heads of the two rails are brought to a red hot temperature, then quenched by jets of compressed air followed by a water spray. Rails so treated by either process are said to provide 60% greater yield strength and 27% greater tensile strength than untreated rail, thus reducing normal rail wear on curves and grades and prolonging rail life.

End hardening alone is designed to accomplish the same results in the restricted joint area where rail is normally subjected to unusual wear and batter.

Improved rail wear qualities are also being obtained by changes in specific amounts of certain elements normally specified for the manufacture of steel rail. The element, silicon, has drawn renewed recent attention though the first 17 heats of so-called "High Silicon" rails were made as early as 1930. Increased shelling of rail and detail fractures from shelling by 1950 led to increased investigation and research into the cause of shelling. This was traced to abnormal shearing stresses imposed on the gauge corner of the head of the rail by wheel loads.

Colorado Fuel and Iron Corporation in cooperation with several Western roads supplied test heats of new rails made with a high silicon content (0.33-0.50 compared to standard 0.10-0.23). AAR Service tests and accelerated tests by the University of Illinois have confirmed greater wear resistance and retarding of gauge corner shelling. Since more than 130 miles of high silicon rail are already installed in "tough" areas on Western roads with average service life apparently extendable from 3 to 13 years, it seems reasonable to expect widespread use of such rail in the future in addition to inductively or flame hardened rails discussed herein. Both means are attempting to accomplish the same basic result—better, stronger, longer lasting rails for all railroads.

None of the new rail treatments or changes in chemical composition discussed above has, to our knowledge, affected either the quality or over-all efficiency of Sperry's rail test systems.

References: Bethlehem Steel Company Booklet 1822—"The Railroad Rail".

A.R.E.A. Bulletin #584 (February 1964) pages 534-604.

A.R.E.A. Bulletin #577 (February 1963) pages 529-541.

Railway Track & Structures (September 1963) pages 26-28. Heat Treating Heads of Rails.

Latest Steel Manufacturing Process

Railroad men and Sperry detector car crews will be hearing more and more about "basic oxygen" steel in the future. Steel made by this new process is said to be similar in chemical composition and metallurgical characteristics to basic open hearth steel described elsewhere in this booklet The differences between the two processes lie chiefly in design of the furnaces employed and the extent to which gaseous, high purity manufactured oxygen is used as a refining agent. In the basic oxygen process molten iron, as produced in a conventional blast furnace, is refined to steel by directing a jet of oxygen onto the surface of the hot metal bath which it penetrates and converts to steel with a high degree of chemical efficiency and unusual speed. It is said that a basic oxygen furnace can turn out a batch of steel to required specifications in less than an hour. That compares with an average of 8 hours for open hearth furnaces.

Two steel companies, Algoma Steel Corporation, at Sault Ste. Marie, Ontario, in 1958, and Colorado Fuel and Iron Corporation, at Pueblo, Colorado, in 1961, have already placed basic oxygen furnaces in operation for production of steel rails. Other steel companies are expected to employ the new process for manufacture of rails as well as other steel products at an early date since new oxygen steel plants will, reportedly, cost substantially less (up to 50%) than new open hearth facilities.

To date increased quantities of new rail made by the basic oxygen process by Colorado Fuel and Iron Corporation (30% of all new rail in 1962) and Algoma Steel Corporation are being laid in track, and on several major Western roads basic oxygen rails are now specified on up to 50% of all rail purchase orders. This trend is expected to accelerate and spread rapidly in the future to most U.S. and Canadian railroads.

Basic oxygen rails have not posed, and are not expected to pose in the future, any unusual test problem or affect the overall quality and efficiency of Sperry's rail flaw detection systems.

References: A.R.E.A. Bulletin #584 (February 1964) pages 530-533.

AAR Research Dept. Report No. ER-33, (April 1963) Tests, Basic Oxygen Rails

Railway Age, (December 10, 1962) pages 15-17--Basic Oxygen Rail.

MAKING STEEL FOR RAILROAD RAILS

The first step in the manufacture of rails is the making of rail steel. For many years, the open-hearth process has been the standard for the production of this quality steel. All Bethlehem rails are rolled from open-hearth steel. Unless otherwise stated, it may be assumed that the procedures and data described in this booklet generally pertain to the making of rails at both the Lackawanna and Steelton Plants.

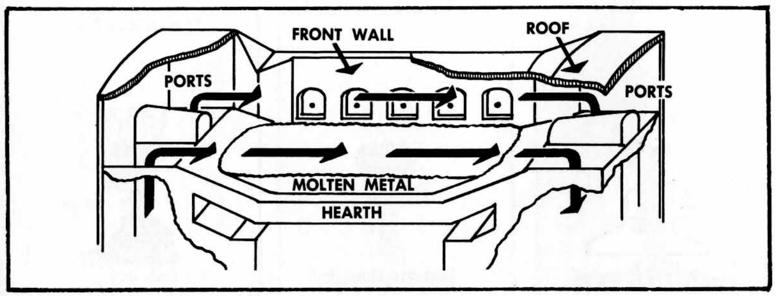
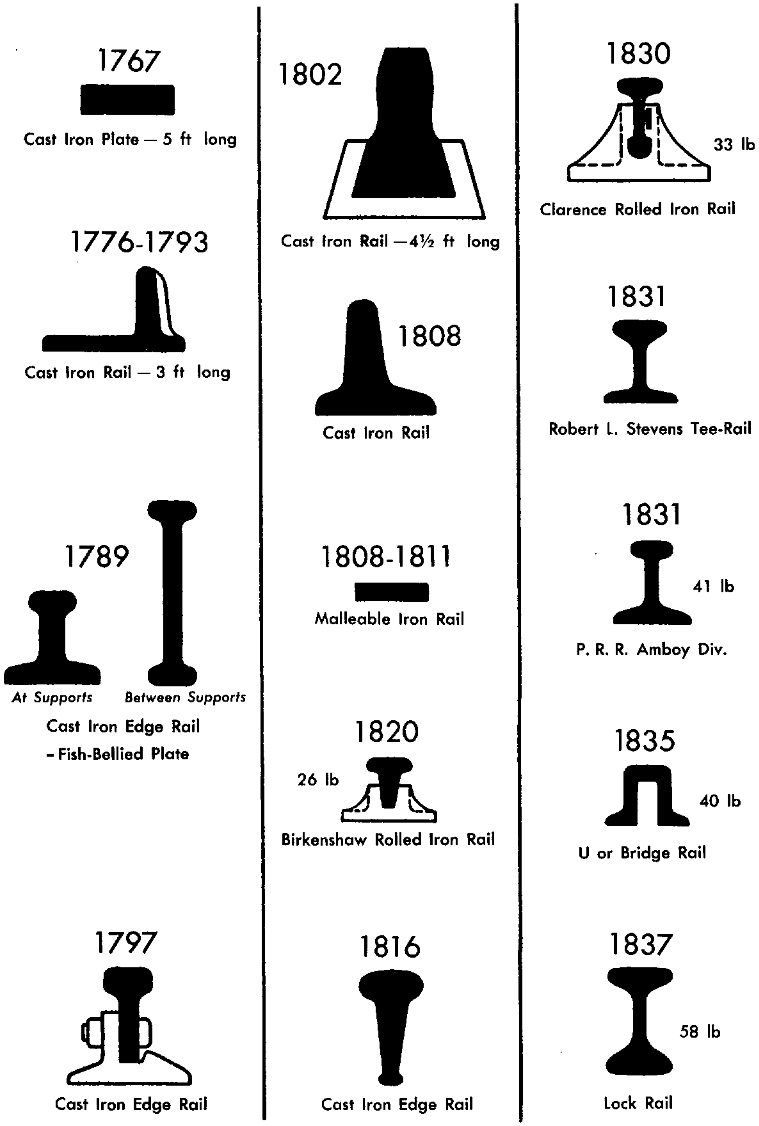
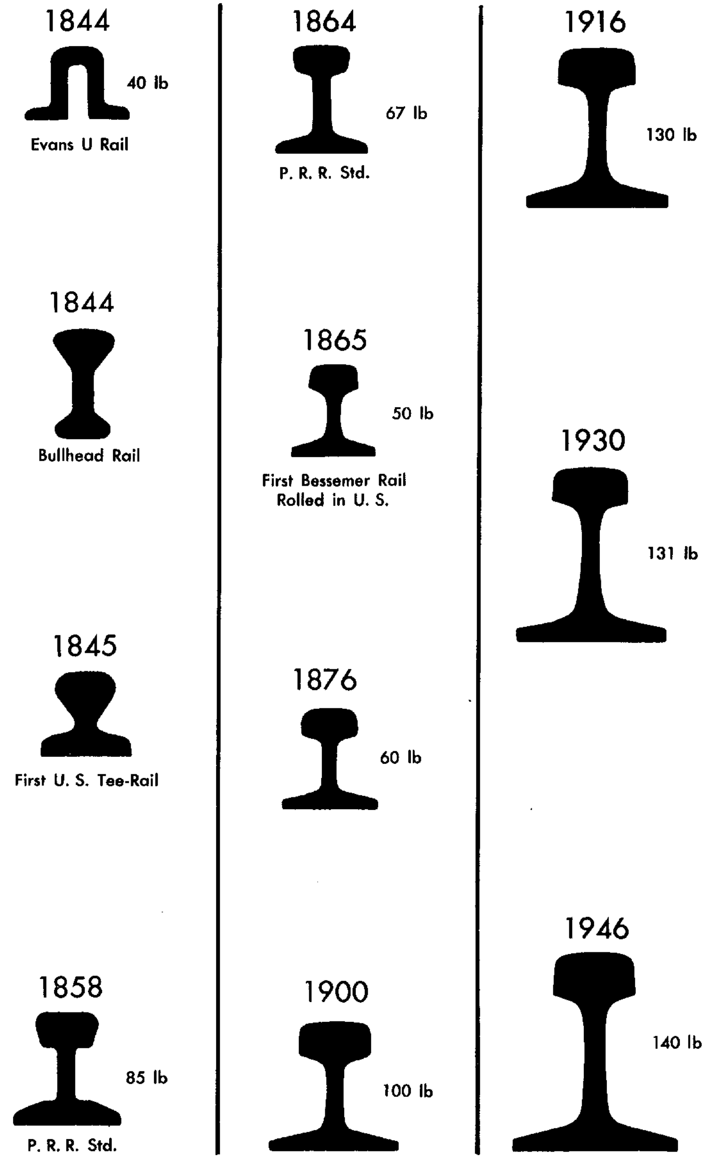


Fig. A

RAIL CROSS-SECTIONS DOWN THROUGH THE YEARS





A typical open-hearth furnace (Fig. A) is about 70 ft. long and 20 ft wide. Most of this rectangular area is occupied by the dishlike furnace bottom, or "hearth". The hearth is formed of basic refractory material supported by a steel structure which also supports the refractory-lined front and back walls, end walls, and roof. The capacity of a furnace is determined by the size of its hearth, and is usually expressed in tons of steel per melt, or "heat". A modern furnace may be of 150 to 400 tons capacity; some even larger furnaces are in use.

At each end of the furnace, ports admit highly preheated air which is directed across the hearth in alternating periods, first from one end, then from the other. This hot air supports the combustion of the fuel —oil, tar, pitch, coke-oven and natural gases, or combinations of these fuels. Sometimes the temperature inside the furnace exceeds 3200 deg. F.

The Rail Begins As a Heat

The metallic product of the batch refinement of raw materials charged into an open-hearth furnace is referred to as the "heat" of steel. Great care must be exercised in producing a heat of rail steel. This care starts with the selection of the raw materials, as the grades of scrap, pig iron, and limestone are of primary importance in the production of steel to be used for the rolling of railroad rails.

Limestone, in an amount equal to about 10 pct of the weight of the metallic charge, is charged into the furnace to build up a slag. Then comes the scrap, which accounts for roughly half the metallic charge. The remaining metallic weight comes mostly from pig iron.

Pig iron is produced in the blast furnace by reducing iron ore in the presence of coke and limestone. The resulting product is pig iron, relatively high in carbon, manganese, phosphorus, silicon, and sulphur which are brought to the proper level in the subsequent steelmaking process. The cast of iron may be delivered to the open-hearth furnaces in its molten state, commonly known as "hot metal," or it may be cast into "pigs" and charged cold at a later date.

The pig iron is added to the open-hearth furnace after the scrap has partially melted down, and the high furnace temperatures rapidly convert the raw materials into a white-hot, bubbling bath covering the hearth.

Then follows the refining period. Here is where exceptional skill and judgment are necessary, as the processing moves toward the chemical requirements dictated by the specifications in the order for which the rail steel is being produced. To make rail steel to the

standard "specs" of the American Railway Engineering Association and American Society for Testing Materials takes long experience, and the latest in metallurgical and scientific equipment. The carbon, manganese, phosphorus, and silicon contents of the steel can be controlled by the steelmaking process. For rail steel, the percentage of each of these elements may vary with the weight per yard of the rail to be rolled from the steel.

Tapping and Teeming

At the proper time, the molten steel is tapped from the open hearth into a large refractory-lined ladle, from which it is teemed into ingot molds. These rail-steel ingots, from which any of the many sections are rolled, are 25 in. by 30 in. in cross-section at Lackawanna and 26 in. by 31 in. at Steelton. The overall height of the ingot will vary with the different sections (weight per yard) of rail to be rolled, but in most cases will be about 7 ft, and the weight about 7 tons. This depends chiefly on the rail-per-ingot ratio most practical for the particular mill processing the ingot.

The gradual contraction of the steel as it cools and solidifies facilitates the stripping or removing of the molds from the ingots. Molds are not stripped, however, until sufficient time has elapsed to permit complete solidification of the steel. Immediately following the stripping operation the ingots are moved hot to the soaking pits.

During stripping and transfer, the surface of the ingots cools appreciably, while the interior may still be above the rolling temperature. Therefore the ingots must be "soaked," or held in the pit at a given controlled temperature for a considerable length of time, until the temperature throughout the ingot is uniform and at the proper rolling point. The ingots are then ready for rolling and are individually delivered to the blooming mill.

How a Rail Gets Its Pedigree

It is of utmost importance to both the manufacturer and the purchaser that each individual rail be identified. The AREA and ASTM specifications require that this identity be shown on each rail in a manner which will be discussed later. Let us return now to the open hearth to see how this "pedigree" is derived.

The identity of the steel rail heat starts with the furnace. Each open hearth at Steelton and at Lackawanna has a furnace number. Furnace numbers which may appear on rails are shown in the list below.

LACKAWANNA MILL

1	8	21	28	35	81
2	9	22	29	36	82
3	10	23	30	37	83
4	11	24	31	38	
5	12	25	32	39	
6	13	26	33	40	
7	14	27	34	41	

STEELTON MILL

247	250	283	286	289
248	281	284	287	290
249	282	285	288	

The heat number of any given heat of rail steel is, in effect, the furnace number to which is suffixed a three-digit figure indicating the cast number of that particular heat from that furnace. For each furnace, this cast number starts at 001 for the first heats tapped in January and July of each year. These cast numbers proceed numerically for each heat cast from each furnace for the first six months and the last six months of each year. For example, heat number 288137 indicates that the steel so stamped came from the 137th heat cast from No. 288 furnace, which is at the Steelton plant. Likewise, heat number 4012 stands for the 12th heat from No. 4 furnace at the Lackawanna plant.

Since the same heat numbers may be used two times in each year, it is necessary to associate the production year and month with the heat number in order to identify the material properly, as will be explained later.

The ingot identity is determined by the order in which the ingots are poured. The first ingot poured from the ladle becomes No. 1 ingot; the next, No. 2 ; and so on. Ordinarily, 15 to 20 ingots may be teemed from a single heat of steel at both the Lackawanna and Steelton plants.

An identifying heat and ingot number thus acquired is carefully associated with that particular steel as it proceeds through the many operations which follow.

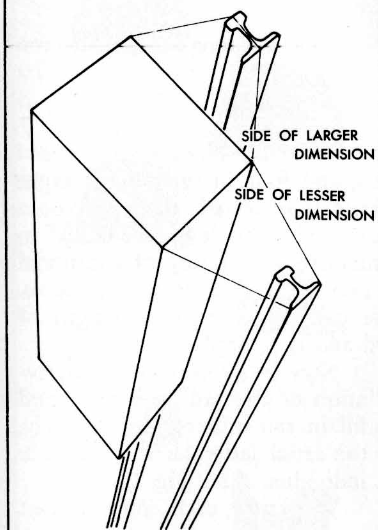


Fig. B

Returning to the blooming mill operation, we find it primarily one of reducing the ingot from its original 25-26 in. by 30-31 in. by 7 ft dimensions, to a rectangular bloom of perhaps 9¾ in. by 8¼ in. in cross section. This is done by a series of forward and backward passes on alternate sides of the ingot. The cross section is reduced in size with each pass until, after 19 or 21 such passes, the ingot has been reduced to the desired rectangular size, and its elongation has progressed from the original 7 ft to possibly more than 50 ft.

It is interesting to note that the rectangular ingot is rolled into a rectangular bloom in such a way that the sides of the ingot having the larger dimension become the height of the finished rail, and the sides of lesser dimension become the head and base. (Fig. B)

The proper amount of bottom and top discard is removed from the now elongated ingot, or bloom, and the remainder is sheared into lengths which, when further reduced, will produce either one or two 39-ft rails. These blooms are known, respectively, as single or multiple blooms. Multiple blooms are preferred by the mill; single rail blooms are avoided whenever possible. However, here again the rail-per-ingot ratio comes into play, and the bloom cuts depend on the number of rails the ingot will produce. This, you will remember, is determined by the size of the rail to be rolled and the height to which the ingot was poured in the open hearth. The number of 39-ft rails normally produced per ingot in each of the two Bethlehem rail mills will vary, as shown below, according to the section to be rolled.

Section Ib. per Yd.	Rails per Ingot	
	Lackawanna	Steelton
100-105	8	10
115	8	8
127-140	6	7

Following removal of the discard, three double blooms are sheared if the ingot is cast to produce six rails, and four in the case of eight rails. When an uneven number of rails is expected, the top bloom is cut to make the single rail. Sufficient additional length is added to the top bloom of each ingot to accommodate the rolling of additional rail bar length from which the nick and break and drop test pieces, which will be discussed later, can be cut. The remaining length of the original ingot bloom is the discard and is scrapped.

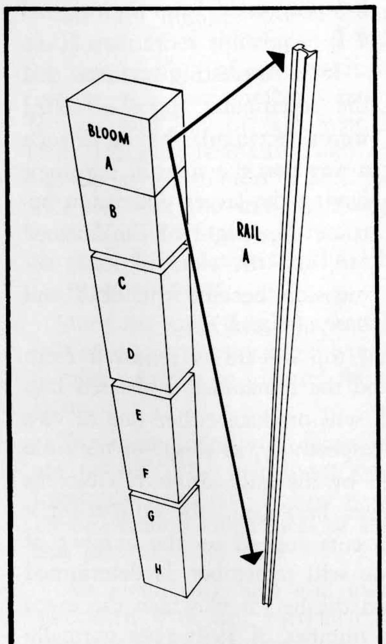
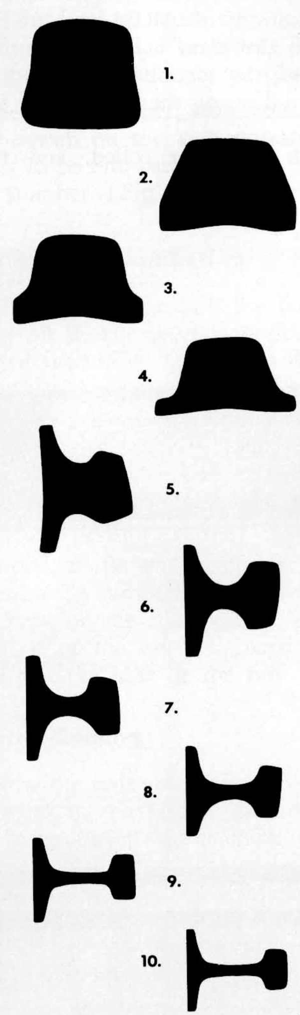


Fig. C

Now let's return to the derivation of the rail "pedigree" and fill in the missing link, namely, the serial letter identifying each individual rail (Fig. C)

We know each ingot is cast to ultimately produce a given number of rails. The top rail from each ingot is lettered "A;" the second, "B"; and so on. If, for example, eight rails are to be produced from an ingot, the bottom rail serial letter becomes "H". Likewise this serial lettering system is applied to the bloom from which each of the rails will be rolled. To illustrate, the four double blooms in an 8-rail ingot would be known as AB, CD, EF, and GH blooms, respectively. The sketch shows this graphically. When the bloom is finally rolled and cut into specific rail lengths, the serial letters go with the individual rails produced.



Typical section contours during rolling of rail.

Fig. D

Normally, the rail section is formed by a series of 10 passes so designed that the form of the original rectangular bloom is progressively developed into the contour and shape of the desired rail section. This requires precision in the design of the rolls, as well as the closest supervision of the rolling operation to insure that the required accuracy of section contour and shape is obtained. (Fig. D)

As in the previous steps of rail manufacture, the rolling of rails must be closely controlled. Usually, a trial rolling with one bloom will be made The trial rail is then gaged by templets to check the base, head width and contour, flange length and thickness, head radii, and "fishing." The rolling of the blooms to rails continues only after the trial rail indicates adherence to the specifications. The rails are checked at frequent intervals, not only for accuracy of section, but for such conditions as collar marks, underfills, roll marks, overfill, guide marks, cracks, seams, or pickups. The sketches show the various roll pass contours for producing a typical modern rail section from the bloom to the finished rail.

How Rail Identification Is Shown

As mentioned earlier, standard specifications of AREA and ASTM require that each rail be identified as to the plant at which the rail was produced, the month and year rolled, the section designation of the rail, the heat number, the rail letter indicating the position of the rail in the ingot, and the ingot number.

The name of the plant, the month and year rolled, and the

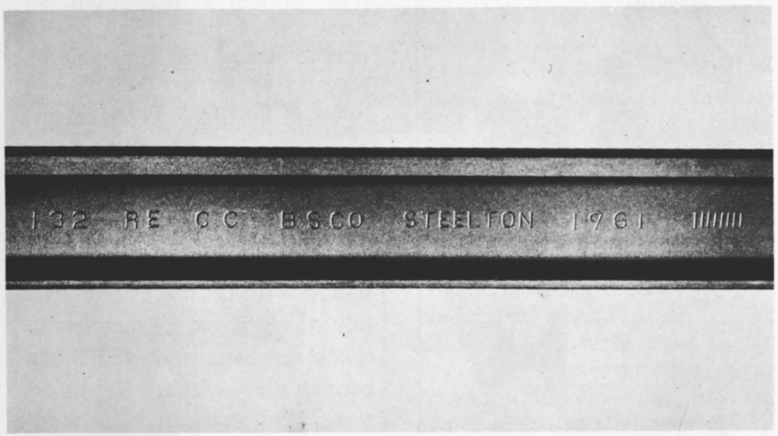


Fig. E

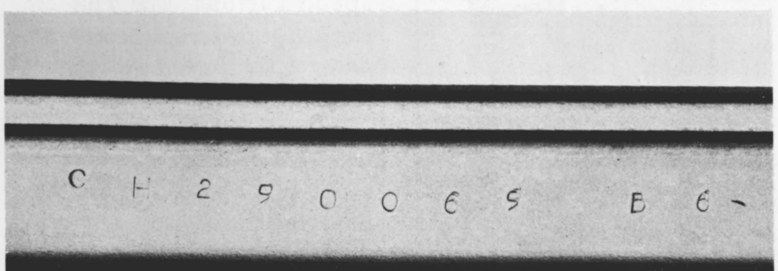


Fig. F

section designation of the rail are shown in the "brand," which is rolled in raised characters on the web of the rail. These are produced by letters and numbers cut into the periphery of the bottom roll in the finishing pass. The letters "CC" are included in the brand to indicate that the rail is to be control-cooled. (Fig. E)

The heat number, rail letter, and ingot number are hot-stamped in the web on the side opposite the brand. When a control-cooled rail is to be end-hardened, the letters "CH" are stamped ahead of the heat number. (Fig. F)

Cutting and Cambering

After rolling, the rails are hot-sawed to length, the standard length being 39 ft. For special applications longer rails can be produced in limited quantities. Cutting is done with hot saws mounted over the runout table beyond the finishing-roll stand. In cutting the rails, allowance must be made for linear thermal contraction, which in a 39-ft rail is about 8 inches. The saws must be positioned very accurately so that the rails will meet the ⅜-in. plus-or-minus tolerance for length after cooling.

Before passing to the "hotbeds" for cooling, the rails are hot-stamped as shown in Fig. F. They are then cambered by passing through the cambering rolls, which bow the rails in a slight arc, with the head on the convex side. This is to offset the differential in contraction of the unequal masses of metal contained in the head, the web and the base of the rail.

Control-Cooling

Now the rails are ready to be control-cooled. One of the outstanding advances in the history of rail manufacture, control-cooling prevents the inception of shatter cracks which may later result in rail breakage. In the controlled-cooling cycle, the rails are cooled in the normal way on hot beds until the temperature falls between 1000 deg and 725 deg F. The rails are then charged immediately into large insulated metal containers with a capacity of 100 to 120 tons each, depending on the rail section, and the container is covered. The cover must remain on the container a minimum of 10 hours. After removal of the cover the rails must remain in the container until the temperature of the top layer of rails has dropped to 300 deg or lower. The temperature between an outside rail and the adacent rail in the bottom tier of the container is recorded. From the time this bottom tier is placed in the container, the recorded temperature must not drop below 300 deg in less than 5 hours for rails weighing less than 100 lb per yard, or 7 hours for 100-lb rails or heavier.

Finishing and Inspection of the Rails

After control-cooling, the rails are sent to the finishing department, where they are straightened and drilled for joint bolts. Then they move to the inspection beds. Here the rails are inspected for surface imperfections of the base, flanges, and head by inspectors who "walk the rails" first with the rail base up, then with the head up. The residual burrs are removed from the rail ends. Chamfering, or beveling of the end face at the top and sides of the head, is done by grinding. In addition, straightness, squareness of ends, and position of bolt-hole drilling all must be checked, as well as section and length of the rail.

Classification

As part of the inspection procedure, rails are classified in accordance with the requirements of the AREA or ASTM specifications. The AREA requires classification painting to facilitate identification of different classes of rails; no painting is required by ASTM specifications. Rails are generally classified as follows:

No. 1 rails are those which are free from injurious imperfections of all kinds. No. 1 rails whose carbon and manganese content are above the mean of the specified range are painted blue on the ends; all other No. 1 rails are left unpainted, except those of less than standard 39-ft length, which are painted green on the ends.

No. 2 rails are rails which (a) do not contain surface imperfections in such number or of such character as to render them unfit for recognized uses; (b) arrive at the straightening presses with sharp kinks or greater camber than indicated by a middle ordinate of 6 in. in 39 ft; (c) are not hot-stamped. A figure 2 is stamped on both end faces and their ends are painted white.

X-Rayls. A test piece, representing the top end of the top rail of each ingot of each heat, having passed the drop test, is nicked and broken. If the fracture of any test exhibits seams, laminations, cavities, interposed foreign matter, or a distinctly bright or fine-grained structure, such top rail is classified as an X-Rayl. An X is stamped on both end faces and ends are painted brown. The specifications of both the AREA and the ASTM contain optional provisions for the elimination of X-Rayls.

"A" rails are the first rails from each ingot after top discard, and are painted yellow.

The Drop Test

All heats of rail are subjected to the AREA drop test. The drop-test specimens consist of three full-section pieces 4 to 6 ft long, cut from the top end of the "A" rail from the second, middle and last full ingot of each heat. The temperature of the specimens must not exceed 100 deg F.

The standard AREA drop-testing machine is used, with a distance between supports of 3 ft for sections under 106 lb, 4 ft for sections 106 lb to 140 lb, and 4 ft 8 in. for sections over 140 lb.

The test specimens are placed head upwards on the supports and subjected to one blow from the 2000-lb tup falling free from the following heights for rails of the nominal weights indicated:

Weight per Yd.	
70-80, inclusive	17
81-90, "	18
91-100, "	19
101-120, "	20
121, and over	22

If all the specimens withstand the above test without fracture, all the rails of the heat are acceptable, subect to final inspection for surface, section and finish. But if one of the three specimens fails, all the "A" rails are rejected. New specimens are then cut from the bottom ends of the same "A" rails, or the top ends of the "B" rails of the same ingots, and then tested. If any of those specimens fails, the "B" rails of the heat are rejected. Test specimens are then taken from the bottom ends of the "B" rails or the top ends of the "C" rails from the same ingots. If none of these fails, the remainder of the rails from the heat are accepted. But if any of the last specimens fails, the "C" and all remaining rails from the heat are rejected.

End-Hardening

To reduce wheel-batter at the rail joint, most railroads now specify that rails be end-hardened. Bethlehem was the first producer to develop the end-hardening of rails, and now uses fully automatic equipment for this process. The unit consists of a bed on which the rails are moved automatically in such a manner that the two ends of each rail pass simultaneously under burners (three preheat burners and one high-heat burner at each end) and an air-quench nozzle.

This heat-treating procedure is applied to new rails after the "ending" and drilling operations have been completed. Consecutive rails are mechanically positioned on skids prior to moving under the preheat burners. The longitudinal location for preheating is precisely controlled by moving feed rollers and a positioning switch. A hydraulic system then moves the rails laterally at specific predetermined intervals through the three stages of preheating burners, then to high heat, which governs the quenching temperatures, then to the air-quenching stage.

Two specimens from each heat are Brinell-tested for hardness, and a report furnished the customer. Rail ends hardened by this process have successfully resisted battering, chipping, and spalling under the traffic of hundreds of millions of gross tons.

Heat-Treatment

Railroads are showing an increasing interest in the use of heat-treated rails, especially on sharp main-line curves, and other points of tough service. The purpose of heat-treating is to improve strength and wear-resistance through improvement of the internal structure of the rail. This, in turn, increases track life, and lowers maintenance-of-way costs.

Rails to be heat-treated are selected from heats which have met all the requirements of standard rail specifications, including control-cooling.

The heat-treating cycle consists of heating the steel to predetermined temperatures for a time sufficient to bring about the desired change in structure, followed by an oil quench. At the end of a carefully controlled period in the quenching tank, the materials are lifted out, placed in the preheated tempering furnace, and held for the proper length of time at the proper temperature to adjust the hardness and toughness of the steel.

DEVELOPMENT OF RAIL TESTING

From the earliest days of railroading, maintenance of the right-of-way has been one of the greatest problems of the operating companies. The greatest single factor of this problem is the prevention of service failures of rail in track.

The causes of rail failures are many. Often the effects are serious—destruction of property and the injury or death of crews and passengers. The early iron strap rail frequently broke loose from its wooden stringers and curled up in "snakeheads" which tore through the wooden floors of the old cars. Cast iron rails crystallized and cracked under the strain of severe climatic changes or sudden shock loads. Bessemer steel rail also showed a tendency toward brittleness in cold weather. The present day steel rails manufactured by the open hearth process, although vastly superior to the older types of rail in both strength and wearing quality, still develop defects. Under today's heavy loads and high speeds these defects will cause rails to fail in service unless inspected regularly.

Many external defects and visible indications of internal defects are overlooked in visual inspections. With a Sands mirror an inspector can visually inspect approximately one mile of rail per day. However, even this type of inspection, acknowledged as the most efficient method of visual inspection, cannot detect those internal separations of the steel within the rail head known as Transverse Defects, and frequently overlooks vertical split heads.

The transverse fissure first came into prominence as an outstanding cause of rail failures as a result of a derailment at Manchester, N. Y. in 1911 in which 29 persons were killed and over 60 seriously injured. In the investigation following the accident, Dr. Howard of the U. S. Bureau of Safety identified a broken rail as the cause of the derailment. A study of the rail revealed a defect which was entirely internal (which Dr. Howard termed "transverse fissure") and which was definitely established as the cause of the rail failure. A number of other railroads began private investigations to determine the prevalence of transverse fissures in their rails. The results of these investigations showed that transverse fissures were wide-spread.

As early as 1877, a patent, No. 189,858 "Mode of Detecting Defects in Railroad Rails", showed the effort to detect defects. This invention called for the energizing of the rail with flux, then picking up variations in residual magnetism.

The railroads of the country requested the U. S. Bureau of Standards in 1912 to undertake a thorough investigation of the prevalence and cause of transverse fissures and to aid in the development of a method of inspection which would accurately locate and measure the size of such hidden defects in rails.

In 1915 the Bureau of Standards began a series of experiments culminating in the development of magnetic testing equipment for locating and measuring transverse fissures in rails. In this method a magnetizing solenoid was passed along the rail setting up a flux. Any leakage of the flux was detected with searching coils which were attached to a sensitive voltmeter. The principle of this apparatus was sound in theory and successful in laboratory tests but in actual tests on track it was found that the equipment was unable to differentiate between actual defects in rails and the strains caused by slipping wheels, surface irregularities, cold working by car wheels, etc. Two railroads and one of the major steel companies made further unsuccessful attempts to adapt this method to field testing.

In 1923 Dr. Elmer A. Sperry, a noted inventor and founder of the various Sperry enterprises, started to develop and build an inspection car that would detect the presence of transverse fissures in the rails while travelling along the track. While Dr. Sperry was engaged in this work, another serious derailment near Victoria, Mississippi, on October 27, 1925 caused the death of 21 persons and the injury of over 100 passengers. Again, the cause of the accident was found to be a broken rail caused by transverse fissure.

Dr. Sperry contracted with the American Railway Association in August 1927 to build a detector car for the AAR and, in addition, to supply a rail testing service to the railroads. This car energized the rail with current and measured variations in potential drop by means of a pair of contacts. While the laboratory tests were satisfactory, the actual conditions in track prevented satisfactory operation. The searching unit, located between the brushes, depended upon contact with the rail. The average conditions of the surface of the rail,—dirt, oxide, and scale on the rail head, prevented continuous contact of the searching units with the rail and caused many false indications. Extensive research was continued to develop a practical means of cleaning the rail before testing, but no solution was found and the method was abandoned.

Far from being discouraged by this failure, Dr. Sperry proceeded, as in the case of so many of his other inventions, with the development of an entirely new principle for the detection of hidden defects in rails,—the induction method of testing.

In the induction method, a heavy electric current of low voltage was passed through the rail, setting up a magnetic field around the rail. A pair of searching coils was suspended at a constant distance above (but not in contact with) the surface of the rail to detect any deflection or variation in the magnteic field caused by fissures within the rail. When these coils passed into the changing magnetic field around the defect a current would be induced within the coils. This current was then amplified to actuate a series of recording pens. The induction principle, greatly perfected and refined, is still the basic principle of Sperry Detector Cars.

Sperry Rail Service then began an extensive long-term program of providing a reliable testing service for all railroads. The Sperry Rail Service was organized to fill the great need for efficient equipment for testing rails in tracks. To overcome the limitations of the early detector car required extensive laboratory research and development combined with practical experience in testing rail in track. Any such long term program could best be carried out by an organization which leased its services and equipment to the railroads rather than sold its detector cars outright. There would be little lag between the development of new testing techniques and their application in rail testing. This policy, established in 1928, has worked out to the definite advantage of the railroads served by Sperry since it has expedited Sperry's continuing program of development. Statistics published annually in the *Sperry Railer* show the remarkable progress made by Sperry over this period of years and confirm the advantage to the railroads of such a policy.

In recent years, this policy has resulted in the addition of ultrasonic detection equipment to the Sperry fleet of detector cars to further improve the efficiency of Sperry Detector Cars. Ultrasonic rail testing was first offered in 1949 with the equipment mounted on a motor car and a hand inspection made at each joint. Within eleven years the Ultrasonic inspection equipment was automated to the point where it could effectively assist the induction systems already in operation. Ultrasonic equipment for the detection of defects in the rail head was added to the detector cars in 1960 and ultrasonic equipment for the detection of bolt hole and web defects was added in 1961. A specially designed all-ultrasonic detector car was first put into operation by Sperry on October 8, 1959, on the New York City subwav system.

Although the Sperry detection equipment was originally designed to detect the transverse fissure, it also detects a large number of other types of defects which render rail unsafe. Such defects, along with the transverse fissure, are fully described in this manual.

In the course of these early investigations of the cause, occurrence, and detection of transverse fissures, the inspection methods employed at the rolling mills came under the scrutiny of the AAR and the steel companies, starting in 1930. Rails were found to be rejected at the mill for serious surface defects, but internal structural weaknesses in the steel, which were potential defects, escaped detection.

When these potentially defective rails are placed in service, dangerous defects often develop under traffic. Production factors which contribute to the manufacture of inferior rails have been minimized through refinement in mill practice, but invisible internal defects still occur in the latest types of rail.

At the present time there are millions of rails in tracks which were rolled prior to the development of the more modern production techniques. In both new and old rail the extent of the growth of microscopic irregularities is still of great concern. The location and size of these irregularities in a rail determines the capacity of that rail to withstand the stresses imposed upon it in service.

EFFECT OF CC RAIL ON SPERRY TESTING

An attempt to solve the transverse fissure problem by elimination of the prime cause (shatter cracks) resulted in the development of the "control-cooled" process of rail manufacture and led to the general adoption of this process in 1936 - 1938 by American steel mills.

After a considerable quantity of controlled cooled rail had been in service for several years, it became apparent that the elimination of shatter cracks was not the complete solution to the true transverse fissure problem, although the number of such defects was obviously far less than the incidence of TF's found in hot bed cooled rail.

Further investigation initiated by the Rail Committee of the American Railway Engineering Association disclosed the fact that these transverse fissures in CC rail were the result of hot torn steel and/or inclusions. Studies of steel mill practices disclosed that one of the outstanding causes of hot tears and/or inclusions was the uncontrolled reheating of the bloom prior to rolling. The correction of this factor has further reduced the incidence of transverse fissures.

The initial goal of eliminating the true transverse fissure by means of mill controls has been successful to the extent of reducing the number of such defects to an insignificant minimum. The controlled-cooled method of rail manufacture has not been successful, however, (nor was it originally intended to do so) in eliminating or reducing, insofar as we are able to determine, defects other than the true transverse fissure. Special heat treating processes of CC rail intended primarily for increasing rail life where traffic conditions are severe are now being employed and field tests are being conducted. It is too early at this time to ascertain what effect if any, these new processes will have on the origin or development of rail defects.

Other transverse defects which are still found in CC rail are detail fractures, engine burn fractures and occasional compound fissures.

Progressive transverse defects will also develop underneath engine burns resurfaced by welding when the area being rebuilt is not properly cleaned or cooled during the process. Longitudinal and miscellaneous defects such as vertical split heads, horizontal split heads, head and web defects and split webs are still discovered in considerable numbers. Rail end defects such as bolt hole cracks and rail end head and web separations appear to be developing in increasing numbers (this has been illustrated statistically since 1961 when large scale rail end testing was commenced. However, the development of rail end defects is primarily a function of wheel and axle loading as well as general joint maintenance and is not associated in any way, so far as we have been able to establish, with whether the rail is control-cooled or hot bed cooled. Incipient pipes or seams are present to some degree in CC rail but, as a rule, are not a specific problem unless the rail is subjected to pressure butt welding.

During 1966 and 1967 approximately 40% of the total mileage tested by Sperry Rail Service was control-cooled rail. Testing policies covering CC rail vary widely from one road to another with some CC rail being tested as often as three times annually. Interval of test is usually based upon frequency of defect development. There are, of course, too many variables such as weather (temperature fluctuations), tonnage (both average wheel and axle loading as well as total tonnage on the lines concerned), speed and type of train operation, and general maintenance practices employed to establish reliably or predict defect frequency.

DEFINITION OF TERMS

bleeding: reddish-brown streak indicating internal rusting.

detected failure: defective rail detected by detector car or visual means.

field side: side of rail head away from wheel flange.

gage side: side of rail head closest to wheel flange.

head checks: transverse surface cracks on the gage corner of rails resulting from cold working of surface metal. These are sometimes referred to as gage cracks.

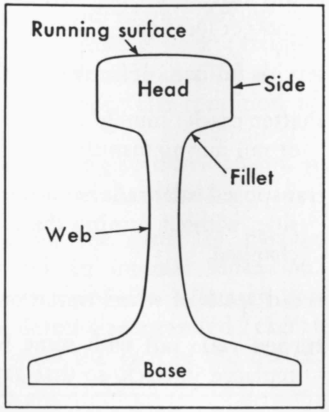


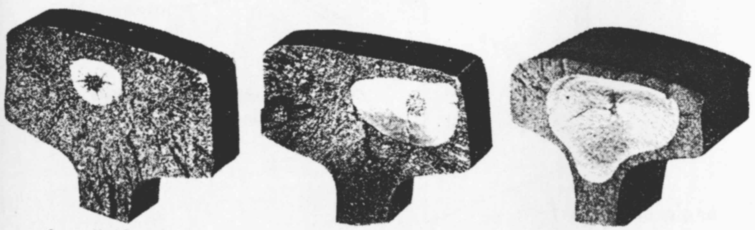
Fig. 11. Rail nomenclature.

heat: one loading, or charge, of metal from a furnace at the steel mill. All rails rolled from the ingots from one heat are said to be of the same heat.

inclusion: small quantity of gas or slag that is trapped in molten steel and remains in after cooling.

nucleus: origin, starting point, or kernel of defective growth in some defects.

per cent size: percentage of rail head cross-sectional area that is weakened by defect (transverse defect only).



Small (0-20%) Medium (21-40%) Large (41-100%)

Fig. 12. Examples of size classification.

rail failure: may be either detected failure or service failure.

relaid rail: worn but still usable rail taken from track and re-used in another location.

service failure: defective rail that ruptures in service.

shatter crack: minute crack in steel, caused by rapid or uneven cooling of rail during manufacture.

transposed rail: rail that is moved from one side of the track to the other side, without turning the rail, so that gage and field sides are interchanged.

tread: path of wheel contact with running surface of rail

turned rail: rail with some wear that has been removed, turned, and replaced in track, so that gage and field sides are interchanged.

DEVELOPMENT OF DEFECTS

The growth of a rail defect depends on a great many variables. The chemical composition of the rail and the amount of rail flexing are factors which must be considered. The type of rolling stock (freight, passenger, or motive power), its weight, and its condition of repair are important, as well as the frequency of these loads. The condition of the roadbed and weather changes which result in track movement also affect growth. With so many variables contributing to development, it is impossible to predict accurately the growth of any defect.

Surface defects may simply enlarge under the batter of passing wheels, or may furnish the focal point for an internal separation. Interior defects actually experience a growth in size, although the type of growth cannot be classified, nor the defect size measured (except by hand test) until the rail is broken to show the face of the defect.

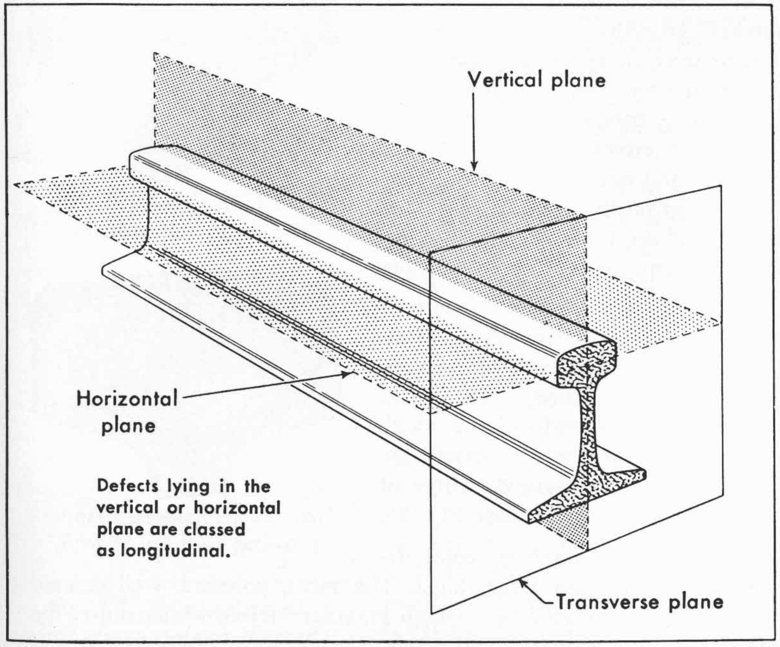


Fig. 13. Relative position of planes through a rail.

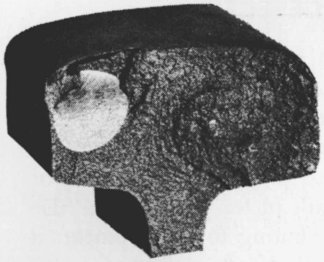


Fig. 14. Detail fracture, showing normal growth.

Furthermore, this classification and measurement is only possible for those defects which are transverse.

After the rail is broken, a transverse defect is measured against the cross-sectional area of the rail head. If half of the rail head cross-section shows signs of defective growth the defect is called a 50 per cent fracture.

When the defective portion of the rail is closely examined, certain characteristics furnish information as to what type of growth was experienced. Sperry bases its classification on this evidence, and recognizes three types of growth in transverse defects:

normal growth — signifies development over an appreciable period of time in very gradual stages. Development is complete, the entire face of the transverse separation being smooth and well defined. There is no limitation on the number of growth rings (if any), or the distance between them, or the time in development. See Fig. 14.

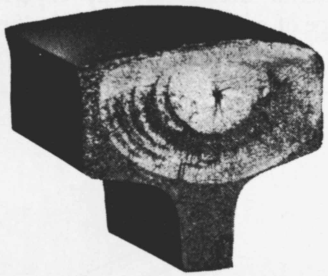


Fig. 15. Transverse fissure, showing rapid growth.

rapid growth — signifies recent development in numerous small stages. The small, polished, well-defined fracture is surrounded by a rough granular surface which shows the outline of several growth rings of gradual increasing size. See Fig. 15.

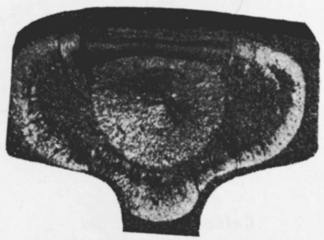


Fig. 16. Transverse fissure, showing sudden growth.

sudden growth — signifies recent development in a few large stages. The small, polished, well defined fracture is surrounded by a rough granular surface which shows the outline of one or two growth rings. The distance between rings will increase directly with the rate of growth. See Fig. 16.

TRANSVERSE DEFECTS IN THE RAIL HEAD

General

A transverse defect is any progressive fracture which occurs in the head of a rail and has a transverse separation, however slight. This general classification is made when the defect is found in track. After the rail is broken for examination, the transverse defect can be accurately identified as one of the following:

Transverse Fissure
Compound Fissure
Detail Fracture from Shelling
Detail Fracture from Head Check
Engine Burn Fracture
Welded Burn Fracture

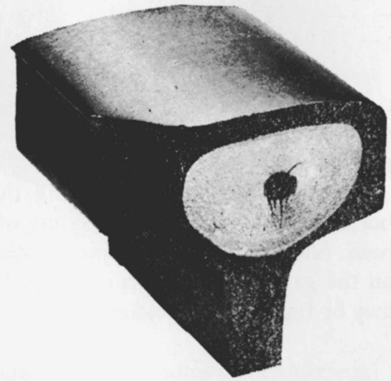


Fig. 17. Large transverse fissure, showing normal growth around nucleus.

All defects showing a transverse component at the time of test are reported as transverse defects by detector cars.

Appearance in Track—The description below applies to all transverse defects EXCEPT the ENGINE BURN FRACTURE, which is described on Page 40. No evidence is visible until the defect reaches the rail surface (cracks out). A transverse defect may then be recognized by one or more of the following characteristics: (See Fig. 18).

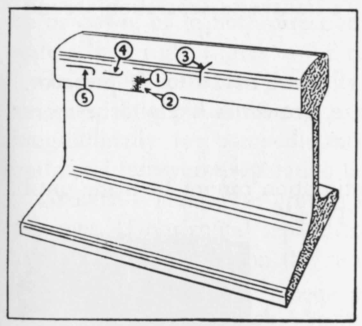


Fig. 18. Appearance of transverse defects (except engine burn fracture) in track.

1. A hairline crack at right angles to the running surface, usually on the field or gage side of the head, or at the fillet under the head; occasionally on the running surface.

2. Discoloration (red or purple oxidation) around the crack. This is called bleeding and is caused by internal rusting.

3. A hairline crack at the upper gage corner of the rail head. On turned rail, this condition may occur at the field corner. Numerous gage cracks are often present, but should cause no suspicion unless a single crack extends much farther down the side and much farther across the running surface than the other cracks.

4. A horizontal hairline crack in the side of the rail head which turns upward or downward at one or both ends and is usually accompanied by bleeding. Under such conditions a flat spot will generally be present on the running surface.

5. A hairline crack extending downward at right angles from a horizontal crack caused by shelling of the upper gage corner of the rail head. Shelling can be identified by the presence of a slight discoloration on the gage side of the running surface. On turned rail the shelly area may be found at the field side.

Classification

Transverse Fissure

Description—The transverse fissure is a progressive crosswise fracture starting from a center or nucleus inside the head of the rail, then spreading outward substantially at right angles to the running surface of the rail.

Origin—The internal nucleus is an imperfection in the steel, such as a shatter crack, or a minute inclusion or blowhole. Impact of the wheels and bending stresses start the growth of a transverse separation around the imperfection.

Growth—Growth is normally slow to a size of 20 to 25 per cent. After the fissure passes a 20 per cent size, growth is likely to be more rapid.

Appearance in Track—Positive identification cannot be made until the rail is broken. See "Appearance in Track" for transverse defects, page 35.

Fig. 19. Face of transverse fissure was blackened or oxidized by air when separation reached rail surface at fillet.

Identification After Breaking—The speci-

men must show a nucleus which is more than ⅜ in. from any surface of the rail head. Separation is substantially at right angles to the running surface, completely surrounds the nucleus, and shows growth originating from the nucleus.

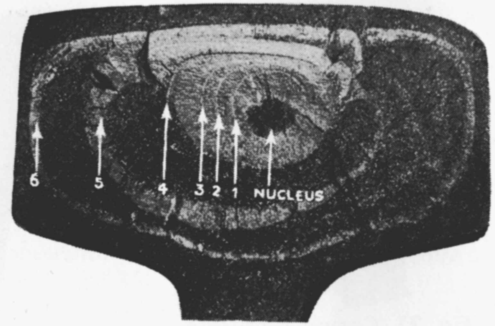


Fig. 20. Transverse fissure, showing rapid growth. Arrows indicate growth rings.

Hazard—The transverse fissure is dangerous because:

1. It tends to occur several places in the same rail, since shatter cracks, inclusions, and blow holes (when present) are common throughout the rail length, and often exist in several rails from the same heat.
2. Failure almost always occurs before the defect becomes visible.
3. Service failure is usually a complete break of the rail across head, web, and base.

Compound Fissure

Description—The compound fissure is a progressive fracture in the head of the rail generally starting as a horizontal separation which turns up or down, or in both directions, to form a transverse separation substantially at right angles to the running surface.

Origin—The fissure generally starts as a horizontal separation from an internal longitudinal seam, segregation, or inclusion. It progresses longitudinally for some distance, then turns upward, downward, or both, and transverse separation begins.

Growth—Transverse growth is normally slow to a size of 30 to 35 per cent. If horizontal separation is great enough to reach the surface and cause a flat spot on the running surface of the rail head, growth will be rapid.

Appearance in Track—Positive identification cannot be made until the rail is broken. See "Appearance in Track" for transverse defects, page 35.

Identification After Breaking—Both longitudinal and transverse sep-

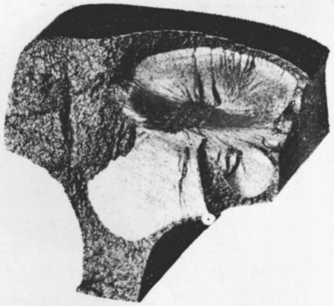


Fig. 21. Compound fissure, showing horizontal separation and several planes of transverse separation.

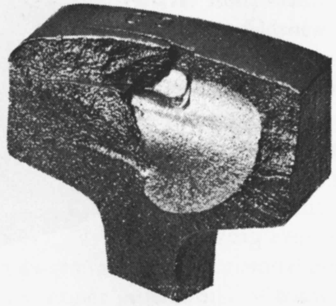


Fig. 22. Compound fissure with very slight horizontal separation.

arations are usually exposed. The longitudinal separation may be as short as ⅛ in., appearing only as a displacement between two transverse planes. See Fig. 21. The longitudinal separation is usually parallel to the running surface. The transverse separation frequently resembles that found in a transverse fissure except that no nucleus is present.

Hazard—The compound fissure is a dangerous defect because:

1. It may occur several places in the same rail, if the seam or segregation exists throughout the rail length.
2. Failure sometimes occurs before the defect becomes visible.
3. Service failure is usually a complete break of the rail across head, web, and base.

Detail Fracture From Shelling

Description—The detail fracture from shelling is a progressive fracture starting from a longitudinal separation close to the running surface of the rail head, then turning downward to form a transverse separation substantially at right angles to the running surface.

Origin—The origin is usually a longitudinal seam or streak near the running surface on the gage side (field side if the rail has been turned). The separation progresses longitudinally, not as a true horizontal or vertical crack, but at an angle related to the amount of rail wear on the gage corner. After some distance, the crack turns downward and inward to form a transverse separation. See Fig. 23.

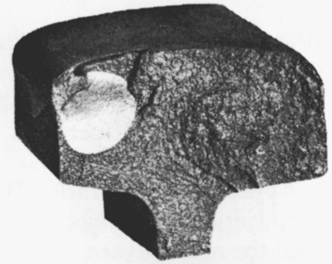


Fig. 23. Detail fracture from shelling.

Growth—The growth is normally slow to a size of 10 or 15 per cent. Growth from a 20 per cent size to a 40 or 60 per cent size is often rapid or sudden, occurring just prior to complete failure.

Appearance in Track — Positive identification cannot be made until the rail is broken. See "Appearance in Track" for transverse defects, page 35.

Identification After Breaking—The longitudinal separation and the streak or seam in which it originated is not often exposed. The transverse component resembles that found in a transverse fissure except that:

1. No nucleus is present in the transverse separation.
2. The transverse separation always spreads from a longitudinal separation in the upper gage corner.

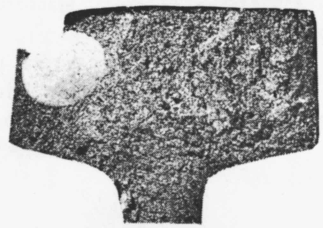


Fig. 24. Detail fracture from shelling, with part of shell chipped off.

Hazard—The detail fracture from shelling is a dangerous defect because:

1. Growth may be rapid or sudden in the early development of the defect.
2. Failure frequently occurs before the defect becomes visible.
3. Service failure is a complete break of the rail across head, web, and base.

Detail Fracture From Head Check

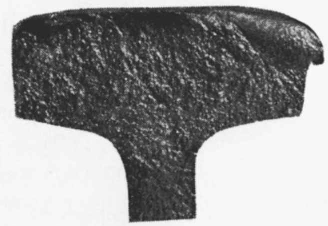


Fig. 25. Detail fracture originating from head check on gage side (turned rail).

Description — The detail fracture from head check is a progressive fracture starting at the gage corner of the rail head and spreading transversely through the head. See Fig. 25.

Origin—The origin is head check in the upper gage corner of the rail, usually caused by concentrated loading which cold works the steel.

Growth—Growth is very rapid after a size of 5 per cent is reached.

Appearance in Track—Positive identification cannot be made until the rail is broken. See "Appearance in Track" for transverse defects, page 35, and Fig. 26.

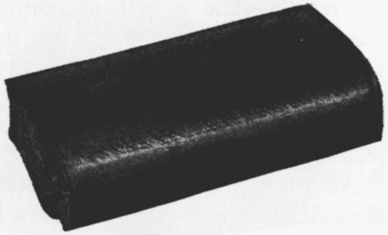


Fig. 26.
Head check on rail surface.

Identification After Breaking — The specimen exposes a transverse separation which starts at the gage corner and spreads in crescent-shaped rings around the point of origin.

Hazard—The detail fracture from head check is a dangerous defect because:

1. It tends to occur several places in the same rail.
2. Many fail completely before a 15 per cent size is reached, because of stresses on the gage at sharp curves.
3. Service failure is a compete break of the rail across head, web and base.

Fig. 27.
Advanced development of head check, where metal has chipped away between small cracks.

Engine Burn Fracture

Description—The engine burn fracture is a progressive fracture in the head of the rail, starting from a burn, with transverse separation substantially at right angles to the running surface. It is usually found compounded with a shallow horizontal separation where the zone of burned metal separates from the rail metal just below the surface. See Fig. 28.

Origin—

1. **Normal Rail**—The slipping engine driver heats a portion of the rail surface, and rapid cooling forms thermal cracks. Pounding of the wheels over this burned area starts a horizontal separation of the burned metal from the parent rail metal and develops a flat spot. Transverse separation may start from a thermal crack in the region of the burn at any time.

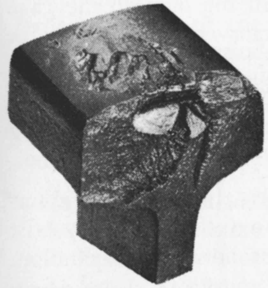
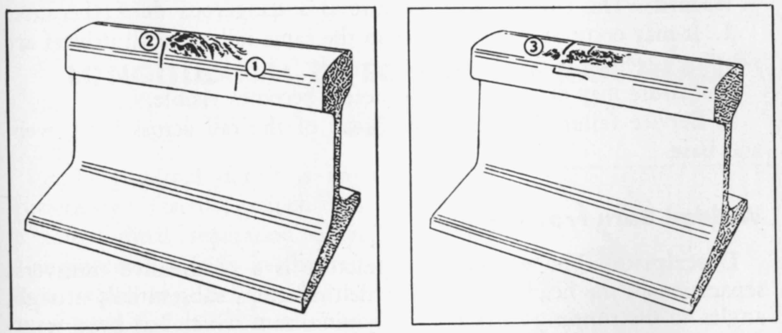


Fig. 28. Engine burn fracture, showing small transverse separation.

Growth—Growth is normally slow to a size of 10 or 15 per cent. After the transverse separation reaches a size of 10 or 15 per cent, growth becomes more rapid.



Gage side **Field side**
Fig. 29. Appearance of engine burn fracture in track.

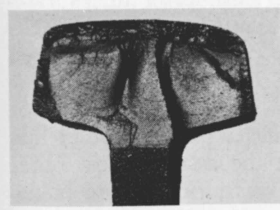


Fig. 30. Transverse separation found beneath a resurfaced engine burn.

Appearance in Track—No sign of a transverse separation is visible until the defect reaches the rail surface (cracks out). An engine burn fracture may then be recognized by one or more of the following characteristics: (See Fig. 29).

1. A hairline crack on the side of the head, in the immediate vicinity of an engine burn on the surface, and at right angles to the running surface. The crack may be visible on either the field or gage side of the head.

2. Transverse thermal cracks extending from the burn to the gage corner and down the gage side of the head as transverse components for at least 1/8 in.

3. A cracked out horizontal separation visible on the field side of the rail head under the burned area, accompanied by one or more thermal cracks which extend transversely to the gage corner.

Identification After Breaking—The specimen always shows the surface burn. The transverse separation will have no nucleus, and may exist at one, two, or three planes anywhere along the horizontal separation. The horizontal separation starts at running surface and slants downward to a depth of 1/8 to 1/4 in. below the running surface.

Hazard—The engine burn fracture is a dangerous defect because:

1. It may occur at several places in the same rail since all drivers are slipping together.
2. Failure may occur before the defect becomes visible.
3. Service failure is a complete break of the rail across head, web, and base.

Welded Burn Fracture

Description–The welded burn fracture is a progressive transverse separation in the head of the rail which develops substantially at right angles to the running surface at an engine burn which has been resurfaced by welding.

Origin—A welded burn fracture is sometimes the result of insufficient "wash out" or cleaning of an old engine burn prior to resurfacing by welding and this essentially fails to eliminate thermal cracks created by the original driver burn. Improper cooling of a resurfaced burn can also create new thermal cracks. See Figure 30.

Growth—Growth is considered to be relatively slow to a size of approximately 15 to 20 percent. The rate of development beyond this stage usually becomes more rapid and, as in the case of most other transverse defects, will be accentuated by heavy traffic, loading or inadequate track maintenance.

Appearance in Track–No sign of a transverse separation is visible until the defect reaches the rail surface (cracks out). A welded burn fracture can then be recognized by a hairline crack at right angles to the running surface The crack may be visible on the field or gage side of the rail head or underneath the head in the head fillet area.

Identification After Breaking—The specimen usually shows external evidence of the rail having been resurfaced by welding i. e. uneven build-up, grinder marks, etc. However, in some cases the refinishing is so complete that verification of the weld is difficult without etching. The transverse separation usually develops at the line of demarcation between the parent metal and the filler metal. This line sometimes has the appearance of a shallow horizontal separation.

Hazard—The welded burn fracture is a dangerous defect because:

1. Failure may accur at a relatively small size.
2. Failure usually occurs before defect becomes visible.
3. Service failure results in a complete break of the rail across head, web and base.

LONGITUDINAL DEFECTS IN THE RAIL HEAD

General

A longitudinal defect is any progressive fracture which has a longitudinal separation only. Longitudinal defects in the rail head which may be classified as internal include two types of defects, both of which can be identified in track.

Horizontal Split Head
Vertical Split Head

All longitudinal head defects found by detector cars are reported according to the type of defect.

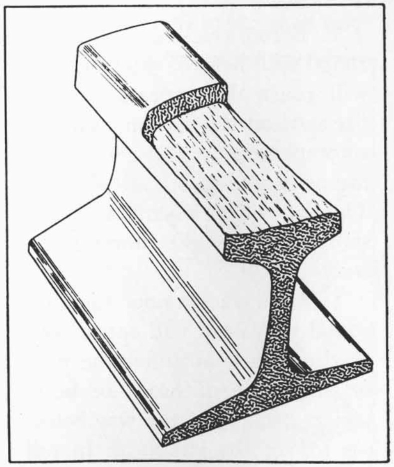


Fig. 31. General appearance of a horizontal split head.

Classification

Horizontal Split Head

Description—The horizontal split head is a progressive longitudinal fracture in the head of the rail, where separation along a seam spreads horizontally through the head, parallel to the running surface.

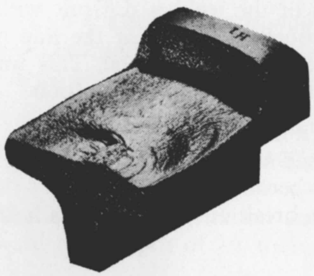


Fig. 32. Horizontal split head with separation extending across most of head.

Origin—The origin is an internal longitudinal seam, segregation, or inclusion. Separation progresses longitudinally and horizontally (parallel to the running surface).

Growth—Growth is usually rapid for the length of the internal longitudinal separation, but may stop altogether. Shock loads can start a transverse separation, in which case the defect would be classified as a compound fissure.

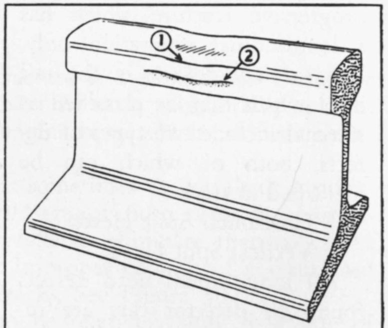


Fig. 33. Appearance of a horizontal split head in track.

1. Before cracking out, a horizontal split head of moderate size will cause the appearance of a flat spot on the running surface, accompanied by a slight widening or dropping of the rail head. The flat will be visible as a dark spot on the bright running surface.

2. After cracking out, the horizontal split head will appear as a hairline crack in either the field or gage side of head, or both, and at least ⅓ of the way below the top of the rail head. In rail laid without cant, the split will usually crack out first on the gage side. In rail laid with considerable cant, the split will crack out first on the field side.

Hazard—The horizontal split head is a serious defect because:

1. It tends to occur several places in the same rail, since the seam or segregation may exist throughout the rail length.

2. It may develop into a compound fissure, in which case service failure is a complete transverse break.

Vertical Split Head

Fig. 34. Vertical split head with split extending into web.

Description—The vertical split head is a progressive longitudinal fracture in the head of the rail, where separation along a seam spreads vertically through the head at or near the middle of the head.

Origin—The origin is an internal longitudinal seam, segregation, or inclusion. Separation progresses longitudinally and vertically (parallel to side of head) for some distance, then gradually turns out to the gage or field side of the head. Sometimes, one end of a vertical split head turns to the gage side with the other end turning to the field side.

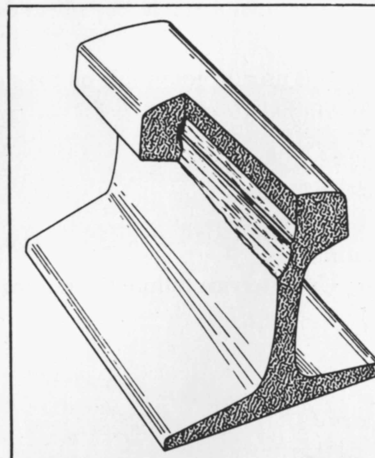


Fig. 35. General appearance of a vertical split head.

Growth — Growth is usually rapid, once the seam or separation has opened up anywhere along its length. It continues rapidly until the split begins to turn outward.

Appearance in Track — See Fig. 36.

1. A dark streak on the running surface.

2. Widening of the head for the length of the split. The side of the head to which the split is offset may show signs of sagging or dropping.

3. Dropping of the head causes

a rust streak to appear on the fillet under the head.

4. In advanced stages, a bleeding crack will be apparent at the fillet.

Hazard—A vertical split head is a dangerous defect because:

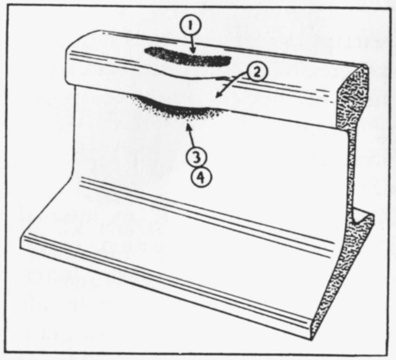


Fig. 36. Exaggerated appearance of a vertical split head in an advanced stage.

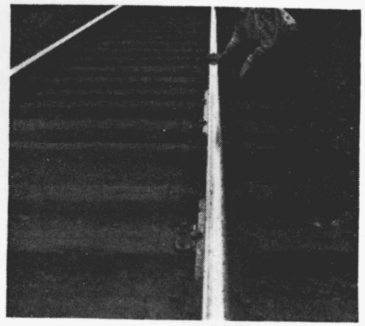


Fig. 37. Dark streak on running surface caused by dropping of rail head.

1. It is usually not visible on the surface until it has grown to a length of several feet.
2. Since a vertical split head usually extends longitudinally for a distance of two to ten feet a considerable portion of the rail is weakened.
3. If the split is on the gage side of the rail and breaks off in service, car wheels will tend to climb to the top of the rail thus causing derailment.
4. Upon service failure the rail may break into several pieces.

WEB DEFECTS

General

A web defect is any progressive fracture occurring in the web of the rail having, primarily, a longitudinal separation. This general classification includes three types of defects, all of which can be identified in track:

Head and Web Separation
Split Web
Piped Rail

All web defects found by detector cars are reported according to the type of defect.

Classification

Head and Web Separation

Description—Head and web separation is a progressive fracture longitudinally separating the head and web of the rail at the fillet under the head.

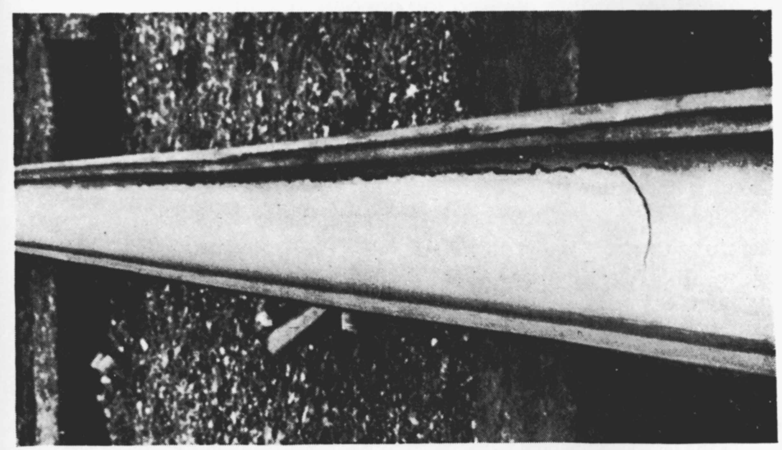


Fig. 38. Length of rail containing a head and web separation.

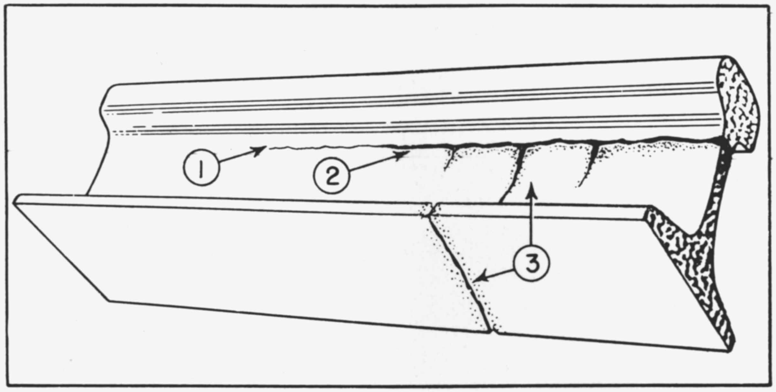


Fig. 39. Appearance of a head and web separation in track.

Origin—Acid action from some fillers used at highway crossings may start corrosion fatigue where the rail head joins the web. Gravel at crossings, excessive speed on curves, or improper canting of the rail can cause eccentric loading of the rail head. Fatigue then appears as "rail strain", or a creped and wrinkled fillet under the head.

Growth—Growth is usually rapid once the rail has been turned, as this moves the loading point to the opposite side of the head.

Appearance in Track—Head and Web separation frequently occurs at highway crossings where visual inspection is impossible. When an examination can be made, head and web separation may be recognized by one or more of the following characteristics: (See Fig. 39)

1. In earlier stages wavy, wrinkled lines appear along the fillet under the head.
2. As the condition develops, a small crack will appear along the fillet on either side, indicating growth through the web. It progresses longitudinally with slight, irregular turns upward and downward.
3. In advanced stages, bleeding cracks will extend downward from the longitudinal separation through the web, and may extend through the base.

Fig. 40. Fillet under head of rail polished to show rail strain.

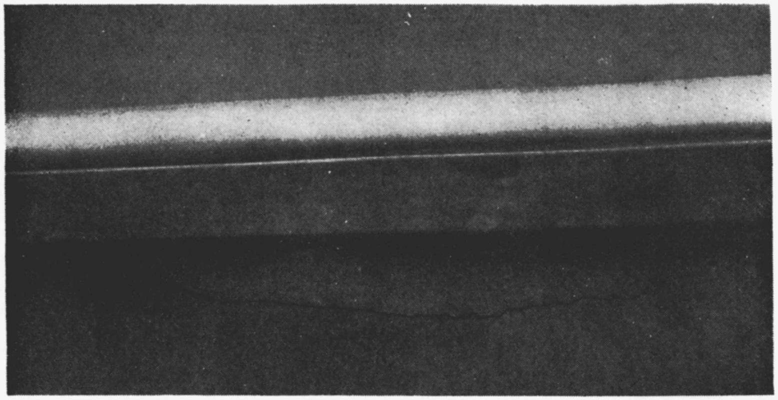


Fig. 41. Section of rail containing a split web.

Hazard—Head and web separation is a serious defect because:

1. **The entire length of rail is usually weakened.**
2. **Upon service failure, the rail may break into several pieces.**

Split Web

Description—The split web is a progressive fracture through the web, which develops in a longitudinal or transverse direction, or both.

Origin—The origin is a seam in the web or damage to the web. Split webs sometimes develop at locations where heat numbers are stamped into the web.

Growth — Growth is usually rapid after the crack extends through web, and is accelerated by eccentric or heavy loading.

Appearance in Track — See Fig. 42.

Bleeding cracks in the web.

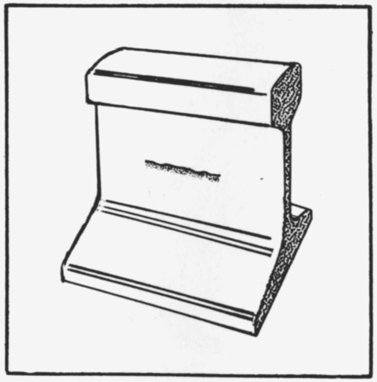


Fig. 42. Appearance of a split web in track.

These may be horizontal, vertical, or a combination of both.

Hazard—The split web is a serious defect because:

1. The rail is weakened for the distance of the separation.

2. Upon service failure, the rail may break into several pieces.

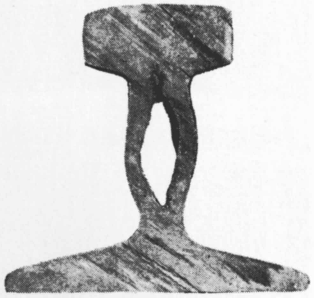


Fig. 43. Piped rail.

Piped Rail

Description—Piped rail is a progressive longitudinal fracture in the web of the rail, with a vertical separation or seam which opens up into a cavity, in an advanced stage of development.

Origin—The origin is a wide longitudinal seam or cavity inside the web, which extends vertically toward the head and base of the rail. This type of defect is seldom found in modern rail in an advanced stage.

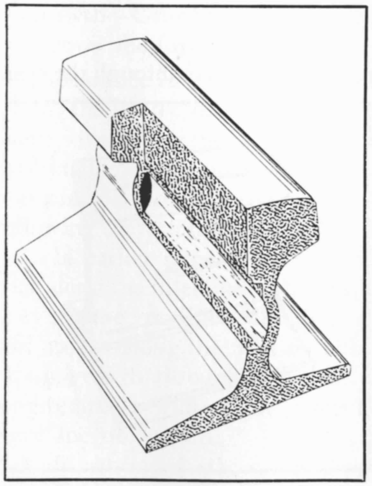


Fig. 44. General appearance of piped rail.

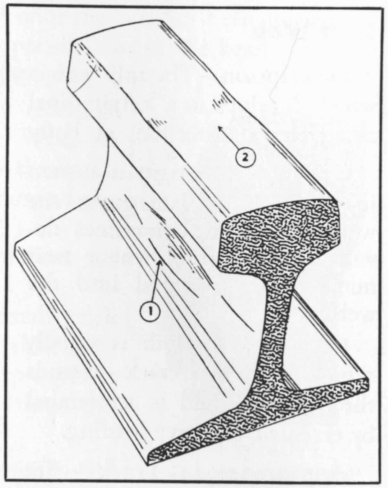


Fig. 45. Appearance of piped rail in track.

Growth—The original seam does not generally grow either vertically or horizontally. However, heavy loads may eventually cause it to spread or open up in a crosswise direction, so as to cause a bulge in the web. Internal seams which might cause little or no trouble under normal traffic conditions tend to open when subjected to pressure butt welding.

Appearance in Track—See Fig. 45.

1. Bulging of the web on either or both sides. Shallow cracks due to distortion may be found in the bulging surface.

2. A slight sinking of the rail head in the area above the pipe.

Hazard—Piped rail is a serious defect because:

1. Rail is weakened for the distance of the pipe.

2. The head is not properly supported by the web where pipe exists.

3. Upon service failure, the rail may break into several pieces.

BASE DEFECTS

General

A base defect is any progressive fracture originating in the base of the rail. This general classification covers two types of defects which can be identified in track:

Broken Base
Base Fracture

All base defects found by detector cars are reported as broken bases.

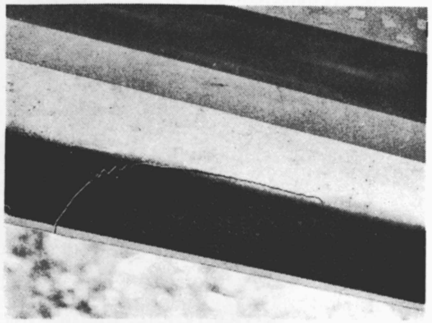


Fig. 46. Broken base.

Classification

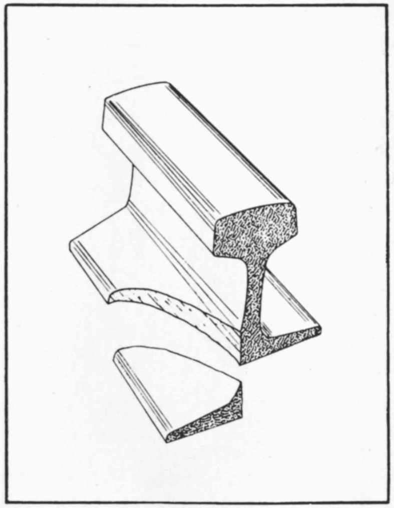


Fig. 47. General appearance of a broken base.

Broken Base

Description—The broken base is a progressive fracture in the base of the rail, with a vertical separation or split. The separation is substantially longitudinal, but usually turns out to the edge of the base. These separations are often called half-moon breaks.

Origin — Separation may be caused by improper bearing on ties or tie plates, or it may originate in a seam, segregation, or inclusion.

Growth—Growth depends on the location of the break and the loading of the rail.

Appearance in Track — See Fig. 48.

1. A crack starting near the junction of the base and web and extending outward to the edge of the base.
2. A longitudinal crack extending along the junction of the web and base.
3. A half moon break in the base of the rail.

Hazard—The broken base is a serious defect because:

1. The remainder of the rail cross section becomes weakened.
2. Upon complete failure, the rail may break into several pieces.

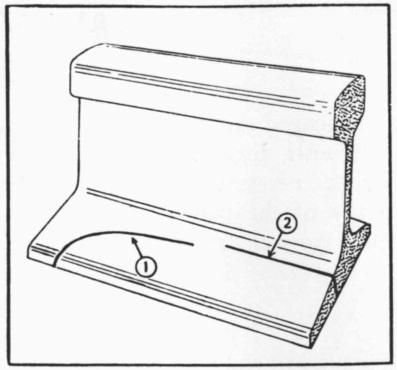


Fig. 48. Appearance of a broken base in track.

Base Fracture

Description—a base fracture is a progressive fracture in the base of the rail which develops substantially in a transverse plane. These defects, as a rule, originate on the outer edge of the base.

Origin—Base fractures are usually caused by a nick or blow on the edge of the base which results in an indentation or step. Damage of this nature is sometimes caused by improper rail handling.

Growth—Growth is relatively slow until the defect has progressed from the edge of the base into the rail approximately one-half inch. From this point a complete and sudden transverse rupture of the rail usually occurs. Base fractures seldom extend progressively farther than one-half inch into the rail before causing a complete break.

Appearance in Track—Base fractures are visable as hairline cracks for the extent of the progressive development into the rail. However, these defects are seldom found visually since a complete rupture usually occurs from a relatively small defect.

Hazard—The base fracture is a serious defect because:

1. Service failure is usually a complete break of the rail across head, web and base.
2. Failure frequently occurs before the defect can be discovered visually.

DAMAGED RAIL

General

Damaged rail is rail made unfit for track, not because of any defect previously discussed, but because of abuse or accident. The extent of damage necessary for removal under this classification depends on the policy of the particular railroad. This general classification includes three types of damage, all of which can be identified in track.

Square or Angular Break (Sudden Rupture)
Kinked Rail
Nicked Rail

Square or angular breaks found by detector cars are reported as broken rails. No other damaged rail is reported unless a defect has developed, in which case it is reported according to the type of defect.

Classification

Square or Angular Break (Sudden Rupture)

Description—The square or angular break is a complete transverse separation of the head, web, and base of the rail.

Origin—In very cold weather, the square or angular break is often caused by unbalanced drivers or some other concentrated form of loading.

Growth—The square or angular break occurs instantaneously.

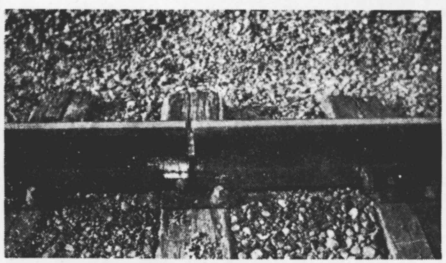


Fig. 49. Square or angular break, showing separation of about half an inch.

Appearance in Track—See Fig. 50.

1. A hairline crack running completely around the rail, usually accompanied by bleeding.

2. A separation of rail at the break, with one or both of the broken ends battered down.

Identification—The faces of the separation are rough and granular, as in Fig. 51. If any sign of a defect is present the break must be reclassified according to the nature of the defect.

Hazard—The square or angular break is a dangerous defect because the rail is completely broken across the head, web, and base.

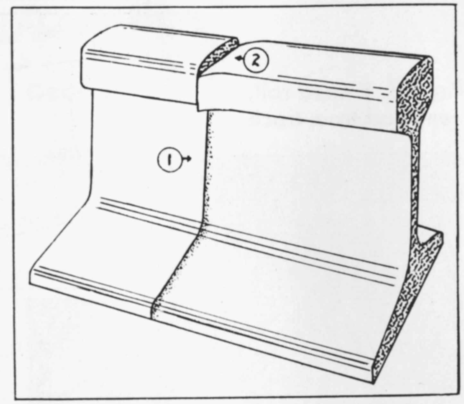


Fig. 50. Appearance of a square or angular break in track.

Kinked Rail

Description — Kinked rail is rail with a series of bends toward the gage or field side (depending on cant of the rail), with permanent set at points equally spaced along the running surface.

Origin—It is caused by unbalanced drivers overstressing the rail on every power stroke. Rail with high cant is more likely to kink along the field side, while rail with no cant usually kinks along the gage side.

Growth—Damage occurs instantaneously.

Appearance in Track—See Fig. 52.

1. Extremely shallow dents or depressions along field or gage side of rail. Hardly perceptible at first, the dents rust over slightly with time and have the appearance of shadows.

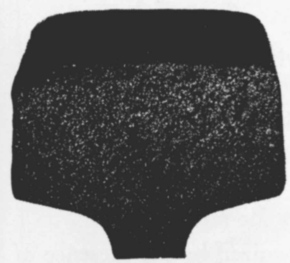


Fig. 51. Face of rail at square or angular break. No sign of any defect visible.

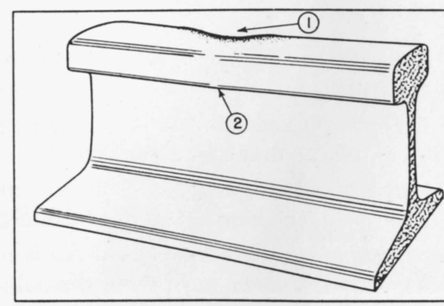
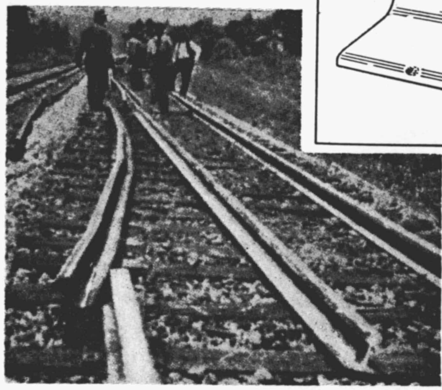


Fig. 52. Appearance of kinked rail in track (considerably exaggerated).

Fig. 53. Kinked rail, removed from track.



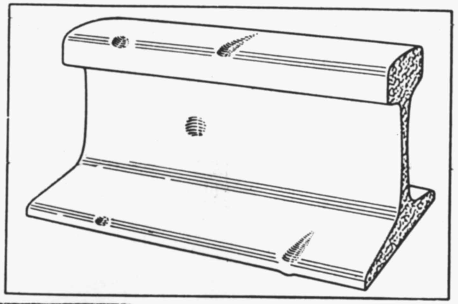


Fig. 54. Appearance of nicked rail in track, showing several common types of such damage.

2. A slight kinking of rail inward if dents are on gage side, or outward if dents are on field side.

Hazard—Kinked rail is not a serious defect, but it is generally removed from high-speed track because:

1. It causes rough riding of rolling stock.
2. Points of concentrated loading may develop defects.

Nicked Rail

Description—Nicked rail is rail that has been nicked on the head, web, or base.

Origin—Nicked rail may be caused by a flat wheel, a broken wheel, a spike mall, or dragging equipment.

Growth—Development of a defect from the nick depends on the location of the nick on the rail and loading of the rail.

Appearance in Track—Nicked rail is recognized by the presence of nicks, cuts, or scars on any part of the rail surface. See Fig. 54.

Hazard—Nicked rail is dangerous if the nicks are deep or sharp enough to cause development of a defect.

SURFACE DEFECTS

General

A surface defect is any imperfection, damage, or deformation at or near the exterior surface of a rail. This general classification includes six types of defects, all of which can be identified in track:

Shelling	Burned Rail
Flaking	Mill Defects
Slivers	Corrosion
Flowed Rail	Corrugation

Surface defects found by detector cars are not reported. Internal defects developing from surface defects are reported according to the type of internal defect.

Classification

Shelling

Description—Shelling is a progressive horizontal separation which may crack out at any level on the gage side, generally at the upper gage corner. It extends longitudinally, not as a true horizontal or vertical crack, but at an angle related to the amount of rail wear.

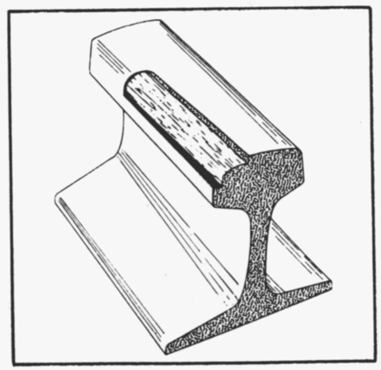


Fig. 55.
General appearance of shelling.

Fig. 56. Shelly spots on gage side of rail head.

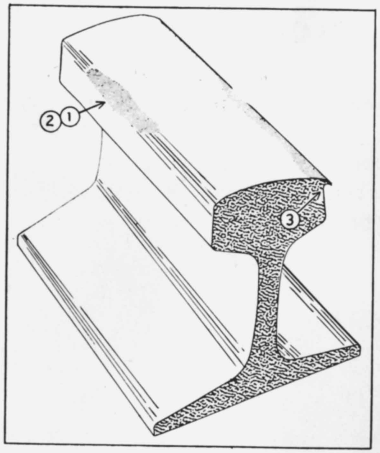


Fig. 57.
Appearance of shelling in track.

Origin — The exact origin of shelling has not as yet been definitely determined. It is prevalent at curves. It is accelerated if streaks or small seams are present and provide stress concentration points. Uncapped shell often shows these characteristics of origin.

Growth—Growth depends on the loading. The separation progresses in the path of least resistance. Shelling may turn down to form a transverse separation, in which case the defect would be classified as a detail fracture from shelling.

Appearance in Track — See Fig. 57.

1. Dark spots irregularly spaced on the gage side of the running surface.

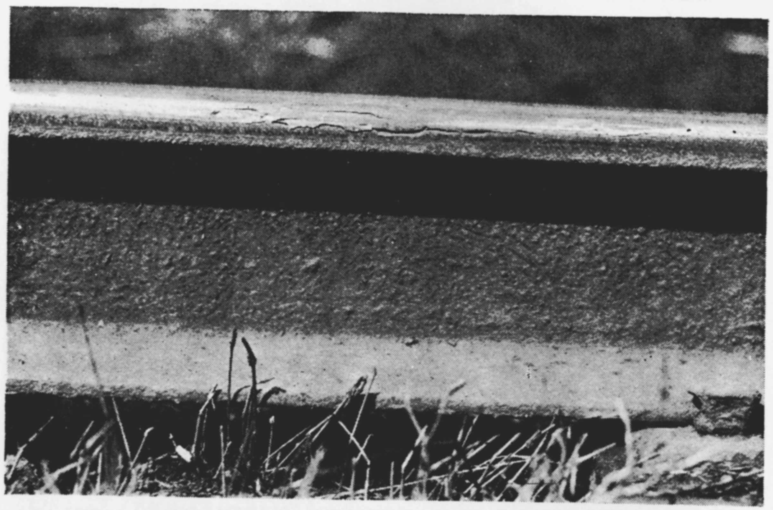


Fig. 58. Close-up of shelly spot on gage side of rail head.

2. Longitudinal separation at one or several levels in the upper gage corner, with discoloration from bleeding.
3. If rail is turned, shelly spots will appear on the field side, with an irregular overhanging lip of metal. Appearance is then similar to flowed rail.

Hazard—Shelling is potentially dangerous because:

1. It occurs most frequently in curve territory.
2. Transverse separation may develop at any stage of shelling or at any point along the shell.

Flaking

Description—Flaking is a progressive horizontal separation on the running surface of the rail near the gage corner, with scaling or chipping of small slivers. Flaking should not be confused with shelling, as the former takes place only on the running surface near the gage corner of the rail and is not as deep as shelling.

Origin—Flaking originates at the surface of the rail. It is prevalent on the high side of curves, switch points, and locations where concen-

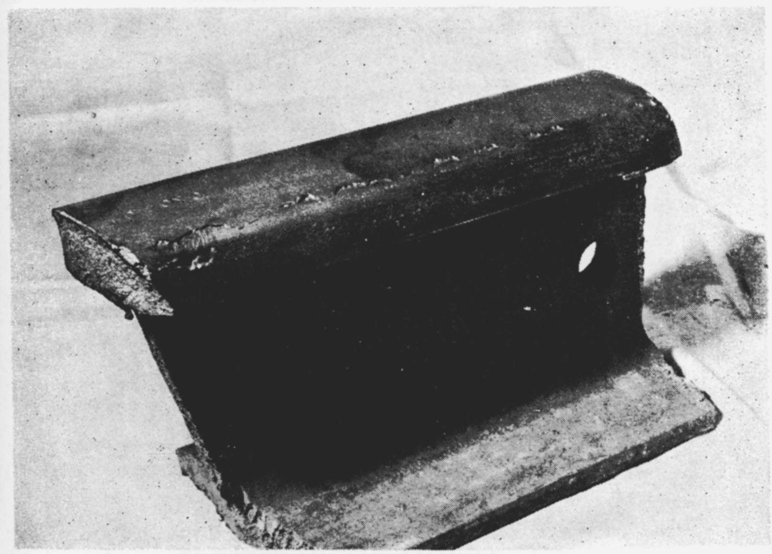


Fig. 59. Section of rail showing flaking.

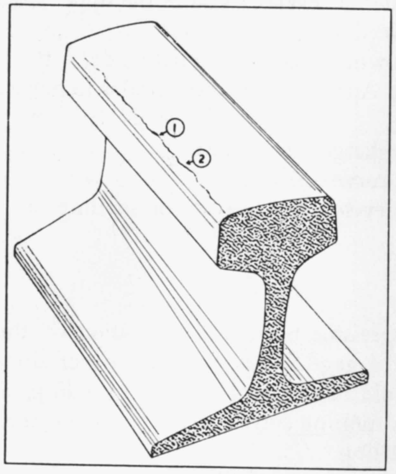


Fig. 60.
Appearance of flaking in track.

trated loading on the tread and gage corner cold works the steel.

Growth—Growth depends on the loading. The separation progresses about 1/32 in. below the running surface toward the gage side of the head, usually coming to the surface close to that point where the tread contour turns downward at the gage side.

Appearance in Track — See Fig. 60.

1. Very shallow depressions with irregular edges, occurring on the running surface near the upper gage corner. Generally will not occur more than ¼ in. from the gage corner of the rail.

2. Horizontal hairline cracks along the running surface near the upper gage corner of the rail head, resembling small slivers.

Hazard—Flaking is not a serious defect. It may develop into shelling or indicate a possibility of shelling in the same rail.

Slivers

Description—A sliver is the separation of a thin, tapered mass of metal from the surface of the head, web, or base of a rail.

Origin—The sliver originates in the rolling process, when a small pre-oxidized section of rail laps over instead of flowing and welding under pressure of the rollers.

Growth—Slivers separate rather than grow, but may chip off, cause batter, or furnish a point of origin for a transverse or longitudinal separation.

Appearance in Track—See Fig. 61.

1. Thin slivers (similar to wood slivers) on the surface of the rail head and parallel to the rail length.

2. Darkened slivers (in advanced stage) giving an appearance much like the vertical split head but without any spreading or crushing of the rail head.

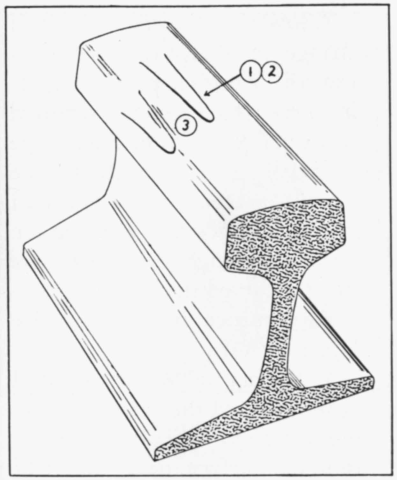


Fig. 61.
Appearance of slivers in track.

3. Slivers on the side of the rail head. Such slivers may be both shorter and thicker than slivers on the running surface. All slivers are generally less than ⅛ in. thick. They form part of the rail contour, lying flat on a surface, but may be cracked loose from rail metal on three sides. If a sliver has been dislodged, only an indentation will remain on the rail surface.

Hazard—Slivers are not serious defects.

Flowed Rail

Description—Flowed rail is a rolling out of the tread metal beyond the field corner, with no breaking down of the underside of the head.

Origin—Flow is due to distortion of the rail metal under repeated loads. This gradual change of the head contour does not damage the metallic structure of the metal.

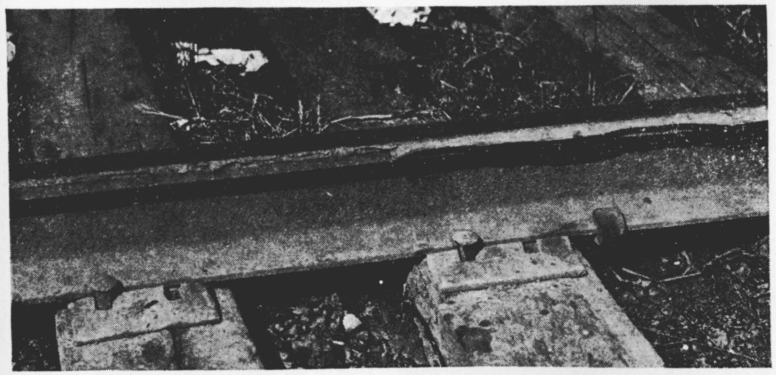


Fig. 62. Section of rail with head flowed to field side, some of lip cracked off.

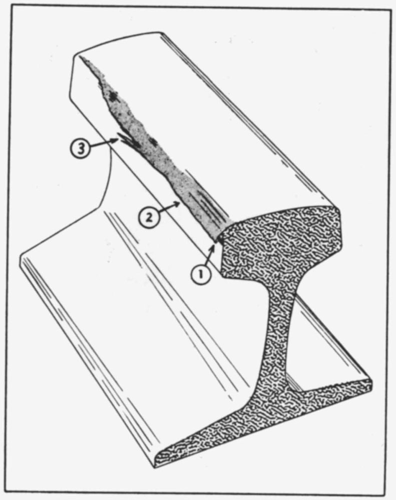


Fig. 63.
Appearance of flow in track.

Fig. 64. Engine burn,
with slight flattening of rail head.

Growth — Flowed rail is a change in shape rather than a growth. It occurs, predominantly in curved track, under repeated service. The extent of the change is usually proportionate to the length of service of the rail. Rail in tangent track may also become flowed, although at a slower rate than in curved track.

Appearance in Track — See Fig. 63.

1. Surface metal on the head flowed toward the field side, giving a creased appearance on the running surface near the field corner.

2. A smooth protruding lip, which may extend the length of the rail.

3. In advanced stage, flow becomes blade-like, jagged, or non-uniform, and may hang down or separate from the rail head.

Hazard—Flowed rail is not a serious defect.

Burned Rail

Description — Burned rail is rail that has been scarred on the running surface by the friction of slipping locomotive drivers.

Origin—It is caused by intense friction heating from slipping drivers, which overheats and displaces tread metal on the running surface.

Growth—The burn does not actually grow. However the damaged area may gradually chip out and roughen under repeated traffic.

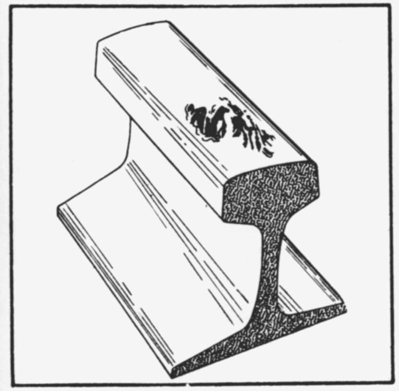


Fig. 65. Appearance of
an engine burn in track.

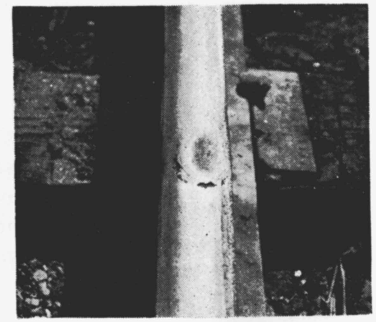


Fig. 66. Engine burn,
showing small thermal cracks.

Appearance in Track—See Fig. 66.

1. A rough spot (round or oval) on the tread of the running surface, where metal has been displaced and solidified.

2. Thermal cracks originating at the rough spot.

Hazard—Burned rail is potentially dangerous because transverse separation may develop from thermal cracks at the burn.

Mill Defects

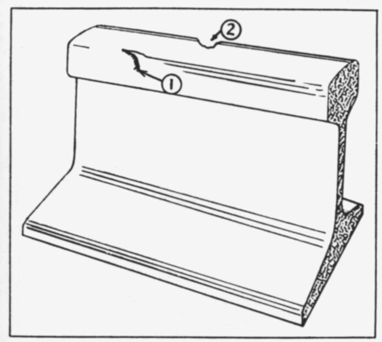


Fig. 67, Appearance of
mill defects in track.

Description—Mill defects are deformations, cavities, seams, or foreign material found in the head, web, or base of a rail.

Origin — Mill defects occur when the ingot is poured. Slag, gas, or foreign material may be included. Metal which splashes on the side of an ingot mold may cool and oxidize to some extent before fusing with the liquid metal.

Growth—Although the defect

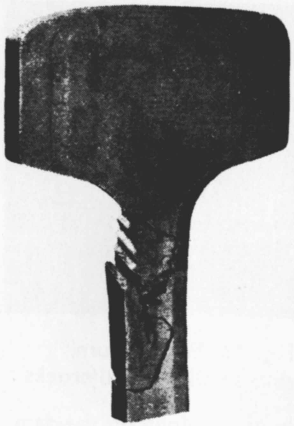


Fig. 68. An extremely unusual example of a mill defect, showing bolt in web.

does not actually grow, it may furnish the point of origin for a transverse or longitudinal separation. Further development depends on the type of mill defect, its location in the rail, and loading of the rail.

Appearance in Track—See Fig. 67.

1. A deformation of the rail head which can cause passing car wheels to batter the rail severely.
2. Broken out inclusions leaving large or dangerous cavities in the side or running surface of the rail head.
3. Inclusion of foreign material in the rail metal.

Hazard—Mill defects are a serious defect, if they are deep or large enough to cause the development of a defect.

Crushed Head

Description—Crushed head is a flattening of several inches of the rail

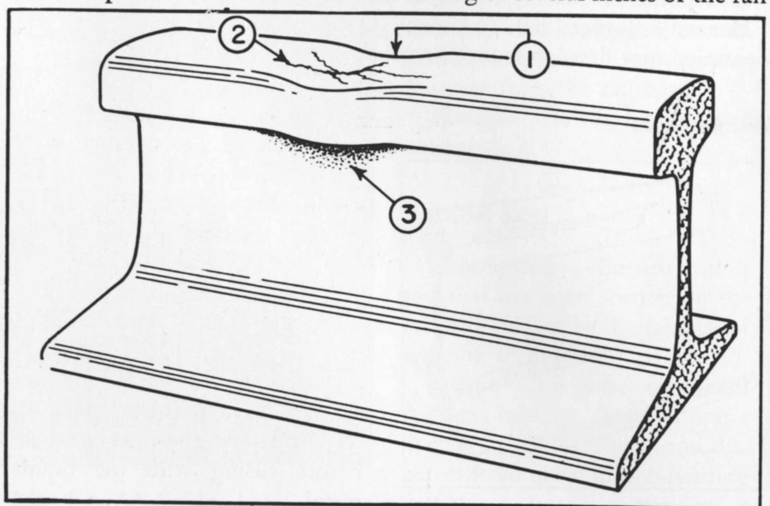


Fig. 69. Appearance of a crushed head in track (exaggerated).

head, usually accompanied by a crushing down of the metal but with no signs of cracking under the head.

Origin—The origin of crushed head is usually a soft spot in the steel of the head, which gives way under heavy wheel loads.

Growth—Growth is caused by the continued passage of heavy loads. Higher speeds and increasing depth of the flat spot accelerate growth.

Appearance in Track—See Fig. 69.

1. A flattening and widening of the head for several inches, with the entire head sagging.
2. Small cracks in the depression on the running surface.
3. In advanced stages, crepe or a bleeding crack may be present at the fillet under the head.

Hazard—The crushed head is not a serious defect, but it is generally removed from high speed track because:

1. It causes rough riding of rolling stock.
2. Points of concentrated loading may develop defects.

Corrosion

Description—Corrosion is the decaying or corroding of the metal on the web or base of the rail which results in irregular pits or cavities.

Origin—Corrosion, as a rule, occurs in wet or damp areas such as tunnels or buried grade crossings and is essentially a rusting away of the metal. Salt brine from refrigerator cars also causes corrosion when a concentration of such traffic occurs.

Growth—Corrosion is usually a slow process which occurs over an extended period of time. However, this process is greatly accelerated by electrolytic action on roads where electricity is the primary means of motive power.

Appearance in Track—Corrosion can be recognized as pits or cavities on the upper base or web of the rail. Severest corrosion usually occurs underneath the base and is therefore not visible whenever the rail is in place in track.

Identification After Breaking—Faces of the break will have the appearance of a sudden rupture with no progressive transverse defect development such as highly polished growth rings. Pits or cavities often one-half inch deep will be evident at failure locations. (See figure 70)

Fig. 70. An example of base corrosion.

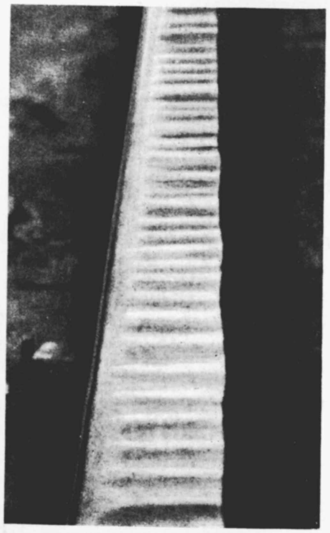


Fig. 71. Appearance of extremely severe corrugation in track.

Hazard—Corrosion is potentially dangerous because complete failure through the head, web and base usually occurs whenever the cross sectional area of the rail section is sufficiently weakened by the corrosive action. Severe impact from flat wheels often causes ruptures when the rail has been previously weakened by corrosion.

Corrugation

Description—— Corrugation, sometimes called "washboard rail", is a series of waves or variations in the rail surface level which are more or less accentuated and irregular as opposed to an ideal profile. The length of the corrugations usually varies from two to three inches.

Origin—Corrugation is generally attributed to a repetitious wheel sliding action of some nature whether through braking or lateral motion across the rail surface.

Growth—This condition is usually created over an extended period of time.

Appearance in Track——Corrugations have the appearance of regular bright and dark streaks across the running surface of the rail. (See figure 71)

Hazard—Corrugation is not considered to be a serious defect but is usually removed from high speed track because of rough riding qualities.

MISCELLANEOUS DEFECTS

General

Many defects which might be classified as miscellaneous have been omitted from this manual because they are seldom encountered and are of little importance. The only serious defects of this classification are the following:

Defective Weld

Detail fracture from welded bond connection

Classification

Defective Weld

Description—A defective weld is a progressive transverse separation within an area where two rails have been joined by welding or a rupture at a weld where improper fusion has occured.

Origin—Defective welds are caused by inclusions, improper fusion during welding, or surface cracks developed from the heat of welding.

Growth—Growth in a progressive fracture is normally slow to a size of 20 to 25 per cent. After the separation passes a 20 per cent size, growth is likely to be more rapid. Ruptures of improperly fused welds will usually occur in handling or when initially exposed to normal traffic conditions.

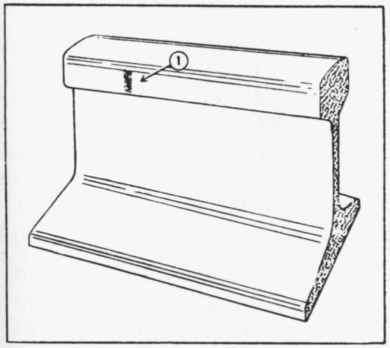


Fig. 72. Appearance of a defective weld in track.

Appearance in Track— No outward sign is visible until the separation reaches the rail surface. A defective weld may then be recognized by a vertical, bleeding crack at the welded portion of the rail joint at key point or points where the separation has reached the surface. (Fig. 72)

Identification After Breaking—The specimen usually shows a progressive transverse separation in the head of rail. (Fig. 73)

Fig. 73. Appearance after breaking of a defective weld caused by an inclusion.

If the fracture is caused by an inclusion or void, the defect will usually originate in the head fillet or base fillet area.

Hazard—The defective weld is dangerous because:

1. Failure frequently occurs before the defect becomes visible.

2. Service failure is a complete break of the rail across head, web, and base.

Detail Fracture From Welded Bond Connection

Description—The detail fracture from a welded bond connection is a progressive transverse defect which develops and expands from the point on the rail head where a head bond is attached by welding.

Origin—It is questionable whether the primary cause of detail fractures from welded bonds is due to thermal cracks being created by rapid or irregular cooling at or near the point where the bond is attached or whether the focal point of the defect is a metalurgic reaction and the resulting penetration of the native metal through a martensite layer sometimes developed between the bond and the rail head.

Growth—Growth is usually very rapid after the defect attains a size equaling 10% to 15% of the cross sectional area of the rail head.

Appearance in Track—No sign of transverse defect is visible until the separation reaches the rail surface (cracks out). The defect can then be recognized by a hairline crack at right angles to the running surface near the point where a welded bond connection is or has been attached to the rail head.

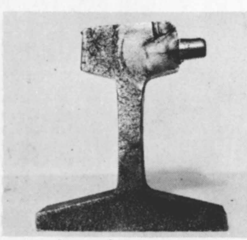


Fig. 74. A detail Fracture at a welded bond connection.

Identification After Breaking—

—The face of the rail shows a polished transverse defect with typical growth rings which have the appearance of gradually enlarging semi-circles with the center or focal point at a welded bond connection. (Fig. 74).

Hazard: The detail fracture from a welded bond connection is a dangerous defect because:

1. Service failure results in a complete break through the head web and base.

2 Growth is exceptionally rapid once the defect develops.

3. Failure usually occurs before there is any external evidence that a defect is present.

WEB DEFECTS IN JOINT AREA

General

Joint area web defects are progressive fractures in the web area of the rail at or near the rail end and are generally associated with conditions resulting from bolted joints. Two types of defects are included in this classification.

Bolt Hole Crack

Head and Web Separation

The above defects when detected are reported according to the above classifications.

Classification

Bolt Hole Crack

Description–A bolt hole defect is a progressive fracture which originates at a bolt hole and progresses away from the hole usually at an angle or along a path other than a perpendicular or longitudinal line.

Origin—A bolt hole crack is usually the result of unusual stresses along the edge of the hole from the bolt itself. These stresses may be caused by pumping or swinging joints, improper drilling, excessively worn joint bars, or abnormal rail end impacts from rolling stock. Focal points of bolt hole cracks may be at a stress contact point between the rail and the bolt or at a burr on the edge of the hole left by the drilling operation.

Growth—Growth of bolt hole defects is erratic when compared with the somewhat predictable development of transverse defects in the rail head. Bolt hole cracks frequently rupture from a very small defect when the rail end is subjected to stresses of an unusual nature.

Appearance in Track—Bolt hole cracks are, of course, not visible until a bolt or the angle bar has been removed, unless the defect has progressed above the bar (through the rail head) or below the bar (through the base). After removal of the joint bar the defect may

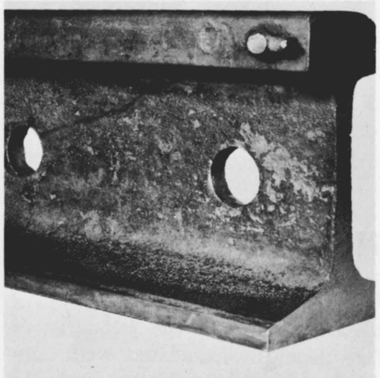


Fig. 75. Bolt Hole Crack.

Fig 76. Bolt Hole Crack

be recognized by a hair line crack extending from the bolt hole for the length of the defect. (See figures 75 & 76).

Hazard—The bolt hole crack is a dangerous defect because:

1. The rail is weakened for the distance of the separation.
2. Upon service failure, the rail end may break into several pieces, thereby becoming a serious derailment hazard.

Head And Web Separation (at rail end)

Description—A head and web separation at the rail end is a progressive fracture, longitudinally separating the head from the web of the rail at the head fillet area.

Origin—The defect originates in the head fillet area at the end of rail and can sometimes be attributed to stresses of an unusual nature from underneath the rail head. However, the prime cause is believed to be eccentric loading of the rail head and the resulting fatigue breakdown at the weakest point on the rail end.

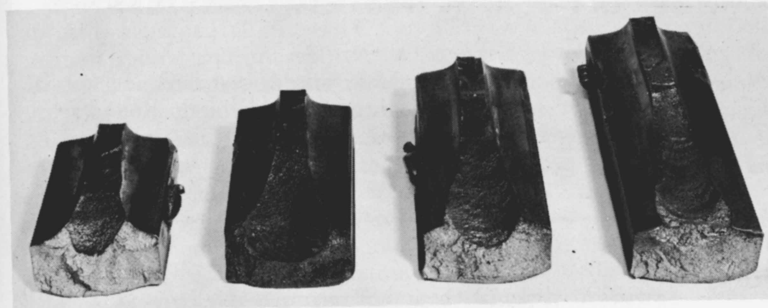


Fig. 77. Rail end head and web separations after complete failure.

Growth—Growth usually occurs in gradual stages but can develop quite rapidly under extreme stress conditions often created by pumping or swinging joints. The length to which these separations will extend before spooning upward into the rail head is unpredictable but will usually turn upward between three and ten inches from the rail end. (see figure 77) Rail end head and web separations sometimes progress downward through the web and base area of the rail but initial failure usually results in the displacement of a piece of the rail head from three to ten inches in length.

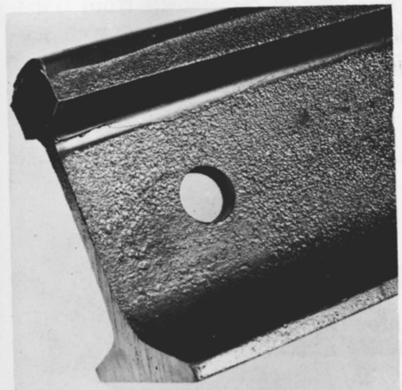


Fig. 78. Appearance of head and web separation prior to complete failure.

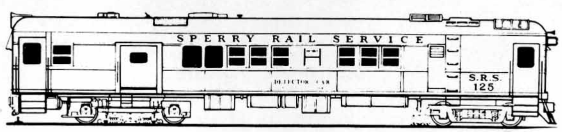
Appearance in Track—Head and web separations will appear as a hair line crack along the head fillet area (see Figure 78) once the angle bars have been removed. With the joint bars in place, visual detection is not possible until the defect has reached an extremely advanced stage of development.

Hazard—The head and web separation at the rail end is a dangerous defect because:

1. The rail is greatly weakened for a distance in excess of the progressive separation.
2. In the event of service failure under traffic, the rail is likely to break into several pieces.

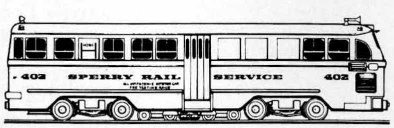
SPERRY'S RAIL TESTING SERVICES

Sperry Rail Service offers a complete line of standard and special in-track rail testing services employing either the induction system, the ultrasonic system, or both, to meet any railroad's standard or special rail testing problems and needs.



INDUCTION-ULTRASONIC CAR

A fleet of 25 large, self-propelled, induction-ultrasonic type rail flaw detector cars are used for complete end-to-end testing of rails in track. The combined induction-ultrasonic equipment now on these cars is capable of detecting all of the usual type of rail defects from transverse defects and split heads to bolt hole cracks and head & web separations at the rail ends while testing at speeds up to 13 miles per hour, averaging more than 40 miles of testing per day.



ALL ULTRASONIC CAR 402

Sperry also offers a high speed joint testing service with its specially designed all-ultrasonic Car 402. Developed and constructed to meet special and unusual test and operating problems for the New York City Transit Authority, this unit is capable of testing 50-90 miles of joints only per day at speeds of 10-15 miles per hour. This special car is made available between scheduled tests on the NYCTA to major railroads desiring a high speed, high quality test of joints only in joint defect problem areas.

With this car, defect information is recorded on 35 mm. tape. There are no stops or backup movements during testing for ground examinations or defect verification as on other detector cars. At the end of each testing day, the film is forwarded to Sperry's Danbury, Connecticut laboratory for processing and "reading" by an experienced team of tape readers who note all suspected defect indications and their exact location in track. These reports are accurate enough for forwarding to proper railroad personnel who arrange for their own local verification of defects and removal from track. A Sperry crew is available, at an extra charge, to perform this verification work in track if the railroad desires.

At the end of 1977 Sperry's induction-type cars had tested more than 6.8 million track miles of rail over a span of 50 years of continuous service to railroads in the United States, Canada, Mexico, Australia and Europe. Over 3,700,000 defective rails have been detected.

Whatever a railroad s rail testing needs may be, Sperry has the specific type of car and equipment and trained personnel to do the job thoroughly, quickly and economically with assurance of the highest quality available, thus providing maximum safety for railroad equipment and personnel and the shipping and traveling public.

RAIL BREAKING PROGRAMS

When detector cars were first used, railroads initiated rail breaking programs as a check on testing methods. Rails marked defective were assembled at some point on the division and broken to make sure that a defect actually existed, particularly in the case of a transverse defect that was not visible.

Other valuable information was obtained at the same time, however, and although railroads have confirmed the accuracy of Sperry Rail Testing, they continue to break rail for many good reasons. Trends revealed at rail breaking programs help the railroad in formulating policies to control usual defect conditions on the road. Important data can be secured on rail that is of special interest to the railroad. In addition, breaking programs are highly educational for division personnel, and lead to a system-wide standard of defect classification.

Data obtained at these programs is also of great value to Sperry in its research and development work, in its perfection of test procedures and personnel, and in its study of defect origin and growth. Consequently, the programs provide Sperry with a very effective means of improving its service to the railroads.

Sperry Rail Service appreciates the opportunity of attending all organized Rail Breaking Programs.

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Features of Sperry's Complete Rail Testing Service

1. The recognized leader in rail test quality, production and experience since 1928.
2. Unrivaled research and development programs for constant equipment improvements and new test systems.
3. A choice of induction-ultrasonic, ultrasonic or all-ultrasonic cars for specific rail testing needs.
4. A competent, experienced sales force advanced from previous detector car positions with an unusual knowledge of rail and rail defects.
5. The best trained, most experienced and efficient detector car test crews available anywhere.
6. Operating, maintenance and administrative manuals on all cars to assure uniform quality, test procedures and operation by car crews.
7. Daily, end of test and special detector car reports on detection results and car movements to each railroad covering each test.
8. A full time field supervisory staff to maintain highest quality performance of crews and equipment.
9. Full time field service crews for scheduled maintenance and periodic overhauls of all test equipment to insure maximum equipment performance and minimum down-time.
10. A detector car scheduling section for test programming and maintenance of field capacity to provide maximum flexibility to meet customer needs at lowest cost.
11. A Quality Control department reporting to top management to maintain a constant independent check on test results of each car and crew.
12. Publication and distribution of "The Sperry Railer", the industry's only periodical devoted exclusively to rail testing news, trends and statistics of Sperry's detector cars.
13. Publication and distribution to railroads of Sperry's 80 page "Rail Defect Manual", the only publication of its kind in the United States containing a wealth of information on rails, defects, rail manufacturing processes, etc.
14. Management and administrative personnel devoted to maximum customer service to protect Sperry's position and reputation as "First in Rail Testing".