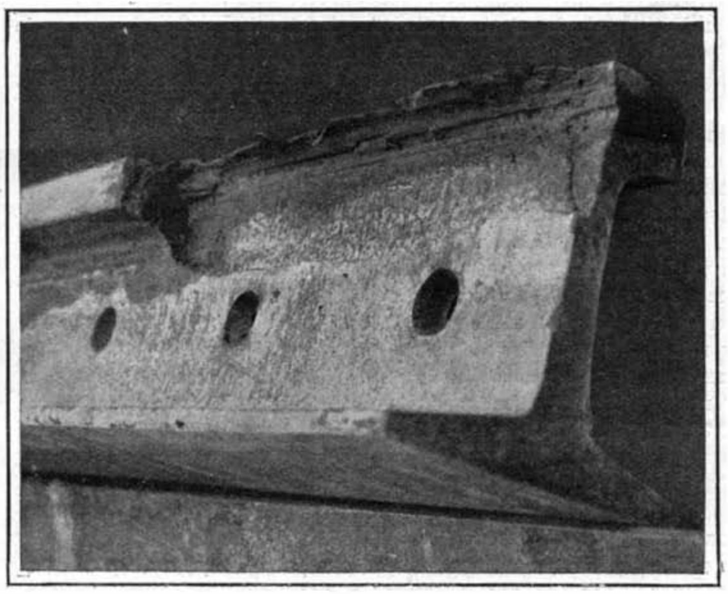
THE PERIL OF THE "BROKEN RAIL"—ITS CAUSE AND CURE.

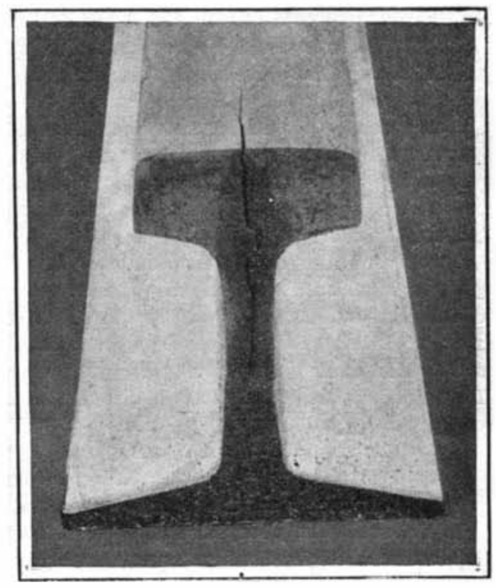
There is nothing to be lost and much to be gained by giving full publicity to any grave peril which threatens the public safety. Among such is to be reckoned the recent alarming increase in the breakage of steel rails on the railroads of the United States. The present crisis was foreseen and foretold years ago by the engineers of the railroads; it is recognized by the rail-makers themselves; and it has been brought forcibly to the public attention in the report recently published by the State Railroad Commission of the State of New York. In this document, which covers the winter months of 1905-6-7, the alarming fact is revealed that the number of broken rails removed from the tracks amounted in 1905 to 1,178, in 1906 to 804, and in 1907 to 2,899, the increase of the number in 1907 over those in 1906 being therefore 360 per cent.

The SCIENTIFIC AMERICAN has recently made a careful investigation of the subject, in the course of which every facility was afforded, both by the engineers of our largest railroad companies and by the leading manufacturers of steel rails. The investigation was made by the Editor in person; and he was given exceptional facilities for examining the private records of the railroads, and the minutest details of the process of manufacture by the rail mills; and he takes this opportunity of acknowledging the courtesies extended.

That there has been a decided increase in the breakage of rails during the past six or seven years, and that this increase is unnecessary and could be avoided by proper methods of manufacture, is the claim of the railroads. The rail-makers admit that breakages have increased; but they attribute it, not to faulty methods of manufacture, but to the great increase which has been made in the weight of the rolling stock and the higher speeds at which the trains are run; and they suggest that the railroads should adopt rails of a heavier section in order to meet the heavier stresses imposed by modern traffic. To this the railroads reply that what is needed is not heavier rail sections but better material; and in proof of this, they point to the fact that even after the weight of the rails had been raised from 80 pounds to 100 pounds per yard, the increase in breakages continued to rise at an accelerated rate.



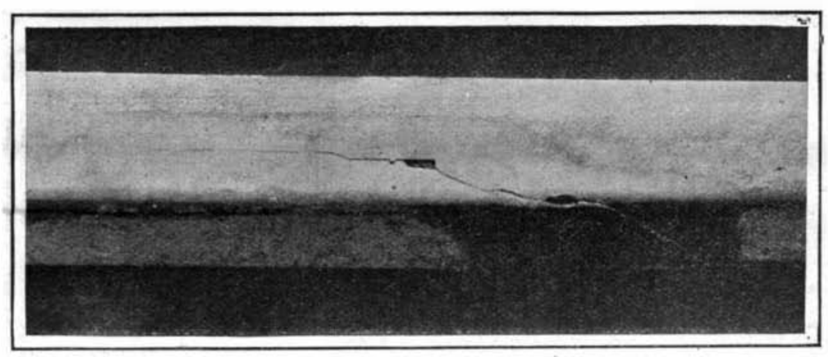
Fracture Due to a "Pipe" and Segregated Material. The Most Dreaded Form of Break; Generally Derails the Train, the Flange of the Wheels Climbing the Rail at the End of the Break.



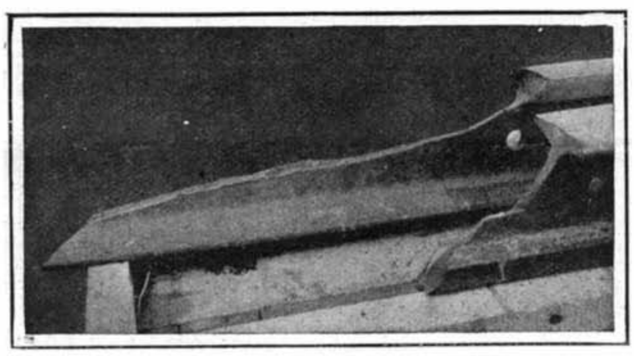
"Piped" Rail. This Fissure is Frequently Invisible in the New Rail, Being Hidden in Its Interior and Only Disclosed as the Rail Becomes Worn.

The engineers of the railroads state that they are anxious to secure rails only of the very highest quality, and that, if it should be shown to be necessary, they are willing to pay the higher price which may be demanded for producing a rail of the desired composition, strength, and wearing qualities. The manufacturers, on the other hand, emphatically declare that *subject to the present conditions imposed by the limitations of the Bessemer process and by the necessity of running their mills at the fullest capacity in order to meet the enormous demand*, they are making the very best possible rail that can be produced. After a careful inspection of one of the largest rail mills in the country, we are satisfied that, subject to the conditions given in italics above, the manufacturers are making about as good a rail as they can.

A few years ago, the failure of rails was not more frequent than might be expected in a steel structure subjected to such extraordinarily severe usage as this important member. At that time it was customary, at least on the more important railroads, for the engineers to prepare their own specifications, and these were accepted by the manufacturers, who gave with each contract a guarantee. As long as these specifications prevailed, an excellent quality of rail was secured. But some six or seven years ago, and about the time of the amalgamation of the steel interests, the manufacturers began to show a restlessness under the existing conditions, and the information was sent out that they could no longer accept the specifications of the railroads, but that because of certain exigencies which had arisen in the railmaking situation, modifications were necessary in the specifications, especially as affecting the composition of the metal. The engineers' specifications had to give way to those prepared by the manufacturers. This was followed, later, by a refusal of any further guarantee. The result, it is claimed by the railroads, has been that an inferior quality of rail has been furnished, and that breakages have increased correspondingly. We are satisfied that the fundamental causes of the present trouble are to be found in the fact that the best quality of ore suitable for the Bessemer process has been exhausted, the present ranges yielding ores which under the Bessemer process are highly unfavorable to the production of the quality of steel desired, and to the further fact that to produce high-quality rails would so greatly limit the output of the rail mills of the country, that they could not possibly keep pace with the demand. Rail-makers start out with the proposition that they must run their mills at a sufficient speed to meet this demand; and they claim, and we believe the claim is made in all honesty and in accordance with the facts, that subject to this proposition, they are turning out as good a rail as the rapid methods of manufacture allow. With the above facts in mind, a brief statement of the conditions of rail making as carried out formerly and to-day will, we think, make the question clear to our readers.

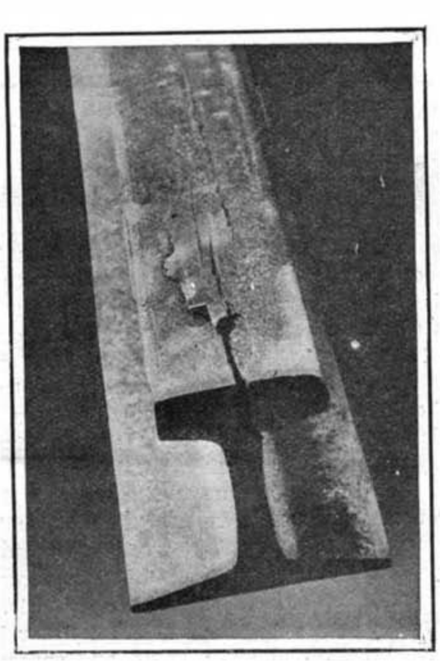


Showing How Fragments Break Out from Side of Head. Due to Flaws Carried Over from Ingot.

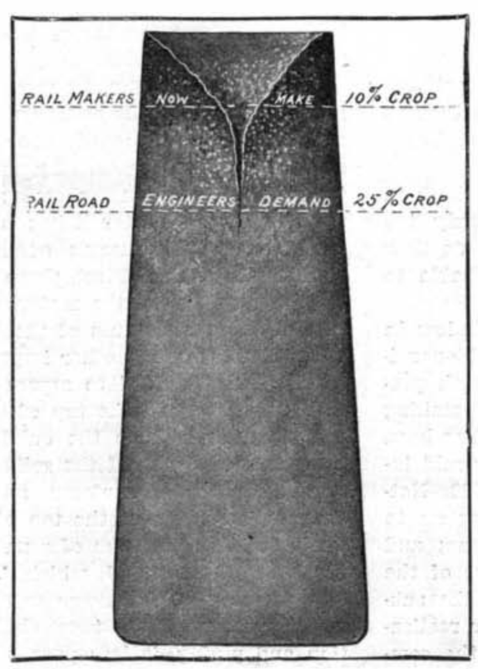


Long Breaks Commencing in Base of Rail, and Extending Diagonally to the Head.

It may safely be said that there is no material in the whole field of steel manufacture, with the exception of armor plate and projectiles, which is subjected to such severe, such absolutely brutal treatment, as the steel rail, enduring as it does every imaginable kind of stress. Its material is subjected to terrific tension and compression. It is alternately bent, twisted, and hammered; and many of these stresses are successively and rapidly applied in the reverse direction. The principal desirable qualities in a rail are hardness to resist crushing and abrasion, and toughness to resist fracture. As we now shall endeavor to show, it has been in the endeavor to secure both of these qualities, that many of the difficulties of the present situation are to be found. Briefly stated, the process of making Bessemer steel rails includes, first, the recovery of the iron from the ore by smelting in a furnace; second, the removal of all of the carbon and as much of the other undesirable constituents as possible by "blowing" in a converter, where these elements are burnt out of the metal as streams of air are forced through it; third, the introduction into the blown metal of the percentage of carbon desired; fourth, the casting of the treated metal, which is now Bessemer steel, into an ingot; and last, the rolling of the ingot



A "Pipe" in the Head of the Rail Started This Fracture. Note Fibrous Structure.



Section Through Ingot.
Impurities and "pipes" form at top of ingot. 25 per cent should be entirely cut off as scrap.

One Half of the Head of Rail Split Away Along the Line of an Old "Pipe."

THE PERIL OF THE "BROKEN RAIL"—ITS CAUSE AND CURE.

down into the finished steel rail. The chemical composition of the steel is determined by the treatment in the converter; where, as above stated, the undesirable elements in the iron are removed, or, as far as possible, reduced in percentage. The impurity which causes the most trouble by producing brittleness in a rail is the phosphorus. But, unfortunately, the phosphorus cannot be removed by the Bessemer process; and, consequently, the percentage which exists in the ore will be found in the finished rail. The carbon, which is the principal hardening element in the rail, can be perfectly controlled. It can be entirely burnt out in the process of blowing, and the desired percentage reintroduced by pouring a certain amount of molten spiegeleisen into the converter after the blowing is over.

By way of illustrating the composition which would give an ideal rail, we will take the case of some rails which were rolled under the specifications of an engineer of international reputation, who has given his whole life to the study of this particular question. These rails were rolled at a leading mill in Pennsylvania, between the years 1897 and 1898:

Carbon = 0.60 to 0.65 per cent.
Phosphorus = not over 0.06 per cent.
Manganese = 1.10 to 1.30 per cent.

In this rail the phosphorus is exceedingly low and the carbon is high; thus securing, as far as the chemical composition is concerned, a rail that combines hardness with toughness. These rails have exhibited magnificent wearing qualities. Some of them, which were laid at the entrance to one of the biggest and busiest terminal stations in this country as long as twelve years ago, have, in the interim, carried a traffic of 350,000,000 tons. Yet in all these years they have shown a wear of only 3/32 of an inch on the head of the rail; and all the joints are to-day in perfect condition. Although this particular lot of rails was of exceptionally high quality, it may be said that the average rails of that period, rolled to the specifications of the engineers of the railroads, were, in a general way, of the same hardness, toughness, and durability. Now, let us compare the composition of those rails with that of the typical rail which is being rolled to-day under the specifications of the manufacturers. The following table shows the composition adopted by agreement among the manufacturers themselves; and it represents the composition of the rails which have been breaking so badly during the past winter, photographs of several of which, taken as they lay along the side of the tracks, are shown in the accompanying illustrations.

Carbon = 0.50 per cent.
Phosphorus = not over 0.10 per cent.
Manganese = 0.80 to 1.10 per cent.

Comparing this composition with that of the earlier rails, it will be seen that the phosphorus has been raised from 0.06 to 0.10 per cent, an increase of over 60 per cent. This increase is one of the chief causes of the brittleness of the present rails. The phosphorus is present, not because of any wish of the makers to raise the percentage, but because the low-phosphorus ores have been pretty well exhausted from the mines, and a grade of ore has been reached which is high in phosphorus. The manufacturers would be only too glad to reduce this percentage; but as long as they use the Bessemer process, they are quite unable to do so.

The only method known by which steel rails low in phosphorus can be made in large commercial quantities and at a moderate price is the open-hearth process. But the number of open-hearth rail-making plants in the country is very limited, and it has been estimated that to put in open-hearth plants would involve first and last an outlay of over $60,000,000. Naturally, manufacturers are desirous of holding on to the Bessemer process in spite of its limitations; and there seems to be little doubt that the cause of the rejection of the engineers' specification and the substitution of their own, is to be found in their realization of the fact that to make steel rails of the combined hardness and toughness demanded by the railroads is no longer possible with low-grade ores under the Bessemer process. When the quality of the ores coming from the mines began to depreciate, showing high phosphorus, the rail mills attempted to meet the difficulty by lowering the percentage of carbon, and for a while they succeeded in turning out rails which were tough enough not to break under winter traffic and heavy load. But these rails proved to be deficient in hardness. They battered down badly and wore away quickly on the curves. In answer to the demands of the railroads, for harder rails, they raised the percentage of carbon; but although they furnished a rail of sufficient hardness, the high carbon and the high phosphorus together gave too brittle a rail, and hence the enormous failure of nearly 3,000 rails in three months in this State alone during the past winter.

So much for the question of the composition of the rail, which, after all, is scarcely more important than the question of its mechanical treatment in the process of casting and rolling. There is no denying that the rail mills have lately been up against a very hard proposition; for not only have they been trying to make tough rails from high-phosphorus ores by a process that was never intended for such a purpose; but they have been confronted by the conditions, that if they were to keep pace with the ever-increasing demand for rails, they must increase the output of their mills, and hurry up the process of manufacture from one end to the other.

Now, as a matter of fact, the only earthly chance for the production of a good quality of rail by the Bessemer process, when the ores are of undesirable quality, lies in the *extension* of the time of manufacture, not in its *curtailment*, as we shall now proceed to show.

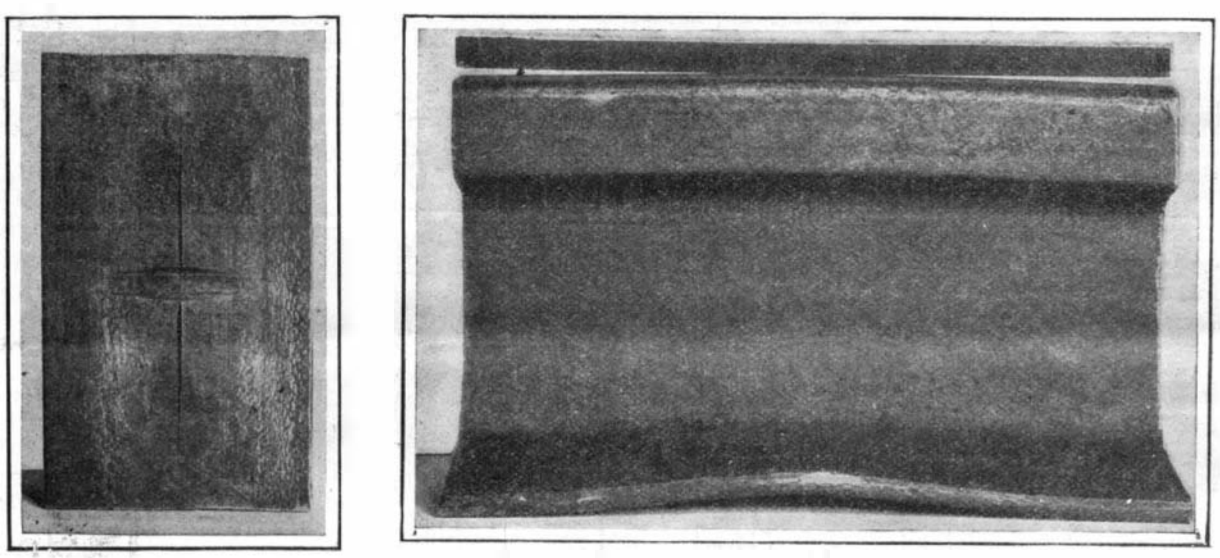
We have already explained that after the molten cast iron has been blown in the converter, the proper percentage of carbon is reintroduced by pouring some molten spiegeleisen into the blown metal. When the addition is made, it is desirable that some little time be given for the necessary reactions to take place; and in the early days of manufacture quite a definite period was allowed before the recarbonized metal was poured into the ingot mold. To-day, however, there is no delay whatever, the spiegeleisen being introduced into the converter at the very time that the latter is being tipped over to discharge its contents into the ladle; and from the ladles the metal is immediately poured into the molds.

Another, and by far the most serious, change which has been made in the endeavor to increase the output and reduce the time of manufacture relates to the cropping of the ingots. By referring to the accompanying illustration, showing a vertical section through an ingot after it has cooled, our readers will see that in the process of cooling two important actions take place. First, there occurs what is known as a segregation of the material; that is to say, certain of the constituents of the steel, such as the carbon, phosphorus, and other impurities, being of lighter specific gravity, tend to separate out from the mass and gather toward the top of the ingot. Also, since the metal cools from the outside toward the center, there is a tendency of the solidifying metal to shrink toward the outer surfaces, and this causes a cup-shaped depression at the top of the ingot, which extends down in the form of a narrow slit or crack into the body of the metal, which, together with gas bubbles, forms what are known as "pipes." Evidently, the upper portion of the ingot, because of this segregation and piping, is less pure, more brittle, and more subject after rolling to contain longitudinal flaws. Consequently, in former days, it was customary to crop off from the ingot from 25 to as high as 33 per cent, and roll the rail out of the remaining two-thirds, the rejected portions being remelted in the furnace.

But in the endeavor to increase the output of the mills and keep pace with the demand, manufacturers have reduced this cropping of the ingot to as low, in some cases, as from 8 to 10 per cent, removing merely the extreme end of the ingot. To take a typical case, an ingot measuring 19 inches by 19 inches by 48 inches long, if cropped 30 per cent would make three 80-pound rails; but with a cropping of only 7 or 8 per cent, the same ingot would produce four such rails.

Now the engineers claim that this extra rail is not reliable, both because of the segregated material which it contains, and because of the fact that as it is rolled down to shape it is liable to include the "pipe," or incipient longitudinal fracture which existed in the ingot itself. The manufacturers, on the other hand, claim that while they cannot produce quite so good a rail from the upper fourth of the ingot, they can still produce a sufficiently good rail for practical purposes. A rail which contains within itself the unclosed, unwelded opening, which was carried over in manufacture from the ingot, is known as a "piped" rail. The manufacturers claim that the breakages rarely occur from "pipes." The engineers contradict this, and say that the experience of last winter particularly shows that "pipes" were the most frequent cause of breakage. It would certainly seem from a study of the accompanying photographs, which were taken at random from hundreds of rails which lay alongside the tracks of one of our leading railroads, that "piping" is by no means an infrequent cause of rail breakages.

From the above considerations we believe our readers will agree that the situation is pretty clearly defined. Evidently, under existing conditions, with the low-phosphorus ores practically exhausted, the only thing left to be done, if we are to have absolutely reliable rails that will not break under the present heavy loads and under the conditions of frozen tracks, is to abandon the making of rails by the Bessemer process and get rid of the phosphorus and other impurities by adopting in its stead the Open-Hearth process; at once return to the slower methods of manufacture of a few years ago; be content to crop more freely from the head of the ingot; and also adopt, in the subsequent manipulation of the rails, a slower process with more frequent passes through the rolls and a more gradual bringing of the rail to its final shape.



Bottom View and Side Elevation of a Rail Tested to Destruction in Testing Machine to Show the Effect of Bending a Rail Across a Tie. This Occurs When a Heavy Wheel Load Bears on the Rail on Each Side of a Well-Tamped Tie. The Effect is Frequently a Break in the Base of the Rail, Starting, as Shown, in a Longitudinal Fracture. Manufacturers Claim That Most Breaks Occur in This Way; Engineers Claim That "Piping" is the Chief Cause.

THE PERIL OF THE "BROKEN RAIL"—ITS CAUSE AND CURE.

THE CONSTRUCTION AND HANDLING OF SUBMARINES.

(*Continued from page* 408.)

age batteries are stowed in tanks inside, at the bottom of the boat, and by a system of clutches the main shaft can be connected to either the motor or gasoline engine.

The "Lake" is a specimen of the even-keel type of submarine, which was launched at Newport News in February, 1906. She has a submerged displacement of 250 tons, is 85 feet long, and has been manufactured in this country and abroad for several years by the Lake Torpedo Boat Company. The term "even-keel" refers to its method of submergence, the vessel attaining submerged depths without changing its longitudinal stability or horizontal trim, as it is unnecessary to point the bow downward in order to submerge. The "Lake" is constructed with steel cigar-shaped hull, over which is built a wooden superstructure, which forms a level deck of a few inches freeboard while the vessel is on the surface. Within this superstructure, and outside of the steel hull, are stored the gasoline fuel tanks, air flasks, etc. Water is also admitted to the superstructure when the vessel submerges. The Lake boat has the same motive power as the Holland boat. The air system also is practically the same as in the Holland boat, but the air flasks are stowed on top of the main steel hull instead of inside. Submergence is attained first by admitting water ballast to tanks contained in the steel hull and superstructure to bring the craft awash, or with tip of sighting hood alone showing above the surface; and then hydroplanes, or horizontal steel wings at the sides of the vessel, are tilted in such manner as to cause the water to impinge against them