distribution of material between the head and the base simplifies the cold straightening process to such an extent that the mill people advise that the work of straightening is less than 40 per cent. of what was required in the old section. The straightening of rails under the cold press is a punishment, which seriously impairs the strength of the rail, and frequently appears to open defects or starts fractures which would never be known in ordinary wear during the life of the rail.

In designing a rail for use in Canada the conditions of winter roadbed must be provided for. The roadbed, when frozen, is absolutely rigid, and, in the process of freezing, ties under which there is a quantity of moisture heave on account of the action of the frost to such an extent as to require wooden shims on the adjoining ties to maintain an even bearing for the rail, and give proper surface to the track. At the time the shimming becomes necessary the rails must bend sufficiently to receive their proper support from the low ties, and, if the rail be too rigid, or too hard, it is liable to break. For this reason, we deemed it wise to limit the height of the rail to 5 or 5⅛ inches, and place the additional strength on those portions of the rail which are most liable to crack or break. This conclusion was arrived at after an experience of seven years, with about 50 miles of A. S. C. E. section of 100-lb. rail, in which, with an equal amount of heaving and equally rigid track, more square breaks occurred with the 100-lb. rails than did with an equal mileage of 80-lb. rails of the same section, handling the same traffic, under like climatic conditions. And in addition to this, I want to say that the chemical composition of the 100-lb. rail is practically identical to the chemical composition of the 80-lb rails to which I referred.

The composition specified by the Canadian Pacific Railway, in which the average carbon for Bessemer rails is .58 per cent., and for open hearth rails is not less than .60 per cent., gives a harder rail than that manufactured under commercial specifications, or demanded by most of the American railways, in which the carbon content is from 5 to 10 points lower. In the introduction of this additional carbon the Canadian Pacific Railway has arranged to reduce the phosphorus in Bessemer to 0.85 per cent., and in open hearth to .06 per cent., whereas the average American specification allows .10 per cent. phosphorus in Bessemer, and for open-hearth the standards are practically the same. This combination gives the Canadian Pacific rail greater hardness, and the same or greater toughness than is secured under the American specifications. The advantages are a better wearing rail and one which does not readily flatten at the joints under traffic. I might say here that rails purchased prior to 1902 gave the Canadian Pacific a great deal of trouble on account of the flattening of the ends. These rails flattened out at the ends as much as half an inch; clearly too soft, or at least too soft at the joints where they received the additional punishment. For this reason it was found advisable to increase the carbon to give us a harder rail, which we hoped would overcome this end flattening, and our new specifications, of which the one printed in this paper is a slight modification, increased the carbon very materially. The increased carbon rails are of such a character that we do not have flattened ends except in rare cases, and these cases are usually rails that are defective, either on account of heat treatment, too low in carbon, or some other defect. The reason for the difference in the carbon and phosphorus for open-hearth and Bessemer rails under the Canadian Pacific specifications is the inability of the acid Bessemer rail manufacturers in the United States to produce, at commercial prices, a low phosphorus rail, so that where the phosphorus is .10 per cent., the carbon should be—I had better say, must be—kept below .50 per cent.; whereas with phosphorus .085 per cent., the carbon should not exceed .63 per cent., and should average about .58 per cent.

It must be remembered, however, that the composition of steel in rails is not the only feature to be considered. In fact, the writer's experience has shown that some of the best rails in service are of the poorest composition. In other words, the heat treatment, which steel receives during its manufacture into rails is of greater importance than the exact chemical composition.

To insure as nearly as possible that Railway Companies receive rails of proper composition test analyses are being made continually while rails are being manufactured, and pieces of finished rail are tested by means of a falling hammer, known as a drop testing machine. If steel in rails were absolutely uniform and homogeneous, these tests would be sufficient to prove the quality of all rails manufactured, but unfortunately this steel is not absolutely uniform and homogeneous, which we note in our micro-photographs—micro-photographs are photographs whose natural diameters are increased about 50 times. By taking a pin point picture of a polished section of a rail, we get a picture showing the structure of the rail. These micro-photographs give us an idea of the magnitude of what we call molecules. While that is scarcely the right term, it does show in the picture what look like crystals, and the size of these crystals gives us an idea of the structure of the metal. When the rails are being manufactured we take pictures of the various heats, right from the centre of the head, and if the micro-photographs show a coarser structure than our specifications called for, rails made from that heat were rejected. Latterly in our experiments, we had thirty-two micro-photographs taken of thirty-two different parts of the same rail, and these micro-photographs looked as though they had been taken from thirty-two different makes of rail. The granular structure is different in the flange from that in the centre of the head, and except as a matter of information, the micro-photographs have been abandoned, so far as our specifications are concerned—in acid etchings, and in fractures, in the individual cross sections of any point of the rail. The point I wish to make there is, if you take micro-photographs, or acid etchings of the end of a rail, and then take them from a fractured section or break in the same rail, the results will be entirely different. In practice we find this also to be true, for the reason that many rails, which break off square in the track and latterly have the pieces drop tested, bend to double the specification requirements before breaking, so that our drop testings when rails are being purchased is very much more of a grab sample than is usually conceded by rail manufacturers or railway men. To overcome this feature as much as possible, Railway Companies employ expert inspectors, men who are familiar with the manufacture of steel in general, and the manufacture of rails in particular, who watch every detail of rail manufacture, discarding heats of steel, improperly-poured ingots, and imperfectly-rolled rails. In fact, it is not uncommon to have 25 per cent. of the output of the mill discarded in the cutting of the top of the ingot, the rail butts, and rejected-finished rails.

A great deal has been written and said recently in connection with broken rails, and the public and the railway world have become aroused on account of the danger in connection therewith.

The term "broken rail" is a general one which applies to rails having small cracks in the base, in the web, flange, or head, and are removed from the track on account of that defect, and of the total number of defective rails removed from the track, the number of those which break off square, like the stem of a clay pipe, is comparatively small.

The most common defect in rails is the splitting of the head, which is caused usually by pipes therein. The second defect on the list is known as flange breaks. These consist usually of the breaking out of a cresent-shaped piece at the base, started by a lap in the base, located usually near the centre, and running parallel with the axis of the rail. These laps are caused by defective rolling, and whilst there is a difference of opinion as to their origin, the writer is of the opinion that they are caused by the intermediate rolls producing more skin, or surface, than can be used in the finished rail, thus causing the skin, or extra surface, to double or lap, which opens and cracks under traffic, especially if cold-straightened at these points.

The third defect is, breaks through the bolt holes. This is the result of a weak web, occasioned by improper rolling, possibly the stretching of the material beyond its elastic limit latterly in the rolls. You are aware that in rolling rails, the