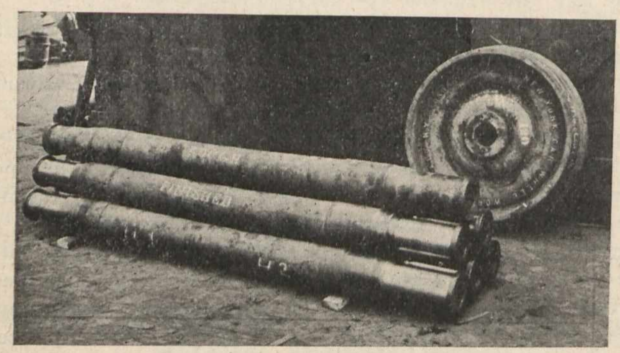
matters are extras, but also upon the question of price to be paid for them. The mere provision, however, that any dispute, difference or question relating to the contract should be settled by the engineer, would not give him power to adjudicate on claims for extras, for extras are matters without the contract, unless specifically provided for therein. Second, where there is no provision in the contract for extras, then the question simply is this, was there another contract for the extra work? And if there was another contract, had the engineer authority to enter into it? Generally speaking, if the written contract does not contemplate extras, the engineer would have no authority to order them, and it would be necessary for the contractor to show that the employer had either expressly, or by the general course of his conduct, given the engineer such wide authority, as would include the ordering of any extra work that he required. The engineer's duty is usually to see that the works contemplated by the contract are carried out in accordance with its terms, and he cannot bind his employer to pay for additional work unless he has been authorized to order it.

HOLLOW PRESSED AXLES.*

BY CAMILLE MERCADER, PITTSBURGH.

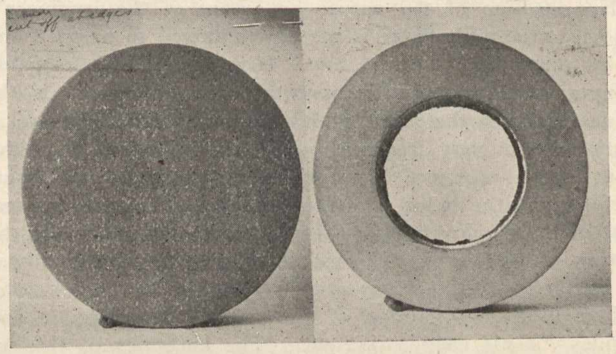
The axle is one of the most important elements used in rolling stock. Upon its strength depends the safety of the whole car superstructure, and upon its freedom from friction the economy in draft. While improved forms of construction have been devised in every branch of the railway equipment, the axles for tenders and cars have been rather neglected, and this portion of the equipment has only kept pace with the other improvements by increasing its size and weight to gain the strength necessary for supporting the greatly increased loads which are now considered standard. A few years past, who would have thought of 110-pound rails, 125-ton engines, 110,000-pound steel cars, and the many other improvements now considered necessary for the economical operation of our great railway systems ?

It is a well recognized fact that steel articles manufactured by pressing are, as a rule, superior to articles made by any other method, and the present tendency is to develop this method in every branch of the iron and steel trade, especially as it insures the most economical production of articles needed in considerable quantities and makes them



Mercader Hollow Pressed Axle.

perfectly true and uniform to the templet, permitting interchange of parts or the making of standard sizes. In order to produce, by pressing, an axle having varying diameters, the following method was proposed by the writer: A rolled round steel blank, uniformly heated, is inserted into a two-part die, having a matrix cavity in the form of a rough turned axle. The diameter of the journals is made equal to the smallest diameter of the axle in the centre, which corresponds to the diameter of the round blank. After the dies are clamped about the heated round the latter is axially perforated simultaneously at both ends by two cylindrical punches, which force the metal of the blank to conform to the shape of the matrix die and fill out the same. The round is heated up to about 1,000 degrees C. and the total hydraulic pressure required for penetration with a punch of 3 inches diameter amounts to about 50 tons. During the last end of the stroke a total hydraulic pressure of about 150 tons is required because the blank loses its initial heat through contact with the dies, and because the end collars upset, at which time the metal may flow back against the punch. Considering the small diameter to be pierced, and the length of the punch, this pressure required to penetrate the blank is, apparently, very small, and it will be conceded by all familiar with the work that a prerequisite to entering the blank lies in allowing the metal to flow freely in the direction of the forward movement of the punch. The presence of the an-



Centre and Journal Hollow Pressed Axle.

nular spaces between the blank and the die fulfills this condition, the metal flowing radially in the direction of the least resistance; the only back flow against the punch is at the end of the stroke. It is obvious that if this back flow existed initially the punch would bend and buckle before entering any great distance. The punch, being tapered, acts as a wedge and the pressure that can be exerted upon the axle blank is consequently enormous. In one of the experiments the heated blank happened to be smaller in diameter than the gripping portions of the dies, and hence was not clamped by them. In this case the punch pushed the metal endwise and upset the blank into the matrix die. The inability of the metal to flow against the punch caused the upper die head, a steel casting weighing 25,000 pounds, to spread, and under a pressure of 200 tons upon the punch the die and the die head broke in the centre.

The strength of the cast steel die head was determined upon the basis of ultimate tensile tests of its material, and it was found that a total lateral pressure of 2,600 tons must have been exerted by the wedge action of the punch in order to break this casting. This occurrence shows that the metal blank, in being punched, can be subjected to an extraordinary pressure. This pressure is exerted throughout the entire length of the axle blank, for it is found that the central part of the axle, where the punch does not penetrate, conforms to the shape of the dies. It cannot be disputed that this great compression improves the quality of the steel in the central part of the axle by destroying the injurious effects of segregation and piping usually found in ingot steel. Regarding the temperature of the heated blank, it may be mentioned that it is absolutely necessary to have the greatest uniformity throughout the body of the blank, the temperature determining the resistance which the punch must overcome.

[Then follows the result of a number of experiments made at the Homestead works.]

Many experiments have been made regarding the material for the punches. Water cooled tool steel punches with cast iron points removably secured were first tried. Such a punch afforded the necessary stiffness, and the cast iron nose withstood heat to a great degree, being self lubricating and not liable to become welded within the blank. The securing of the cast iron nose to the punch was found, however, to be too weak, owing partly to the small diameter of the punch and partly to the fact that having at that time no cross rolls, the blank was not straight, and the punch followed the course of the blank and hence fractured, the nose breaking and remaining in the axle. Solid crucible steel punches were then tried, but it was found that by the great pressure exerted the point of the punch welded to the axle blank, requiring great power to extract it. The

* Extracts from a paper read at the May meeting of the Iron and Steel Institute.