shells would be especially liable to this defect. The contrary was, however, found to be the case in this particular instance, and experience has proved that the cast shell supplied by the Hadfield Company are free from the suicidal tendency amongst projectiles. We are assured that though the larger part of the total number of shells supplied to the Navy are made by the Hadfield Company, and though many thousands of proof and other rounds have been fired, yet not a single case of spontaneous fracture has been reported from the smallest calibres up to the big 13.5in. shell. The Royal Navy has thus been supplied with a shell which is at once cheaper and superior to the class of projectile formerly in use.

Owing to the introduction of Krupp cemented armour of improved description it has been found necessary to introduce a new type of projectile having a somewhat smaller bursting charge than that of the armour-piercing shell to which reference has been made: the charge of the latter shell being from about 2½ per cent. to 3 per cent. of the total weight. To meet this demand the Hadfield Company have produced what is known as the "Heleon" shell. In testing at their own proof-butts the company have succeeded in sending these shells through plates of a thickness equal to the calibre of the projectile, the latter being in a condition to burst after penetrating the plate. Even better results have been obtained at Shoeburyness, a "Heclon" 6-in, capped projectile having perforated 7 inches of Krupp cemented armour, the shell being recovered in the rear of the plate in a condition for bursting. More recently a further trial of the Hadfield projectile took place before Lord Roberts, when a 12-in. armour-piercing shell, weighing 850 lbs., was successfully fired against a Krupp 9-in. non-cemented plate inclined to an angle of 30 degrees. The velocity was 1,911 foot-seconds, and the striking energy 21,500 foot-tons. This projectile was taken by the Government officials at random from a lot of 400, and if it had failed it would have meant the rejection of the whole order to the value of many thousands of pounds. The fact gives an idea of how much depends on the success of a single round, and the large amount the manufacturer stands to lose in the case of failure of any one projectile. The country may rest assured that under such stringent conditions the manufacturers of projectiles will spare no pains to render every unit absolutely trustworthy.

The Hadfield Company have given attention to means of defence as well as to attack. They have quite recently produced a shield for the protection of gun-mountings which has been found to possess somewhat unusual qualities. It is, like the projectiles, of cast steel, the metal being a special description to which the name of "Era" steel has been given. One of these shields, 6 inches in thickness, was recently attacked by a 1.7-in. armour-piercing shell, fired at a velocity of about 2,100 foot-seconds, and it successfully resisted the projectile. A 6-in. common shell was next fired at the same plate with a velocity of 2,035 foot-seconds, the striking energy being about 2,875 foot-tons. This merely made a slight indentation about an inch deep. A lyddite shell of the same calibre, and with the same velocity and striking energy, was next fired at the shield, the result being similar to that of the last-mentioned round. Finally, the plate was attacked by a 6-in. armour piercing shell, fired with a velocity of 2,039 foot-seconds, and having 2,880 foot-tons striking energy. This effected perforation, though it is believed that the projectile burst on the outside of the plate. Mr. Hadfield states that the "Era" cast steel plate can be yet further improved, but as it stands it is superior to the ordinary forged steel, such as is now used for gun shields, as the latter would have been perforated under any of the above tests. A Krupp cemented 4½-in. plate, which, of course, was forged, broke up under similar tests to those above given. The difference in thickness of the shield and plate must, however, not be overlooked.

These results, especially those obtained with projectiles, possess great interest for both civil and military engineers. It has long been held that to produce trustworthy steel articles it is necessary to put mechanical work on the metal, that is to say, that it should be forged either under the hammer, in the hydraulic press, or by rolling. To attempt to produce steel structures that would stand the enormous stresses that the Hadfield projectiles and gun-shield have undergone simply by casting would formerly have appeared the height of folly to the orthodox metallurgist or engineer, although there have been a few who have held more sanguine views in regard to the possibilities of the material. It would, of course, be extremely interesting if we could give the means by which the Hadfield Company have achieved these results, but this we are unable to do. The money that is sometimes spent—first in laboratory research, and afterwards in experiment on full scale—represent very large sums indeed, many thousands of pounds often being devoted to the working out of a single detail, or perhaps simply to arrive at a negative result. In the conduct of all industries depending on the scientific application of natural laws this feature is rapidly becoming more and more serious as time passes and the processes of manufacture increase in complexity. One can understand, therefore, that the directors of manufacturing establishments, having spent large sums upon gathering knowledge, look on data thus acquired as one of the assets of the business, and feel they are no more entitled to make such knowledge public than they would be to give away any part of the plant or machinery of the company. It must therefore suffice to say that the success of the Hadfield cast steel is the result of chemical research into the action of often minute differences in proportions of alloys of iron and of the subsequent special heat-treatment the material receives. In both these fields of research Mr. Hadfield has spent much time and labour, as the numerous contributions he has made to various scientific and technical societies bear evidence

Abroad manufacturers have been quick to recognize the need for a fully staffed and equipped research department, and the amounts expended annually for this purpose in some foreign works appear almost incredible. It is only by enterprise of this nature, however, that manufacturers can keep in the van of progress, and, properly directed, this so-called "non-productive" expenditure brings a rich reward. In Great Britain we have been somewhat apt to relegate research work to the laboratories of professors, the manufacturers devoting themselves to what are styled "practical results." This divorce of practice and theory does not lead to industrial success; and we cannot do better in support of this view than quote from a speech of Sir William White's made at a recent meeting of a technical institution:—

"I do not think it is a wholesome thing to suppose that all research work should be conducted in laboratories separate from works. I have the greatest respect for work done by engineers like Professor Arnold and Mr. Stead in private laboratories, but I hope to see the time when the example of Mr. Hadfield will be more widely followed in this country and when inquiries, both scientific and practical, will be carried out on a very large scale in the works of manufacturers all over the country."

The visitors to the Hecla works were shown other things besides artillery experiments and projectiles, steel castings and forgings of nearly all types being produced. Amongst these the most prominent were the castings for tramway and railway work, both for permanent way and rolling stock. The "Era" manganese steel, the discovery of which was due to Mr. Hadfield, and was the outcome of a long series of laboratory research extending over some years, lends itself especially well to such "track" work as points and crossings. Manganese steel stands alone in regard to being both hard and tough, so that it has very great resistance to wear, or attrition, and at the same time is not brittle, as ordinary hard carbon steel is. The advantage thus offered for railway or tramway points and crossings, which are subject to both abrasion and shock to a high degree, will be at once apparent. Unfortunately the hardness of manganese steel prevents its being machined, as no steel tool will cut it, and it can only be used as cast.

The works of the Hadfield Company cover in all 80 acres. The seel foundry is said to be the largest in the country, probably in the world. It is 1,020 feet long, and covers six acres. The engineering shops, which are filled with machine