The Research Department, Woolwich.[1]

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II.

Metallurgical Branch.

THE metallurgical branch of the Research Department had been established for some years before the war, the staff consisting of four metallurgists. As work increased, additions became imperative, and before the armistice the scientific staff numbered thirty-seven, of whom a number were women. At the end of 1916 the branch removed into a new building 120 ft. long and 55 ft. wide, divided into laboratories well equipped for mechanical testing of all kinds, chemical analysis, microscopy and photomicrography, experimental heat-treatment, the thermal study of alloys, and other branches of physical metallurgy. Figs. 4 and 5 show two of these laboratories. The machine shops of the Department, on which metallurgical work made great demands, were much extended and improved.

During the war the metallurgical branch was mainly occupied with a great variety of problems connected with the metallic materials of warlike stores used by the Navy, Army, and Air Force. The work was carried out in close association with the Ordnance Committee and other Departments concerned. It is possible to mention here only a very few of the specific problems attacked.

Before the war the manufacture of gun forgings was in the hands of a few armament firms of long experience, but with the great increase in output which took place from 1915 onwards a wider source of supply was drawn upon. The heat-treatment applied was not always the most suitable, and sometimes caused serious irregularity of properties throughout the forgings. Much was done to define the temperature limits appropriate to the different steels employed and to secure their application, thus eliminating those weaker tubes which were so frequently found among those which failed by stretching, choke, or expansion. The inspection tests were improved, especially in the determination of the yield point, a matter of great importance in a highly stressed structure such as a gun.

The extreme brittleness of some gun forgings put forward for test directed attention to the occurrence of "temper-brittleness" in nickel-chromium steel, and made investigation an urgent necessity. Slow cooling in the furnace after tempering was identified as the main cause of this form of brittleness, which is detected by the notched-bar impact test, and was accordingly forbidden by specification. Examination of samples representative of forgings in current supply made at the beginning of 1916 and at the end of 1918 showed that the notched-bar impact figure of the average nickel-chromium steel forging had very greatly improved, with no detriment to the other mechanical properties. The study of the notched-bar test was continued in association with the British Engineering Standards Committee, and much knowledge was gained as to its significance and conditions of application.

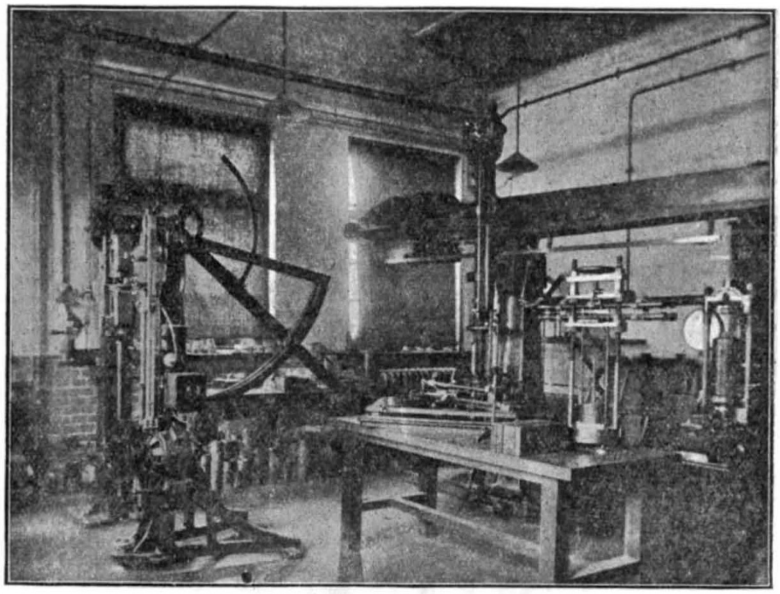

FIG. 4.—Portion of mechanical testing laboratory.

Much time has been given to the study of the elastic properties of steels and of the effect of overstrain and recovery, a subject of importance in connection with the strength of guns and their construction by methods involving the use of internal pressure.

Erosion, wear, and the development and extension of cracks in the bore have been studied in rifle and machine-gun barrels, as well as in guns. Many questions were solved in connection with the design and manufacture of bullet envelopes and the cores of armour-piercing bullets.

A method of applying the Brinell hardness test for the individual testing of H.E. shells which for one reason or another were in question as to their strength was developed, and resulted in the successful utilisation of very large numbers of shells which might otherwise have been rejected.

The numerous components of ammunition and

[1] Continued from p. 712.

fuzes were the subject of many investigations. As an example may be mentioned the hammer of the No. 106 fuze. This was liable to failure at a time of great output until the causes of difficulty were ascertained and sound methods of manufacture established. The introduction of a simple form of heat-treatment rendered possible the use of a rapid and economical stamping method which greatly assisted supply.

An investigation carried out upon brass small arm cartridge cases gave very complete information connecting the behaviour of the case in the rifle with its properties, and especially with its hardness. The hardness is chiefly dependent on the degree of cold-work received in the final drawing operation, and manufacturers were assisted by information as to the requisite hardness at different parts of the case and the dimensions of the necessary tools for producing it. The measurements to ensure exact control of the hardness have been made possible by the use of a small machine designed in the Research Department shortly before the war for the determination of the hardness of very thin specimens. In this machine, which has proved useful in many unexpected ways, the Brinell test may be made on samples one-hundredth of an inch or even less in thickness, with balls as small as 0·8 mm. in diameter.

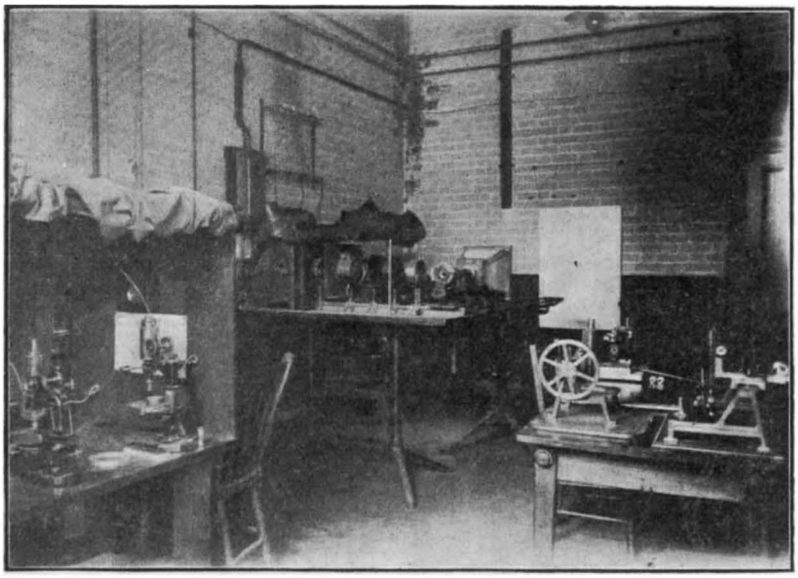

FIG. 5.—View in microscope room.*

A thorough investigation of the phenomenon of "season-cracking" in brass and its prevention by low-temperature annealing has had a useful application in the removal of internal stress from cartridge cases.

Methods of casting brass ingots have been much improved. The long, narrow moulds formerly employed for ingots to be used in the manufacture of rod were productive of troublesome defects in the finished article.

The occurrence of the "extrusion defect," a central core of unsound material, in brass rod used for fuzes led to an extended study of the extrusion process, in which the flow of the hot brass is liable to form internal defects in a remarkable and characteristic way. A method of controlling the plastic flow to produce entirely sound rod has been devised.

The necessities of the war demanded that first consideration should be given to the solution of immediate practical problems. The use of substitutes and alternative methods of manufacture when supplies ran short, the easing of specifications to increase output with safety, the adaptation and introduction of inspection tests to meet changing conditions, the examination of enemy material, the tracing of causes of failure and the discovery and application of remedies, provided a large field for investigation. Work on the fundamental properties of metals and alloys, which is so necessary if research in applied metallurgy is to continue to be fruitful, was, however, continued throughout the war, and is now being further developed.

Radiological Branch.

In the beginning of 1916 the question of the penetration of metals by X-rays was first considered by the Research Department. After experiments with various types of apparatus under different conditions, it was found possible to penetrate a block of steel half an inch in thickness and show internal flaws. The Department at once realised the possibilities involved in this new use of X-rays as applied to Service requirements, and took steps with the best apparatus available to evolve a technique for applying the new method as widely as possible, not only for detecting flaws in steel, but also for the examination of various articles, such as unknown enemy ammunition, where for reasons of safety it was desirable to know the internal construction before breaking down. X-rays were also applied to many Service stores for the purpose of indicating defective assembly, and for discovering faults such as blow-holes and internal flaws in metals.

As research progressed it became apparent that in order to obtain the best results the whole subject of radiology needed careful study so that its methods might be modified and adapted to this new use. More powerful tubes and high-power electrical machinery were essential, and the photographic side of the subject required special treatment. A general scheme of research on the subject of radiology as applied to the examination of Service materials was consequently undertaken, and this included the construction, in the Department, of special apparatus and high-tension electrical machinery; research was also undertaken on such associated subjects as the detection of feeble radiation and the measurement of its intensity.

Certain progress has been made, with the result that X-rays are being used to a much greater extent as research proceeds. X-ray examination of welds is the only method by which their soundness can be demonstrated, and it is now possible to penetrate more than 2½ in. of steel to show internal flaws. Fig. 6 shows part of one installation in the Research Department for the examination of materials.

Proof and Experimental Branch.

All guns are tested to a pressure in excess of their working pressures, and the ballistics of all lots of propellants are ascertained, by firing into sand butts. Carriages, recuperators, and many small stores are also similarly proved before acceptance.

Velocities are measured by means of Boulangé chronographs, and pressures by means of copper crushers in piston gauges. Flat-headed shot are used, to keep the penetration into the sand butts as low as possible.

Experimental firing, which principally consists in the determination of the weights of propellant necessary to give specified ballistics under various conditions, is also undertaken, and for this purpose the proof butts staff work in collaboration with the internal ballistic branch, by which the preliminary calculations are made.

Considerable expansion of *personnel* and *matériel* was necessary during the war to cope with the vast amount of proof and experiments. At the armistice the staff had increased to nearly ten times its pre-war figure, and included a number of women, who were most efficiently performing their trying duties on the firing batteries.

Internal Ballistic Branch.

Starting with a staff of two in the early part of the war, the branch numbered at the armistice more than twenty members, who dealt with all problems relating to the internal ballistics of propellants and the internal design of guns for all the Services. Newer and more powerful apparatus has been devised for determining the burning characteristics of explosives, and a great improvement has taken place in methods of analysing data. This is especially noticeable as regards the ballistic design of ordnance. The old system of calculation in use prior to the war was based on trial and error, and involved a series of laborious and lengthy operations. It had the added disadvantage of restricting the calculator to working out this result with one definite set of initial conditions only, and consequently no certain predictions could be made as to whether the best combination of charge weight, propellant size, chamber capacity, etc., had been employed.

It was thus frequently found that the finished gun was not suitable for the original purpose in view. Research into the thermodynamical properties of propellants led to the construction of a more accurate theory on which to base design, and, apart from the economy effected in the labour of calculation, it became possible to select with considerable accuracy the best and most economical combination for any ballistic requirements. Also by an application of the calculus of variations the calculator is now enabled to predict with considerable accuracy the probable deviation in the ballistics from round to round, a valuable criterion of the practical utility of a design.

The application of this new theory effected considerable changes in design. For example, it was found that large reductions could be effected in the chamber capacities of several guns, with corresponding reductions in the charge weights, without affecting the ballistics. This modification had the result of materially increasing the life of the guns, and the reduction in charge weight effected an appreciable economy in the financial cost of each round, a serious consideration in view of the magnitude of the scale on which operations were conducted.

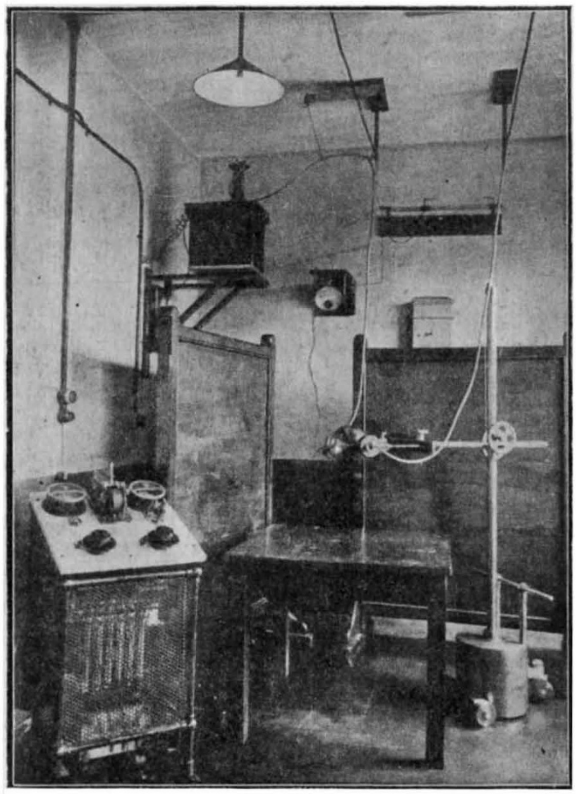

FIG. 6.—Portion of radiological laboratory.

Since the armistice the ballistic branch has been to a large extent occupied in digesting and interpreting the data amassed during the war, the results being published in the form of R.D. Reports.

A programme has been drawn up for future research, and good progress is being made in all branches of the science and its applications.