The Research Department, Woolwich.

By SIR ROBERT ROBERTSON, K.B.E., F.R.S.

I.

Explosives Section.

THE Research Department at Woolwich has been in existence under various titles since 1900. Prior to 1914 the staff was small; thus for the seven years preceding the war the chemical branch had a staff of eleven chemists only, and the metallurgical branch of four.

The subjects occupying the chemical staff before the war were connected with the stability of explosives, the investigation of new explosives (such as tetryl, for which a manufacturing process was worked out and issued to a Government factory), and research on the properties of explosives and on the means of initiating them in Service components. These researches proved to have a double importance, in that they not only enabled immediate answers to be given to many questions that arose early in the war, when there was no time for prolonged research, but also afforded the staff the training necessary to meet the demands which became urgent on the outbreak of hostilities.

After the beginning of the war the increase in work imperatively demanded a larger staff, and more chemists were appointed, until at the beginning of 1917, the home supply having failed, permission was obtained to withdraw from France members of the Special Brigade, R.E., of whom more than thirty were transferred to the Department. Finally, the chemical staff numbered 107 chemists and physicists distributed in an organisation which had been gradually evolved, comprising sections for dealing with the different classes of work, such as organic chemistry, physical chemistry, analytical and general chemistry, physical investigation, calorimetry, stability, pyrotechny, applications of high explosives, fuse design, and records.

With increasing work and staff, new buildings for explosives investigation became necessary, and new laboratories were erected, including a well-appointed building (Fig. 1) for physico-chemical research, embodying many of the ideas of Prof. Donnan, and a new range of factory buildings and houses for a variety of specialised work. Climatic huts for storage trials under dry and moist conditions, which have always been an important feature of the Department, were increased in number. In the explosives section the laboratories occupy a space of 64,272 sq. ft., and the buildings for experimental work on a larger scale 38,170 sq. ft. The Department's facilities for testing processes evolved in the laboratory on the semi-manufacturing scale have proved of the utmost value, affording confidence as to the practicability of processes on the full scale.

The Research Department acted as a central bureau for explosives research required by the Navy, Army, the Air Service, and the Ministry of Munitions. Many subjects were referred to it by the Ordnance Committee. Its work is embodied in official minutes and in collected researches termed R.D. Reports.

Trinitrotoluene.—One of the first subjects undertaken after the outbreak of war was the provision of an efficient and rapid process for the manufacture of T.N.T., especially without the use of oleum. From the results of a large series of nitrations in the laboratory, a process was evolved characterised by several novel features, and this was put to the proof on the semi-industrial scale, a plant being designed and erected in the Department (Fig. 2) for the nitration on the quarter-ton scale, with appropriate arrangements for the mixing and concentration of acids. This small plant substantiated in a remarkable manner the process evolved from the laboratory work, and from the start turned out T.N.T. of good quality. The scheme of temperature-rise, the composition of the acid mixture, the nitration in cycles, the process of "detoluation," and other features of the process found immediate application in the large Government factories that were designed and erected by Mr. Quinan, and also in numerous private works built at this time.

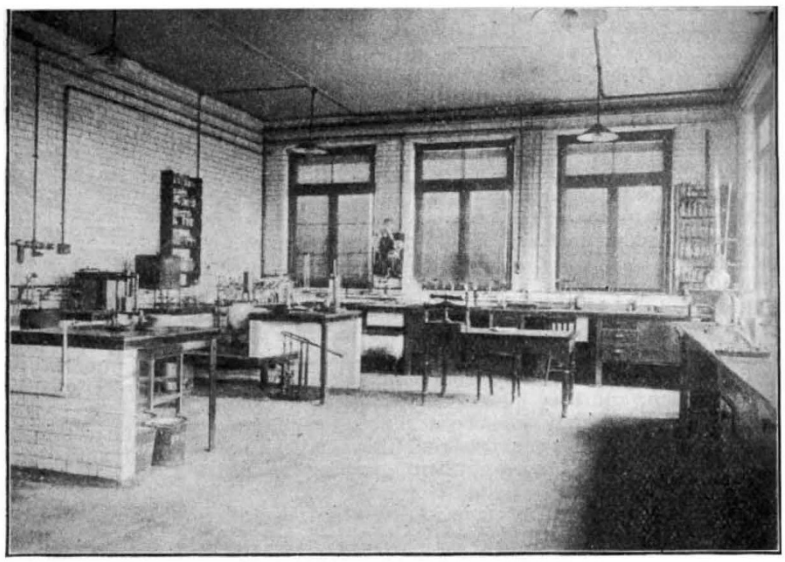

FIG. 1.—A physico-chemical laboratory.

These features have been little altered by later experience. Chemists were trained on this small plant for the purpose of starting Government

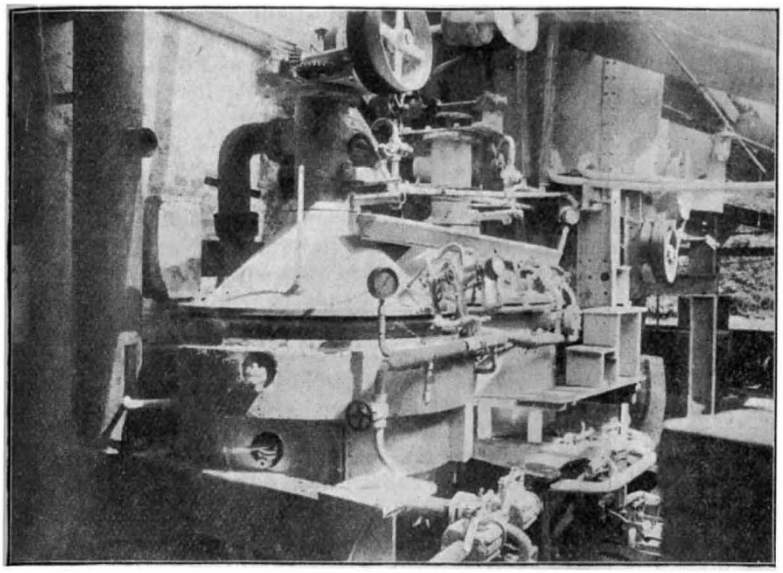

FIG. 2.—Small nitrating plant used to demonstrate the T.N.T. process.

and private factories, and for a time a few tons a week of the product were purified by alcohol-benzene in another plant erected in the Department to supply the Service with high-grade T.N.T. for exploders.

A study of T.N.T. in all its aspects was undertaken. Much attention was given to the chemistry of T.N.T., the proportions in which the isomers occur in the crude product being determined by thermal analysis, and investigations made on their interactions, stability, sensitiveness, heat values, and explosive properties.

Amatol.—As it soon became evident that the supply of the high explosives in use, lyddite and T.N.T., would not suffice, the Department put forward mixtures of ammonium nitrate and T.N.T., the amatols, as a result of study of their properties and of the violence they exhibited in shell-bursting trials. Gun trials substantiated the trials at rest, and their adoption quickly followed. Various methods of filling these mixtures into shell were at this time worked out, many of which have since been applied on the very largest scale.

It was found that 80/20 amatol (80 parts of ammonium nitrate to 20 of T.N.T.) was less easy to bring to detonation than lyddite or T.N.T., and required special arrangements in the train of initiation of detonation. These were successfully devised, and good and trustworthy detonation of our shell was secured. An illustration is here given (Fig. 3) of the fragmentation of an 18-pr. shell filled with 80/20 amatol.

As 80/20 amatol is practically smokeless, the constituents being arranged for complete combustion, mixtures producing a white smoke for indicating the point of burst were worked out for inclusion in the shell-filling. Ultimately, amatol became practically the only explosive for land and aerial warfare, and justified its choice based on the early estimate of its properties and capabilities. In 1917 the production was at the rate of about 4000 tons a week. It is economical in that it makes use of a cheap ingredient, and has explosive properties that render it very suitable for the purposes for which it is used.

The Department continued the study of amatol especially with regard to its chemical stability and compatibility with the various materials with which it came into contact. Certain impurities in ammonium nitrate were discovered to be objectionable, and investigation of this led to an improvement in the purity of the ammonium nitrate supplied.

R.D.B. Cordite.—When the available quantity of acetone became quite inadequate for the cordite required, the Department brought forward a new type of cordite (Research Department "B" or R.D.B. cordite) as a result of experimental incorporations with ingredients chosen to give the same ballistics as ordinary cordite. It could be

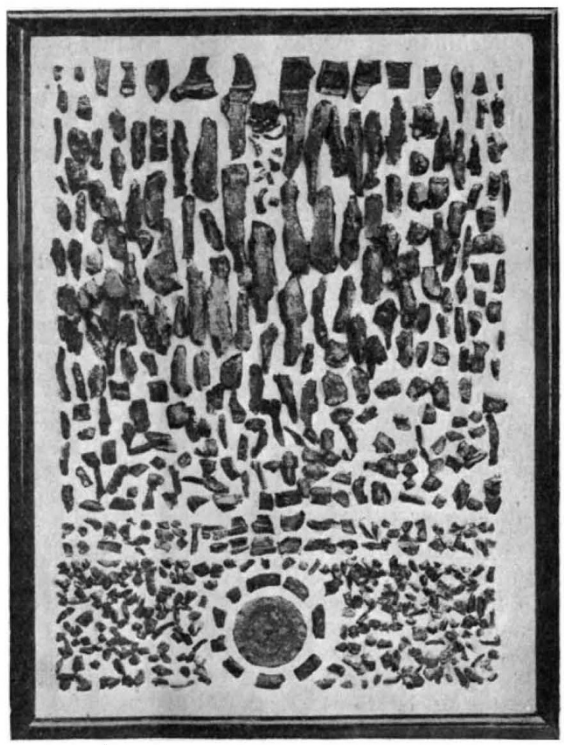

FIG. 3.—Fragmentation of 18-pr. shell by 80/20 amatol.

made with no alteration in the plant required for the manufacture of propellants. Instead of acetone, the solvent employed was ether-alcohol,

and instead of gun-cotton, a lower nitrate of cellulose was used. The great factory at Gretna, also built by Mr. Quinan, manufactured R.D.B. cordite exclusively, and this soon became the only propellant made in this country for the Land Service. It was produced both by Government and by private firms in enormous quantities.

The need for ether and alcohol for this propellant led to the restrictions imposed on alcohol.

The recovery of the new solvent presented new problems, and investigations on these were undertaken, which have increased our knowledge of the principles underlying the absorption of vapours.

As difficulties arose in the gelatinisation of the special nitrocellulose required for this powder, the Department continued its studies on the viscosity of cellulose and nitrocellulose with important results, which formed the groundwork of the procedure adopted in supply for obtaining uniformity in the cotton used in the nitration, and a diminished usage of solvent in the incorporation.

Other Explosives.—Many other explosives for special naval and land purposes were put forward by the Department and adopted by the Service after their properties had undergone investigation.

Design of Ammunition.—A feature of the work is the close connection between mechanisms connected with ammunition and the utilisation in them of explosives the properties of which have been found specially suitable. The Department was fortunate in the success which has attended its percussion fuse (No. 106), which played such an important part in the war.

Pyrotechnics.—New demands occasioned by the war led to the study of compositions for pyrotechnic and incendiary purposes and to chemical investigations on the compatibility of the ingredients used. Many new compositions were devised and adopted for signals, stars, and incendiary shell.

Study of the Theory of Explosives.—The study of the chemical constitution of nitro-compounds has been referred to; but a large amount of information the usefulness of which has been reflected on Service requirements has accrued from the development of systematic work on such subjects as the calorimetry of explosives, for which new methods and apparatus have been devised, their sensitiveness, their rates of decomposition and of detonation, and the pressure of the blow they develop. The last was an extension of the work of the late Prof. B. Hopkinson, and has been fruitful in advancing knowledge of theory as well as in providing instruments for quantitative registration of the effects of explosives contained in Service components.

General.—The high quality and efficiency of our ammunition, in spite of shortage and the need for providing substitutes, have been obtained as a result of the continuous application of chemical and physical research. The research initiated and carried out provided in numerous cases methods for the production of explosives, and demonstrated the conditions for their safe employment; principles of fundamental importance were discovered which were utilised in the designing of ammunition; causes of failure at early stages were discovered, thus avoiding unsatisfactory issues of material; and substitutes and alternatives, without which some of our great war manufactures could not have been carried on, were sought and discovered.

(*To be continued.*)

The Earliest Known Land Flora.[1]

By PROF. F. O. BOWER, F.R.S.

II.

COMPARISON of these four fossil species from Rhynie with other fossils already known from the early Devonian period shows that a very homogeneous flora existed at that time, consisting chiefly of leafless and rootless land-living plants. These and other characters, such as their large, distal, sometimes solitary, and often forked sporangia, stamp these plants as exceptionally primitive. Among living plants the nearest of kin to them are clearly the Psilotaceæ, a family which has long presented a problem in morphology and classification. It comprises two living genera, Psilotum and Tmesipteris. Both genera are rootless. Their imperfect morphological differentiation is shown by the fact that botanists are not yet agreed whether their lateral appendages are to be held as truly foliar or not. Psilotum is native throughout the tropics, and is represented by two well-marked species. The commonest, *P. triquetrum,* has upright and shrubby aerial shoots, with radial construction and frequent bifurcations. These spring from leafless underground rhizomes, profusely bifurcated. They are covered with rhizoids, and contain a mycorrhizic fungus. On the lower part of the aerial shoots simple spine-like leaves are borne, but towards the distal ends these are replaced by forked spurs, between the prongs of which a synangium, usually with three loculi, is seated. The aerial shoot is traversed by a vascular strand consisting of xylem in the form of a hollow many-rayed star, with sclerotic core, and branch-strands run out to the appendages. The whole is covered by epidermis with stomata, and the cortex provides the photosynthetic tissue. Tmesipteris is represented by only one species, limited to Australasia. It grows usually among the massed roots that cover the stems of tree-ferns, but sometimes upon the ground. Its general form is like

[1] Discourse delivered at the Royal Institution on Friday, April 30

Continued from p 684.