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~~CONFIDENTIAL~~

Ministry of Supply

THE ARMAMENT RESEARCH DEPARTMENT

Notes prepared on the occasion of the visit of Delegates to the Informal Commonwealth Conference on Defence Science

WEDNESDAY, JUNE 5, 1946.

FORT HALSTEAD.

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View at Headquarters Station
Fort Halstead

CONTENTS

General Programme

1. Introductions

2. Film and Coffee Interval in A.R.D. Library. The film will illustrate the growth of the Department, together with some of its more outstanding achievements.

3. Manufacture of R.D.X.. An exhibit illustrating the chemical processes in the manufacture of this explosive. The original R.D.X. plant will be on show.

4. Developments in H.E. fillings for Service weapons. Particular reference will be made to super-heavy bombs, measurement of blast, and to the part played by the Department in the development of Hollow Charges.

5. Recent Developments in Propellants, with particular reference to flashless propellants and to rocket propellants.

6. The Application of Radiological Methods to Service Problems. Applications to bomb and mine disposal, and to the study of detonations by means of flash radiography will be illustrated. (Note: Other aspects of the Department's work, in particular the Weatherproofing of Stores and Climatic Trials will be shown, in collaboration with C.E.A.D. at Fort Halstead in the afternoon).

7. Inspection of Proof Butts. P. & E.O. will give a brief talk on the work of the Proof and Experimental Establishment. The "Tankard" gun will then be demonstrated.

Detailed Programme

10.30 a.m. - Arrive at Armament Research Department Library.

Introductory talk by D/C.S.A.R.,
Dr. F.J. Wilkins, Ph.D., B.Sc..

Talk by Departmental Information Officer.

Film.

Inspection of selected apparatus.

Coffee will be served.

11.00 a.m. - Tour of the Department and inspection of exhibits (see General Programme).

	Red Party	Blue Party	White Party
Party Conductor -	Dr.H.J.Poole, Ph.D.	Mr.A.Highfield, M.A.	Mr.C.S.Bryant, M.A.
Exhibit			
H.E.	(2) 11.21 11.37	(3) 11.38 11.53	(1) 11.06 11.20
R.D.X.	(1) 11.02 11.13	(2) 11.21 11.32	-
Propellants	(3) 11.44 11.56	-	(2) 11.27 11.41
Radiology	-	(1) 11.03 11.17	(3) 11.44 11.58

The numbers in brackets refer to the order in which the exhibits will be seen.

12.00 p.m. - Leave A.R.D. by bus for Proof and Experimental Establishment

12.08 p.m. - Talk on P. & E. Establishment by (Brigadier G.H. Hinds, O.B.E.,

12.13 p.m. - Ballistic Measurements with a demonstration of the Tankard (recoilless) Gun

12.25 p.m. - Leave for R.A. Mess.

Lunch at Royal Artillery Mess (by kind permission of the Officer Commanding)

THE ARMAMENT RESEARCH DEPARTMENT

Early History

(a) 1902-1914

The Armament Research Department is the successor of the Research Department, Woolwich, which in its turn was developed from the Experimental Establishment founded in 1902. The Experimental Establishment was formed as the result of recommendations of the Explosives Committee - later to become the Ordnance Board - which was formed at the close of the Boer War to examine the cause of the defective performance of much of our armament. The Chairman of this Committee was Lord Rayleigh and the members included Crookes, Haldane, Noble and Ewing. The new Department was placed under the charge of Dr. Silberrad and a staff of approximately half a dozen chemists was appointed.

During the first decade the staff was steadily increased to approximately 20 scientists and a metallurgical section was added. The Proof and Experimental Establishment, which had conducted experiments in ballistics since the 17th century, was also added to the Department. During this period Dr. Robert Robertson, now Sir R. Robertson, K.B.E., joined the staff as its chief chemist, as did also Dr. G. Rotter, G.M., C.B., C.B.E., later Director of Explosives Research.

The main achievements of this small band of scientists were in the fields of applied propellants, and high explosives and their manufacture. They laid the foundations on which the modern design of armaments has been built and further they drew the broad outline for the development of modern processes for the manufacture of high explosives such as T.N.T. and tetryl. Fundamental concepts such as, for example, the use of a booster to build up the detonation of a charge, which are now accepted as common practice all owe their origin to the work carried out in the Department in these early years and it can be safely claimed that there are few explosive munitions which do not employ devices which resulted from research initiated in that period.

(b) The First World War 1914-1918

The outstanding contributions of the Department in the first World War concerned both cordite and high explosives. The unexpected scale of that war found the country totally unprepared for the manufacture of explosives and munitions in the quantities needed. The production of cordite M.D. was only possible in quantities sufficient for the Navy chiefly because the essential volatile solvent acetone was not available in sufficient amount. The Research Department produced, for the Land Service, cordite R.D.B. in which the solvent was a mixture of ether and alcohol; and practically the whole of the cordite used in that war by the Army was of this type.

In the high explosives field the production capacity of the country for lyddite, then the standard high explosive, was quite inadequate to meet the large demand for filling high explosive shell and other munitions. A pilot plant for

View at Woolwich

the manufacture of T.N.T. was installed at Woolwich and concurrently with the necessary research programme to produce a manufacturing process, a production of as much as 3 tons per week was obtained. The plant served both for a limited supply of high explosives and for the training of chemists to staff the new explosives factories where the large quantities needed for the war output were mainly produced.

Of no less importance was the development of amatol which economised T.N.T. by enabling its admixture with up to four times its weight of ammonium nitrate.

Between the Wars 1919-1939

(a) Propellants

In the years immediately after the first World War the Research Department employed about 150 scientists. These were divided into three main branches, i.e. those of the Directors of Explosives, Ballistics and Metallurgical Research respectively. Later a Radiological Branch, smaller than the above, was added.

Of the many problems thrown up by the 1914-18 war, probably the largest single item was that of the stabilisation of cordite. The older types of cordite and nitrocellulose powders which contained as stabiliser mineral jelly and diphenylamine respectively, suffer from a very serious defect, namely, that small particles of included foreign matter, particularly those containing sulphur, are liable to give rise to corrosion spots which cause rapid local decomposition of the cordite, with rise of temperature. Under certain conditions these "corrosions" were found to spread from stick to stick, the heat developed being sufficient to cause the spontaneous ignition of the propellant. In this manner serious explosions had occurred in magazines and battleships; the loss of H.M.S. 'Bulwark' at Sheerness is a case in point. The Research Department overcame this defect by replacing all or part of the mineral jelly in the cordite by sym.diphenyl diethyl urea, now called carbamite, which prevented the growth of the "corrosions". Typical cordites which contain this material are cordite S.C., cordite H.S.C./T., cordite W.M. and cordite S.U.

Another important defect in the cordites used in 1914-18 resulted from the use of volatile solvents in their manufacture. The cordite had to be stoved for periods of weeks to drive off the volatile solvents and the stoving operations caused irregularities in the dimensions of the propellant and consequently in its ballistics. Carbamite has, however, the important property that it is soluble in nitroglycerine, the solution being an efficient gelatiniser for nitrocellulose. This rendered possible a process by which the ingredients of the cordite are mixed under water, and gelatinised without volatile solvent before pressing. The final cord is produced by heating the gelatinised material and extruding it, in its final form, from a heated cylinder. With experience it was found that not only was it possible on the manufacturing scale to control accurately the size of the cordite, but also to introduce such checks in its manufacture that the energy content of the propellant was kept constant within approximately one or two parts in a thousand. With cordite manufactured to this high degree of regularity in size and composition it was found possible to dispense with a proportion of gun proof, an advantage of very considerable value in the recent war.

Yet another important disadvantage of the older cordites was the brilliant large flash produced at the gun muzzle. This flash not only blinded the gun layer but revealed the gun position to observers stationed up to several miles away. The flash was found to be due to hot gases from the exploded propellant coming into contact with the atmosphere and there re-igniting. This suggested a means of preventing gun flash by reducing the tendency of these gases to ignite by so altering the composition of the propellant that the gases were cooler or contained a lower proportion of inflammable material. This was achieved by introducing into the propellant composition a compound very rich in nitrogen. The compound selected was nitroguanidine, now known in its finely divided form as picrite. Several propellants containing this compound were developed of which the most important is cordite R.D.N.. This propellant has two other important advantages. Firstly, should it prove possible to arrange for cyanamide production in this country, its ultimate raw materials are almost entirely coal and lime, thus saving imports, and secondly, it causes much less erosion of the gun barrel than the older types of cordite, with a consequent large increase in the number of rounds that can be fired before the gun becomes too worn to give accurate ballistics.

Yet another important improvement in propellants was achieved during the period between the two wars, namely the substitution of cotton cellulose as a raw material by the much cheaper and cleaner wood cellulose. The Department developed methods of purifying wood pulp to permit its use in cordite manufacture, and in 1940 this material was selected as the standard cellulosic material for the Naval cordite S.C.

Although the problem of producing a stable cordite was effectively solved, there still remained in magazines throughout the world large quantities of pre-1918 cordite, both in bulk and in munitions, as the country's war reserve stocks. With these there was the ever present risk of spontaneous ignition. Sample tests of the cordite could obviously not be depended upon to detect local corrosions likely to cause inflammation, but a test was devised to give warning of possible danger. In this test there is inserted into the cordite container a small test paper which can be viewed beneath a glass window. A rapid change in the colour of the test paper gives unmistakable indication of approaching danger. With the aid of this test, dangerous cordite can readily be detected and removed for destruction. In this way the risk of spontaneous fires was practically eliminated and the premature destruction of large quantities of quite satisfactory cordite avoided.

The stability of the cordite was also studied by storing cordite in "climatic huts" where tropical climates can be imitated or the conditions exaggerated so as to produce in a few months the decomposition expected in the tropics over a period of years. A travelling chemist was also charged with the inspection of cordite and other explosives at selected stations throughout the Empire.

(b) <u>Ballistics</u>

Meanwhile important advances were being made in ballistics. New mathematical theories of internal ballistics were worked out which enabled full use to be made of improvements, both in the propellants and in the design of guns, and of the metals used for their manufacture particularly in the direction of saving weight of equipment and improving ballistics. To this end important improvements were made in methods of ballistic measurement; an improved form of spring gauge was developed for measuring pressure time transients and later the introduction of piezo-electric gauges for recording gun pressures permitted the recording of "pressure-space" curves for guns; a very marked advance of utmost importance in the whole subject of gun design. More recently the classical Boulengé chronograph for measuring velocities was replaced by electronic devices such as the counter-chronograph which is more flexible in use and which, in conjunction with photo-electric cells, can be used for velocity measurements in the field and on board ship. There were also developed new methods of measuring the strains produced by firing in gun barrels, while apparatus was devised to record more accurately recoil motions and buffer pressures. All these advances have proved of the greatest assistance to the gun designer, and the marked improvements in design and performance of guns, which is so noteworthy a feature of the inter-war period owes much to the advances made in the accuracy of recording and the theoretical interpretation of the results developed in the Ballistics Branch of the Department.

The same Branch also carried out a long investigation into the subject which is now designated Low Pressure Ballistics, involving the controlled burning of cordite charges. The object of controlled burning is to produce gas which can be utilised to operate machines designed to develop considerable mechanical power for short periods. Cordite charges which were developed for such purposes consisted mainly of large size sticks or normal-size sticks coated on the outside so as to constrain them to burn slowly from end to end. Among the more important applications of this new technique were the catapult launching of aircraft and the starting of aircraft engines. Other developments to assume considerable importance in the last war were fluid ejection projects, particularly flame throwers.

A particular example of Low Pressure Ballistics received considerable attention by the Ballistics and other Branches of the Department in the 1930's, namely the use of cordite as the propellant for A.A. rockets. Prototype A.A. rockets were produced and their possibilities clearly demonstrated at trials carried out in 1938 in Jamaica. The results were of such importance as to justify the formation of a new Department to specialise on the new type of weapon.

(c) High Explosives and Initiators

An immediate requirement, arising chiefly from the battle of Jutland was for H.E. shell which would not explode on impact with ships' armour but for which the detonation of the H.E. should be delayed until the shell had penetrated the armour and reached the interior of the ship. The Research Department solved this problem by first producing shellite as the shell filling and then developing a special detonating delay fuze incorporating the R.D. gaine.

The first World War also demonstrated the need for the use on the largest possible scale of high explosives, shell, bombs and other forms of ammunition and it was inevitable that there should be a general demand for an explosive of much increased power. The Department examined several hundred new explosives, until it became evident that a considerable advance could be achieved from either tetranitropentaerythrite or cyclotrimethylenetrinitramine ('cyclonite') now known as R.D.X.. R.D.X. was selected for a variety of reasons and work was concentrated on the development of an economic manufacturing process. A continuous process was produced and an experimental plant was erected at Woolwich. In its important essentials this is the process which was later developed at Waltham Abbey and in the full scale plants operated in the last war.

The more important applications of R.D.X. are in munitions where the highest possible explosive performance is required, such as, in particular, A.A. shell, torpedoes and certain forms of aircraft bombs. R.D.X. itself was found to be too sensitive to shock for these purposes, and it was necessary to desensitise it by the admixture of beeswax or by other means.

Also by the controlled milling of R.D.X. with an oily composition there was developed a plastic explosive which could be moulded into close contact with steel rails, girders, etc. so that when detonated the maximum cutting effect was produced. Its adaptability led to a great variety of specialised uses in demolition.

Simultaneously, new methods of assessing the performance of high explosive munitions were sought. Modern cathode ray oscillograph and piezo gauge technique was utilised for measuring blast and fragment velocity from H.E. munitions. Studies were also made of the effect of H.E. munitions on typical targets. In this way knowledge of the basic principles of the performance of such munitions was very considerably advanced.

The various components of explosives munitions also received continuous attention. Improvements were effected in fuzes, particularly in the functioning of the explosive train, while the initiation of explosives by electrical heating was also studied. As a result of the work on the performance of H.E. the Research Department is now widely consulted on matters concerning the performance of explosives, on such subjects as the safety aspects of the design of magazines and munition dumps, and on conditions of transport of explosives.

(d) Metallurgy

Between the first and second World Wars, basic work in various branches of metallurgy was undertaken, partly with the assistance of grants from the Department of Scientific and Industrial Research. For example, steels and non-ferrous alloys were developed to meet the increasing demands for improved properties which were being imposed by mechanised warfare and by the ever-growing power of explosives and propellants. Investigations into overstrain and internal stress in steel in relation to the development of the auto-frettage method of gun manufacture, and into the erosion of gun-steels and the development of light armour plate were also made. Pioneer work undertaken before 1918 on the season cracking of brass led to the adoption of low-temperature annealing, not only of cartridge cases, but also of condenser tubes and cold-worked brass generally. Examples of work which had an important industrial as well as Service application were the study of the aluminium brasses and the consequent introduction of aluminium brass condenser-tubes; the development of ternary lead alloys with a greatly increased resistance to cracking, later used widely for cable-sheathing and water-pipes; methods of improving the casting of brass ingots, which resulted in improved surface quality of rolled sheet and drawn work; studies of the structure of steel ingots and of the properties of cast steel at high temperatures (part of the programme of work co-ordinated by Research Committees of the Iron and Steel Institute); fundamental work on the crystallisation of metals from the liquid state; basic work on the structure and properties of electrodeposited metals, which paved the way for the development of methods of lining guns by electrodeposition, and of other Service and industrial methods.

View at Waltham Abbey

(e) Radiology

Radiographic methods were first introduced into armament research in 1917, and the period between the wars saw the development of radiological methods as an established procedure for investigation and inspection. Thus the Aeronautical Inspection Department was advised and assisted in using radiology for the inspection of stressed castings. A fuze examination set was constructed for C.I.A. for the routine inspection of simple types of fuze made of aluminium or brass. Mobile sets were constructed for the examination of heavy steel castings and welded structures in situ, for the Admiralty. Radium was introduced to extend mobility and also the range of wall thickness that could be examined. Cast T.N.T. blocks for shell were examined for presence of cavities and cracks, and cordite for the presence of fissures. Attention was paid to other methods of non-destructive testing and magnetic methods were introduced for the detection of fine cracks in steel forgings and castings. Crystal analysis methods were developed to determine grain size, the extent of annealing and cold work, and the presence of preferred orientation.

The foregoing account represents only the highlights of the work carried out in the period between 1919-1939. It can be said that during this period there were very few types of munitions which did not come under review and for which improvements were not effected. Chief among these may be mentioned improvements in pyrotechnic compositions and here it can be safely claimed that the quality of the pyrotechnic mixtures employed by our Services was superior to that of any foreign competitor. Other items in which improvements were effected were small arms ammunition, grenades, flame throwers, incendiary stores and others too numerous to mention in this abridged account.

Rearmament and the Second World War 1939-1945

When rearmament was speeded up, the position with regard to the quality of our munitions could be viewed with some confidence. We had an excellent Naval propellant of the older type in cordite S.C.. We had developed a flashless propellant which was superior to anything possessed by the enemy and it only needed that the country should manufacture sufficient carbide and cyanamide for it to be largely independent of imports. For high explosives we had the explosives of the last war with improved manufacturing processes and the new explosive R.D.X. when extra power was needed. We also had pyrotechnic compositions of proved quality. The design of weapons and ammunition had proceeded apace with the developments in the fillings and we had reason to hope that our researches had covered such a wide range that it would be unlikely that the enemy could be ahead of us to any significant degree in the technical aspects of ammunition.

The immediate problem to be faced was shortage of supplies and during the period between 1938 and 1940, the Department's main task was to bring to bear the experience gained by its scientists to the task of alleviating or removing production difficulties and advising the Services and the factories as to where hampering restrictions on quality or dimensions could be eased so as to step up the output.

Once the war started however, it became necessary to meet the changing tactics of the war by new forms of munition At the outset, aircraft combat played a very important part in hostilities and this Department was required in collaboration with the Design Department to produce a variety of types of small calibre ammunition for use in air to air combat.

The most important achievement in this direction was the production of new designs of incendiary small arms ammunition of which the essential filling consisted of a Research Department composition containing aluminium and magnesium, S.R.365. This proved extremely effective and has not been superseded.

The increasing complication in the technical equipment used in the war is also well exemplified in the small arms field. The calibre of small arm fully automatic guns has been increased from a maximum of .5" in the last war to 40 mm. in this war. There are now more than a dozen different types of small arms weapons ranging from 0.22" fully automatic weapons upwards. For almost every weapon the range of ammunition includes ball, armour piercing, high explosive, incendiary and tracer ammunition which is required to give a visible trace only over certain closely specified ranges. These requirements could only be met by a large expansion of the staff occupied on this work and by the development of special methods for the study of the performance of the ammunition and the kinetics of the mechanical parts of machine guns.

The campaigns in Flanders and France and later that in Libya showed the imperatively urgent task of finding means to penetrate heavy tank armour by gun fire or other means. A variety of munitions was produced for this purpose, including the new 17 pr. gun and the P.I.A.T. which fires a bomb with a "hollow-charge" H.E. filling. The hollow-charge principle has led to important developments in the attack of armour and other protective devices and its full scope has probably not yet been realised. The most important advance came from this Department in collaboration with the Design Department in the production of the "Sabot", a form of high velocity projectile containing a tungsten carbide core. For use in 6-pr. ammunition the Sabot was produced just in time for its extensive use in the campaign following D-day, and its value can be well assessed from a message received from Field Marshal Sir Bernard Montgomery that the Sabot had put us ahead of the Germans in ammunition design, and from a telegram received from the War Office Branch known as Weapons Technical Staff Field Forces, which described its performance as "One shot - One tank - Can't miss".

At the outset of the war, Air Force bombs were mostly of the General Purpose (G.P.) type. As the war advanced and the large scale bombing of Germany developed there was a progressive change towards a bomb designed to give the maximum blast effect on above ground buildings. The result was the very large bomb with a light casing and a maximum quantity of high explosive. This introduced special problems of filling and initiation and the experience of the Research Department was found to be of utmost value at this stage. The Department had by then acquired better facilities for the study of the performance of H.E. shell and bombs at new testing ranges at Shoebury and Millersford. At these stations the Department was able to continue its work on the assessment of the performance of H.E. munitions, developing improved methods of measurement and statistical methods of analysis of results. Admixture of aluminium with high explosives had been shown by the Department in between the two wars to have distinct possibilities and the new tests confirmed the advantage to be most important in the production of blast. On the basis of these experiments, the 'Minols' were introduced largely as the filling for bombs, while 'Torpex', which is an aluminised mixture of R.D.X. and T.N.T. was introduced as the H.E. filling of torpedoes and large bombs. 'Torpex' was the explosive which breached the Ruhr Dams, while a modified version of Torpex was the filling in the large penetrating bomb which secured success in attacks upon the 'Tirpitz' and other special targets. The Department was responsible for the filling of heavy blast bombs up to the 12,000 lb. and the 22,000 lb. penetrating or 'earthquake' bombs.

The new tactics of bombing also called for special pyrotechnic stores, in particular those required by the Pathfinder Force to guide the bombers to their targets, and further it was found profitable to replace a considerable proportion of the high explosive shell and bombs by incendiary bombs. In collaboration with other departments, this Department developed new incendiary fillings for this purpose, in particular the gelatinised petroleum fillings, as well as fillings with a magnesium basis.

The Metallurgical Branch necessarily took on far more of a development and far less of a research character. The activities of the branch were largely devoted to the important but non-spectacular duties of assisting design and inspection departments and firms in the production of metals and products of satisfactory quality, to finding suitable metals to substitute for those in short supply and to examining armament captured from the enemy. By stationing representatives with Inspection Departments in various important centres of metallurgical activity, advice and assistance on difficulties arising in production could be given promptly. Much time was saved to industry by the reclamation of over-machined parts by electrodeposition, in plants many of which were designed by, or operated on advice from, the Metallurgical Branch, and numerous other examples can be given of the work of the Branch during the war. In addition, the Branch played an important part in the formation and smooth-running of the Ministry of Supply's advisory department on Technical Application of Metals.

The radiological methods for the detection of flaws in metal parts also found the greatest application during the last war. The penetrating power of X-rays for these purposes has been improved and it is now possible to take photographs through a foot or more of metal. Besides X-ray tubes, radon was used as the source of penetrating rays. The methods developed were found to be invaluable in the examination of unexploded enemy bombs both for the purpose of ascertaining the best methods of immunising the bomb as also for detecting booby traps.

A comparatively recent advance in radiography is the development of the technique for taking X-ray photographs with an exposure time of less than one millionth of a second. For the first time this has enabled us to follow the detonation of explosives, the flight of a bullet in a barrel or in the region of the muzzle flash, and so on.

Proof and Experimental Establishment

The headquarters of the P. & E.E. is at the present time at Woolwich. Proof of guns is an old established procedure and has been done at Woolwich since about 1680, though the present site did not come into use until about 1870. The head of the present P. & E.E. is known as the Proof and Experimental Officer, a post held alternately by Naval and Military Officers. P. & E.O. is the direct descendant of the Proof Master, whose duties were laid down by the Royal Warrant of Charles II dated 25th July, 1683. The first officer of the Royal Artillery to hold this post was appointed in 1783 at a salary of £120 per annum. Difference in cost of living and increased intricacy of weapons has resulted in the present P. & E.O. receiving a somewhat higher emolument.

In 1907 the P. & E.E. was absorbed into the recently created Research Department and has remained a department of this organisation to the present time, thus ensuring the necessary close contact with the scientific branches to enable them to collaborate freely in the various trial firings which arise.

On the outbreak of war in 1939 the staff of the P. & E.E. consisted of fourteen officers, eighty-four men of the Royal Artillery and one hundred and ninety civilians. With this staff proof was done at Woolwich and at a small two-bay range at Melton Mowbray. A certain amount of proof work was also done under P. & E.O.'s supervision at Bellingham (Northumberland) and Eskmeals (Cumberland), two ranges operated by Messrs. Vickers Armstrongs Ltd..

With the rapid expansion in armaments new ranges had to be built and old ones enlarged, thus during 1940 Melton was enlarged by the addition of four more bays, and proof was commenced at a new range at Inchterf, about ten miles N.E. of Glasgow. This range consisted of two batteries and eleven bays and had been commenced in October, 1939.

In November 1941 a new range was completed at Melton for proof of Tank Armour, a similar range having been completed at Inchterf in July. In August 1942 a further new range was opened near Sheffield for proof of Armour, while in April 1944 a small range was opened in the R.O.F. at Cardiff in order to overcome the difficulty of transporting guns to Melton Mowbray from the Welsh area.

It will be seen that Ranges were spread over the country to serve the main manufacturing areas.

(a) Woolwich - London
(b) Melton Mowbray - the Midlands
(c) Cardiff - S. Wales
(d) Sheffield - handy for the H.Q. for the steel industry
(e) Bellingham - N.E. England
(f) Inchterf - Scotland

By 1944 the staff of P. & E.E. had increased to forty officers, three hundred and seventy warrant officers and other ranks, and a civilian staff of about eight hundred.

In 1939 an average of 1230 rounds were fired weekly at Proof Ranges. By 1944 this had risen to 10400 rounds, in addition to the proof of 34200 guns and mortars and 8900 carriages and mountings.

Organisation

In the foregoing the history and work of the Department has been very briefly outlined. A short account will now be given of its organisation.

During the first and second World Wars it was attached to the Ministries of Munitions and Supply respectively but except for these periods it has been part of the Department of the Master General of Ordnance in the War Department. It has now been finally incorporated in the Ministry of Supply.

Until 1942 the Chief Superintendents of the Department and their deputies were alternately Naval and Military Officers, with the technical and scientific branches under civilian scientists as Directors or Superintendents. The Department was thus Inter-Service in character - as was its work - and it has close linkage with two other long established Inter-Service Departments, the Ordnance Board and the Design Department.

In 1942 there were important changes in the Ministry in the administration of research and development. The Armament Development Board was formed under the Chairmanship of Engineer Vice-Admiral Sir Harold Brown, G.B.E., K.C.B., (retd.), the Senior Supply Officer, and the members of the Board included the Service Directors, D.N.O., D.G. of A. and D. Arm. D., the President of the Ordnance Board and the Chief Superintendents of the Research and Design Departments. The chief functions of the new Board were the direction of policy and coordination of research and development.

The old Research Department and Design Department Woolwich now became the new Armament Research (A.R.D.) and Armaments Design Departments (A.D.D.) respectively, and an eminent scientist (Professor J.E. Lennard-Jones, F.R.S.) and engineer (Mr. (now Sir) F.E. Smith) were appointed as heads of the Departments. Further, in order to facilitate collaboration between the two Departments their headquarters were moved to Fort Halstead. Service contacts were provided by the attachment to each Department of three Senior Service Representatives - one for each Service.

Another change, progressively introduced during the war and now formalised was for the ordering Departments to put their requests for research and development direct to the A.R.D. and the A.D.D. instead of through the Ordnance Board as hitherto. This necessitated the provision of machinery for the joint examination and progressing of such projects by both Departments and a system of technical panels has been evolved, each panel dealing with a definite and restricted range of subjects.

Meanwhile collaboration between the A.R.D. and the Universities has been steadily fostered partly by the attendance of members of the A.R.D. at the Ministry of Supply Scientific Advisory Council or its Committees and partly by the extension of a system of extra-mural contracts with the Universities for researches for which the University selected has special facilities. Both these schemes will form an essential part of the post war organisation and are at present under discussion. A complementary scheme for collaboration with industry will also be worked out.

The technical branches in the A.R.D. at the end of the war included three branches dealing with explosives, two with ballistics, a branch for theoretical research in armaments and a metallurgical branch. There was a scientific secretariat and P. & E.O. was attached to the Department.

The post war organisation is not yet settled and is dependent on far reaching changes now being made in the organisation of research and development in the Ministry. It is thus only possible to indicate certain features of the future organisation which experience has shown will be necessary. A central group for theoretical research in armaments has proved its value and is expected to play an increasingly important part in the work particularly as provision is being made for the allocation of more staff to fundamental or 'long-dated' research than was possible between the two wars. The need for greater emphasis on research in chemical manufacture was clearly shown during the last war and provision has been made for this work at Waltham Abbey, where an experimental factory and chemical engineering research will be harnessed to organic chemical research on explosives and their raw materials. In the A.R.D. there are now two ballistic sections, one for Internal Ballistics and one for Terminal Ballistics and there are plans for a more comprehensive study of external ballistics. Schemes for the closer collaboration with the A.D.D. are under discussion.

It must be some time before the final plans for the post war department emerge but it has been sufficiently indicated that no attempt is being made to fix the war time organisation. A degree of flexibility is being achieved which will ensure that the A.R.D. can adapt itself to the rapidly changing methods of warfare and permit it to play as important a rôle in the future of armament research as it has done in the past.