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Summary of
activities at PERME
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THE PROPELLANTS, EXPLOSIVES AND ROCKET MOTOR ESTABLISHMENT OF THE PROCUREMENT EXECUTIVE, MINISTRY OF DEFENCE: THE HISTORY AND CURRENT ACTIVITIES OF THE WALTHAM ABBEY DIVISION

The Establishment occupies the site of the former Royal Gunpowder Factory established in 1787 on the premises of a gunpowder mill then in the possession of the Walton family. Under the first Director of the Factory, Sir William Congreve and his successors the production and quality of black powder were greatly improved - the US Ordnance Manual of 1862 records that no one makes better powder than the Waltham Mills. Manufacture of guncotton was begun in 1872 and of cordite in 1891. Later the factory undertook the manufacture of more advanced explosives and propellants, culminating in the production of RDX at the beginning of the Second World War - the factory was the only source of this explosive in the UK for some years. The Branch structure below has evolved from the time when the Establishment assumed the name of the Explosives Research and Development Establishment in 1948, by which date much of the work of the former Research and Development Department at Woolwich Arsenal had been transferred to Waltham Abbey.

The Explosives Branch is concerned with the development of initiating (primary) explosives and the assessment of the sensitiveness of explosives and propellants and of the hazards associated with their use

The General Chemistry Branch supports the other Branches with chemical and other analysis by classical and instrumental methods, including spectroscopy, gas and liquid chromatography, X-ray crystallography (including computer analysis of data), thermal analysis, assessment of the compatibility of explosives and propellants with materials of construction, by development of electronic and mechanical instrumentation and the provision of glassworking, mathematical, computing, library and information services.

The Non-Metallic Materials Branch covers development and small-scale production of items in plastics and rubbers for use in association with explosives and propellants and in other exacting environments, simulated and natural weathering of materials (conducted in association with a tropical exposure site in Queensland Australia), design and fabrication of components in composite materials using asbestos, carbon fibre, glass fibre and 'whisker' reinforcements, automated testing of plastics for creep, flexural and tensile properties over a wide temperature range, synthesis of high-performance polymers and instrumental study of polymers by infra-red, NMR, UV and visible spectroscopy, vapour phase and gel permeation chromatography and by thermal analysis methods

The Process Research Branch is involved in synthesis of organic compounds (low molecular weight and polymeric) for use in explosives and propellants, development of chemical engineering processes for explosives and propellant ingredients to full production if needed, pilot plants for the manufacture of new or otherwise inaccessible materials and with the grading and alignment of the fibrous reinforcements referred to above

Propellants 1 Branch is engaged in the development of propellants for guns, rockets and other uses from nitrocellulose and nitric ester bases and the ballistic assessment, calorimetric and combustion evaluation of these propellants

Propellants 2 Branch was responsible for the development of the plastic propellants used in UK and overseas meteorological rockets, using poly-iso-butylene binder and has gone on to develop the use of polyisoprene binders to extend the useful temperature range of this family of propellants: the Branch is also concerned with the development of propellants using rubbery binders developed from telomers ('liquid rubbers'), with the (static) ballistic assessment of small rocket motors, the rheology of propellants and the study of adhesion, adhesives and sealants

The present name of the Establishment was adopted in February 1977 when the Waltham Abbey Division was combined with what had been the Rocket Propulsion Establishment

PROPELLANTS, EXPLOSIVES AND ROCKET MOTOR ESTABLISHMENT, WALTHAM ABBEY ESSEX EN9 1BP
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ERDE

ERDE was formed in 1945 to carry out, on behalf of the Services, research and development concerned principally with ingredients and compositions for all types of explosives and propellants; the work and staff had a strong bias towards chemistry although physics and engineering were also represented. The field of interests in the Establishment has now widened considerably to include, in addition, many aspects of materials technology in the fields of rubbers, plastics and composite engineering materials, including high-strength composites based upon ceramic whiskers, but the bias towards chemistry remains.

The work of ERDE is organised in the following groupings:

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|------------------------|--|
| Propellants 1 & 2 | Formulation of new solid propellants and the study of ballistic and mechanical properties. Combustion kinetics. Rheology of heavily loaded, two-phase systems, and the mixing of stiff pastes. Adhesives and adhesive strength properties. |
| Explosives | The development of explosive compositions and research on explosion and detonation. |
| Non-metallic Materials | New organic polymers; synthesis, characterisation and stability. Processing and mechanical properties of composite materials. |
| Process Research | Development and research on chemical and processing plant, instrumentation and remote-control systems. The growth and mechanical properties of ceramic whiskers. Heat transfer properties of fluids. |
| General Chemistry | Synthesis, analysis and thermochemical properties of organic and inorganic compounds. Development of new analytical methods particularly those based on physical techniques such as chromatography, spectroscopy and crystallography. |

Within these main groupings a wide range of topics in both research and development is actively investigated. In addition to the equipment appropriate for modern chemical and physical-chemical research, the Establishment operates a variety of good facilities for testing, evaluating, and investigation by special techniques; supporting services include sections responsible for electronics and glass technology. An Elliott 903 computer is in use and access is available to large fast computers. The library has a wide coverage of appropriate journals and reference works and includes a well equipped lecture theatre seating 120.

Apart from being linked with the Rocket Propulsion Establishment, Westcott, ERDE maintains close contact with other Government Establishments and with universities, and has a special relationship with the University of East Anglia.

Every encouragement is given to individual scientists to publish accounts of their work in the open literature.

ERDE is situated 12 miles from the centre of London on a site adjacent to the green belt countryside of Essex and Herts; the residential areas of Epping, Chingford, Enfield and Hertford are within easy reach and the area is well served by London Transport buses. From Waltham Cross BR Station (1 mile) a frequent service of electric trains connects with the Victoria Underground line, providing easy access to Central London.

An adjacent modern housing estate provides living accommodation of good standard for married scientific staff joining the Establishment.

There is an active Sports and Social Club which provides club premises and organises social events such as dances. Subsections of the club specifically provide for those interested in any of the following: Association football, badminton, bridge, chess, cinema, cricket, croquet, drama, golf, music, sailing, table tennis, tennis.

London and the surrounding districts, of course, provide opportunities for almost every kind of leisure activity.

This brief outline of the activities of ERDE can do no more than mention in general terms the main fields of our interests; more detailed information is given in a brochure obtainable on request from the Director, Explosives Research and Development Establishment, Waltham Abbey, Essex EN9 1BP.

ERDE

THE EXPLOSIVES RESEARCH AND DEVELOPMENT ESTABLISHMENT OF THE PROCUREMENT EXECUTIVE, MINISTRY OF DEFENCE: ITS HISTORY AND CURRENT ACTIVITIES

The Establishment occupies the site of the former Royal Gunpowder Factory, established in 1787 on the premises of the gunpowder mills then in the possession of the Walton family. The RGPF, under the direction of Sir William Congreve and his successors, greatly improved both the production and quality of black powder (the US Ordnance Manual of 1862 records that no one makes better powder than the Waltham Mills). Manufacture of guncotton was begun in 1872 and of cordite in 1891. Later the Factory undertook the manufacture of more advance explosives and propellants, culminating in the production of RDX at the beginning of the Second World War, the Factory being the only source of this explosive in the UK for some years. The Branch structure below has evolved from the time when the Establishment assumed its present title in 1948, by which date much of the work of the former Research Department at Woolwich Arsenal had been transferred to Waltham Abbey.

Explosives Branch. Development of initiating explosives and assessment of explosives performance and of sensitiveness and hazards associated with the use of explosives and propellants

General Chemistry Branch. Chemical analysis by classical and instrumental methods (including spectroscopy and gas and liquid chromatography), thermal analysis, compatibility of explosives and propellants with materials of construction, X-ray crystallography (including computer analysis of data), development of electronic and mechanical instrumentation, glassworking, mathematical, computing, library and information services

Non-metallic Materials Branch. Development an small-scale production of plastics and rubbers for use in exacting environments; simulated and natural weathering of materials (conducted partly at the Joint Australian-UK Tropical Research Unit in Queensland, Australia), fabrication of composites using asbestos, carbon fibre and glass fibre reinforcement, synthesis of high performance polymers and instrumental study of polymers by infra-red, nuclear magnetic resonance, ultraviolet and visible spectroscopy, vapour phase and gel permeation chromatography and thermal analysis methods.

Process Research Branch. Synthesis of intermediates and ingredients (low molecular weight and polymeric) for explosives and propellant systems, scale-up of processes to viable full-scale production routes and generation of data for the design of large-scale plant, maintenance of pilot plant facilities and manufacture in pre-production quantities of new or otherwise inaccessible materials, process development to reduce cost and improve quality of ingredients in regular demand and study of thermophysical properties of solids, liquids and gases over wide temperature and pressure ranges

Propellants 1 Branch. Development of propellants for guns, rockets and other uses from nitrocellulose and nitroglycerine bases; ballistic assessment, calorimetric and combustion studies on such propellants

Propellants 2 Branch. Development of plastic propellant with poly-iso-butylene and polyisoprene binders as used in UK and foreign meteorological rockets, development of propellants using rubbery binders developed from telomers ('liquid rubbers'), ballistic assessment of propellants for rockets, rheology of propellants and study of adhesion, adhesives and sealants

Engineering Facilities Branch. Workshop support to Scientific Branches, plant installation and maintenance, site maintenance and provision of project engineering support

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Guide to
Science and Technology
in the UK

mechanical (light structural research, and special heating and cooling problems).

Electronic Techniques

Projects Group

Projects (1) - mathematical, modelling and evaluation techniques (study of performance and design of complex systems by means of mathematical models of these).

Projects (2) - aircraft systems (mechanical); aircraft systems (electrical); trials.

Projects (3) - component development.

(xii) *Inspection* - inspection of aircraft, aircraft accessories, raw materials and manufactured parts; measurement of complex shapes; weight and centre-of-gravity determinations.

(xiii) *Workshops* - Work Planning, Development and Advisory Services

Development - development of workshop processes; technical services; advisory and training services.

Other Services

Manufacture - general engineering, maintenance and wind-tunnel operation.

Manufacture - general machining.

General Engineering

Maintenance

Wind-tunnel Operation.

(B) EXPLOSIVES RESEARCH AND DEVELOPMENT ESTABLISHMENT

The main fields of work at the Explosives Research and Development Establishment (ERDE) is R&D of explosives, solid rocket-propellants and initiatory and pyrotechnic compounds for use by the UK armed services. Other activities relate to non-explosive substances - polymers, elastomers and adhesives - and the employment of refractory whiskers in ultra-high-strength compositions designed for engineering applications. One specialised branch carries out development of processing equipment for the explosives industry and can also prepare pilot-scale quantities of unusual chemicals. The site occupied by the establishment has been used for explosives making since 1560; originally in private hands, the powder mills were purchased by the government in 1787 and were taken over by the ERDE at the end of the Second World War.

Research and development is conducted by seven technical branches, with supporting drawing offices, engineering production, library and information services. The branches comprise one for explosives, two for propellants, two for materials, and one each for analysis and ingredients and chemical engineering.

The Explosives Branch concerns itself mainly with the development and trial of sensitive initiatory explosives, of explosive and electrostatic risks, applications of high-speed photography for recording mechanical and explosive phenomena; noise evaluations (including sonic-boom measurement); realisation of remote control methods for use in the manufacture and development of explosive substances; gas kinetics; and polymer

technology, for which a small-scale development plant and laboratory facilities equipped to investigate physical and ageing characteristics are available.

The subject of propellants' research at ERDE is divided into two main branches: propellants based on nitro-cellulose; and composite propellants based on plastic or rubbery binder systems. These branches are denoted Propellants 1 and Propellants 2, respectively. The first branch carries out the processing on an experimental scale of nitro-cellulosic propellants, work which involves factors similar to those found in plastics processing; studies of the combustion mechanism of propellants and of the degradation of organic materials; rates of burning and calorimetric measurements in connection with ballistic properties; and a variety of non-destructive testing techniques.

Propellants 2 makes precise measurements of the thermal conductivity of liquids, gases and supercritical fluids and is equipped to undertake equivalent assessments in respect of the viscosity and dielectric constants over wide ranges of temperatures and pressures. It studies convective and radiative heat transfer from flames and gases; and investigates convective heat transfer to cryogenic fluids in the neighbourhood of the critical point and at supercritical pressure, and to liquids under supercooled, boiling and supercritical conditions. Other work concerns the development of sealants and adhesives for metals, plastics, leather, and paper; the rheological conduct of various stiff pastes; surface chemistry of highly viscous organic liquids; measurement of the size and distribution of particulate solids; and the technology of the formulation, manufacture and handling of stiff pastes and slurries based on curable and non-curable liquid organic polymers.

The two other related branches of ERDE are called Materials 1 and Materials 2. Materials 1 carries out both fundamental and applied chemical and physical research in the realm of polymers. It also operates an advisory service on polymer applications, and, jointly with a Tropical Research Unit in Queensland, Australia, supervises long-term environmental trials of these materials. The Branch, under the heading of polymer physics and engineering, investigates the physical parameters of non-metallic materials and reinforced plastics; its work in polymer chemistry covers the synthesis of polymer systems, the characterisation of polymers, and the stability of polymers when subjected to heat, ultra-violet light and high-intensity radiation; and research into the development and applications of the polymers includes injection moulding, extrusion, milling, and compression moulding, the measurement of physical properties, and the effect of such contaminants as explosives, propellants and gasoline.

Materials 2 branch studies fibre-reinforced materials and undertakes research into the growing of short fibres, or whiskers, in ceramics. Equipment for this work includes high-temperature (about 1,600°C) furnaces and high frequency heating apparatus; processing plant for sizing whiskers; micro- and macro-testing machines for whiskers; and both an electron microscope and various optical instruments.

The sixth technical branch studies the preparation, the properties, and the reactions of constituents of explosives and propellants. Known as the Analysis and Ingredients branch, it also deals in polymer technology and can offer advice on many aspects of hazardous chemical materials, particularly the properties of stability and compatibility. The branch carries out the synthesis of explosives and studies the constituents of chemical fuels, oxidisers and antioxidants, ballistic additives, stabilisers and curing agents. The branch utilises a wide range of instruments and apparatus, including spectrometers, refractometers, optical microscopes, calorimeters, chromatographs, and an atomic absorption spectrophotometer, and has a selection of environmental testing ovens and combustion equipment. For crystallographic research, it possesses X-ray apparatus, goniometers, a powder diffractometer, and a polarising microscope.

The Chemical Engineering Branch of the ERDE is equipped to make various hazardous substances and mixtures and is especially concerned with safety, instrumentation, and remote control techniques. It can manufacture experimental high explosives, ingredients for polymers and rocket propellants, asbestos whiskers and other short fibres, on pilot-scale and full-scale levels. Work on crystallization includes nucleation and crystal growth, and the control of shape, size, and size distribution of crystals. Other

activities include intensive drying - or stripping - of high boiling liquids; theory and practice of mixing stiff pastes; and the design and manufacture of special scientific glassware and electronic instrumentation systems.

A few important, exploratory aspects of explosives research at ERDE are undertaken by small study groups not part of the main branches. The investigations are concerned with spectroscopy, flame and explosion phenomena, and autoxidation and antioxidants.

(C) ROYAL RADAR ESTABLISHMENT

The Royal Radar Establishment (RRE) is the largest centre for research in electronics in the United Kingdom. Its history can be said to have begun, simply enough, with the then new technique of radio direction finding (rdf) in 1935, work in which R.A. (later Sir Robert) Watson-Watt, of the Radio Research Station (RRS) at Slough, Buckinghamshire, was involved as the head of a small team of scientists. This team was transferred, also in 1935, to the coast of Suffolk where it functioned under the administration of the Air Ministry and was joined by an Army research team which was interested in rdf as an aid to the direction of anti-aircraft guns and searchlights.

In 1939, at the outbreak of the Second World War, the Air Ministry team was evacuated briefly to Dundee, Scotland, during which period it was known as the Air Ministry Research Establishment (AMRE), and the Army team was sent to the Air Defence Research Establishment at Christchurch, in Hampshire. The following year, AMRE returned also to southern England (Swanage, Dorset) and its title was again changed - to Telecommunications Research Establishment (TRE). During the course of the war, TRE was transferred to Malvern, in Worcestershire, and the original Army team became first the Air Defence Research and Development Establishment and later the Radar Research and Development Establishment (RRDE). TRE and RRDE were merged together as the Radar Research Establishment - which became the Royal Radar Establishment in 1957. Officially, RRE is regarded as having originated in 1942, when the Malvern period began. The Establishment became a research station of Min Tech in February, 1967, and of the Ministry of Aviation Supply in October, 1970.

The principal objective of RRE is still to apply electronic techniques to the development of equipment for the armed services of the United Kingdom. A second important activity is R&D in the field of air traffic control (ATC) on behalf of the DTI (which is responsible for British civil aviation). Yet another function is the application of appropriate results of the R&D effort for industrial purposes, work which is carried out by an Industrial Applications Unit. When the situation requires it, prototype civil equipment may be constructed by the RRE in association with industrial companies. Substantial support is given in all this work by the Physics and Electronics Department, which is concerned with research in semiconductor technology and analogous subjects, computers, and computer software for real-time usage. An Electronics Materials Unit serves to promote the industrial production of high-grade crystals; in doing this, the unit provides the initial supplies of material.

The technical departments of the RRE are serviced by three other departments: engineering (which possesses workshops, equipped with many advanced machine tools and other equipment, and drawing and design offices); an aircraft department - which operates a fleet in which experimental electronic equipment can be test-flown; and an administration department.

Until recently, a College of Electronics was associated with RRE. The college served chiefly to train craft and technician apprentices, and also undertook the induction of new entrants to RRE and provided specialist electronic courses. However, it has now been closed, and the academic training of RRE apprentices has been transferred to Worcester Technical College.

(D) AEROPLANE AND ARMAMENT EXPERIMENTAL ESTABLISHMENT

In the early days of military aeronautics, in 1914, a small-scale unit was formed at