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Military research.

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Industry benefits from military research

Now part of the Ministry of Technology, the Explosives Research and Development Establishment is keen to share much of its expertise and facilities with British industry. ERDE has projects in several fields of industrial interest, amongst which are fibre-reinforced materials and the growth of refractory whiskers

1 Dr L J Bellamy, Director of ERDE, looks forward to fruitful collaboration with industry

In February 1967, the Explosives Research and Development Establishment, at Waltham Abbey, Essex, became part of the Ministry of Technology, and thereby the whole of British industry became the beneficiary of a wealth of expertise, facilities and knowledge which has been diligently built up in this world-famous armed-services laboratory since its foundation in 1945. Dr L J Bellamy, **1**, the director of ERDE, is justifiably proud of the services that his team of nearly 200 scientists and engineers can offer industry through the Mintech Interlab and industrial liaison schemes. And he keenly hopes that industry will respond to ERDE's implementation of the Ministry's policy of encouraging its establishments to work more closely with industry, and will see ERDE as an organization geared to the needs, and sensitive to the special problems, of industrial research activities.

Dr Bellamy and his colleagues are confident that the response will build up and that there will be many fruitful collaborations with commercial concerns once industry recognizes the changing emphasis at ERDE between military and civil research. Undoubtedly, the recent—and first ever—Open Days (12-14 June) will have helped this cause enormously.

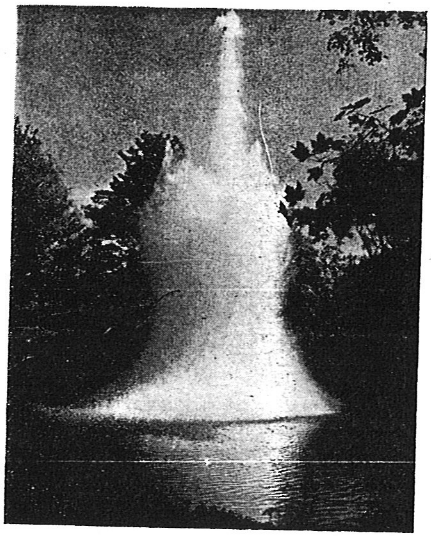
In its early years, ERDE was concerned exclusively with work (much of which gained world-wide recognition) on liquid and solid propellants and explosives to meet the stringent requirements of the three armed services. (Waltham Abbey has been associated with explosives since the 16th Century and many of the buildings of the now defunct Royal Gunpowder Factory are still used by ERDE.) But the past ten years or so have seen an extension of the Establishment's work to cover non-explosive materials—a shift of emphasis no doubt reflecting to some extent the change of the operating Ministry: first, Supply, then Aviation, and now Technology. Today, about 20% of ERDE's total research and development effort is devoted to high explosives and initiating compositions, 50% to propellants (almost exclusively solid), and 30% to polymers, elastomers, adhesives and fibre-reinforced materials.

Despite the dilution of the explosives and propellants work and the shift of emphasis towards more civil research, all three armed services still depend exclusively on ERDE for the development of their new propellants and explosives, and to solve their problems in this area. And it must be emphasized that ERDE is the only Government establishment concerned with research on, and development of, solid propellants, and is the sole place in the UK where solid composite rocket propellants are developed.

There are seven scientific-cum-technological branches within ERDE. Two of these are concerned with the non-explosive materials, one with responsibility for the chemistry and physics of polymers and allied substances, the other undertaking work on fibre and whisker-reinforced materials and on the growth of refractory whiskers (long needle-like crystals).

Then there are two branches dedicated to propellants, one dealing with those based on nitrocellulose, the other with composite propellants using plastic or rubbery binder systems. The Explosives Branch is primarily absorbed with improving and evaluating, **2**, the performance of high explosives and initiating compounds, and with assessing safety requirements. (An important function of ERDE is to provide safety information—summarized in a 'Safety Certificate'—to almost all users of explosives and propellants.)

The job of the Chemical Engineering Branch is to provide the means and equipment for processing substances on a production scale (pilot-plant work). Among its special interests are unit operations such as crystallization and mixing. The investigation of the preparation, properties and reactions of a wide range of ingredients of explosives, propellants and polymers is the brief of the Analysis and Ingredients Branch. It also offers an advisory service on the stability, compatibility and surveillance testing of hazardous materials. Another



2 The effectiveness of an underwater explosion can be measured from the shape of the shock wave it generates

advisory service is run by Materials 1 Branch (which has long-term environmental testing experience) on the applications of polymers.

High strength composites

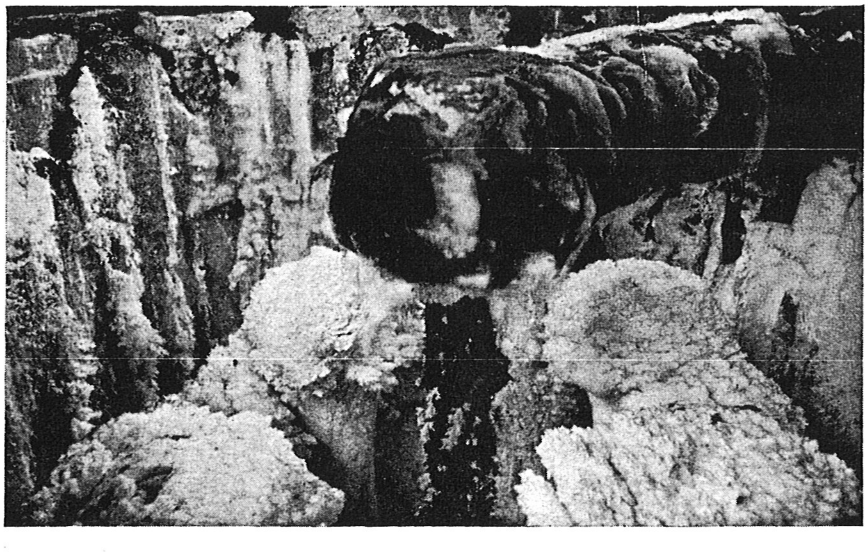
One of the major interests of ERDE—and one that will attract increasing attention from industry as conventional materials reach the limits of their development in certain applications—is the fibre and whisker-reinforcement of metals and thermoplastics. This work is now concentrated on the use of two types of reinforcement—refined graded asbestos fibre for good properties at the lowest cost, and silicon carbide whiskers for the best properties at a reasonable cost on a mass production basis.

The incorporation of asbestos and chopped carbon fibres, and of silicon nitride, silicon carbide and potassium titanate whiskers, into a wide variety of thermoplastics (polyethylene to nylon) has been studied at ERDE for the last two years. The results have shown that graded-asbestos fibre reinforced plastics are technically the most promising composites. Strongly in their favour, too, is the cheapness and availability of asbestos. So these asbestos composites should prove strong competitors to comparable glass-fibre reinforced plastics.

This work has revealed the importance of the length/diameter ratio in determining the degree of reinforcement obtained, and the significance of surface-treating the asbestos fibre (glass fibres are usually surface treated) to improve the resin-to fibre bond strength. Some of the tensile and flexural results obtained

Polymer	Specific gravity g/cm³	Tensile strength lb/in²	Flexural modulus lb/in² x 10⁶	Price of polymer pence/lb
Polypropylene	0·91	4,400	0·15	39
+ 40% asbestos	1·24	6,800	0·77	
Toughened polystyrene	1·04	3,500	0·27	19
+ 40% asbestos	1·36	9,500	2·02	
ABS	1·04	5,300	0·22	40
+ 30% asbestos	1·27	13,900	1·13	
Polycarbonate	1·22	9,500	0·25	72
+ 30% asbestos	1·42	16,000	1·46	
Nylon 6	1·14	11,000	0·3	72
+ 30% asbestos	1·48	19,000	1·0	
Nylon 66	1·12	11,000	0·3	72
+ 30% asbestos	1·33	19,000	1·3	
glass-filled	1·33	18-24,000	0·8-1·2	78

3 Tensile strengths and flexural moduli of six commonly used thermoplastics, unfilled and filled with graded asbestos fibre



4 Silicon nitride whisker wool in a high-temperature reactor. When removing the whiskers, the operator wears a protective breathing suit to avoid inhaling the very fine whisker dust which arises during handling

at ERDE for commonly used materials filled with graded asbestos fibre are shown in **3**. Tensile strengths up to 24,000 lb/in² and flexural moduli up to $1·6 \times 10^6$ lb/in² have been achieved with materials capable of being processed on conventional injection moulding machines. Moduli up to 6×10^6 lb/in² can be obtained with styrene based composites, but these materials are difficult to mould except by the use of ram-jet injection moulding or by compression moulding.

The best mechanical properties of a composite are attained by packing in the maximum number of fibres. This means aligning the fibres, which preferably should be straight and stiff. (Most pressings have been of a particular chrysotile asbestos about 2 mm long and 50 μ in diameter.) ERDE has refined two wet processes for aligning fibres after they have been cleaned and sieved into lengths. In one, they are extruded (4-5 ft/sec) into alignment in a 'frozen' filament of alginic acid carrier (2% fibre and 3% alginate) which is wound into a mat, and then cut off, washed and dried. The alginate is removed by controlled combustion leaving the aligned fibres. In the other process, the viscous carrier is glycerine. The alignment is still brought about by extrusion (this time through a slit) and the carrier is removed by suction from a filter bed. The excess glycerine is washed off and recycled. This process is operated on both a batch and continuous basis.

With both processes, alignment can be achieved with asbestos fibres, chopped carbon fibres, glass fibres, mixed fibres, and whiskers such as silicon carbide. The mats or sheets of aligned fibres are built up to the shape required (the sheets can be crossed or laid in the direction the strength is required), resin is added and the shape moulded in a heated press or autoclave to the finished form. To ensure a high enough packing density of the fibres, pressures up to 1,000 lb/in² are necessary.

Alongside their work on reinforced plastics, the ERDE materials scientists have been studying whisker-reinforced metals. A number of fabrication techniques and host metals have been tried, from which has emerged a 'pressure casting' process. For silicon carbide in aluminium, this process produces void-free composites with the whiskers intact and completely stable. Billets and various shapes (including actual components) have been made in this way and have been hot worked and machined.

The silicon nitride and carbide whiskers for the reinforced materials projects are grown in ERDE. Thus the Establishment has built up an enviable body of expertise in vapour phase chemical reactions—the only satisfactory way of mass-producing silicon nitride and carbide whiskers—and has accumulated considerable data on the design of high-temperature chemical reactors in which the whiskers are grown. Typically, 1 kg of raw 'wool' of silicon nitride whiskers can be grown in 60 hours at 1,400°C in an ERDE reactor, **4**.

Polymer technology

One industrial outgrowth of work for the armed services, particularly the Army Department, is the development of rubber-proofed fabrics for use in flexible storage containers for a wide range of liquids, hovercraft skirts and aircraft arrester tapes. Another project of industrial interest is the design and strength testing of joints between the proofed fabric sections of Dracone flexible barges and large pillow tanks.

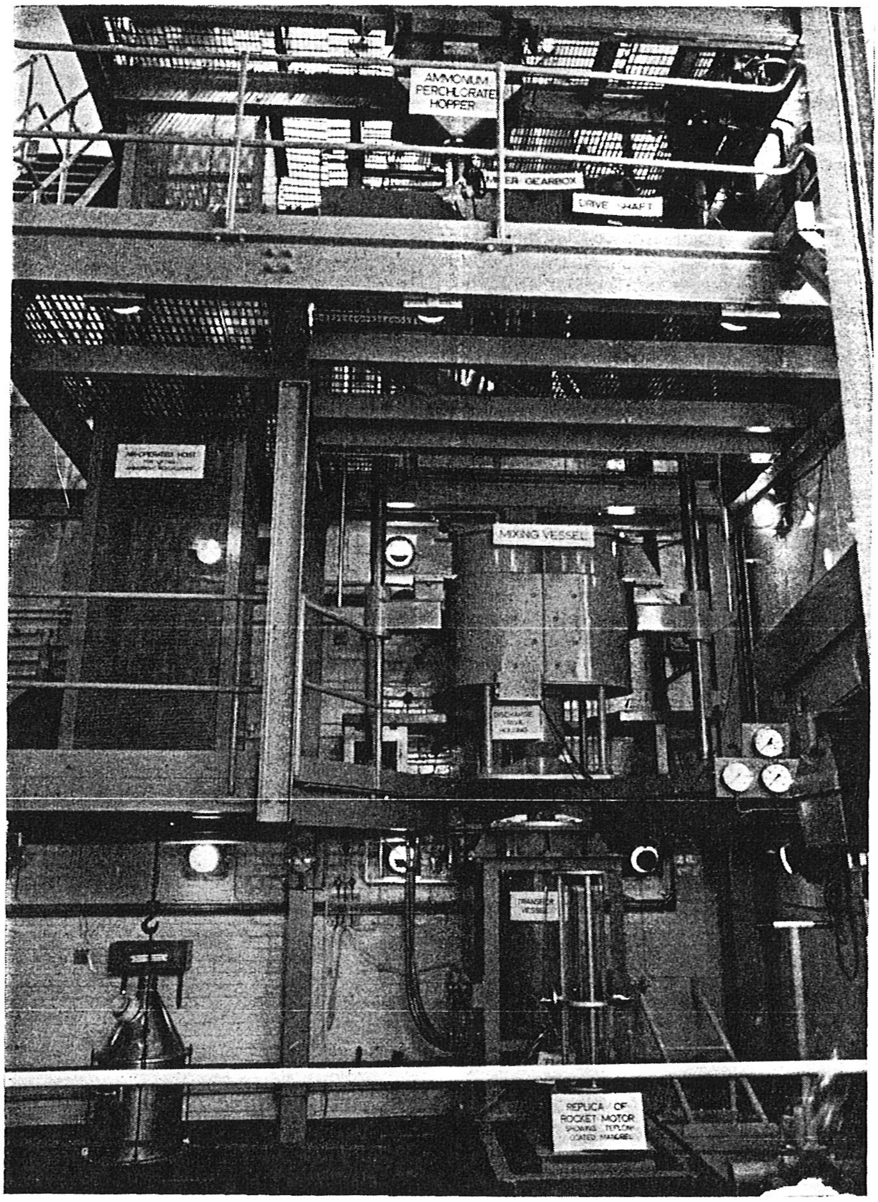
The evaluation of new plastics and rubbers is also carried out at ERDE. Special moulds have been designed to produce test specimens that are needed for the measurement of the properties of these materials, and an investigation is in progress into the production of inexpensive injection moulds made from metal-reinforced thermosetting resins.

Accelerated and tropical ageing trials are other key features of ERDE's polymer research programme, which also includes the investigation of component failures under a variety of operational conditions. An outcome of an investigation could call for the development of new materials as the only satisfactory solution to the problem. This is exemplified by the creation of a series of high electrically conducting rubber compounds to prevent the build-up of static electricity on the solid rubber tyres of tracked vehicles. The best of these rubbers also proved to have first-rate wear characteristics and favourable thermal properties, and one of them, L7/70, is being evaluated in commercially produced tyres.

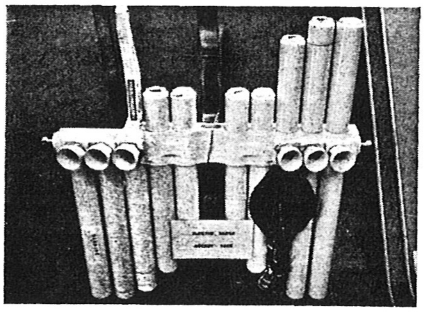
Solid propellants

Because the UK's advanced solid propellant research is the responsibility of ERDE, the Establishment has had to build up an impressive range of facilities for processing all types of propellant—from laboratory to full-scale production plant—and for evaluating these propellants.

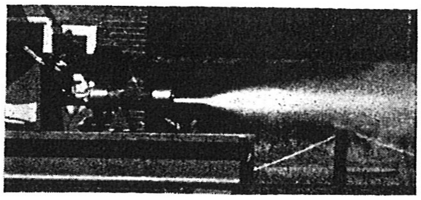
The solid propellants developed at ERDE are not only used in weapons but also in space research vehicles and meteorological rockets, and as convenient sources of packaged power for the Martin Baker ejection seat, **6**, fire-drenching equipment, engine starters,



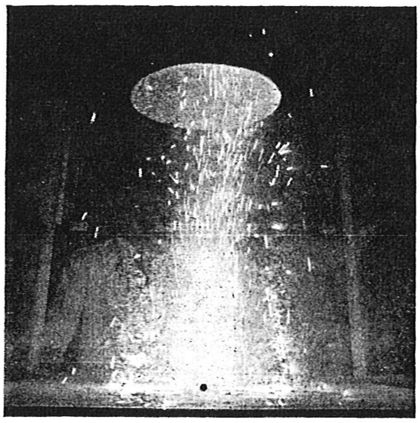
5 The mixing and filling plant for rubber propellants. The mixing vessel is in the dropped position. An interesting feature is the use of a labyrinth fluid seal to protect the blade-shaft carbon seal from the hazards of dust in the mixer



6 Martin Baker ejector-seat power-pack. The rocket layout is determined by the seat structure, not by ballistics



7 Testing small rocket motors on a static firing bed



8 Solid propellant burning at atmospheric pressure in a special cabinet for temperature studies

and signal and line-throwing rockets. Essentially, four types of propellant—plastic (UK invention), rubber-based, extruded cordite and cast double-base—are used to produce the wide range of characteristics needed for different applications. The control of burning rate, the improvement of energy content, wider temperature range of operation (—60° to + 160°F is often demanded), and the reduction of smoke and flash are some of the problems currently being tackled, **7**, **8**.

A key feature of ERDE's work on rubber composite propellants is the N550 mixing and filling plant, **5**, which was constructed in 1962 to the Establishment's design and specification. At present, it is adapted for the filling of several small rocket motors from a single mix, but it could equally well be used for a large motor requiring several mixes. The nucleus of the plant is a Baker Perkins stainless steel vertical mixer, capacity up to 300 kg, specially designed to handle viscous propellant slurries efficiently and safely. Two equal-speed, semi-helical mixing blades rotate in fixed bearings. The water-jacketed vessel, which has a figure-of-eight cross-section, is raised and lowered hydraulically. Blade-to-vessel clearance is 6 mm. The plant incorporates an automatic drenching system actuated by an infrared detector, and mixing or discharging can be carried out in an inert atmosphere or under a vacuum of 5 mm of mercury. All potentially hazardous operations are remotely controlled from a separate concrete building.

Advanced explosives

To improve the performance of high explosives and propellants, new and untried components have to be experimented with as oxidizers, fuels and binders, and high quality charges have to be made for assessment. ERDE has now developed a facility for undertaking this exploratory work in complete safety. With the Advanced Explosives Remote Processing Facility, a wide range of new compounds, in quantities equivalent to 15 lb of TNT, can be handled. Ingredients can be stored in isolation, transported to processing areas, and accurately dispensed. Compositions can be vacuum-mixed and moulded, heat-cured in isolated ovens, and inspected, X-ray examined, assembled into test charges, and fired. The whole sequence is remotely controlled and the operators are fully protected and separated from the explosives by heavily reinforced concrete structures which can withstand repeated explosions.

Consultative service

ERDE offers a limited, free consultative service to industrial firms which have problems related to expertise readily available in the Establishment. But problems involving extensive research or demanding the use of equipment and special facilities may be undertaken for a fee. Free or not, there is much in ERDE which could be of immediate benefit to a host of British engineering firms. They should test the service. □