✓ WASC 2275

History of Westcott

History of Westcott

By Mark Perman

CONTENTS

1. INTRODUCTION

Although rockets were used by the British Navy as long ago as 1801, during the Napoleonic Wars, the continuous history of rocket technology in this country dates only from just before the Second World War, when the Projectile Development Establishment Aberporth was set up by Dr H.J. Poole - "The Father of British Rocketry".

At the end of World War II the full realisation of German achievements in rocketry stimulated British interest and motivated Sir Alwyn Crow and Sir William Cook, of the Ministry of Supply, to form the Guided Projectile Establishment, to be responsible for research and development on ground-1aunched guided missiles.

The 623 acre site at Westcott, 9 miles west of Aylesbury, was a disused RAF base which had been used from September 1942 to April 1945 by No. 11 Operational Training Unit, RAF, and from April to May 1945 as a prisoner of war repatriation centre.

Many of the existing buildings were utilized and, because these had been intended to last only for the duration of the war, extensive conversion and modernisation were necessary to provide laboratories, specialised facilities, a drawing office, workshops, fuel storage installations, a photographic laboratory, a wind tunnel, and test beds for firing rocket motors. From the early aerial view shown in Fig. 1 it is possible to identify many features still in existence today, including the main runway, the main workshop which was originally an aircraft hangar, and the P2 Test Site referred to in Section 5.

The earliest test beds were designed for liquid propellant rocket engines; mainly for combustion system research and development. Massive test beds permitting the static testing of complete missiles were also constructed, taking advantage of Ordnance Factory experience of building construction. After a serious accident in November 1947 stringent safety precautions were promulgated and applied to the construction and operation of test sites so that, for instance, there was no direct vision between the test team and the motor or missile, as illustrated in Figure 2 which is a photographic reproduction of one of the oldest drawings made at Westcott. By 1949 some 15 test beds were in operation and by 1951 the number had increased to 24 including one for solid propellant motors of 8 tons thrust.

In 1947 the Establishment became the Rocket Propulsion Department of the Royal Aircraft Establishment. Its terms of reference were narrowed to "research and development on all aspects of rocket propulsion for civil and military applications", while work on non-propulsion aspects of guided weapons was transferred to the newly named Guided Weapons Department of the RAE. After Cook left Westcott Alec Baxter was transferred from Farnborough as Superintendent, and later in 1947 Air Commodore Charles Dann was appointed as Chief Superintendent. In 1951 Dann was succeeded by Dr T.P. Hughes who remained until Mr J.E.P. Dunning took over, as Director, on December 1st 1955 - a post which he held until 1972.

At Westcott the research was organised in sections on Heat Transfer, Combustion Chamber Design, Fuel Supply, Materials, and Instrumentation. Much of the initial work was in the field of air breathing propulsion.

2. THE FIRST LIQUID PROPELLANT ENGINES

Following German practice, research in the immediate post-war years was concentrated on liquid bi-propel1ant rocket engines, mainly for military purposes. To gain knowledge of the "state-of-the-art" in Germany investigations were carried out on German missiles and their propulsion units, with a team of German scientists and technicians - some from the Peenemunde Establishment which developed the German V2 rocket - on the staff. In the guided weapons programme emphasis was on air-to-air and surface-to-air defensive missiles, of which three types were being developed, i.e. Red Duster, Red Shoes (predecessors of Bloodhound and Thunderbird respectively) for the Army and Seaslug for the Navy.

The RAE required flight test vehicles for the study of aerodynamic, structural and control problems encountered at supersonic speeds, and between 1946 and 1951 engines were developed at Westcott for the first two of these. The engine for the RTV (Rocket Test Vehicle) I, using liquid oxygen and a mixture of methyl alcohol and water was the first liquid propellant rocket engine developed in Great Britain. The RTV I, illustrated in Figure 3, was used in pioneering work on control and guidance, the results of which formed the basis of systems that were to remain in use for many years. The KPI engine for the RTV II, powered by hydrogen peroxide and kerosine, was developed in the early 1950s.

A series of engines using hydrogen peroxide and C Fuel (57% methanol, 30% hydrazine hydrate and 13% water) was also under development during this period and included the Beta I, a twin combustion chamber unit developed in 1948/49 which was used by the Fairey Aviation Company for a model vertical takeoff subsonic aircraft. This was followed by the larger Beta II used in supersonic aircraft. Also developed were a liquid oxygen/kerosine engine providing a thrust of 4000 pounds for 3 to 5 minutes and used as a booster for aircraft, and the KP4 engine for the GPV Test Vehicle.

Since its earliest days the Establishment has collaborated closely with industry. An early collaborative project was the Gamma engine designed at Westcott and made by Armstrong Siddeley Motors (subsequently Bristol Siddeley and now BAJ Vickers Ltd) which acquired the design in 1955. This engine, using HTP steam and kerosene, formed the propulsion unit of the Black Knight re-entry research vehicle, first launched in 1958, and was the first British rocket engine to have self-driven pumps and to incorporate a silver plated nickel gauze catalyst to accelerate the decomposition of the hydrogen peroxide, thereby bringing about spontaneous ignition of the kerosine by hot steam and oxygen. A schematic diagram of the Gamma 2 engine is shown in Figure 4.

An engine powered by nitric acid and kerosene was used in the NK 1 - a flight test vehicle which demonstrated the feasibility of storing nitric acid in a propellant tank for periods of over a year and paved the way for the development of packaged liquid propellant technology. Because of its capability for long term storage nitric acid was chosen as the oxidiser for Seaslug.

In the Services alarm arose from the handling and storage problems associated with hypergolic (spontaneously igniting) propellants, and attention was turned first to non-hypergolic systems using hydrogen peroxide, nitric acid and liquid oxygen, and secondly to the development of safer monopropellants. Although a number of monopropellants were already in use which were relatively easy to store and handle, most tended to behave as high explosives, and more stable compositions were therefore sought. The first of these developed at Westcott was based on a solution of ammonium nitrate and methylamine nitrate in water with the addition of a catalyst. The main disadvantage of these propellants was their poor low temperature limit and further research was aimed at improving this.

3. THE BEGINNING OF SOLID PROPELLANT MOTOR TECHNOLOGY

Work on solid propellant motors was started in 1949. An urgent requirement for supplies of new types of solid propellant boost motor for missile trials was recognised. New test beds were constructed and the Solid Propellant Laboratory area was established. Initially, work was concentrated on motors using extruded cordite with a steel motor case, and on improving the technology of loose inhibited cordite charges. Motors developed during this early period included Gosling, Magpie, Linnet, Scarab and Ladybird. The Gosling motor was used as the boost motor in early trials of Red Duster, Red Shoes and Seaslug.

In 1951 discussions were held by representatives of the Directorate of Guided Weapons Research and Development, the RAE/RPD and the Explosives Research and Development Establishment, Waltham Abbey, on the allocation of responsibility for development of solid propellant motors between the establishments and the Royal Ordnance Factories. Established policy was for ERDE to be responsible for propellant development and for RAE/RPD to be responsible for design and development of motors, for their incorporation into the missile, and for missile trials, while the Royal Ordnance Factories were responsible for the production of motors and other components of missile systems. Recommendations were made that the trials stage should be transferred to the ROFs, which thus assumed responsibility for development of the missile system with the motor as a component part, for the final clearance of the missile and all its components, for large scale production of motor hardware and for propellant manufacture and filling. An estimate of the number of filled motors required per year for the next few years was 25000, and the amount of cordite propellant required, 1000 tons.

Concurrently with these policy decisions ICI Ltd were given a contract to develop and manufacture motors using charges manufactured by the cast double base process and to set up their own production facilities. Thus began the collaboration which still exists whereby IMI Summerfield (formerly a subsidiary of ICI Ltd) carries out design, development, testing and manufacture of motors using the cast double base system.

During the late 1940s new plastic propellants based on ammonium perchlorate and polyisobutene were developed at the Explosives Research and Development Establishment, Waltham Abbey, continuing the pioneering work of Dr Poole at PDE Aberporth. Their use created a need for new techniques of filling the motor case and shaping the charge, and to meet this demand an experimental filling factory was instigated at Westcott in 1950 and completed in 1952. Limited numbers of cordite and plastic propellant boost and sustainer motors were filled to enable trials to be carried out before large scale production was consigned to the Royal Ordnance Factories. The advent of plastic propellants marked a milestone in the history of solid propellants, making the technique of case bonding possible for the first time. The range of burning rates and motor diameters available to the motor designer was considerably widened by this innovation and large motors filled with several tons of propellant became feasible. An early design based on this concept was the sustainer motor for Red Shoes.

The technology of solid propellant motors advanced rapidly, their ease of handling and readiness for immediate use making them the preferred choice for military use. By 1953 they had become, with the exception of the ramjet sustainer engines in Red Duster, the sole means of propulsion for British guided missiles - a virtual monopoly which they maintained until the mid-1960s.

4. EARLY SUPPORTING RESEARCH

As motor technology developed throughout the 1950s, so too did the need for supporting research, particularly in such fields as materials, chemistry, and physical and chemical studies of combustion processes. In 1951 a Combustion and Materials Division was formed to carry out research in support of the Liquid Engines and Solid Motors Divisions.

Collaboration with industry was intensified and contracts were placed with firms in the plastics and metals industries, particularly with Imperial Metal industries Ltd.

Early research on combustion followed two main trends: the effect of droplet size and pressure on the burning rates of liquid propellants; and the general characteristics of combustion and flow in rocket engines, using specially designed transparent rockets working at low temperatures and low pressures, and obtaining flow patterns by photographic techniques. One successful outcome of this work was the development of a stable monopropellant.

Materials research was concentrated on substances such as ceramics which were resistant to high temperatures and compatible with nitric acid. Zirconia, silicon carbide and a composite consisting of zirconium carbide bonded with molybdenum were among the materials found promising. Success was achieved in the development of ceramic combustion chambers and in new methods of fabricating combustion chambers. The Westcott establishment collaborated with ERDE Waltham Abbey in the search for suitable propellant tank materials. All available metals were investigated to determine their compatibility with nitric acid, and a technique for the film protection of light alloys was devised. The use of plastics, especially the f1uorocarbons, as substitutes for metals was considered for the first time and these too were tested for their compatibility with nitric acid, with a view to their use as propellant tank materials. Materials used in the fabrication of rocket motor components included Fibreglass resin and Durestos.

Other work undertaken in the early 1950s was concerned with expulsion charges, turbo-pumps, propellant feed systems and gas generators.

To keep pace with the expanding research programme new facilities were constructed including a Valve, Spray and Flow Laboratory for measuring valve and injector performance, cold and hot chambers for accelerated ageing tests, and a 9 metre (30 foot) tower on which a motor of 4000 pounds thrust could be fired on a turntable, as shown in Figure 5, enabling radio attenuation measurements to be made free from ground reflection effects and with the beam intersecting the exhaust jet at various angles. The completion, in 1952, of a new laboratory block for research on internal ballistics, heat transfer, pump development, etc. permitted the incorporation under one roof of much of the chemical and physical work which had hitherto been housed in remotely scattered buildings. By the mid-1950s the total staff of the Establishment amounted to nearly 1000.

5. MAJOR ACHIEVEMENTS OF THE 1950s

In 1953 the principle of the ballistic missile was conceived and it was decided that a liquid bi-propellant engine was best suited for this purpose. In 1955 Rolls Royce contracted to build an engine, designated RZ1 and using liquid oxygen and kerosene, which formed the propulsion unit of the Blue Streak ballistic nuclear deterrent.

To investigate the aerodynamic and acoustic phenomena associated with the launching of Blue Streak from underground tests were carried out at RPE with models at scales of 1/60 and 1/6. A model launcher was constructed from octagonal rings of reinforced concrete fastened together. Apertures in its walls accommodated the recording apparatus used for the tests. The 1/60 scale tests were made with a brass model measuring 2 inches in diameter and operating with compressed nitrogen (Fig. 6). For the 1/6 scale tests a model 21 inches in diameter was fabricated from light alloy sheet, and Gamma HTP/kerosene engines were installed. The site chosen for the development of Blue Streak was Spadeadam Waste in Cumberland, and Figure 7 shows the missile on its test site. Testing of the engine was undertaken at Westcott and demanded massive facilities capable of handling thrusts greater than any yet encountered, as well as new measuring and recording equipment, and additional safety devices. With this objective the P2 site which had already been modified for vertical firing was prepared and tests were started in 1958. A diagram of the site is shown in Figure 8. By I960 over 500 firings including ignition tests had been made.

After the cancellation, in 1960, of Blue Streak as a ballistic missile negotiations began which resulted in the formation of the European Space Research Organisation (ESRO) and the European Launcher Development Organisation (ELDO). Under ELDO its development as the first stage of the launch vehicle for Europa I was begun and work at Westcott continued on the RZ engines for this project.

A significant contribution to Britain's Upper Atmosphere Research Programme was the development, between 1955 and 1956, of the Raven motor. Measuring 5.26 metres (17 feet) in length and 455 mm (18 inches) in diameter and containing 975 kg (one ton) of plastic propellant, this produced a thrust of 11500 pounds for 30 seconds and was used as the propulsion unit of the Skylark Upper Atmosphere Research Vehicle which reached altitudes of over 100 miles as a single vehicle. An early launch is shown in Figure 9.

The development of the Cuckoo and Goldfinch motors also using plastic propellant, to act as boost motors, enabled even higher altitudes to be attained and Skylark rockets now reach altitudes of over 800 km (500 miles), with payloads exceeding 140 kg (300 pounds) consisting largely of sophisticated instrumentation for the measurement of energetic particles and electrical fields. Skylark is the only British sounding rocket capable of investigating the structure of the upper ionosphere and the origin of auroral particles. Since its first launch in 1957 over 375 Skylark rockets have been launched, including a number on behalf of Germany, Sweden, Norway, the Argentine and ESRO. Development over the years has led to its reputation as one of the world's most versatile sounding rockets which can be adapted to suit a wide range of applications.

The Cuckoo motor was also used as a second stage in Black Knight. The Rook motor, similar in size to the Raven but filled with a faster burning propellant, was used as the first stage boost of the Jaguar supersonic test vehicle.

A series of three solid propellant motors with short burning times was required by the RAE Structures Department in 1957 for use in work on flutter in aircraft structures. Because the motors were to be fired simultaneously or at regular intervals, on manned aircraft, reliability and safety were of paramount importance. The outcome of this project was the development of the Imp I, Imp II and Imp III motors, using plastic propellant. The range of Imp motors, the smaller of which share a common 25.4 mm case, has since been widened to include motors with burning times varying from 0.0125 to 0.07 seconds.

Development of the Snifter range of motors, using extruded double base charges and having burning times between 0.0135 and 0.07 seconds, with a standard 22 mm case, also resulted from this requirement. The standardized design of both these ranges of motor has the advantage that, by changing the propellant composition and nozzle throat diameter, new variants can be introduced to meet new requirements as they arise.

6. ADMINISTRATIVE CHANGES

The administrative link with RAE was severed in August 1958 and the name of the Establishment changed to the Rocket Propulsion Establishment, under the Controller of Guided Weapons and Electronics, Ministry of Supply. Close collaboration was maintained with RAE and with ERDE, Waltham Abbey and the Royal Radar Establishment, Malvern. Further administrative changes were to follow: in 1959 the name of the MOS was changed to Ministry of Aviation and in 1966 this was absorbed by the newly formed Ministry of Technology. After the dissolution, in 1970, of "Mintech" the RPE became the responsibility of the Ministry of Aviation Supply until it was transferred to the Ministry of Defence in 1971.

7. CIVIL PROJECTS OF THE 1960s

Rapid growth in solid propellant motor technology continued throughout the 1960s. The attainment of higher altitudes and greater payloads aroused the interest of the Meteorological Office and, in collaboration with Bristol Aerojet, the Chick and Bantam motors were developed at Westcott for the Skua Meteorological Test Vehicle which was first fired in January 1964. Over 50 Skua vehicles were launched during the next two years and it was purchased by the French and Spanish Governments. The Lapwing motor was developed to form the propulsion unit of a larger meteorological sounding vehicle, Petrel, which is capable of launching 14 kg to an altitude of 200 km.

In May 1966 development was begun of Black Arrow, Britain's only satellite launching vehicle, designed to launch a payload of 1^5 kg (320 pounds) into low polar orbit. The design was based on Black Knight and the materials used included aluminium alloy, steel, titanium and magnesium. The first stage was powered by a Rolls Royce Gamma 8 engine burning kerosene and hydrogen peroxide, with eight combustion chambers, and the second stage by a Gamma 2 engine, also using kerosene and hydrogen peroxide. At RPE effort was concentrated on the development of the Waxwing apogee motor, illustrated in Figure 10, to form the third stage of Black Arrow. Special facilities were required for the testing of this motor under vacuum conditions. Other motors developed for use in Black Arrow included the Siskin II and the Imp XV.

The first launch from Woomera in June 1969 was a failure and of two subsequent attempts, in March and September 1970, only the first was successful. Black Arrow made its first operational flight from Woomera in October 1971, placing the satellite Prospero into near-polar orbit.

8. PACKAGED LIQUID PROPELLANT MOTORS

In the field of liquid propellant motor technology it had long been realised that, to compete with solid propellant motors in terms of storability and ease of handling, revolutionary designs were needed for use by the Armed Services.

Advances in guidance and control techniques had imposed a demand for a tenfold increase in missile range and thus for propulsion systems with improved performance capable of meeting this requirement. By the late 1960s a growing awareness had arisen in the UK of the advantages of packaged liquid propellant motors - sealed units which form an integral component of the propulsion system and can be stored in readiness for instant use when required - a feature which has obvious advantages for military applications. Attention was therefore turned from the development of conventional liquid propellant systems for civil applications to research aimed at the inception of a packaged unit which would meet the severe demands of military use, including storability, the capability to withstand wide extremes of temperature and rough handling, high performance, a smoke-free exhaust, variable thrust and the facility of being stopped and re-started.

At Westcott the propellant combination inhibited red fuming nitric acid and mixed amine fuel was selected and the advantages of packaged systems have been demonstrated in flight trials of a specially designed test vehicle.

9. EXPANDING RESEARCH OF THE 1960s

The continuing demand for rocket motors to satisfy a wide diversity of applications imposed an increasing need for supporting research aimed at providing motors with improved performance and reliability, while the new technology of packaged liquid propellant motors created problems of materials compatibility and strength of components. During the 1960s the research programme was diversified and included work on materials and techniques of construction, the compatibility of liquid propellants with materials, rocket motor performance, the attenuation of radio signals by rocket exhaust plumes, various catalysts for hydrazine decomposition, and thrust vector control.

An extensive programme on cryogenics, aimed at the development of liquid hydrogen as a rocket fuel, for use in the third stage of a satellite launching vehicle, was begun in 1962.

The RPE retained an interest in satellite propulsion until 1973 and a programme on resistojets and electrical propulsion was carried out, with specially equipped laboratory facilities.

Several major building projects were completed, including a new office block in 1968 and a new materials laboratory shortly afterwards. The addition of a computer to the Establishment's facilities permitted more rapid analysis of data, and made possible the use of predictive techniques in areas where experimental assessment is difficult or impracticable, such as rocket exhaust plume technology.

The expertise gained by the research teams has occasionally found application beyond the field of rocket propulsion. Following the wreck of the Torrey Canyon in March 1967 and the extensive pollution which ensued the RPE was asked, by the Committee of Scientists on the Scientific and Technological Aspects of the Disaster, to investigate the possibility of disposing of oil from wrecked tankers by burning. Tests were carried out, beginning with small scale tests during 1968/69 and culminating, in November 1970, in a test involving the burning of about 175 tonnes of crude oil. From the results of the tests recommendations were made on the disposal of oil in the event of future similar disasters.

In the field of instrumentation also, devices have been developed, such as strain gauges, pressure transducers and test rigs, which have far-reaching applications in many spheres of industry, research and engineering.

10. EVENTS OF THE LAST DECADE

In 1971, in accordance with the recommendations of the White Paper on Government Organisation for Defence Procurement and Civil Aerospace, the RPE became the responsibility of the Procurement Executive of the Ministry of Defence. As part of the rationalisation of defence research establishments it was merged with the Explosives Research and Development Establishment, Waltham Abbey in January 1973, with one Director responsible for the unified Establishment.

A further change aimed at co-ordinating the work of PERME and the Rocket Motor Executive was made in 1975 when the RME was transferred from its London Office to Westcott. The role of the RME is the management and commercial exploitation of all the UK rocket motor capabilities, including the MOD agency factory, IMI Summerfield, and its responsibilities include the negotiation and acceptance of contracts for the design, development and production of rocket motors for UK defence and civil applications and for overseas customers. In 1976 the posts of Director ERDE/RPE and Head of RME were combined. In February 1977 ERDE/RPE was re-named as the Propellants, Explosives and Rocket Motor Establishment (PERME).

PERME received its first Royal visit on October 5, 1978, when HRH the Duke of Gloucester unveiled a commemorative plaque to mark the opening of a new canteen building, before touring the site to see exhibitions of the work of the Establishment, and to watch firings of liquid and solid propellant motors. The Duke was presented with a memento of his visit from the Engineering Workshop.

In February 1980 an exhibition was held at Aylesbury Civic Centre at which members of the public were given an opportunity to see a representative selection of the work of the Establishment.

11. CONCLUSIONS

During its relatively short history of 35 years PERME Westcott has successfully developed over 500 rocket motors for many different applications including defence, space research and meteorological investigation, and embracing a wide spectrum of size and performance.

Projects for which motors have been developed include the surface-to-air Bloodhound and Thunderbird missiles, the Red Top and Firestreak air-to-air missiles, the Blowpipe shoulder launched anti-aircraft missile, the Seawolf ship defence missile, the Sea Skua anti-ship missile, the Skua and Petrel meteorological sounding rockets, a wide range of Skylark sounding rockets and the Black Arrow launch vehicle. Motor diameters range from 22 mm to about 1370 mm, total impulses from 11 Ns to 9,500,000 Ns, and burning times from a few milliseconds to 300 seconds.

As the demands of the Services become increasingly severe, propulsion units for rocket systems will inevitably be required to possess an even wider range of characteristics, longer service life and greater reliability combined with light weight, low cost and safety in handling.

The Strathcona Report of 1980 has cast doubt and speculation on the future of the Establishment, and reductions in financial and manpower resources have imposed severe curtailment of the research programme. Nevertheless, effort continues towards the development of new and improved systems to satisfy the needs of the future.

Acknowledgement

I would like to thank Mr B Payne of the Graphics Section for his help in locating some of the illustrations for this Memorandum.