PERME

Waltham Abbey

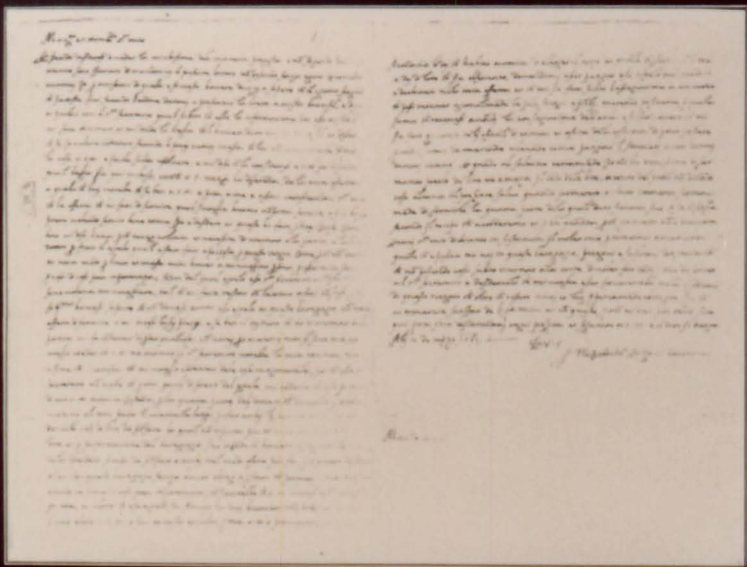
ROYAL VISIT PANELS

5th October 1978

WALTHAM ABBEY AND EXPLOSIVES

400 Year Association

In 1561 JOHN TAMWORTH of Waltham Abbey was involved in negotiations with an Italian, Marco Antonio Erizzo, for the supply of saltpetre and sulphur – ingredients of GUNPOWDER.



THE EARLY POWDER MILLS

The importance of the privately-owned mills was recognized by contemporary writers:

1662 "Gunpowder . . . more made by Mills erected on the river Ley, betwixt Waltham and London, than in all England besides."

Thomas Fuller – Worthies of England

1735 "Curious Gunpowder Mills . . . esteemed the largest and compleatest Works in Great Britain."

John Farmer – History of Waltham Abbey

1771 "Gunpowder mills, upon a new construction, worked by water . . . they are reckoned the most complete in England."

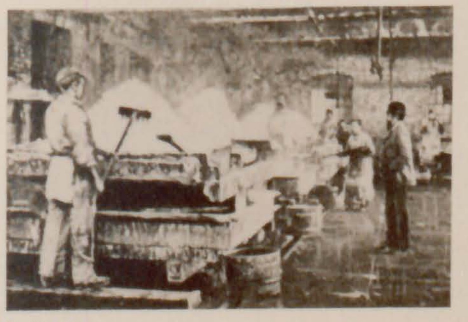
History of Essex

THE POWDER MILLS IN 1735

The earliest-known illustration published whilst the Mills were owned by the Walton Family.

THE MANUFACTURE OF GUNPOWDER

Preparation of Ingredients



Saltpetre
Refined by recrystallisation

Sulphur
Refined by distillation

Charcoal
Prepared from alder, dogwood and willow

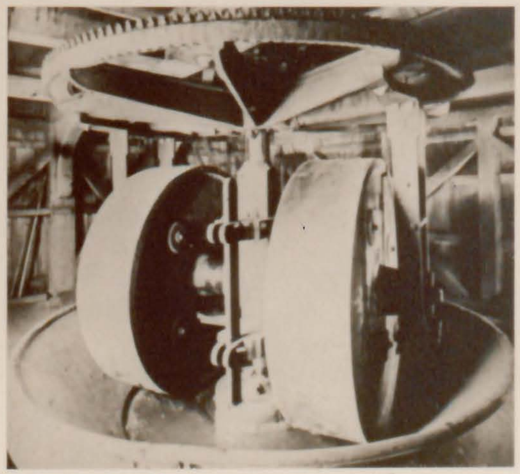
Mixing

After being ground separately the ingredients were mixed in the proportions:
Saltpetre 75, Sulphur 10, Charcoal 15

Mixing House

Incorporation

The mixture was then spread on the stone beds of Incorporating Mills, moistened with water and worked for 3 hours under edge-runner mill stones.



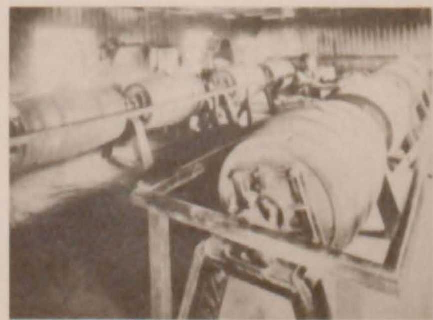
Incorporating Mill

Processing

The product was broken down, pressed and then granulated to the different sizes required for muskets, rifles and larger guns.

Before being sent to the magazines the powder was dried, dusted and glazed to make it more durable.

Granulation



Glazing

Transport

Trucks and powder boats were used within the Royal Gunpowder Factory and sailing barges for the journey down the River Lea and the Thames to Woolwich.

THE ROYAL POWDER MILLS

LIEUT. GENERAL SIR WILLIAM CONGREVE

In 1787 SIR WILLIAM CONGREVE, 1st Baronet, made successful proposals for the purchase by the Crown of the Powder Mills from John Walton for £10,000.

The improvements he introduced enabled great savings to be made in the manufacture of gunpowder.

By test firings he proved that Waltham Abbey powder was the best in the country.

THE CONGREVE ROCKET SYSTEM

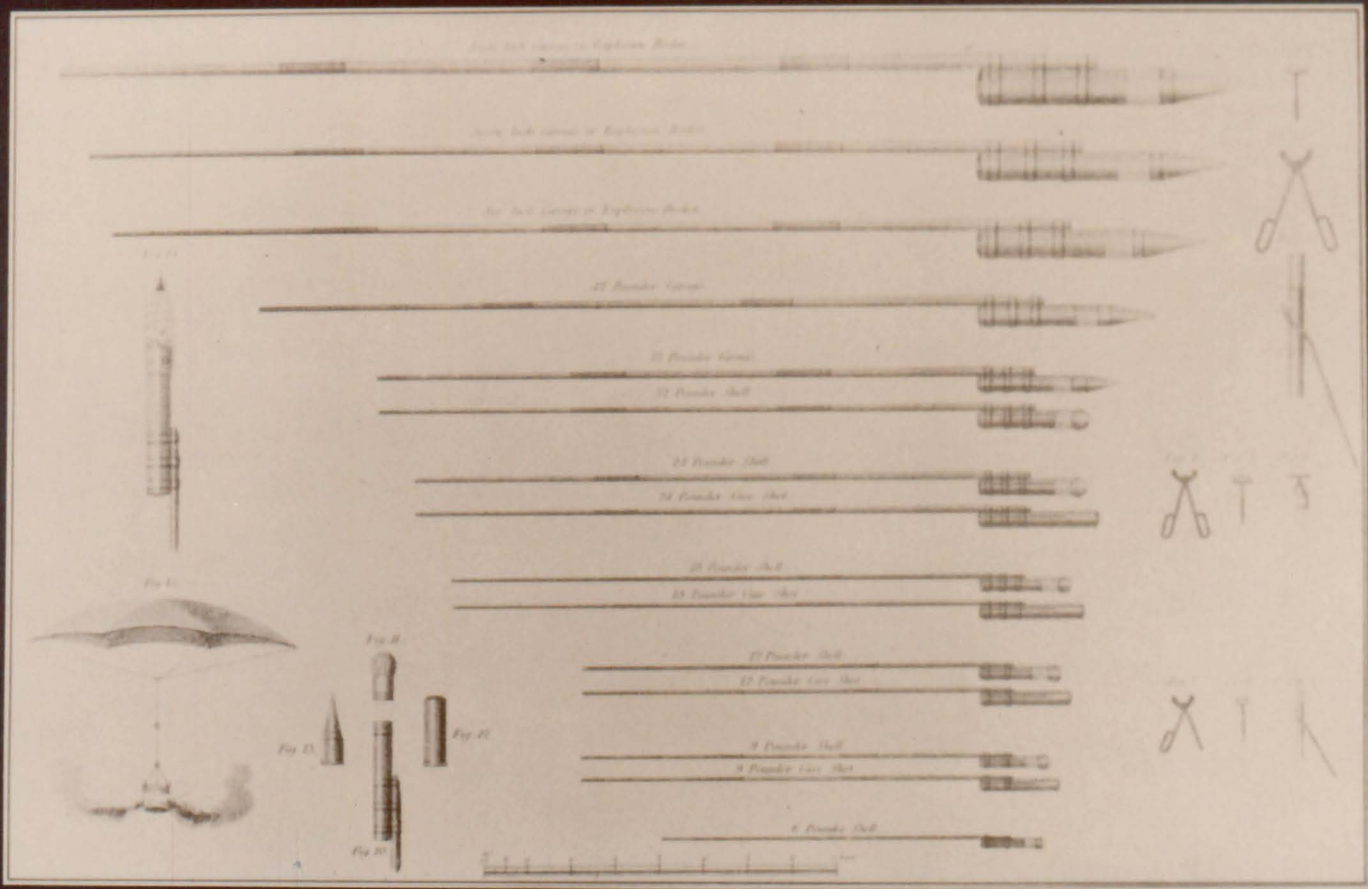
In 1805 SIR WILLIAM CONGREVE, the 1st Baronet's son, developed the gunpowder rocket for military purposes.

The rockets were used in several campaigns:

1806	Boulogne
1807	Copenhagen
1813	Passage of the Adour
1813	Leipzig
1814	Bladensburg
1814	Fort McHenry
1815	Waterloo
1816	Algiers

The wording "the rockets red glare" in the national anthem of the USA refers to the use of the Congreve Rockets against Fort McHenry.

THE CONGREVE ROCKET SYSTEM



Congreve Rockets

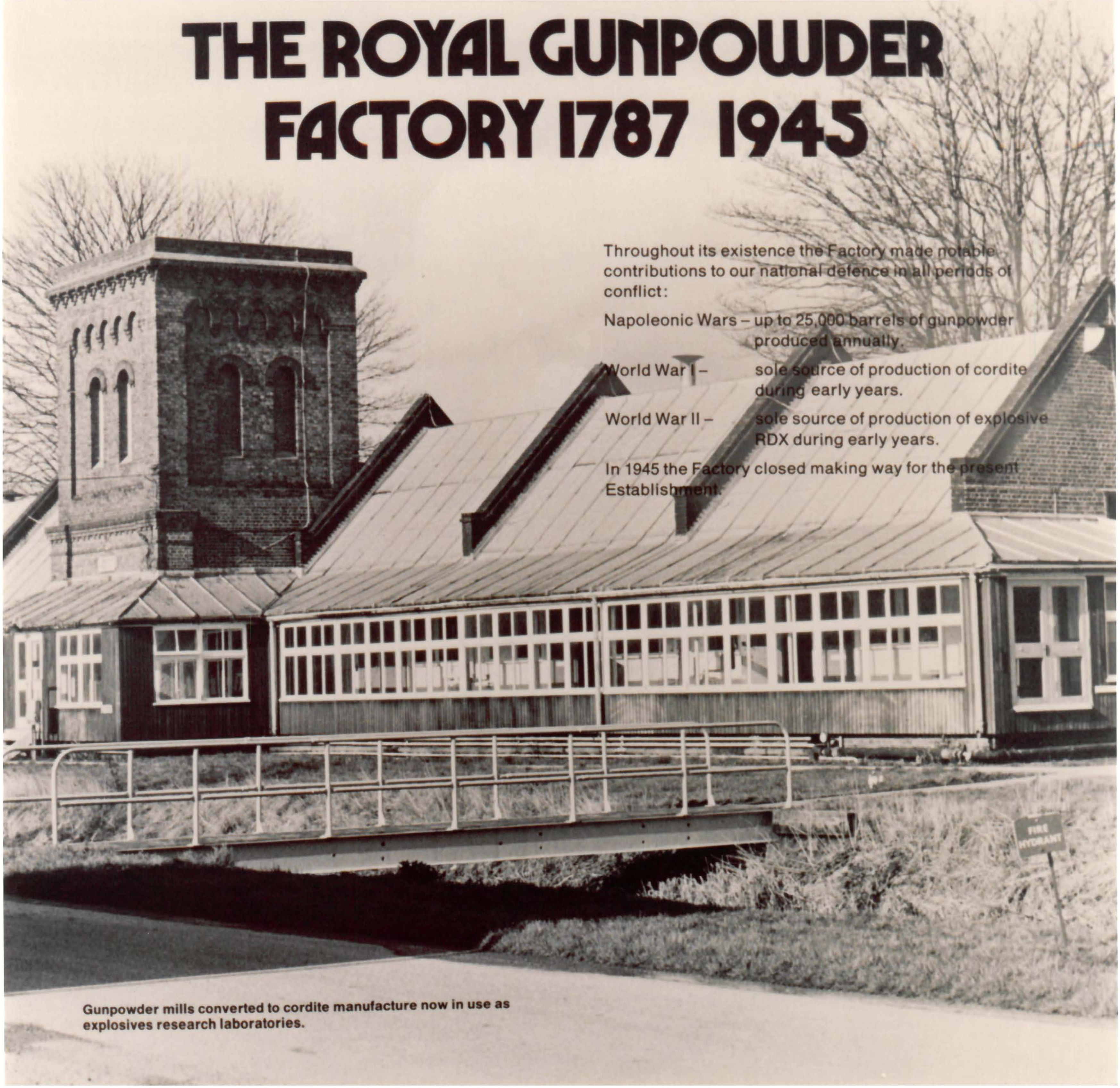
Firing a 32-pounder Rocket

THE ROYAL GUNPOWDER FACTORY 1787 1945

Throughout its existence the Factory made notable contributions to our national defence in all periods of conflict:

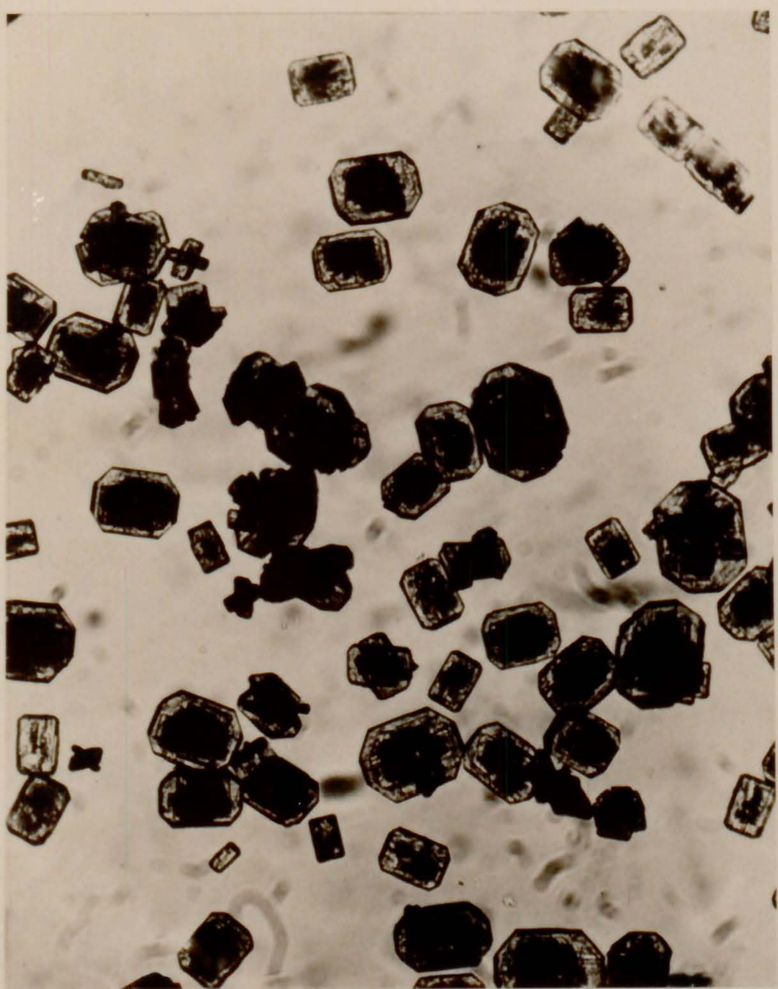
Napoleonic Wars –	up to 25,000 barrels of gunpowder produced annually.
World War I –	sole source of production of cordite during early years.
World War II –	sole source of production of explosive RDX during early years.

In 1945 the Factory closed making way for the present Establishment.



Gunpowder mills converted to cordite manufacture now in use as explosives research laboratories.

RD1300 INITIATING EXPLOSIVES



Mercuric Nitrotetrazole
A new detonant developed at PERME

More than 70 compositions including:

Lead and Silver Azides
Normal and Basic Lead Styphnates
Lead Dinitroresorcinates
Lead Azotetrazole
Barium Styphnate
Potassium Picrate
Coprecipitated Systems

PERME has unique facilities and expertise to develop these most sensitive and hazardous explosives from laboratory to full production scale.

RD1300 Explosives are used in:

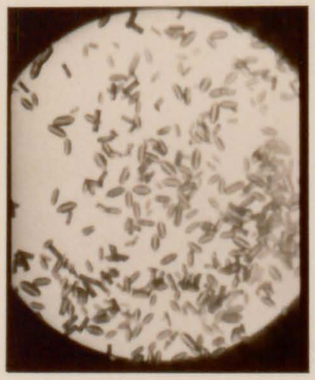
Detonators
Igniters
Fuzeheads
Delay Elements
Actuators
Cutting Devices
Electric Caps
Fuzes
Safety and Arming Units
Small Arms Ammunition

Developed primarily for ROF production of military stores in the UK, RD1300 Compositions are also manufactured in USA, Canada, Australia, India, Pakistan, Sweden, Belgium, Italy, France and S Korea.

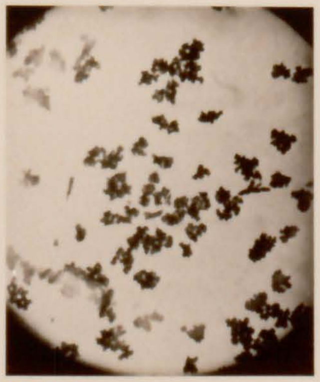
RD1300 INITIATING EXPLOSIVES

Crystal Form (Morphology) is tailored to meet varying Service requirements.

Lead Azide



SLA



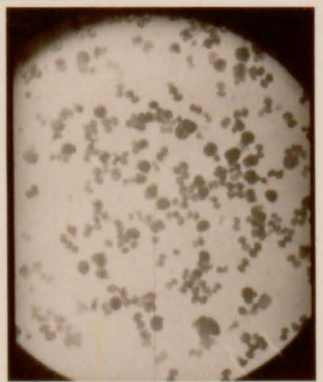
RD1339

RD1343

RD1352

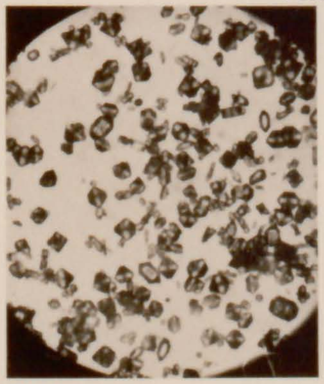
Lead Dinitroresorcinate

RD1358



RD1358G

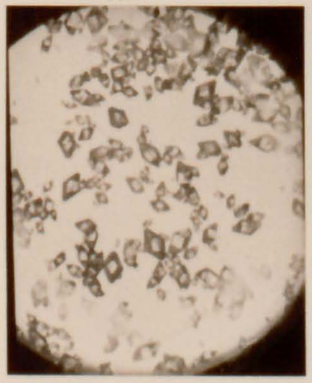
Potassium Picrate



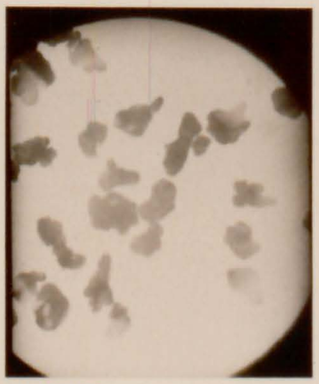
RD1369

RD1371

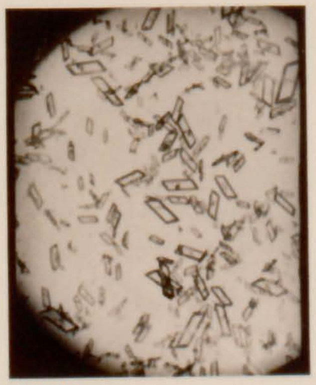
Barium Styphnate



RD1320



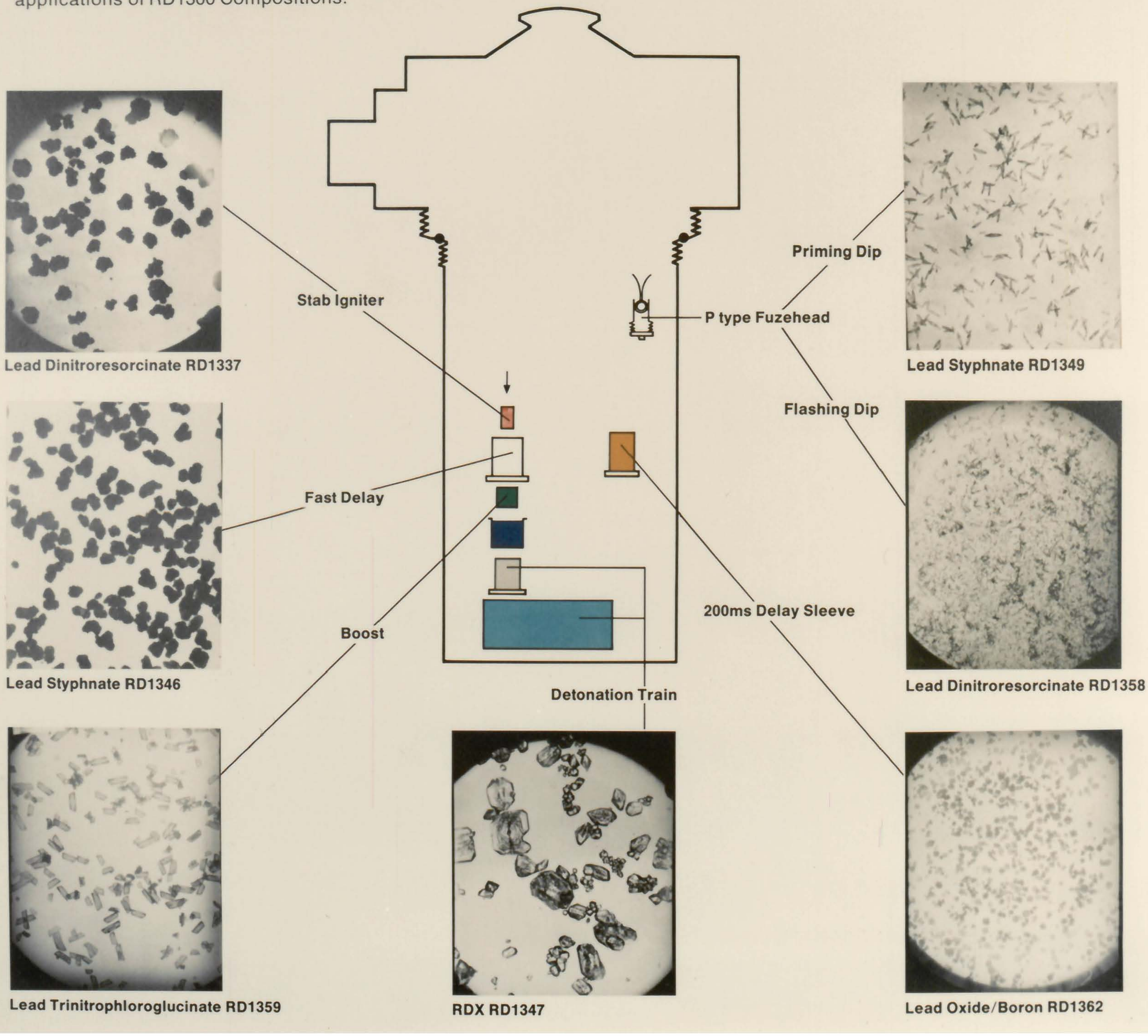
RD1320B



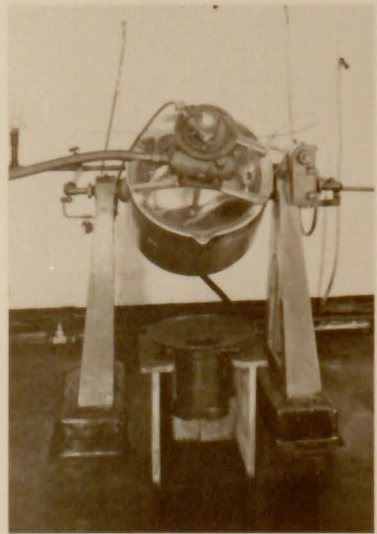
RD1340

RD1300 INITIATING EXPLOSIVES

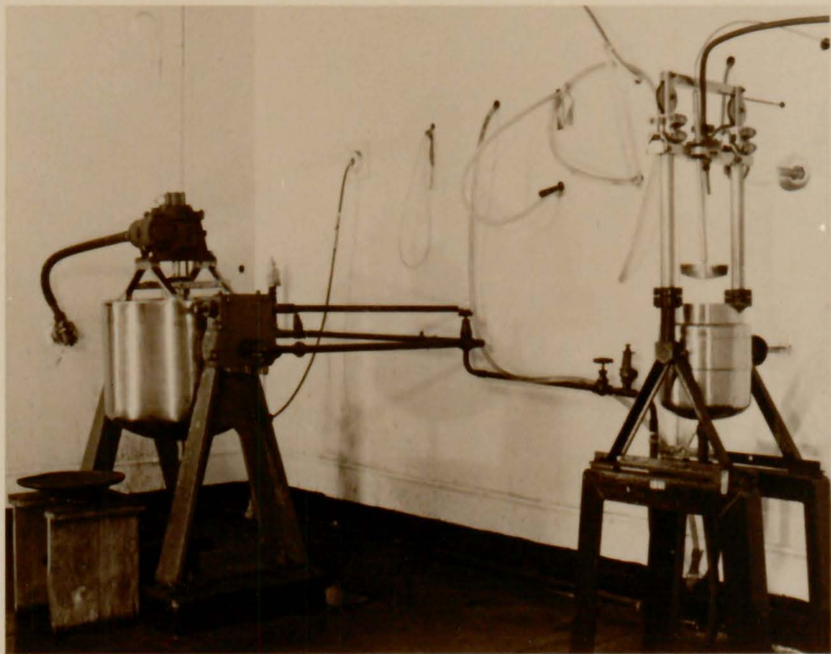
Diagrammatic Fuze Assembly illustrates some typical applications of RD1300 Compositions.



INITIATING EXPLOSIVES MANUFACTURE


Product transfer


Sieving


Precipitation


Drying

VULNERABILITY OF ROCKET MOTORS TO FRAGMENT ATTACK

HM Ships carry missiles on deck or in magazines. An attacked motor may burn, explode or detonate, and other weapons may become involved. The extent of hazard will be influenced by motor design and environment. A basic investigation of the problem uses standardised equipment with systematic variation of relevant factors.

Fire

Explosion

Detonation

EXPLOSIVES SENSITIVENESS AND HAZARD

The following six small scale tests are performed so that the MOD Safety Certificate can be drawn up.

1 Rotter Impact

2 Mallet Friction

3 Temperature of Ignition

4 Bickford Fuze

5 Train

6 Electric Spark

The Section continually attempts to devise new or modified types of tests. Two are shown.

EXPLOSIVES SENSITIVENESS AND HAZARD

A variety of larger scale hazard tests are carried out including:–

- Large Sealed Vessel Test for storage and transport classification.
- Spigot Drop Test for assessment of intrusion hazard.
- Gap Tests for shock initiation sensitiveness.
- Ad hoc Tests to answer other specific enquiries.

PROPELLANTS FOR GUNS AND SMALL ARMS MORTARS

Waltham Abbey supplies RARDE and RSAF with propellants for their weapon developments. These requirements include

Improved:
- Energy
- Ignition
- Physical properties
- Physical regularity
- Development of manufacturing technique

Reduced:
- Barrel wear
- Cost
- Temperature coefficient
- Signature

MEASURING GUN PROPELLANT GEOMETRY

Internal ballistics depend on charge size and shape. **Total surface area** governs maximum pressure. **Distance between surfaces,** the "web", and the burning rate determine action time.

Traditional measurement uses a travelling microscope and is slow and tedious.

A computer-linked travelling microscope is fast but still tedious and only measures web size.

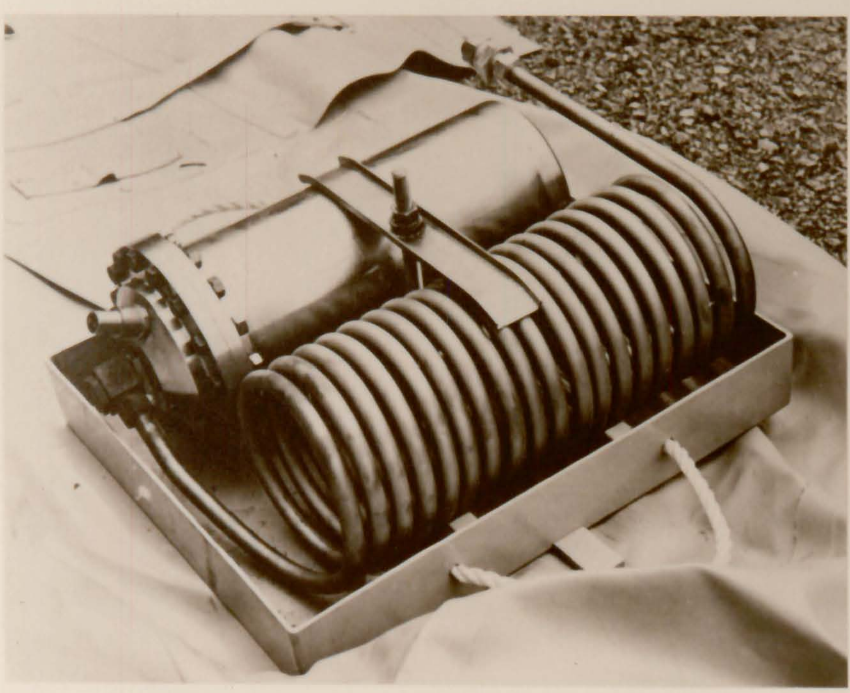
Modern image analysers give rapid measurement and print out of statistics of both web and surface area.

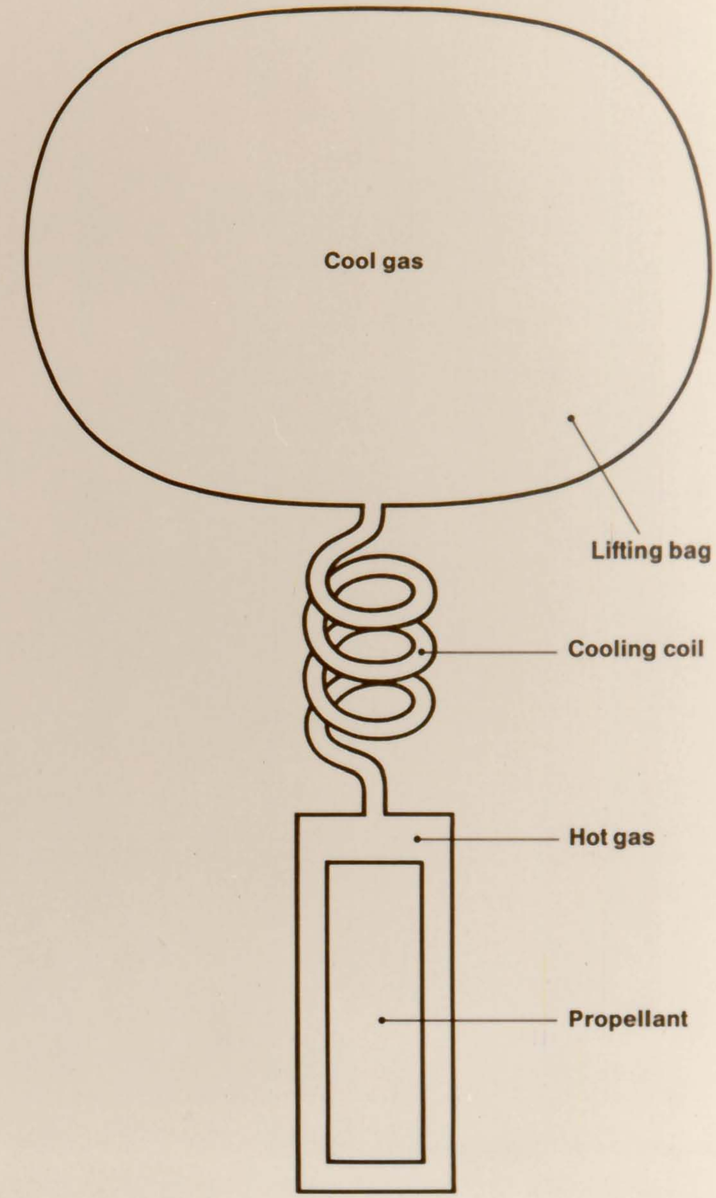
GAS GENERATOR POWERED LIFTING BAG

Cooled propellant gas is used to inflate a bag for raising objects from the seabed to the surface.

Co-operative programme between Waltham Abbey and Leafields Engineering.

Development for the Royal Navy
But further use for North Sea oil rigs is projected.





WALTHAM ABBEY PI BRANCH

- Provides a unique range of **modern propellants** based on **nitrocellulose.**
- Develops novel propellants for civil and military applications for **guns, mortars and rockets.**
- Conducts **scientific research** into propellant properties and ingredients.
- Plays a vital role in providing **support for ROF production.**
- Develops **new processes** and techniques.
- **Co-operates with industry** in developing novel propellant engineering applications.

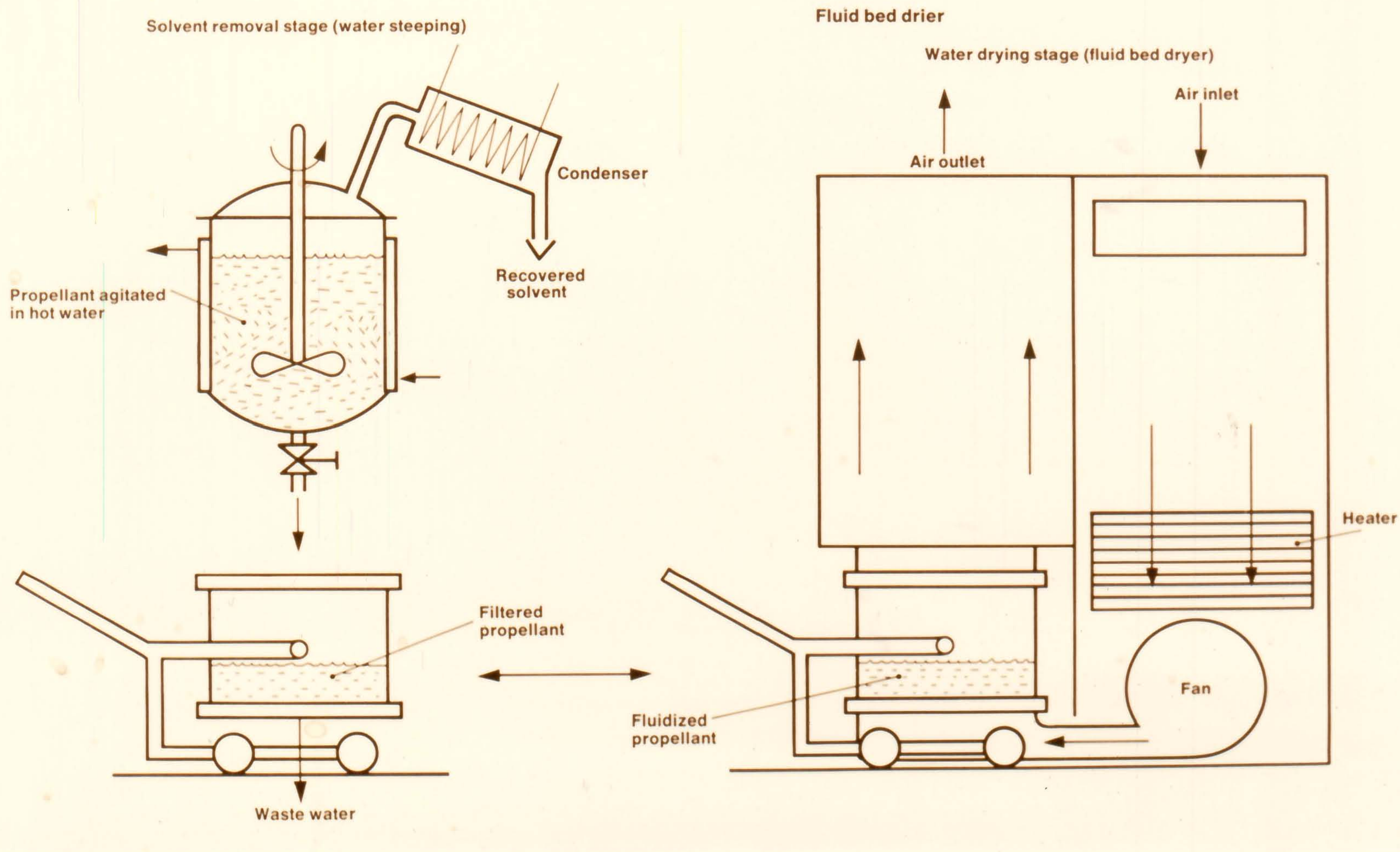
ROCKET PROPELLANT APPLICATIONS

Rocket Propellants developed at Waltham Abbey are used in:

- Unguided Rockets
- Power Cartridges
- Guided Missile Boost and Sustain Motors
- Canopy and Seat Ejectors
- Expulsion Devices
- Ejector Release Units

A NEW RAPID DRYING PROCESS FOR PROPELLANT GRANULES

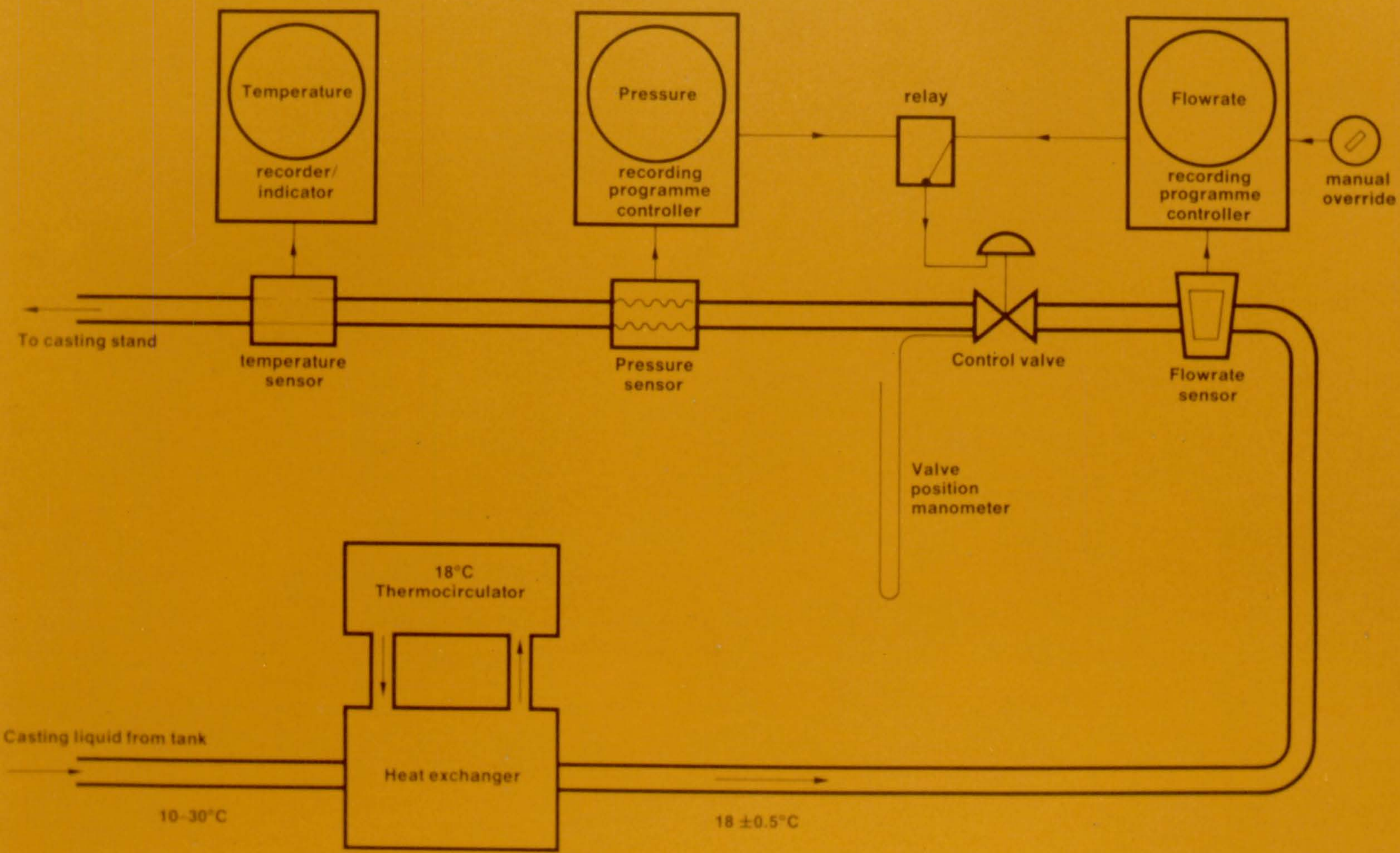
The high air flowrate through the fluidized bed speeds up drying and increases uniformity of product.
Fluid bed dryer.



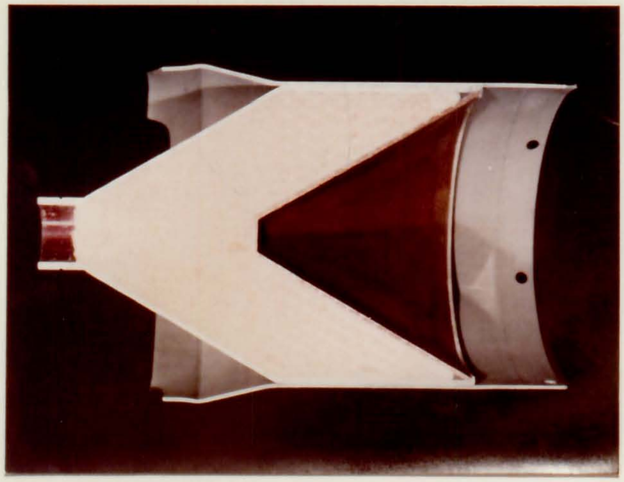
AUTOCASTING

Experimental casting control system for the manufacture of cast-double-base rocket motors.

The casting liquid at a standard temperature and flow-rate follows a pre-determined programme giving improved reproducibility.



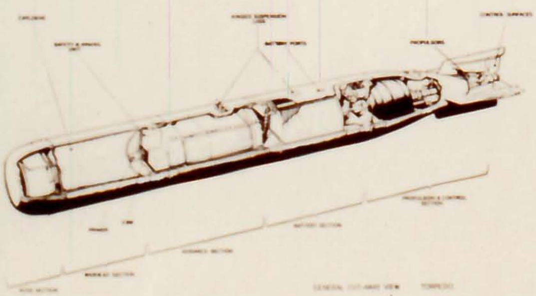
HIGH EXPLOSIVE COMPOSITION DEVELOPMENT



Sectioned shaped charge warhead

Effect of warhead on armour

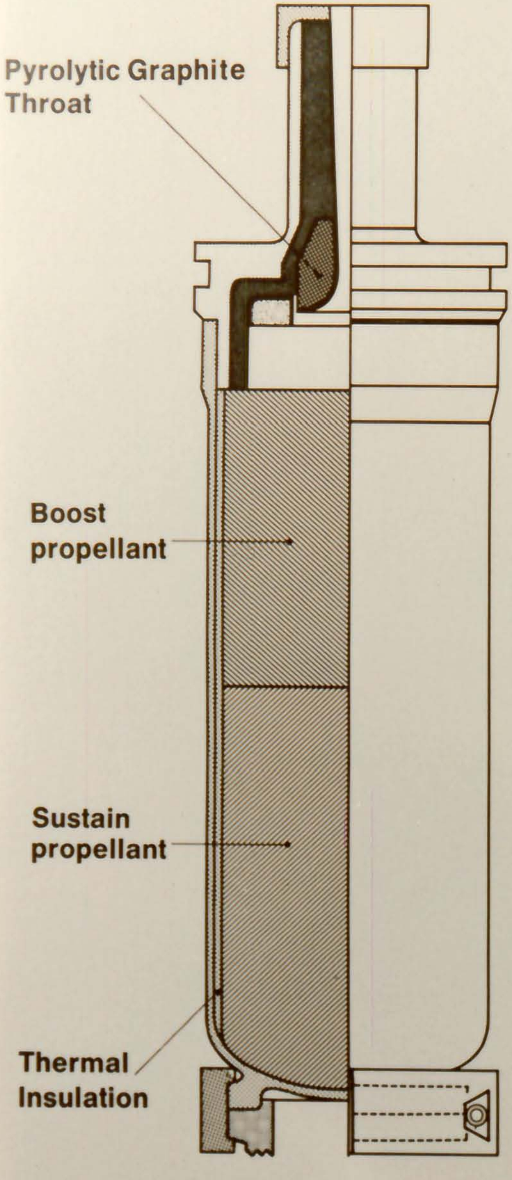
New and improved High Explosive Compositions → **Greater performance**



Section of torpedo warhead

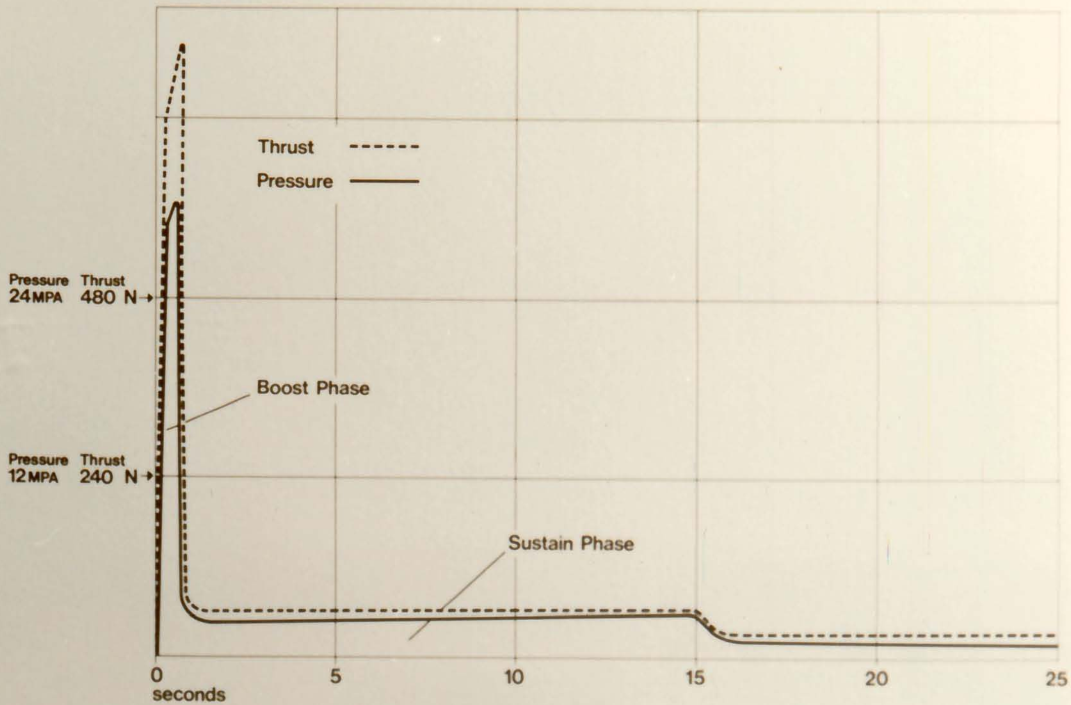
Effect of Torpedo warhead

AIRBORNE RADAR DECOY MOTOR



Plastic Propellant is a British development which has excellent temperature cycling capability. Recent improvements have considerably extended the operating temperature range.

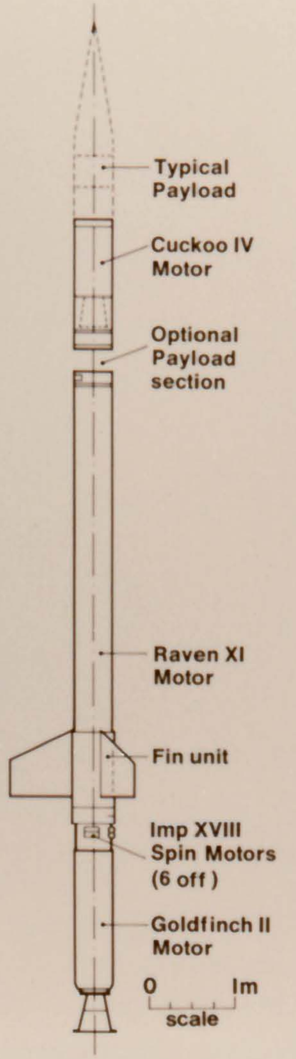
PERME is developing a rocket motor as a case bonded, cigarette burning, dual thrust solution for an air launched radar decoy system, taking advantage of plastic propellants unique properties.



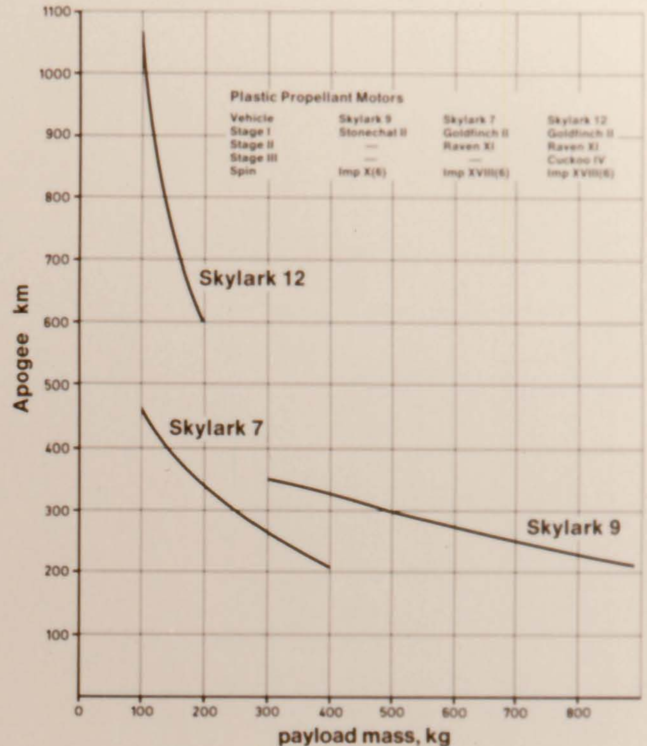
PLASTIC PROPELLANTS IN HIGH ALTITUDE SOUNDING ROCKETS

Thousands of highly reliable rocket motors, all using plastic propellants developed at PERME, have been used in Skua, Petrel and Skylark vehicles. These have been highly successful in carrying meteorological, geophysical and materials processing experiments to high altitudes. New generations of plastic propellants are under test in uprated Cuckoos, for 3rd stage Skylark motors.

"Skylark Launch"



Skylark 12



Apogee Performance

LAW

(Light Anti-Armour Weapon)

Rubbery Propellants group plays an essential part in the development of this efficient new anti-tank weapon.

Efficiency depends on accuracy.

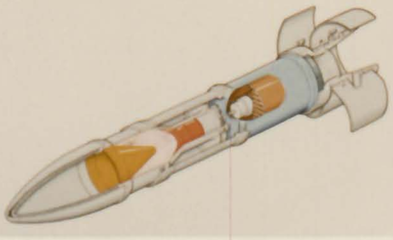
Accuracy requires high velocity -300 metres per second.

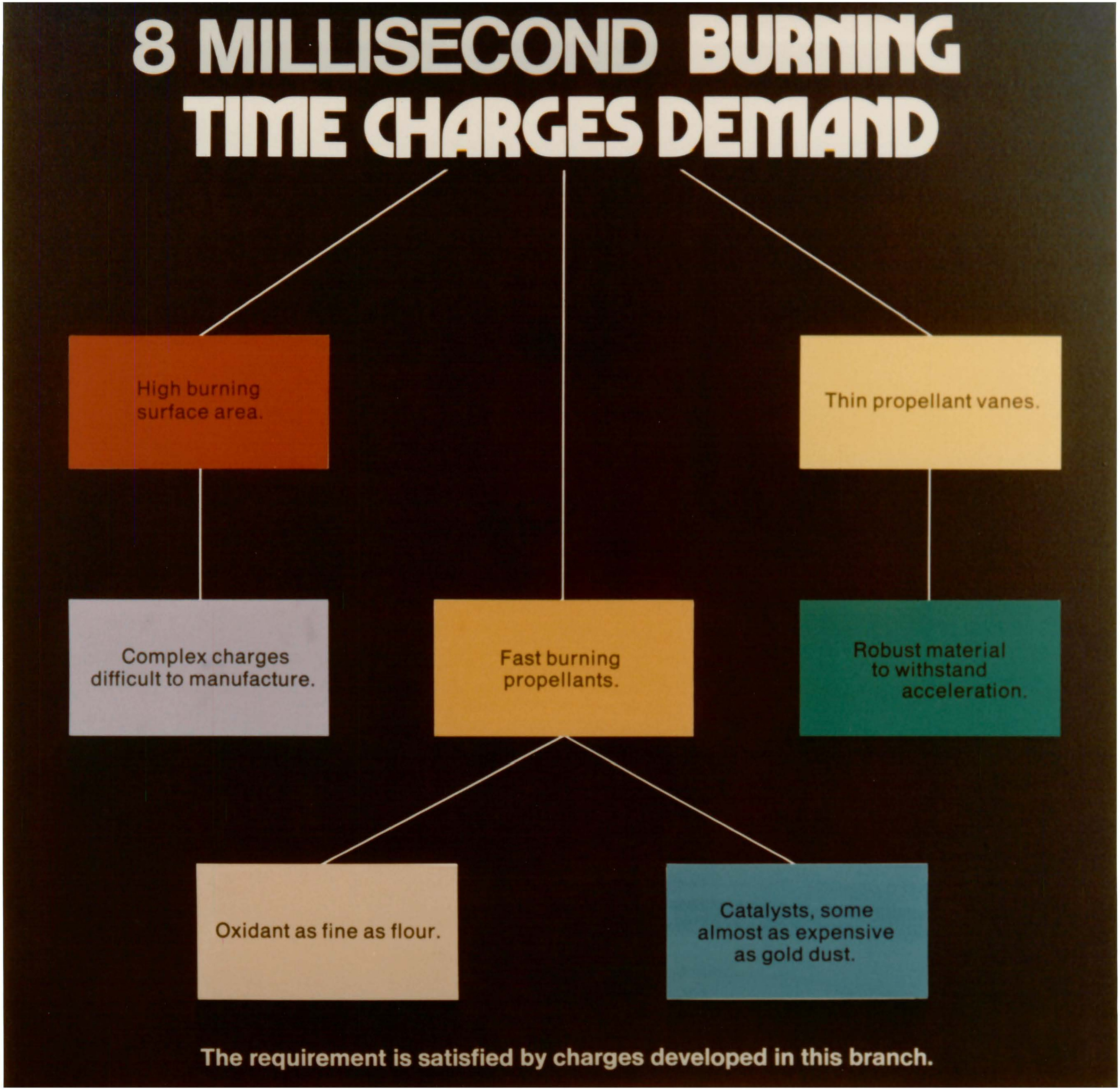
High velocity demands high acceleration-7000 times gravity.

High acceleration is achieved by an ultrashort (8 millisecond) burning time rocket motor.

The projectile

PD design



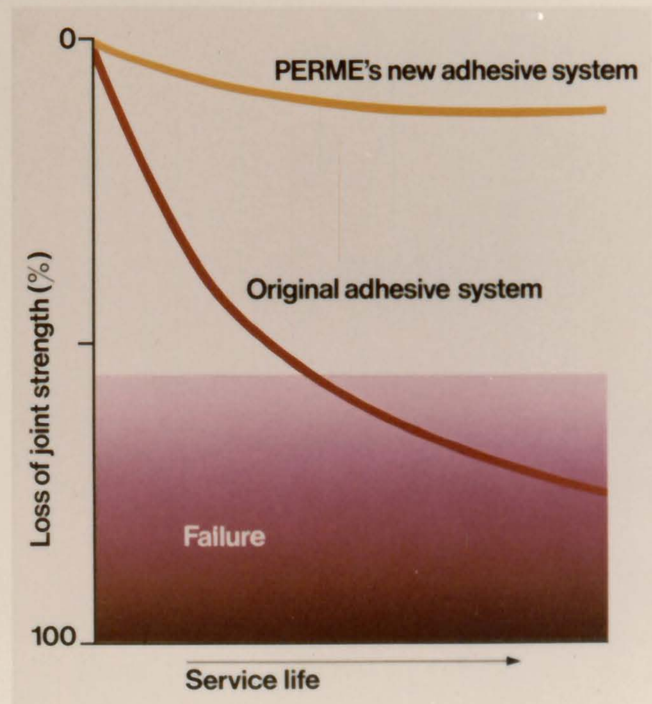

8 MILLISECOND BURNING
TIME CHARGES DEMAND
High burning surface area.
Thin propellant vanes.
Complex charges difficult to manufacture.
Fast burning propellants.
Robust material to withstand acceleration.
Oxidant as fine as flour.
Catalysts, some almost as expensive as gold dust.
The requirement is satisfied by charges developed in this branch.

ADHESIVES IN ROCKET MOTORS

The Rapier Missile

The motor body for this advanced surface-to-air missile is prepared by helically winding layers of flat metal strip and bonding the layers together. This technique allows high tensile-strength steels to be employed and produces an extremely strong, light, pressure-vessel. Thus, Rapier's motor depends absolutely on its adhesives. Predicting and increasing the service-life of such components is of vital importance.

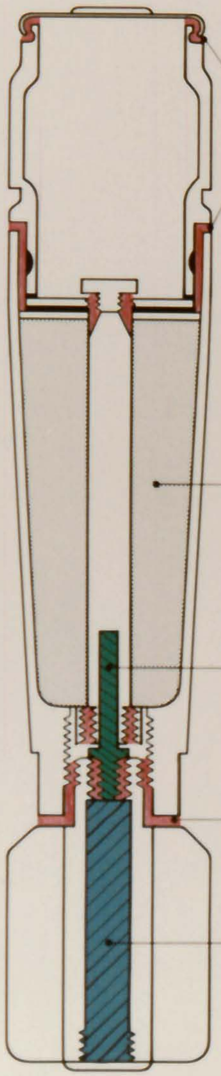
Rapier Missile being fired.



ADHESIVES IN DEFENCE EQUIPMENT

55mm Parachute Mortar Flare

This mortar employs a sealant developed at P.E.R.M.E. which is compatible with virtually all propellants and explosives.



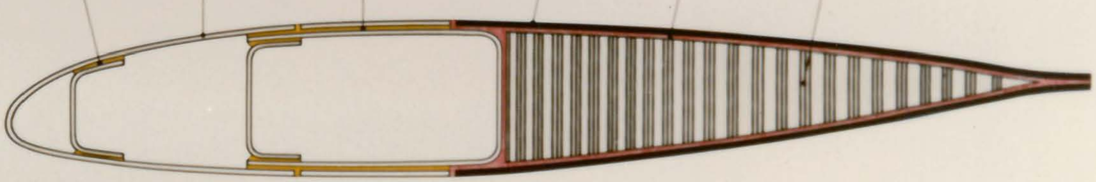
In addition to work on adhesives for rocket motors P.E.R.M.E. maintains an advisory service on adhesives in Defence Equipment.

Flotation Screen for Fighting Vehicles

Extensive use of adhesives for all water-tight joints

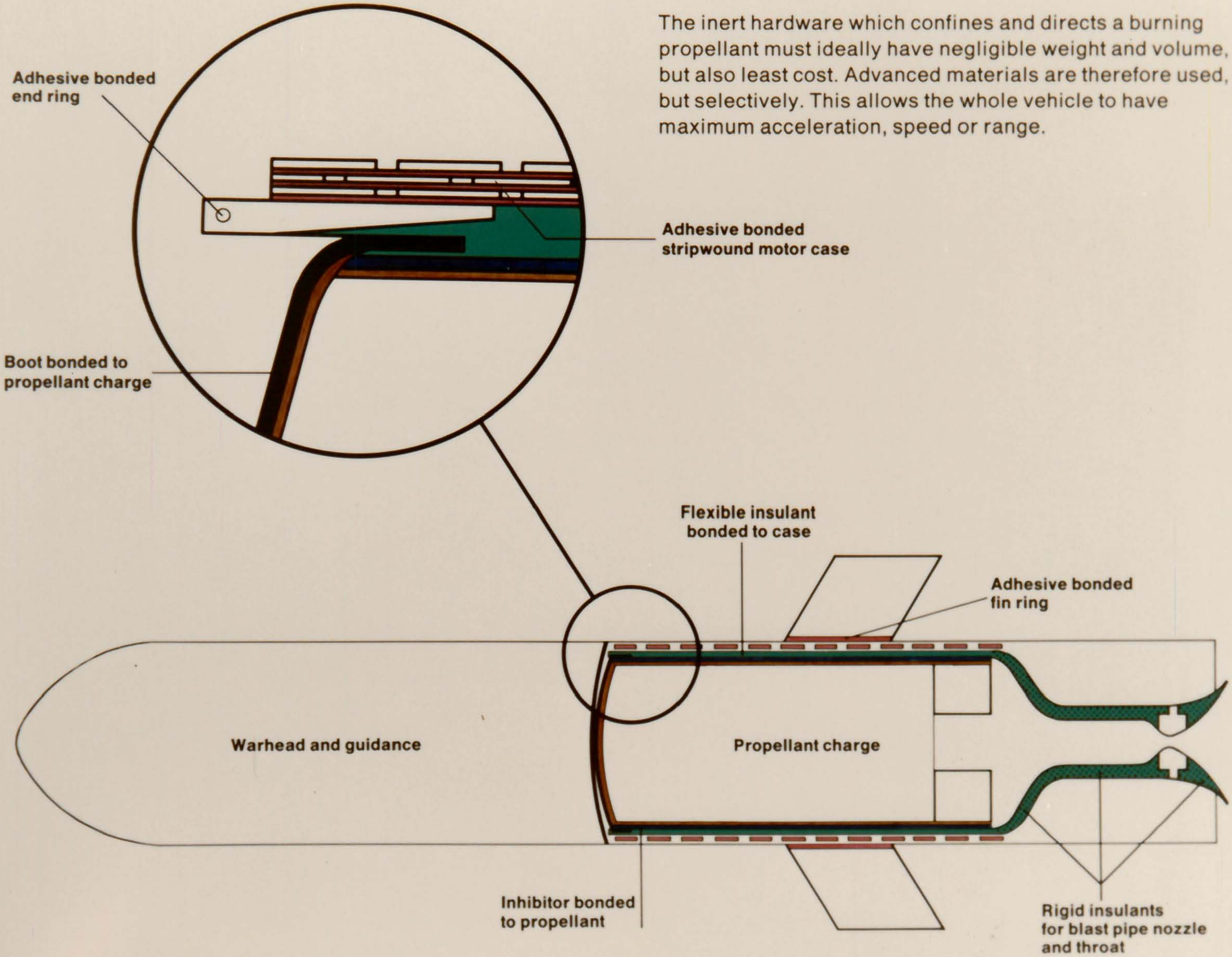
Lynx Helicopter Blade

Adhesives enable an advanced aerodynamically contoured blade to be produced giving remarkable speed and manoeuvrability to the LYNX helicopter.

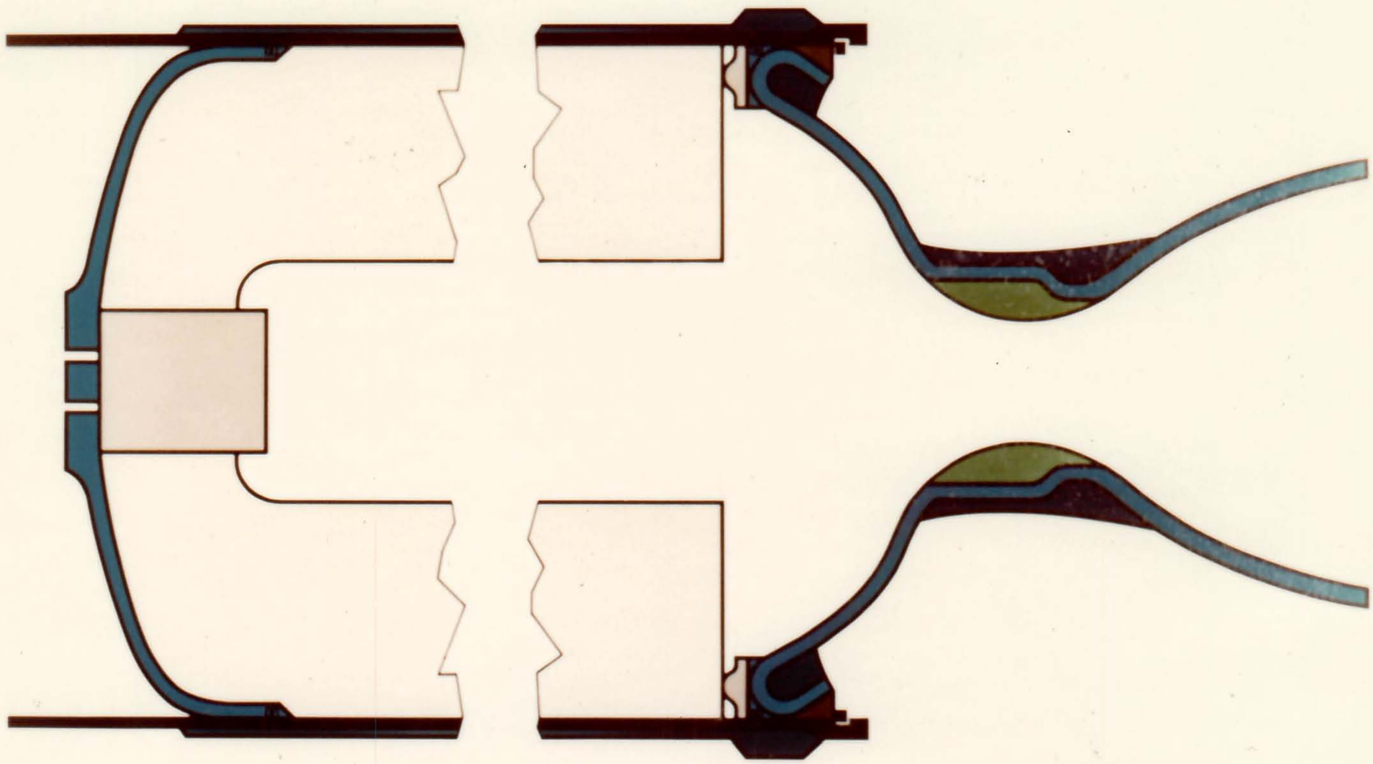


DEVELOPMENTS IN MOTOR HARDWARE

The inert hardware which confines and directs a burning propellant must ideally have negligible weight and volume, but also least cost. Advanced materials are therefore used, but selectively. This allows the whole vehicle to have maximum acceleration, speed or range.



In this long-burning motor, the volume and weight of all hot lining materials must be kept small but the structure can be designed for low cost. Adhesive bonding is particularly important here.



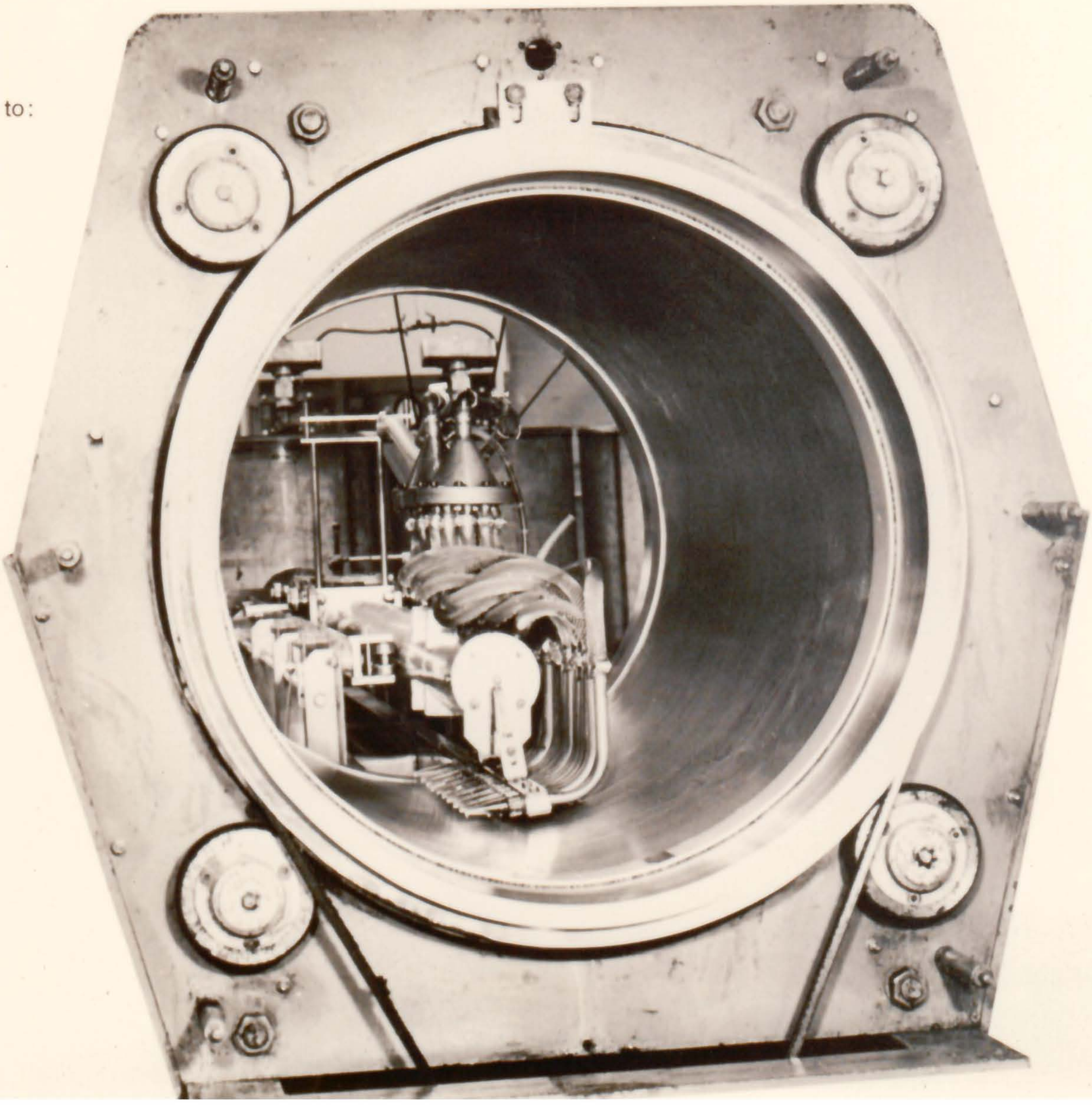
This design for a short-burn motor shows how 40% of the structure weight is saved by use of lightweight composites

THREE WAY STRETCH WITHOUT THE SPLITS

The plant produces a new composite sheet which solves fabrication problems in the aerospace industries. The aligned short fibre material combines the virtues of commercial fibre "prepreg" with the ability to stretch in three modes to conform to very complex shapes.

The product is supplied to:

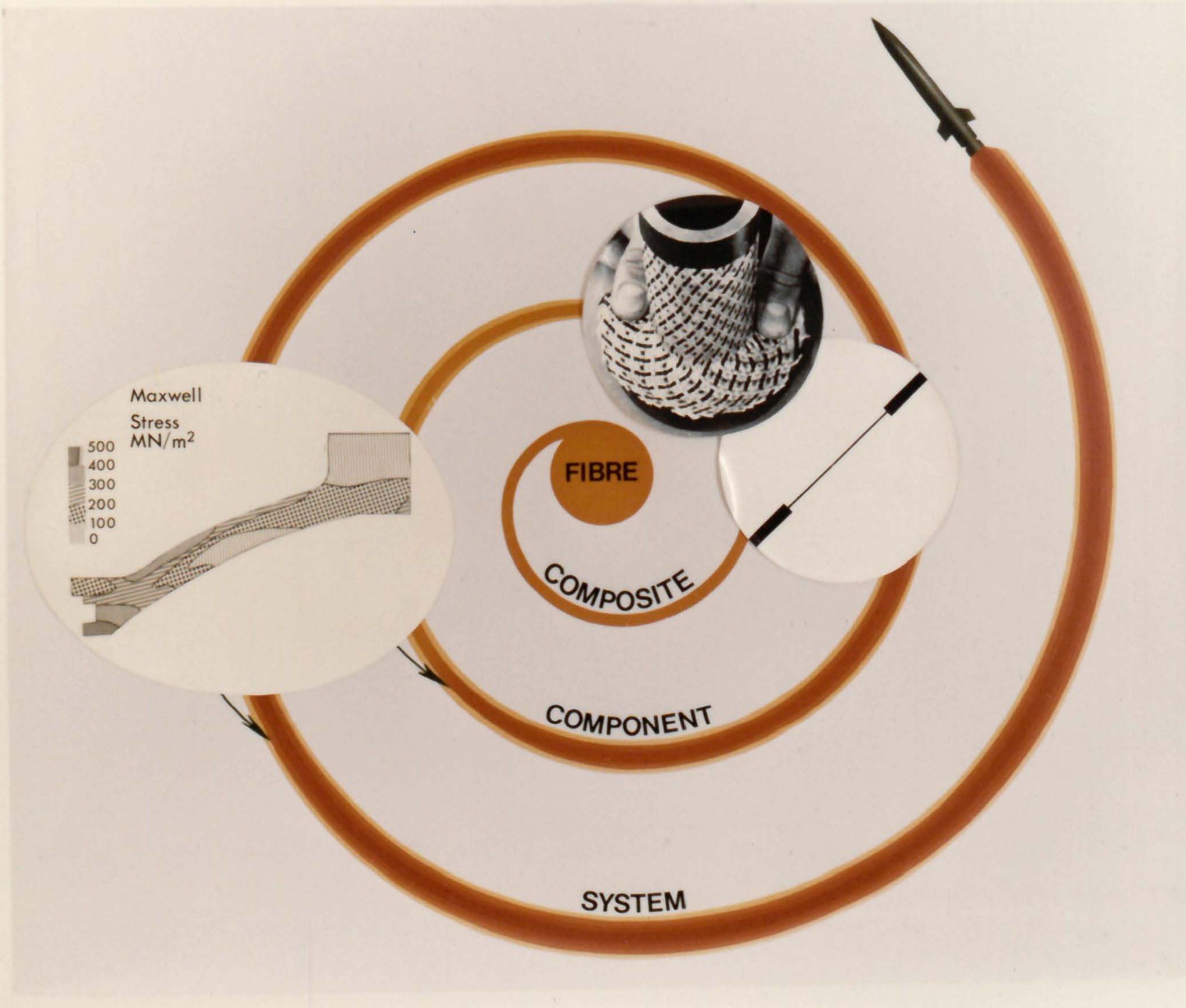
British Aerospace Civil
British Aerospace Military
Rolls Royce
Westland Helicopters
Bristol Aerojet
Lockheed Air Corporation
MBB



COMPOSITE MATERIALS

Demonstrator components get the already developed materials into service more quickly and provide the experience which guides future research.

Basic thermal and mechanical studies identify lighter, safer and cheaper compositions for the future.



ORGANIC CHEMISTRY FOR DEFENCE REQUIREMENTS

Research on new Explosives starts here

Coupling Reactions of TNT

Synthesis of Energetic Monomers

Synthesis of Burning Rate Catalysts for Propellants

Initial Synthesis

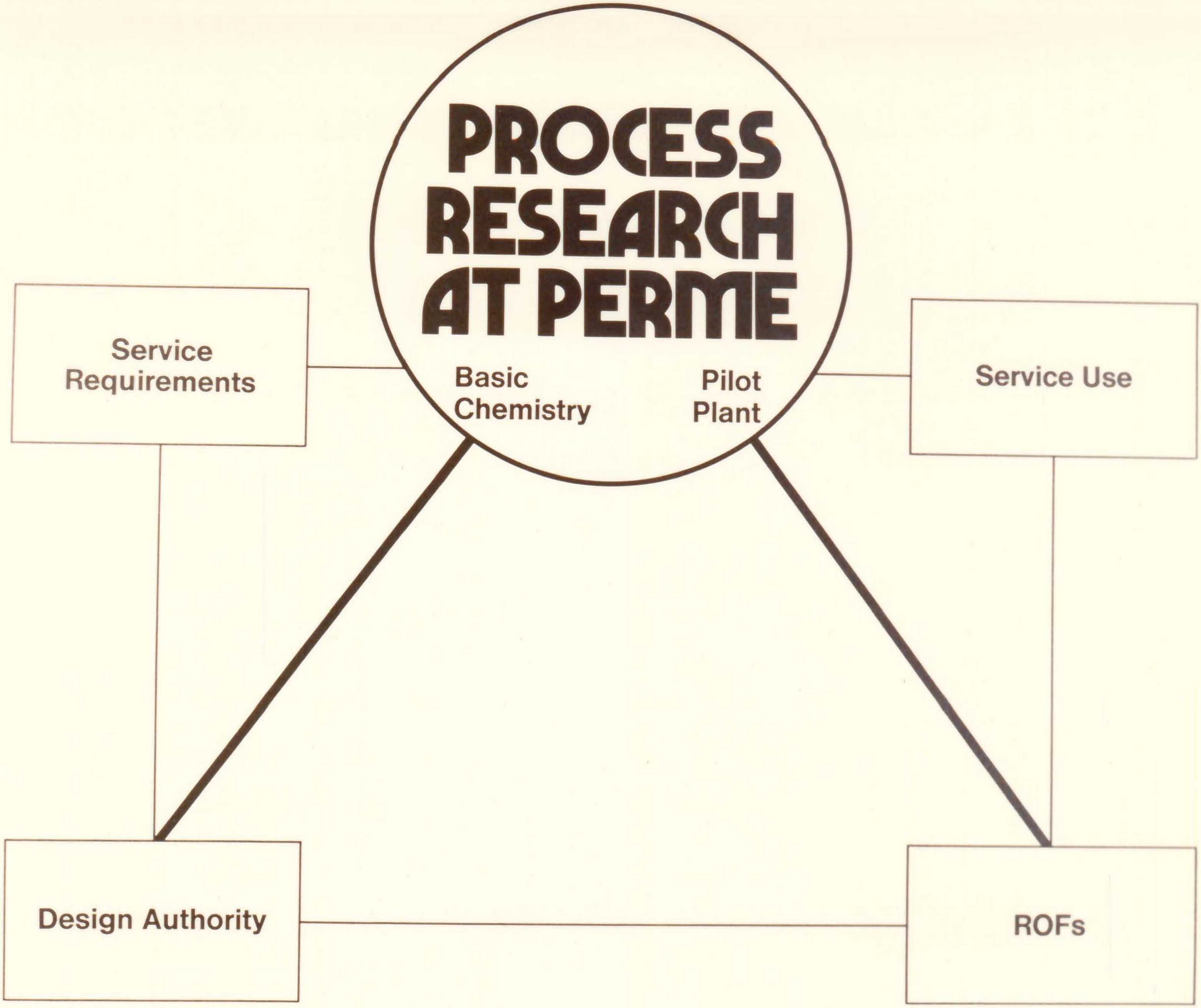
Scale-up Preparation

High Temperature Nitrations

Kinetic Studies

Continuous Chlorination

Laboratory Studies for Production Processes



Developing the manufacturing processes for a wide range of propellant and explosives ingredients. PERME is the national centre of R and D in this field.

CRACK-FREE SHELL FILLINGS

PERME developed the chemical process for the manufacture of the nucleating agent and supplied material for the pre-production evaluation of the shell filling.

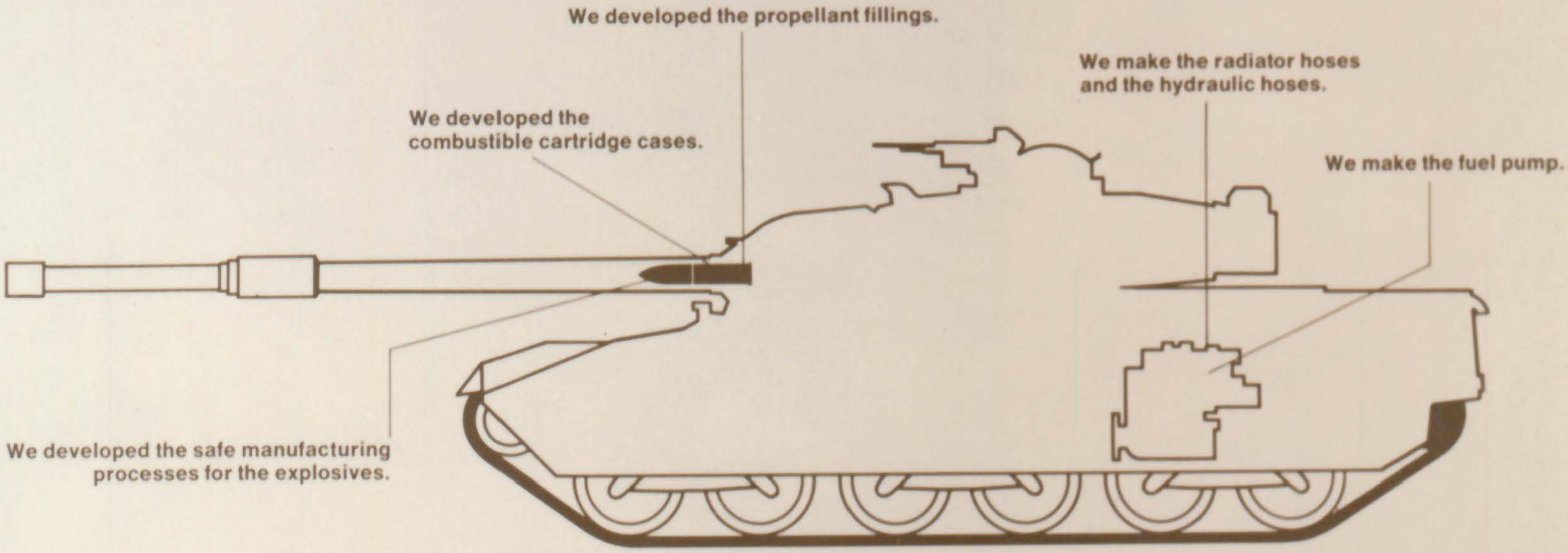
At present in service with FH70

Large shell fillings of TNT based explosives can crack during manufacture.

This can be prevented by using nucleating agents.

PERME PROVIDES THE DETAILS WHICH MAKE THINGS WORK

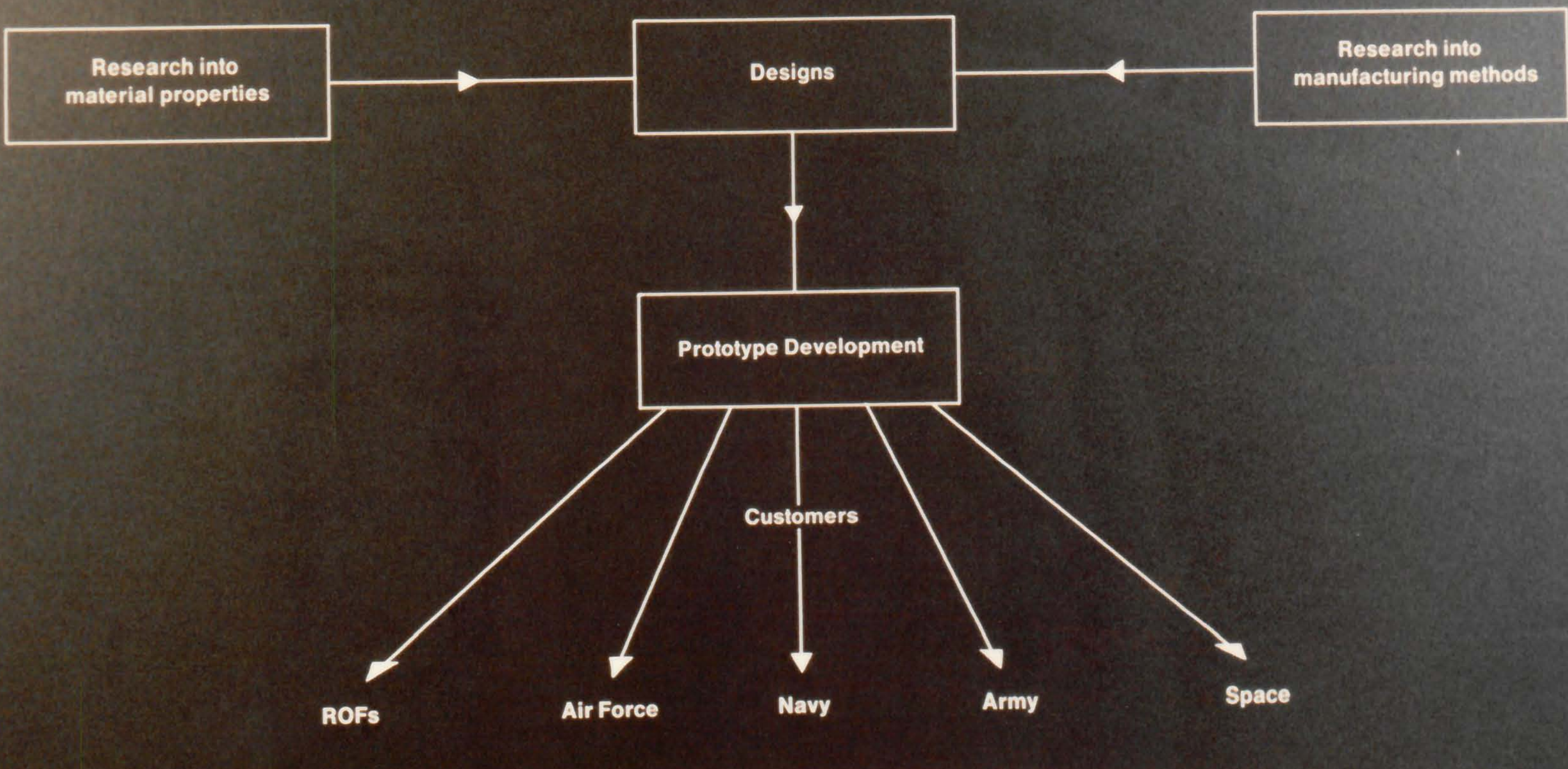
The Chieftain Tank would not be effective without our unique knowledge of all the chemical ingredients and their manufacturing processes.



PLASTICS AND RUBBERS DEVELOPMENT AND APPLICATIONS

A unique facility within MOD combining consultative design and manufacturing expertise over the whole range of rubbers and plastics.

Photographs of facilities/component

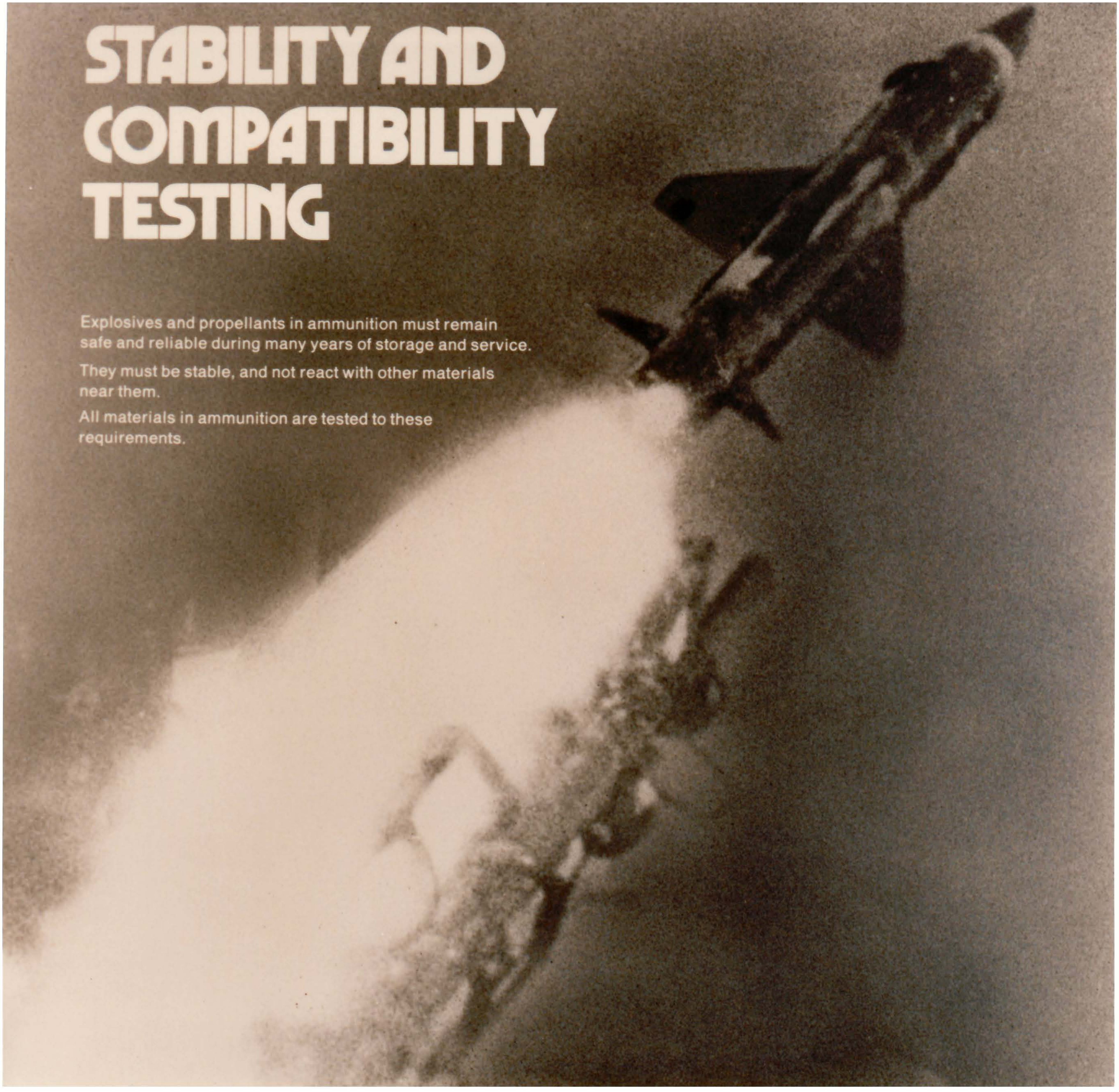


STABILITY AND COMPATIBILITY TESTING

Explosives and propellants in ammunition must remain safe and reliable during many years of storage and service.

They must be stable, and not react with other materials near them.

All materials in ammunition are tested to these requirements.



SAFETY AND ARMING MECHANISM

Detonators must have:

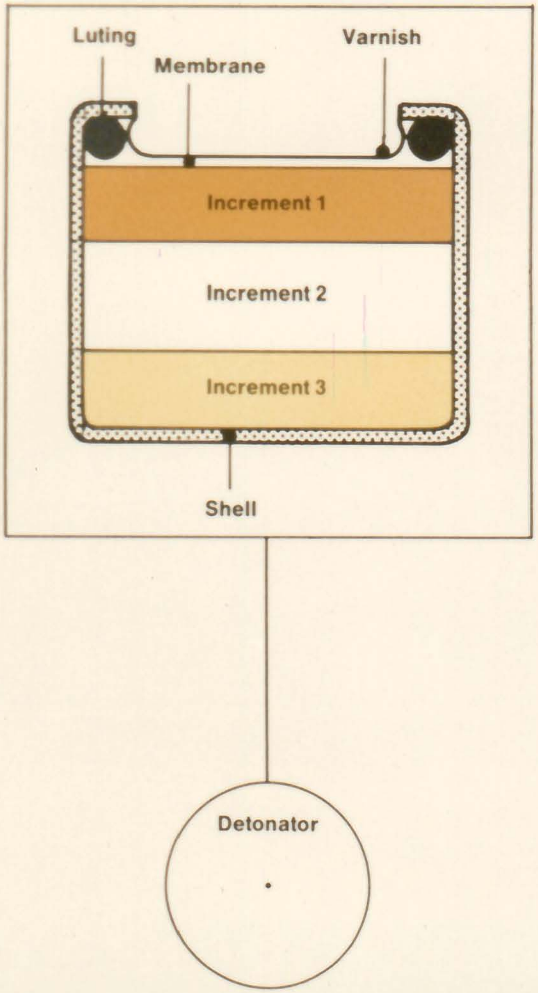
Stability of fillings.

Compatibility between increments.

Compatibility of metal shell.

Compatibility of sealants and varnishes.

No effect from moisture and other volatiles.



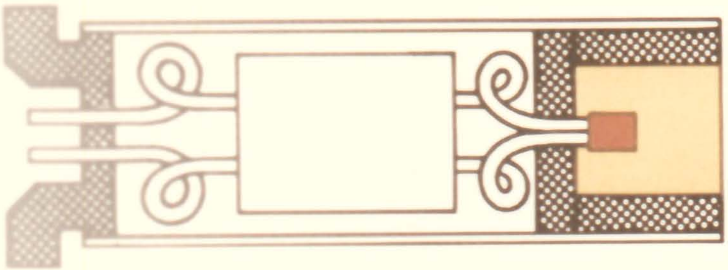
Safety and Arming Mechanisms are complex assemblies containing many materials.

The explosive items are small and must be able to survive in vapours generated by other non-metallic components, all of which are tested.

ROCKET MOTOR

Compatibility between explosive compositions in fuzehead and between fuzehead and pyrotechnic mixture.

Igniter

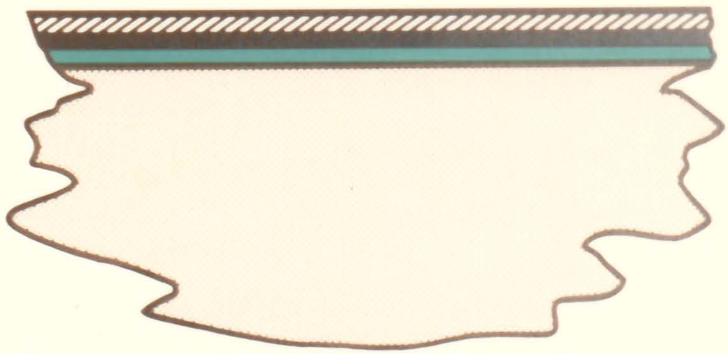


Propellant inhibition materials

No reaction with propellant.

Acceptable level of absorption of propellant ingredients.

Must remain bonded.



All components must be compatible with propellant fillings

Exterior paint

Sealants

O-rings

Venturi components

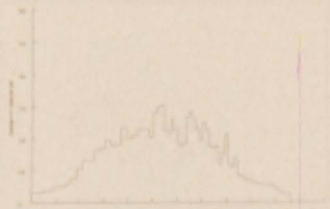
Propellant stability.

Safe life assessment.

Low gas evolution.

WORLDWIDE UV MONITORING PROGRAMME USING PPO FILM

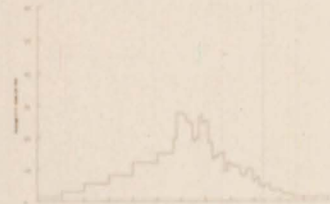
Average U.V. dose per day



(A) Yellow-Knife

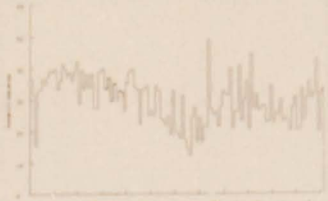
(B) Boston

(C) Yuma



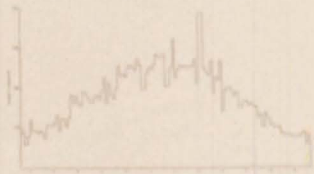
(D) Reykjavik

(E) PERME Essex



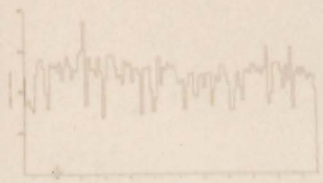
(F) Panama

(G) Oslo

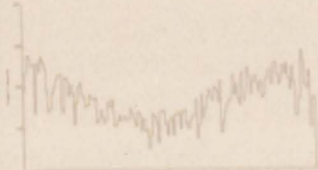


(H) Cyprus

(I) Salalah



(J) Gan

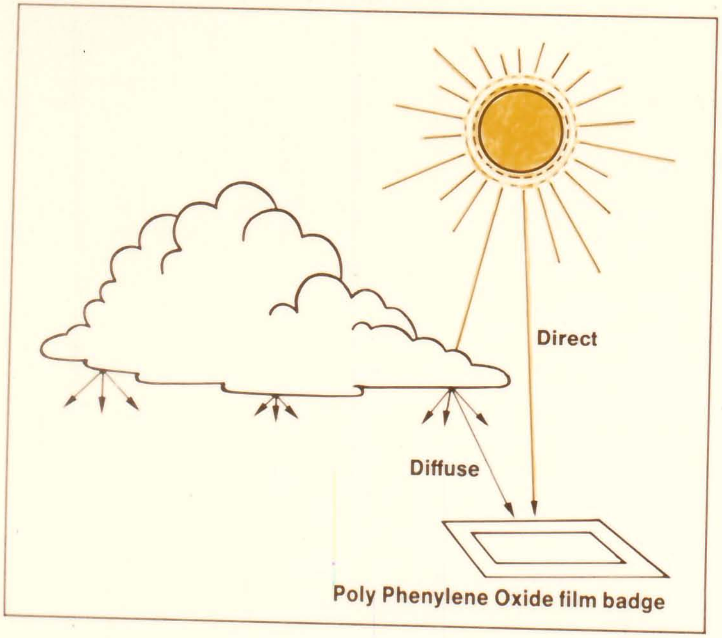


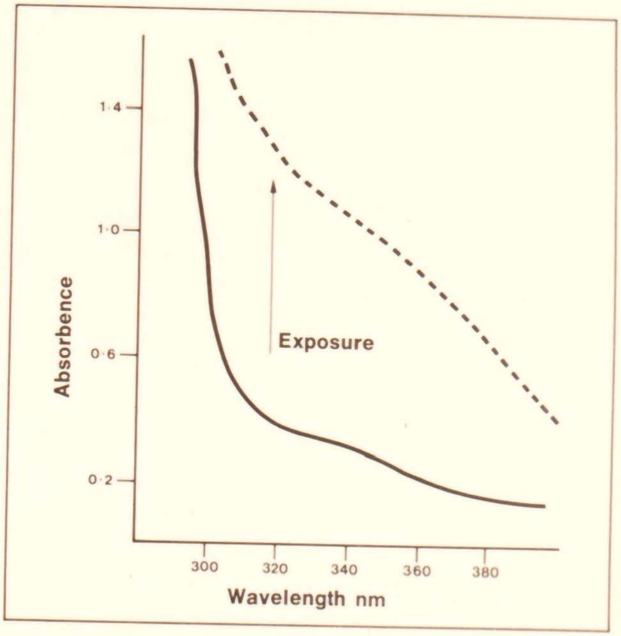
(K) Innisfail

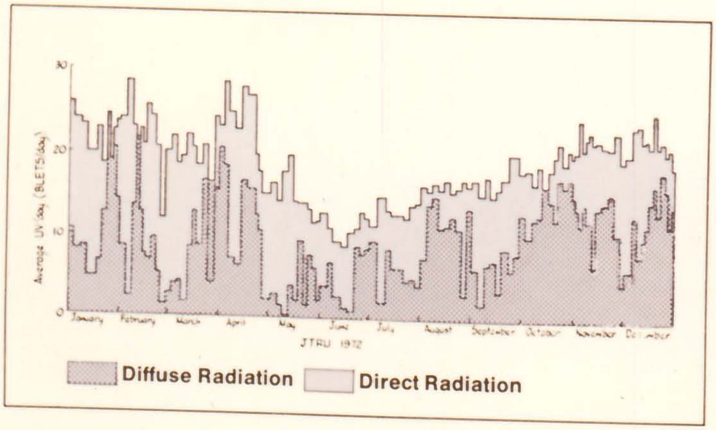
(L) Melbourne

MONITORING SOLAR ULTRAVIOLET RADIATION

Method: measures degree of colour change of PPO film which is caused by solar UV radiation.



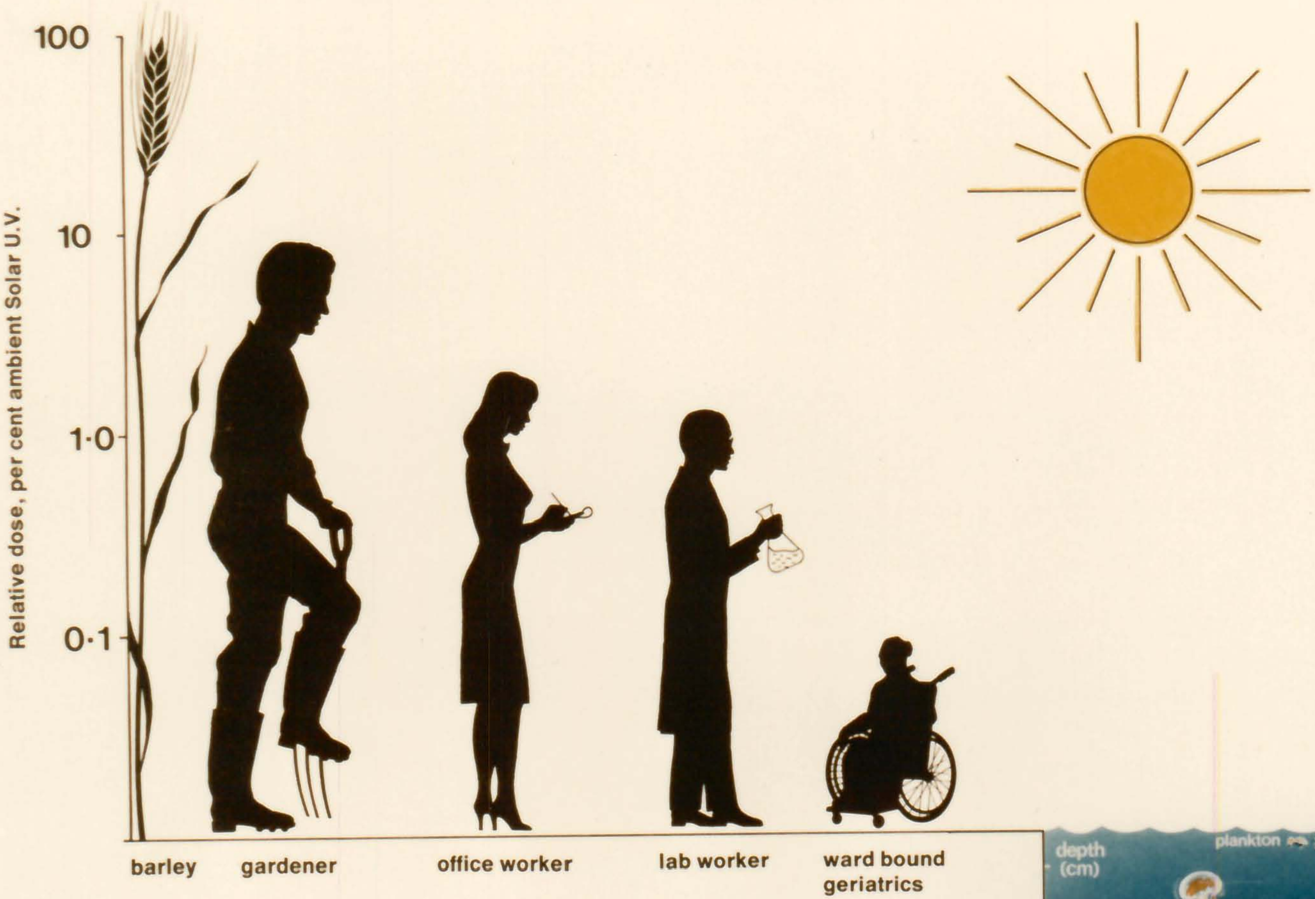




J.T.T.R.E. Innisfail

HARMFUL AND BENEFICIAL EFFECTS OF UV RADIATION

Relative U.V. dosage of various personnel and plants



UV measurements made with Polysulphone Film which has an erythema action spectrum similar to human skin.