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ERDE BOOKLET c. 1968
Activities + Facilities

Explosives Research & Development Establishment

Research and Development Activities and Facilities

MINISTRY of TECHNOLOGY

Gb Bromberger

EXPLOSIVES RESEARCH & DEVELOPMENT ESTABLISHMENT

RESEARCH and DEVELOPMENT ACTIVITIES and FACILITIES

ERDE MINISTRY of TECHNOLOGY WALTHAM ABBEY ESSEX

HOW TO CONSULT ERDE

ERDE is able to offer a limited, free consultative service to industrial undertakings on problems related to expertise available in the Establishment.

Problems involving more extensive investigations or the use of equipment and special facilities may be undertaken for a fee, subject to the demands of the Establishment's research and development programme.

Enquiries may be made

(*a*) by letter, addressed to The Director
ERDE
Ministry of Technology
Waltham Abbey, Essex;

(*b*) by telephone, asking for Heads of specific branches or ERDE Industrial Liaison Officer (01-97 23688).

ERDE TELEPHONE NUMBER

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CONTENTS

INTRODUCTION

The primary function of the Explosives Research and Development Establishment is to undertake research on, and development of, explosives, propellants and related exothermic compositions to meet the present and future requirements of the three Services. The Establishment is also actively engaged on materials work, concerned principally with the chemistry and physics of polymers, and with new engineering materials based on refractory fibres.

To exercise these functions, ERDE maintains a staff of scientific, technical and engineering personnel representing a wide range of disciplines but with particular expertise in chemistry, chemical engineering and physics. Research and development tasks are shared by seven technical branches supported by drawing office, machine shop, electronics and glass engineering facilities, and by appropriate library and information services.

It is the purpose of this book to give a brief outline of the work of the technical branches, especially those aspects involving expertise, facilities or equipment which are likely to be of interest to industrial undertakings.

MANAGEMENT ORGANIZATION

Director	Dr. L. J. Bellamy
Principal Superintendent/Development	Dr. G. H. S. Young
Special Merit 'B' Post	Mr. G. K. Adams
Heads of Branches	
Explosives	Mr. E. G. Whitbread
Propellants 1	Dr. W. G. Williams
Propellants 2	Mr. P. R. Freeman
Materials 1	Dr. R. L. Williams
Materials 2	Prof. J. E. Gordon
Analysis and Ingredients	Dr. I. Dunstan
Chemical Engineering	Mr. R. G. Ross
Chief Engineer	Mr. S. J. Lowdell
Chief Safety Officer	Mr. J. V. Griffiths
Chief Administrative Officer	Mr. S. F. M. Whiteside
Individual Merit Scientists	Dr. A. W. H. Pryde (Chemical Engineering)
	Mr. G. W. C. Taylor (Initiatory Explosives)
	Dr. N. Uri (Autoxidation)
	Mr. H. Ziebland (Heat Transfer)

EXPLOSIVES

Head of Branch E G WHITBREAD

The Explosives Branch deals primarily with the development of sensitive, initiatory explosives and high explosive and propellant compositions of improved performance. Trials are performed to assess sensitiveness and hazards associated with all explosive materials.

ACTIVITIES AND FACILITIES

Explosive Risk

Standard tests designed to evaluate and to compare the explosive risk of materials are based on impact and friction sensitiveness, ease of ignition, susceptibility to burn to detonation, and shock sensitiveness. Results enable recommendations to be made regarding type of hazard, degree of protection and appropriate storage requirements.

Armoured cupboards for small-scale tests (up to 30 g) and instrumented firing site facilities for larger quantities (up to 4·5 kg). Firing site for small-scale underwater tests.

Electrostatic Risk

Electrostatic risks associated with handling explosive powders, vapour/air, and gas/air mixtures are assessed by measuring

(*a*) electrostatic voltages and charges on transferring solids or liquids, or on separating surfaces;
(*b*) comparative electrification of materials, especially fabrics and plastics;
(*c*) electrical resistance of floors, footwear and items of equipment;
(*d*) susceptibility to ignition by capacitor type discharge.

Electrostatic voltmeter (30—18 000 volts); resistance meters (up to 10^{16} ohms); facilities for measuring electrostatic spark sensitiveness of powders.

High Speed Photography

This technique is used to record mechanical and explosive phenomena, to investigate shock initiation of explosives and to determine propagation velocities.

Portable 16 mm ciné camera (100—18 000 frames/sec): framing camera (25 frames at 150 000 — 4 × 10^6 frames/sec), installed in 2·25 kg explosives test facility; streak camera (writing speed 0·7 mm—9 mm/microsec), installed in 4·5 kg explosives test facility. Printing facilities include conversion of 35 mm frames into animated 16 mm film, and colour printing of negatives of explosive phenomena with particular reference to correct colour balance.

Noise Evaluation

Measurement and analysis of impulsive noises including those of long duration (e.g. sonic booms), and their simulation by explosives. Techniques for generating a wide range of pressure waveforms in air may be applied to studying the behaviour of structures to shocks of this kind.

Apparatus to record shock waves in air down to 5 N/m^2 (0·1 lbf/ft^2).

Remote Control Methods

Development of remote control methods for manufacturing and testing dangerous explosive materials.

Process bays (limit 7·25 kg TNT equivalent) in which hazardous operations can be performed by remote control. Remotely operated mixing, extruding and injection moulding unit (4·5 kg) with temperature, vacuum and shear rate controls on mixer (viscosities 2—3 000 poise). Strong bay (limit 1·35 kg TNT equivalent) with master slave manipulators (3·5 m extended reach), X-ray facility (250 kv), and armoured viewing window. Capability for melt-mixing and moulding, or for pressing explosives, and for carrying out basic machinery operations on explosive charges by remote control. Closed circuit TV available to position all remotely-controlled operations.

Gas Kinetics

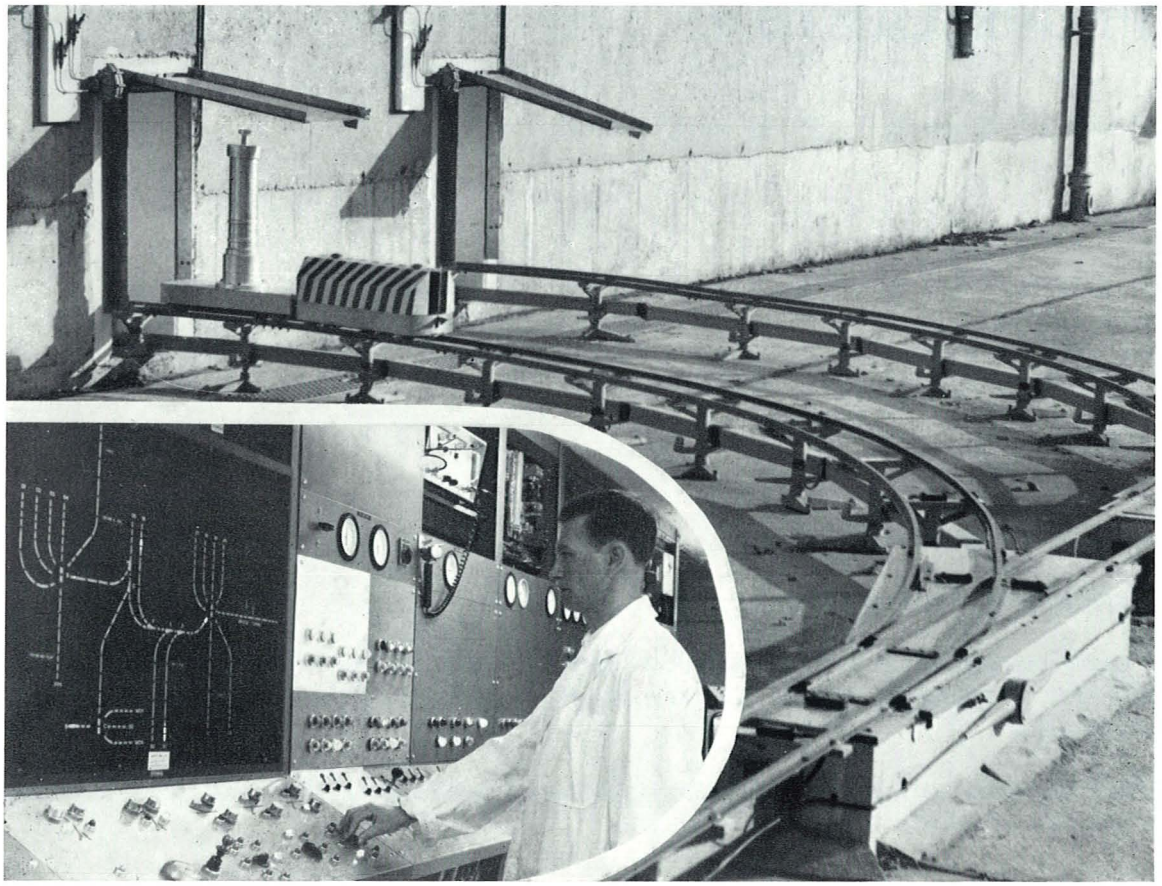
Kinetics and mechanisms of gas-phase reactions and general free radical chemistry using static and discharge-flow techniques. Reactions of alkyl and alkoxy radicals, nitrogen oxide and nitrogen dioxide. Mechanisms of gas-solid reactions.

High vacuum techniques and product analysis by vapour-phase chromatography, infra-red and mass spectrometry. Emission spectroscopy.

Polymer Technology

Cure chemistry of polyurethane elastomers prepared from di-isocyanates and hydroxy-terminated polyesters and polyethers; optimization of physical properties of heavily-loaded rubbers.

Small scale plant facility for development work; laboratory equipped to study physical properties and ageing characteristics.



REMOTE-CONTROL TRANSPORTATION OF HAZARDOUS MATERIALS
A five-inch gauge electric railway system used to transport hazardous materials between manufacturing, testing and storage areas.

PROPELLANTS 1

Head of Branch W G WILLIAMS

Propellants 1 Branch is largely concerned with the development of propellants based on nitrocellulose. Work is undertaken on methods for controlling ballistics, and to devise ballistic assessment techniques. Attention is also given to the quality control of propellants by non-destructive tests involving X-ray or ultrasonic inspection.

ACTIVITIES AND FACILITIES

Propellant Processing

Experimental processing of nitrocellulose-based propellants poses problems similar to those involved in processing plastic materials, especially consideration of viscosity control and particle size.

Plant for rolling and extrusion of incorporated materials; preparation of felted paper tubes with high length/diameter ratios.

Combustion

Investigations of propellant combustion using techniques equally applicable to combustion of fuel oils and gases. High temperature degradation of organic materials, research capable of being extended to flammability and flame-proofing of plastics.

Equipment to measure temperature profiles at burning surfaces, and appropriate instruments (infra-red and ultra-violet spectrophotometers and gas chromatographs) for flame decomposition product analysis.

Ballistic Properties

Burning rates and calorimetric measurements. Experimental techniques are available to study solids, liquids, and gases, and to determine precise heats of combustion, formation and wetting.

Equipment to measure static and dynamic pressures for fractions of a second or longer in ranges up to 31 MN/m^2 (4500 psi). Calorimeters with platinum resistance thermometry systems (precision better than $1 \times 10^{-3}°C$).

Non-Destructive Testing

The integrity and bonding of propellants are inspected by radiographic and ultrasonic test methods which may also be used to investigate conventional plastics and bonded systems.

Radiographic (400 kV) and ultrasonic (375 kc/sec through transmission) inspection equipment.

PRECISION CALORIMETRY
An NPL-pattern bomb calorimeter for determining heats of combustion with an accuracy approaching 1 part in 10^4.

PROPELLANTS 2

Head of Branch P R FREEMAN

Propellants 2 Branch is responsible for research and development on composite propellants based on plastic or rubbery binder systems. The facilities include laboratories for quality control, including ballistic and physical property assessment, together with small- and large-scale manufacturing plants.

Basic and applied research on rheology and adhesion is performed to improve the mechanical behaviour of solid propellants and to provide an advisory service on the use of sealants, adhesives and lutings. A Section concerned with heat transfer and low temperature research uses specialized engineering techniques to study heat transfer parameters of materials under conditions encountered in liquid propellant rocket engines.

ACTIVITIES AND FACILITIES

Thermal Conductivity

Precision measurements of thermal conductivities of liquids, gases, and supercritical fluids (12°— 650°K; up to 300 MN/m²); facilities equally suitable for measuring viscosity, dielectric constant, etc. over wide ranges of temperature and pressure.

Air conditioned laboratory for precision temperature measurement; protected annexe for compressing gases and liquids; thermal conductivity cells: Phillips helium-filled cryogenerator (12° — 90°K); liquid nitrogen-filled metal thermostat (90° — 220°K); recirculating Turbotherm-filled liquid thermostat (300° — 650°K).

Convective and Radiative Heat Transfer from Flames and Gases

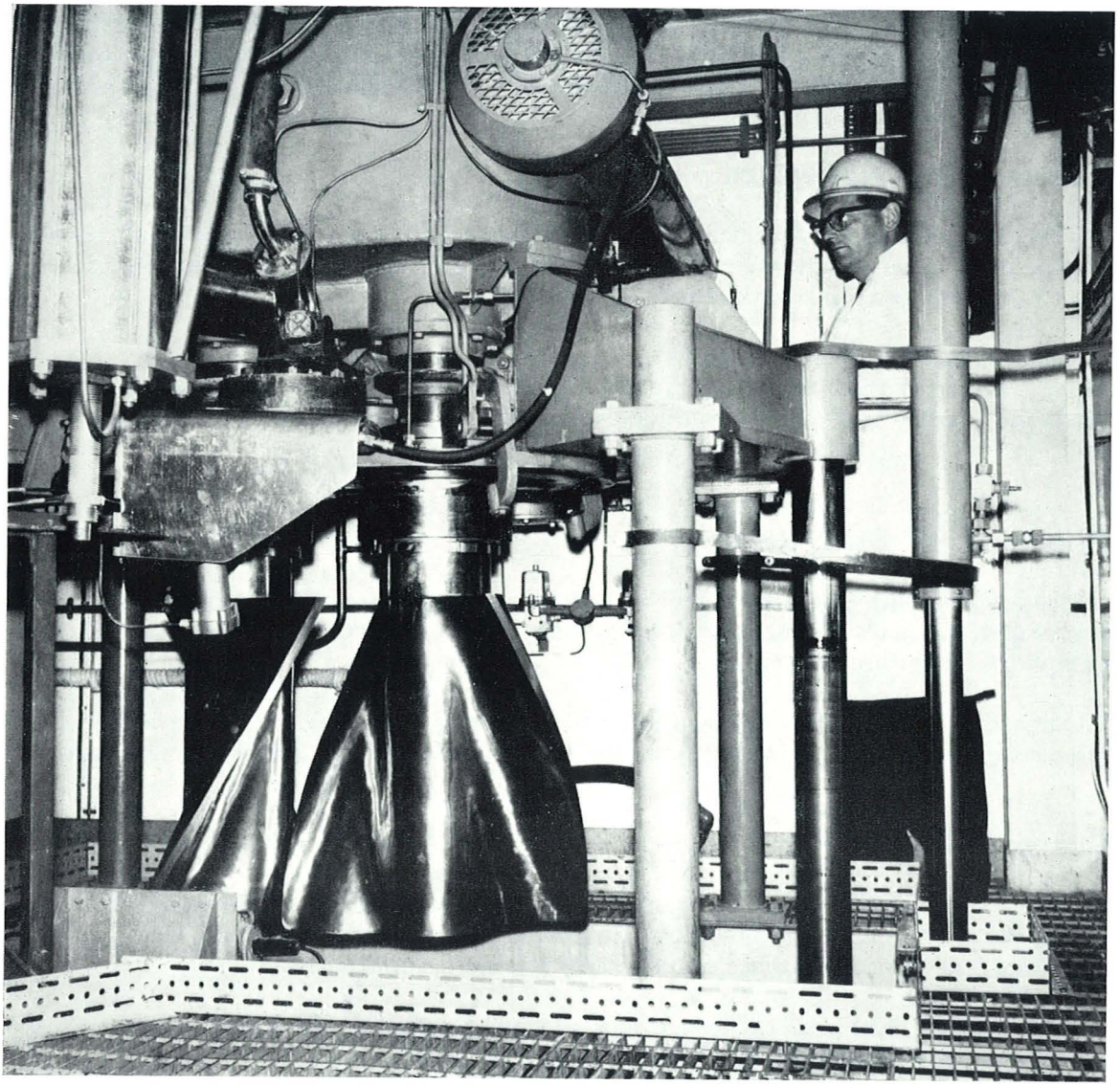
Studies of convection and radiation from flames and combustion gases (up to 3800°K; 10 MN/m²); radiative emissivity of water vapour (1500°—3500°K; 0·5—10 MN/m²).

Two instrumented test cubicles; water-cooled combustion chambers; black-body furnace to calibrate radiation sources.

Heat transfer from heated gas under disturbed or under-developed flow conditions; effects of burner head design and Reynolds number.

Horizontal tubular test rig using electrically heated nitrogen as heat transfer fluid (maximum temperature, 620°K at 10 kW energy dissipation; maximum pressure, 6 MN/m²).

Design, construction and operation of high-pressure combustion chambers; novel techniques for cooling surfaces; measurement of convective heat transfer from dissociating gases; instrumentation to measure temperature, flow rates, electrical energy, and small pressure differences at high static pressures.



VERTICAL MIXER FOR RUBBERY-TYPE SOLID PROPELLANTS
The mixing pot has been lowered for removal of the propellant mix.

Convective Heat Transfer to Cryogenic Fluids

Convective heat transfer to fluid hydrogen in the vicinity of the critical point and at supercritical pressures; fluid dynamics of cryogenic fluids.

Remotely-operated test rig in which cryogenic fluids flow through asymmetrically heated rectangular ducts (maximum energy dissipation, 40 kW; maximum pressure, 5 MN/m²).

Convective Heat Transfer to Liquids

Convective heat transfer from electrically heated surfaces to aviation kerosine under subcooled, boiling, and supercritical conditions.

Closed-loop apparatus with rectangular test-section channel containing heated tube (maximum power, 10 kW; maximum pressure, 10 MN/m²; maximum fluid flow rate, 1·2 kg/sec). Photographic observation using Fastex ciné camera (18 000 half-frames/sec) and 0·2 μsec argon flash lamp.

Sealants and Adhesives

Development of lutings and cements for threaded joints, etc., and adhesives for metal, plastics, paper, and leather; study of tensile and shear strength, and of stress-strain behaviour of adhesives, joints and solid propellants (— 50° to 60°C).

Instron universal testing machine (load, 10^{-3} — 5000 kg; cross-head speed, 10^{-3} — 10 mm/sec; cross-head travel, 1 m) with thermostatic chamber. Hydraulically-operated high-speed test machine (strain rate up to 10 cm/sec); Sanborn twin-channel recorder (10 ms response) and Tektronix oscilloscope. Test rigs for joint strengths.

Rheology of Stiff Pastes

Dependence of rheological behaviour of highly concentrated solid-in-liquid dispersions on nature of solids, solids loading, magnitude and distribution of particle size, nature and viscosity of liquid, temperature and test methods.

Plastometers to study flow and deformation behaviour including fatigue effect of cyclic compression and extension, effect of imposed hydrostatic pressure, and response to biaxial strain. Brittle point apparatus.

Surface Chemistry

Surface tensions of highly viscous organic liquids; effect of molecular weight and temperature. Study of contact angles and interfacial tensions between viscous liquids and inorganic salts, and their dependence on surface contaminants (moisture, surfactants).

Equipment for surface tension and contact angle measurement; thermal siphoning technique for growing large perfect crystals of inorganic salts.

Particle Size Analysis

Measurement of size and size distribution of particulate solids (0·1 — 150μ).

Sharples Micromerograph (humidity- and temperature-controlled); photo-extinction sedimentometer; gas adsorption and various types of gas permeability apparatus for surface area measurement.

Technology of Pastes and Slurries

Formulation, manufacture, and handling of stiff pastes based on curable and non-curable liquid organic polymers.

Vertical mixers (capacity, 300 kg; maximum viscosity, 20 000 poise); horizontal mixers (150 kg; 10^7 poise); de-aerating pug-mills; hydraulic processing and small-scale extruding equipment.

MATERIALS 1

Head of Branch R L WILLIAMS

Materials 1 Branch undertakes basic and applied research on the chemistry and physics of polymers with particular regard to synthesis, characterization, degradation, and mechanical behaviour under a range of test conditions. The Branch offers an advisory service on the applications of polymers, and supervises long-term environmental testing at the Tropical Research Unit, which is a joint project with Australia.

ACTIVITIES AND FACILITIES

Polymer Physics and Engineering

Study of the physical properties of non-metallic materials and reinforced plastics: stress-strain curve, strength, fracture energy, damping capacity, creep, fatigue, stress relaxation, and dimensional stability. Effects of rate of deformation, temperature and moisture. Stress relaxation tests on rings and beams; dynamic mechanical properties of discs. Compression cell to study effects of dynamic, static, and creep loading.

Hounsfield apparatus (extension rate, 0·0013 — 50·8 cm/min; temperature, — 80° to 80°C); Baldwin machine; Goodbrand machine (fibre test). Avery Izod impact machines (capacity 17 kg.m; maximum loading rate, 18 × 10^2 kN/sec; photographic recording with 35 mm. streak- or 12 000 frames/sec Fastex-cameras). Flywheel machine (fracture energies at impact velocities of 130—1 300 cm/sec). Ultrasonic equipment (150 kc/sec—2 Mc/sec; up to 80°C). Rotating beam machine (fatigue properties).

Polymer Chemistry—Synthesis, Characterization, and Stability

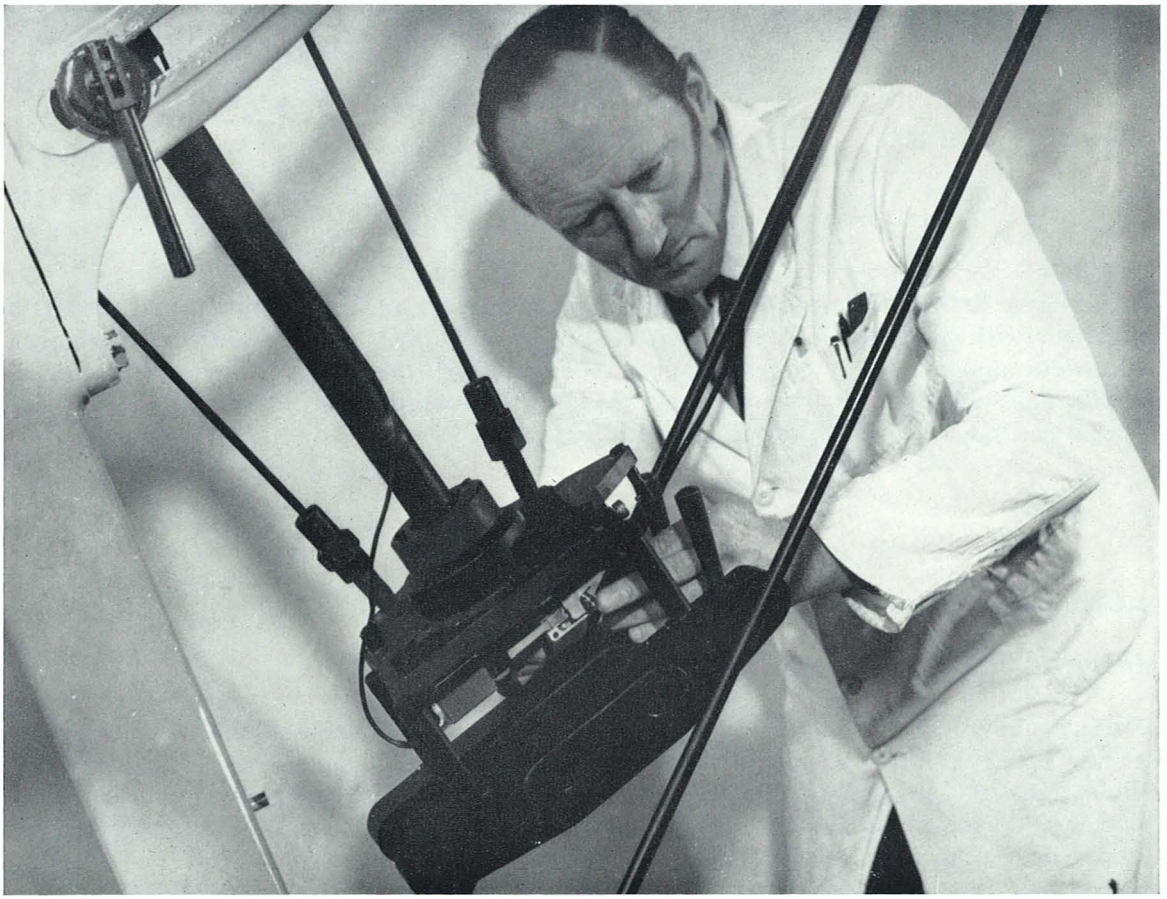
Investigation of novel and potentially useful polymer systems; monomer and polymer synthesis, polymer fractionation, mechanism and kinetics of polymerization, reactions of polymers.

Characterization of polymers by molecular weight (viscometry, osmometry, light scattering, and end-group analysis), spectroscopy (IR, UV and NMR), dilatometry, bulk viscometry, compressibility and thermal expansion measurements, and by optical examination of polymer morphology.

Stability of addition and condensation polymers to heat, ultra-violet light, and high energy radiation; effects of chemical structure, impurities and environment. Mechanism and kinetics of degradation and its effect on molecular weight and physical properties.

MOLECULAR WEIGHT *Hewlett-Packard 502 high-speed membrane osmometer (maximum operating temperature 130°C); Brice-Phoenix Series 2000 Universal light scattering photometer with MSE high-speed centrifuge.*

BULK PROPERTIES *Epprecht Viscometer (0·1—10^6 poise, 0°—180°C); linear expansion apparatus for glass transition temperatures; pressure balance (temperature controlled to ±0·001°C).*

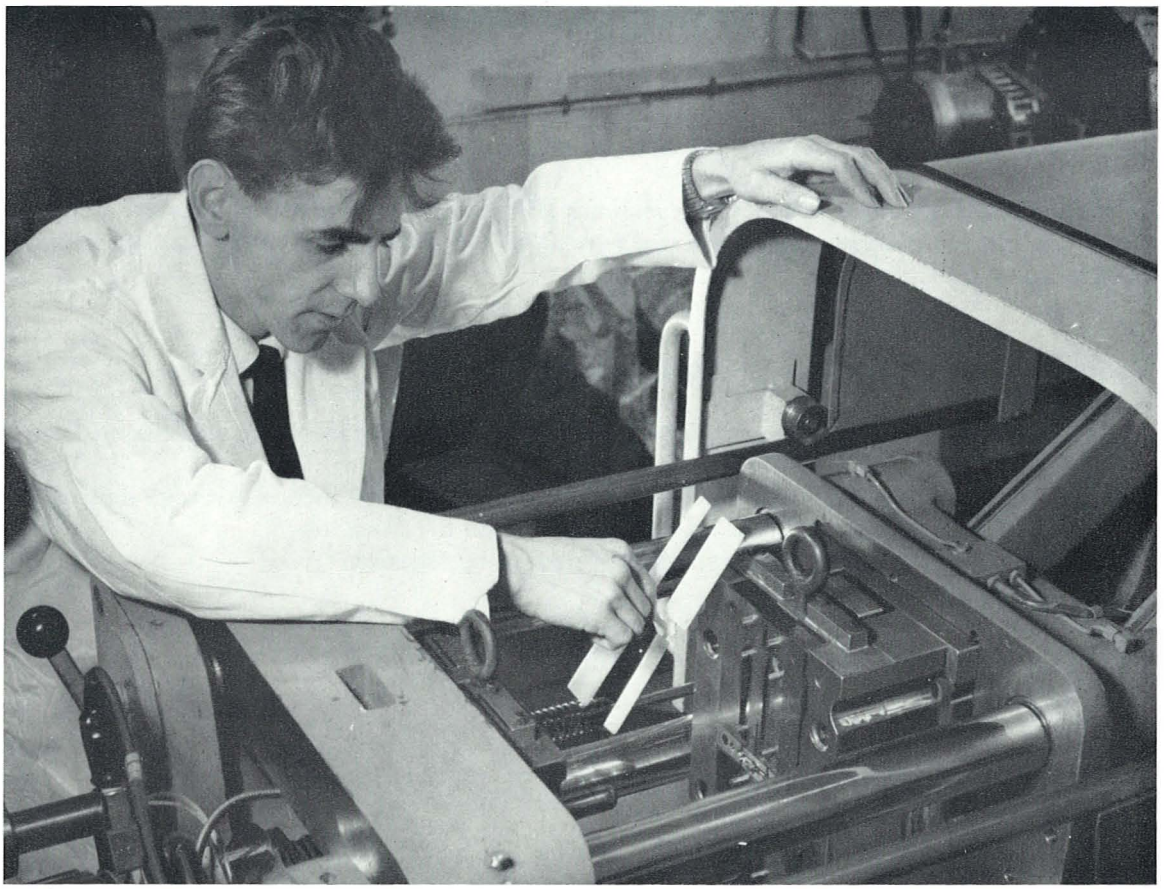


AVERY IZOD PENDULUM IMPACT APPARATUS

A pendulum impact tester modified for tensile and flexural impact tests to investigate the engineering life of non-metals.

NUCLEAR MAGNETIC RESONANCE MEASUREMENT

This 60 M/c instrument is used for characterization and structure determination of a wide range of organic compounds.



HORIZONTAL INJECTION MOULDING MACHINE
Test pieces for mechanical property assessment being produced in a constant torque, injection moulding machine.

SPECTROSCOPY *PE R10 60 M/c NMR spectrometer (variable temperature probe, spin decoupling unit, probes for* ^{1}H, ^{11}B, ^{19}F, *and* ^{31}P; *PE 337 grating spectrometer (4000—400* cm^{-1}, *ATR attachment); Unicam SP 500 spectrometer.*

MICROSCOPY *Gilett and Sibert time-lapse microscope (35 mm and 16 mm (ciné) photographic recording).*

DEGRADATION *Mercury lamp, xenon arc, molten salt- and fluidized sand baths.*

GAS CHROMATOGRAPHY *PE Model 801 (dual column analytical instrument, linear programming); Pye Model 105/15 (automatic preparative gas chromatograph, linear programming).*

Polymer Development and Applications

Processing and curing of new rubbers and thermoplastics by injection moulding, extrusion, milling, and compression moulding. Measurement of physical properties, and the effect of contaminants (e.g. explosives, propellants, petrol, etc.). Accelerated and tropical ageing trials to assess useful life. Investigation of failures. Manufacture of special components; antistatic and conducting rubbers.

Proofed fabrics: preparation, mechanical properties, and advice on the design of proofed fabric structures.

PROCESSING *Wide range of mills, mixers, hydraulic presses and injection moulding machines. Facilities for the synthesis of polyester-polyurethane rubbers. Small-scale equipment for preparing proofed-fabric samples.*

TESTING *Physical properties; permeability of materials to organic fluids and water; ageing ovens to simulate hot/dry and hot/wet conditions; continuous and intermittent stress relaxometers. Carbon arc equipment for special exposures.*

Joint Tropical Research Unit, Queensland

Four sites are available for the exposure of small specimens to atmospheric weathering.

(*a*) INNISFAIL Latitude 17° 32′S. Average annual rainfall 140 inches. Average daily mean temperature 74°F; relative humidity 83 to 87. Sites are
(i) Hot/wet, jungle, i.e. sunlight screened off by foliation.
(ii) Hot/wet, clearing.

(*b*) CLUMP POINT Similar latitude and conditions to Innisfail but the site is
(iii) Marine.

(*b*) CLONCURRY Latitude 20° 43′S. Average annual rainfall 17 inches. Average daily mean temperature 78°F; relative humidity 39. The site is designated
(iv) Hot/dry.

MATERIALS 2

Head of Branch J E GORDON

Materials 2 Branch carries out research and development on fibre-reinforced materials and on the growth of ceramic whiskers.

High Temperature Equipment

Furnaces of various types for operation up to about 1600°C; high frequency heating equipment; temperature measuring devices.

Fibre Processing Plant

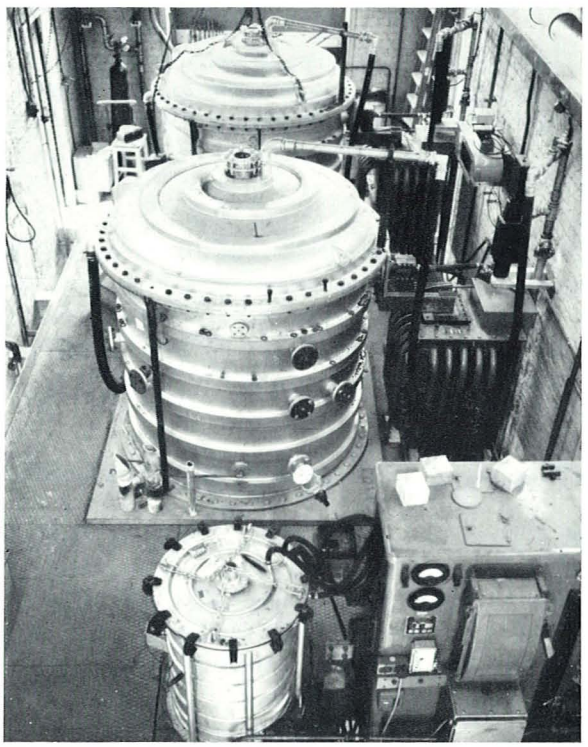
Equipment for sizing whiskers and other short fibres.

Fibre Testing Equipment

Marsh micro-testing machine and various macro-testing machines.

Microscopes

A range of optical microscopes and a J.E.M. 7 electron microscope.



'BRAN TUBS'
High temperature furnaces for synthesis of silicon nitride whiskers.

ANALYSIS AND INGREDIENTS

Head of Branch I DUNSTAN

The Analysis and Ingredients Branch investigates the preparation, properties and reactions of a wide range of ingredients related to explosive, propellant and polymer technology. The Branch offers an advisory service on the stability, compatibility and surveillance testing of propellants, explosives and other hazardous materials. New analytical methods are developed to assist quality control, and a range of specialized techniques and facilities are used to provide an analytical service for the Establishment.

ACTIVITIES AND FACILITIES

Synthesis and Characterization

Synthesis of explosives and ingredients of solid propellants and polymers (fuels, oxidizers, ballistic additives, stabilizers, curing agents, antioxidants, etc.); studies to optimize yield and purity and to reduce hazard (toxicity, thermal decomposition, etc.).

General techniques of preparative chemistry, and supporting facilities: armoured cupboards; PE Model 237 grating spectrometer (4000—650 cm^{-1}); Unicam SP 500 spectrometer; various refractometers and optical microscopes, including Kofler hot-stage instruments; molecular weight determination by semi-micro ebulliometry and micro-cryoscopy.

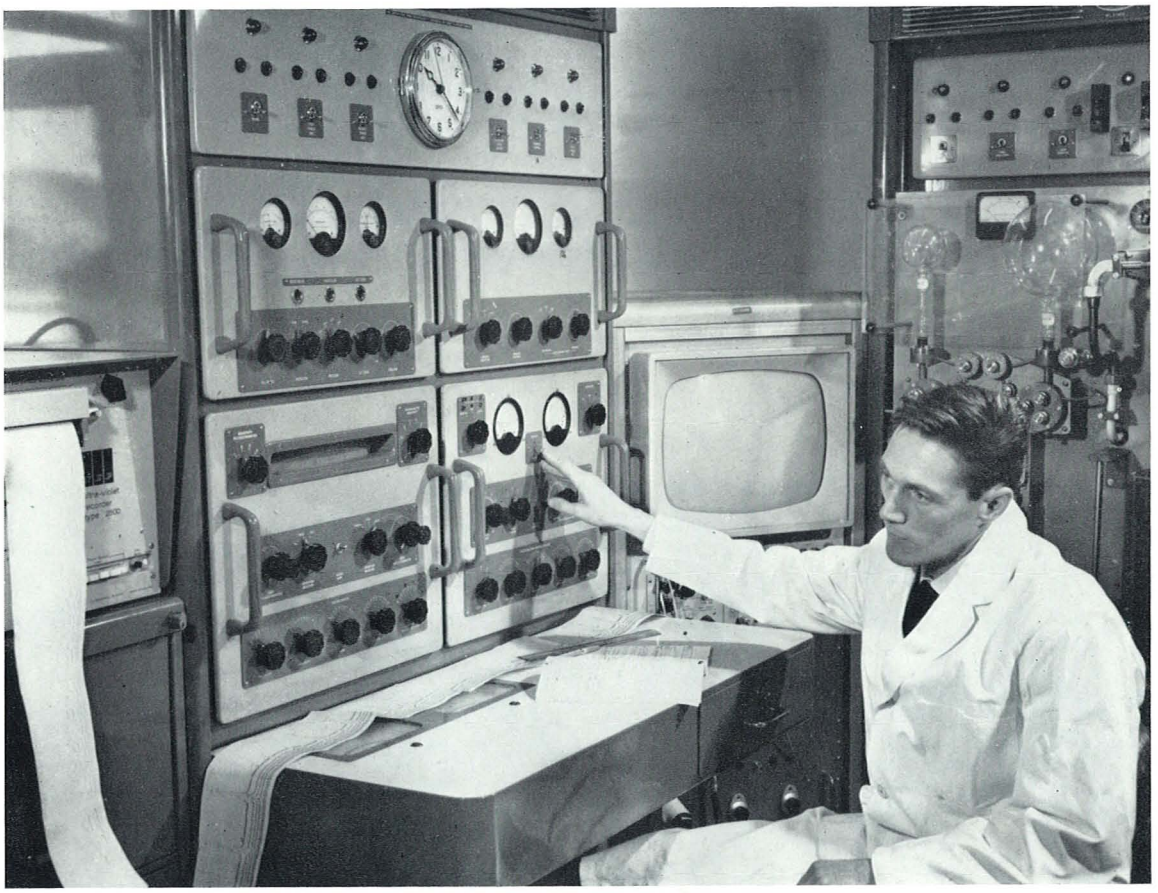
Stability and Compatibility

Kinetics and mechanism of thermal decomposition of explosives and exothermic compositions; ignition phenomena and build-up to low order detonation; compatibility of explosives, propellants, etc. with materials (e.g. polymers, plastics, metals, adhesives, varnishes and paints); effect of severe environmental conditions on storage stability. New techniques to investigate thermal stability.

Environmental testing ovens and standard stability test facilities. Master slave manipulator. Stanton thermogravimetric balance (maximum temperature, 250°C); PE differential scanning calorimeter, Model 1 (−100° to 500°); *heat flow calorimeter (sensitivity, 30 μwatts); multirange temperature recording equipment (−200° to 500°C). Photomicroscopy of samples heated in vacuum. Advance Model TC 2A electronic timer counter (1 μsec).*

Chemical Analysis and Physical Methods

Separation, identification, and analysis of the constituents of explosives, propellants, polymers, rubbers, etc.; determination of functional groups, elemental composition, and molecular weight; trace metal analysis. Estimation of purity, and investigation of quality control and specification tests. Studies concerned with gas and solvent vapour analysis; molecular and crystal structure; thermochemical characteristics (phase changes, low temperature behaviour and thermal decomposition); cure- and post-cure chemistry of polymeric systems; non-aqueous titration; mass spectrometric and polarographic analysis.



MASS SPECTROMETRY
An AEI Model MS2H mass spectrometer capable of performing isotopic and chemical analyses on very small quantities of material, including solids.

CHROMATOGRAPHY *Wide range of standard equipment for analytical- and preparative-scale column- and thin layer chromatography; Craig counter-current extraction apparatus; Varian Aerograph Model 1522 gas chromatograph (dual column, linear programming); PE Fraktometer; pyrolysis attachment.*

SPECTROSCOPY *PE Model 257 grating spectrometer (4000—650 cm^{-1}) ATR attachment, micro- and heated cells; modified Grubb Parsons S3A spectrometer (3500—250 cm^{-1}); PE Model 137 UV spectrometer; Unicam SP90 atomic absorption spectrophotometer.*

MASS SPECTROMETRY *AEI Model MS 2H*

MICROANALYSIS *Combustion equipment (C, H, N); Schöniger flask (S, halogens); Mechrolab Model 302 vapour pressure osmometer (molecular weights up to 20 000).*

POLAROGRAPHY *Beckman Electroscan 30 (various electrometric analysis techniques).*

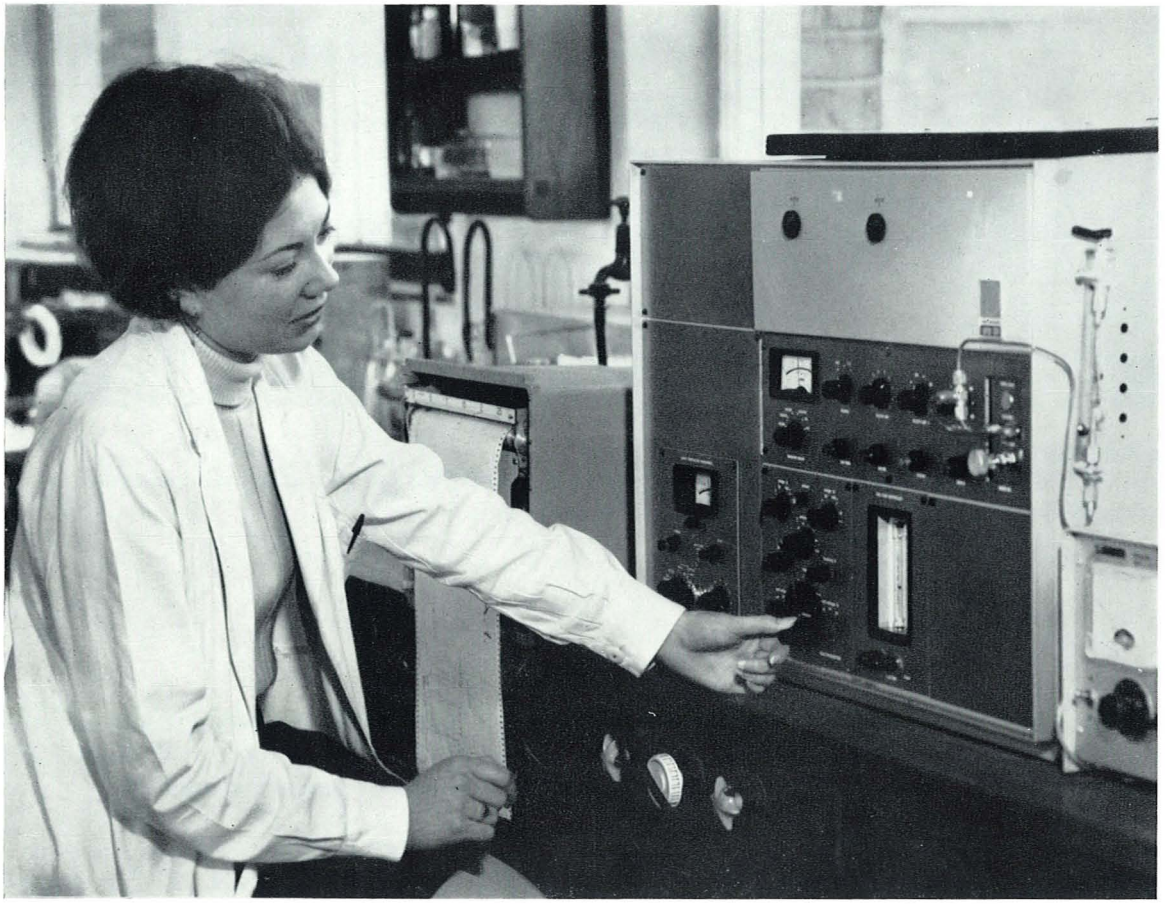
RADIOCHEMISTRY *Tracer laboratory; Panax standard- and low background Geiger counters; Isotope Development Ltd. solid and liquid scintillation counters.*

THERMOCHEMICAL ANALYSIS see *Stability and Compatibility.*

Crystallography

Application of optical and X-ray diffraction to identification and characterization of compounds; phase analysis of mixtures, polymorphism, crystal orientation, and crystal structure analysis.

Equipment includes three X-ray generators, one being a high-power rotating anode set, X-ray powder cameras, goniometers (Weissenberg, oscillating crystal and optical), an X-ray powder diffractometer, and polarizing microscope with heating stage.



GAS CHROMATOGRAPHY
This technique is particularly useful for identifying and estimating volatile constituents of complex mixtures.

CHEMICAL ENGINEERING

Head of Branch R G ROSS

The Chemical Engineering Branch is concerned with means and equipment for processing chemicals on a production scale. Plant and facilities are designed for the manufacture of hazardous compounds and mixtures with particular emphasis on safety, remote-control, and instrumentation. The Branch has special interests in unit operations such as crystallization and mixing, and in the development and application of instruments and apparatus based on electronic and glass engineering techniques.

ACTIVITIES AND FACILITIES

Large-scale Production

Development of laboratory syntheses on to pilot- and full-scale processes; pilot plant operation; manufacture of experimental chemicals and materials, including high explosives, polymer and rocket ingredients, whiskers and aligned inorganic fibres.

Protective enclosures, with remote control, for processing experimental quantities of dangerous chemicals (i.e. fire, explosion, toxicity risks): one for large laboratory-scale glass plant; another for 2·5 kg pilot plant scale, equipped with a closed circuit television loop.

A wide range of pilot-scale plant, including: plant for concentrating nitric acid free from nitrous acid; nitration and sulphonation unit with brine cooling, remote control and acid mixing plant; glass-lined oil heated reactors for polymer manufacture; and plants to classify and align asbestos and other whiskers for making composite materials.

Separators such as decanters; pressure-, vacuum- and rotary filters; batch and continuous stainless steel centrifuges; liquid centrifuges; and dry powder sieves.

Dryers, including hot air-, vacuum tray- and rotary-steam tube types.

Grinding plant, including jaw crusher; roll mill; edge-runner mill; hammer mills; and 'micronizer' fluid energy mill.

Mixers: double cone powder blender; medium and heavy paste mixers.

Packed, gas-liquid absorption towers.

Distillation: a 5-cm glass 'molecular' still; a 50-litre glass batch distillation unit; glass distillation column of high efficiency for high vacuum and 150°C; similar unit in stainless steel for pressure distillation up to 1 MN/m².

Crystallization

Studies of nucleation and crystal growth; control of crystal shape, size, and size distribution.

Laboratory equipment for measuring nucleation and crystal growth rates in a stirred cooling crystallizer.

Pilot crystallizers: Kestner evaporative; Oslo type; and pulsed tube type, for performance studies and production of crystalline products.

Intensive Drying or Stripping

The intensive drying (or stripping) of high boiling liquids which may be sensitive to heat or excessive turbulence.

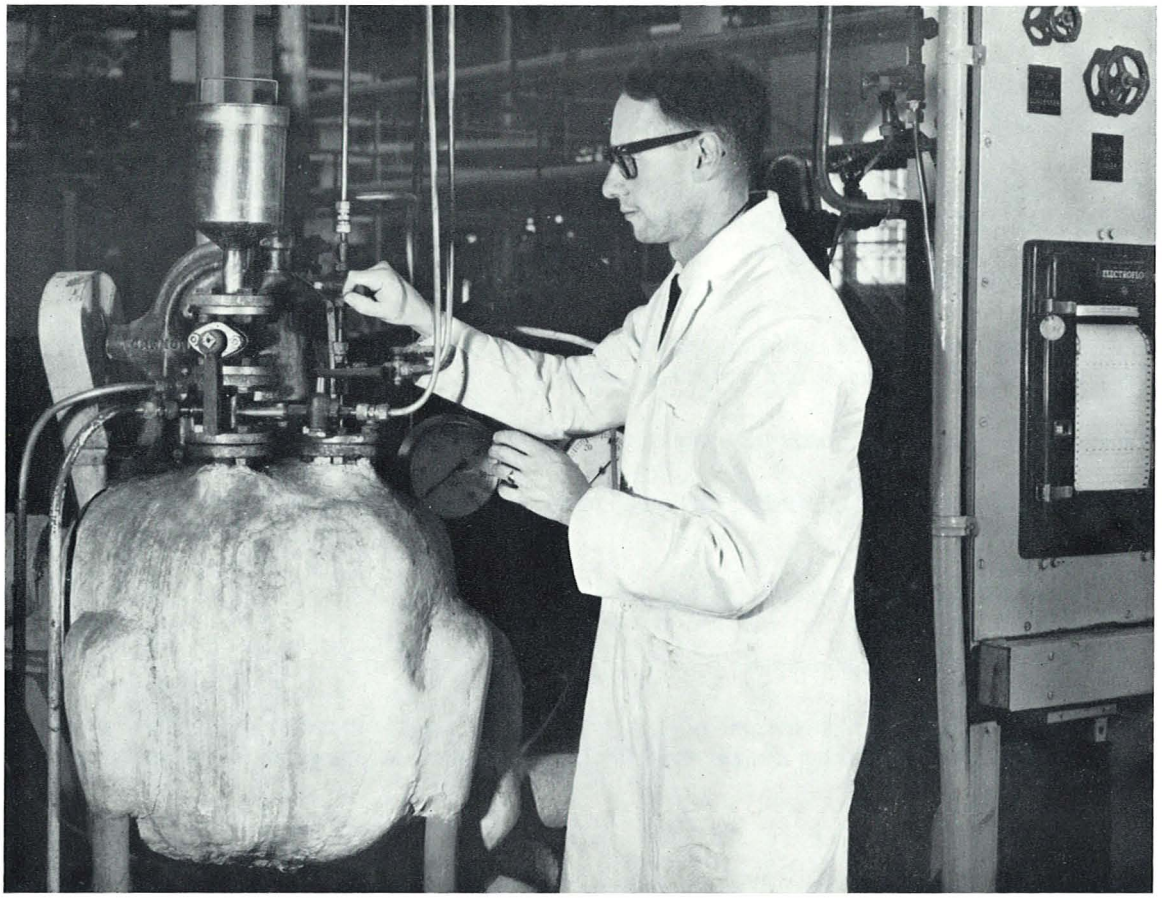
Continuous plant (11·5 kg/h), based on single passage of liquid down a column packed with a battery of vertical helical coils.

Equipment Design

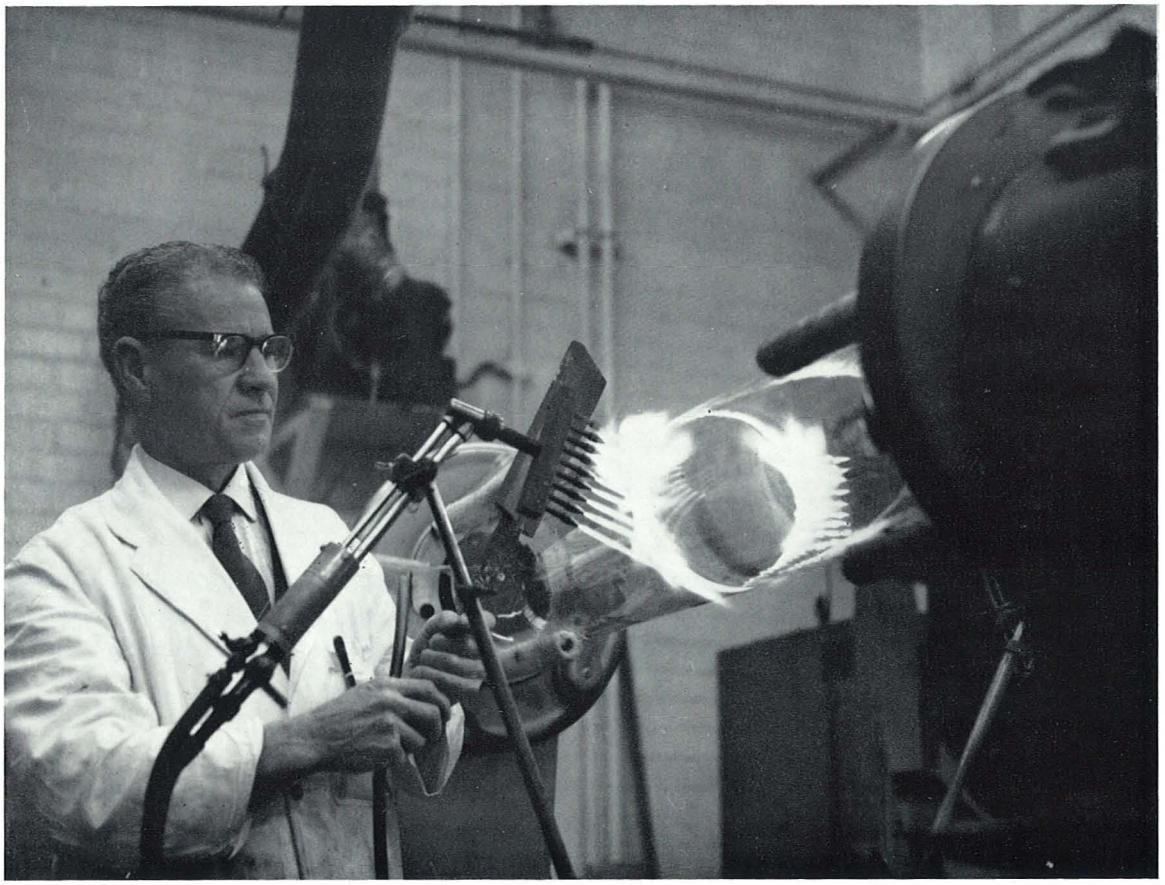
Remote control devices for safe handling and processing of hazardous substances. Theory and practice of mixing stiff pastes: performance and safety of mixers, blade clearances, shaft seals.

Instrumentation and Glass Engineering

Design and construction of special electronic instrumentation systems and scientific glassware.



PLANT FOR POLYESTER MANUFACTURE
An example of the development of laboratory syntheses on to pilot-scale processes.



GLASS ENGINEERING
The glass engineering workshop is equipped to undertake construction of scientific glassware ranging from special laboratory articles to the large-scale item shown here.

MISCELLANEOUS RESEARCH ACTIVITIES

In addition to research and development work performed by the Branches described above, certain specialized or exploratory research topics are undertaken by small groups under the direction of Dr. L. J. Bellamy, Mr. G. K. Adams, and Dr. G. H. Young.

Spectroscopy

Studies of factors affecting infra-red absorption spectra of complex molecules; assignment of absorption bands and interpretation of spectra.

Unicam SP 100 spectrometer (3650—300 cm^{-1}); Grubb Parsons GS2 grating spectrometer (4000—650 cm^{-1}); Unicam SP 700 spectrometer (55000—4500 cm^{-1}); attachment to determine emission spectra in the visible region; time-resolved luminescent spectroscopy in the visible region (resolution, 1 μsec).

Flame and Explosion Phenomena

A small computer installation is being planned, and computer programmes are available for calculation of flame and explosion properties, and the thermodynamic properties of two-phase, multi-element systems in chemical equilibrium.

Autoxidation and Antioxidants

Kinetics and mechanism of free radical chain reactions in solution; catalysis of oxidation-reduction reactions by heavy metals; effect of oxidative degradation, light, and ionizing radiation on polymeric materials. Research aimed at preventing or inhibiting oxidative degradation. Design and assessment of new antioxidants; mechanism of antioxidant action, particularly synergistic effects (mixtures of free radical acceptors; free radical acceptor and chelating reagent or S-containing peroxide decomposer); inhibition of autoxidation by metal chelates.

Warburg apparatus and equipment for automatic recording of oxygen uptake; facilities for photochemistry and radiochemistry.

INDEX OF ACTIVITIES

Titles of branches have been abbreviated as follows:

E	Explosives	M1	Materials 1
P1	Propellants 1	M2	Materials 2
P2	Propellants 2	AI	Analysis and Ingredients
CE	Chemical Engineering	Misc. Res.	Miscellaneous Research

INDEX OF FACILITIES

THERMOMETERS	
Platinum resistance	P1
Multirange recording	AI
ULTRASONIC INSPECTION EQUIPMENT	
Propellants	P1
Polymers	M1
ULTRA-VIOLET SPECTROMETERS	
General purpose	AI, M1
Continuous scanning	AI, Misc. Res.
VISCOMETERS	
Bulk viscosity	M1, P2
Intrinsic viscosity	M1
X-RAY EQUIPMENT	
Radiographic inspection	P1, E
Crystallographic analysis	AI

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Explosives Research & Development Establishment

Research and Development Activities and Facilities

MINISTRY of TECHNOLOGY

EXPLOSIVES RESEARCH & DEVELOPMENT ESTABLISHMENT

circa 1968
(Open days)

RESEARCH and DEVELOPMENT ACTIVITIES and FACILITIES

ERDE MINISTRY of TECHNOLOGY WALTHAM ABBEY ESSEX

HOW TO CONSULT ERDE

ERDE is able to offer a limited, free consultative service to industrial undertakings on problems related to expertise available in the Establishment.

Problems involving more extensive investigations or the use of equipment and special facilities may be undertaken for a fee, subject to the demands of the Establishment's research and development programme.

Enquiries may be made

(*a*) by letter, addressed to The Director
ERDE
Ministry of Technology
Waltham Abbey, Essex;

(*b*) by telephone, asking for Heads of specific branches or ERDE Industrial Liaison Officer Waltham Cross 23688; (STD) 97-23688 Inner London; (STD) 0992-23688 Outside London.

CONTENTS

INTRODUCTION

The primary function of the Explosives Research and Development Establishment is to undertake research on, and development of, explosives, propellants and related exothermic compositions to meet the present and future requirements of the three Services. The Establishment is also actively engaged on materials work, concerned principally with the chemistry and physics of polymers, and with new engineering materials based on refractory fibres.

To exercise these functions, ERDE maintains a staff of scientific, technical and engineering personnel representing a wide range of disciplines but with particular expertise in chemistry, chemical engineering and physics. Research and development tasks are shared by six technical branches supported by drawing office, machine shop, electronics and glass engineering facilities, and by appropriate library and information services.

It is the purpose of this book to give a brief outline of the work of the technical branches, especially those aspects involving expertise, facilities or equipment which are likely to be of interest to industrial undertakings.

MANAGEMENT ORGANIZATION

Director	Dr. L J Bellamy
Deputy Director	Dr. G H S Young
Special Merit 'B' Post	Mr. G K Adams
Heads of Branches	
Explosives	Mr. E G Whitbread
Propellants 1	Dr. W G Williams
Propellants 2	Mr. P R Freeman
Non-metallic Materials	Dr. B L Hollingsworth
General Chemistry	Dr. I Dunstan
Process Research	Mr. H Ziebland
Chief Engineer	Mr. R Fisher
Chief Safety Officer	Mr. J V Griffiths
Chief Administrative Officer	Mr. S F M Whiteside
Individual Merit Scientists	Dr. A W H Pryde (Chemical Engineering)
	Mr. G W C Taylor (Initiatory Explosives)
	Dr. N Uri (Autoxidation)

EXPLOSIVES

Head of Branch E G WHITBREAD

The Explosives Branch deals primarily with the development of sensitive, initiatory explosives and high explosive and propellant compositions of improved performance. Trials are performed to assess sensitiveness and hazards associated with all explosive materials.

ACTIVITIES AND FACILITIES

Explosive Risk

Standard tests designed to evaluate and to compare the explosive risk of materials are based on impact and friction sensitiveness, ease of ignition, susceptibility to burn to detonation, and shock sensitiveness. Results enable recommendations to be made regarding type of hazard, degree of protection and appropriate storage requirements.

Armoured cupboards for small-scale tests (up to 30 g) and instrumented firing site facilities for larger quantities (up to 4·5 kg). Firing site for small-scale underwater tests.

Electrostatic Risk

Electrostatic risks associated with handling explosive powders, vapour/air, and gas/air mixtures are assessed by measuring

(*a*) electrostatic voltages and charges on transferring solids or liquids, or on separating surfaces;
(*b*) comparative electrification of materials, especially fabrics and plastics;
(*c*) electrical resistance of floors, footwear and items of equipment;
(*d*) susceptibility to ignition by capacitor type discharge.

Electrostatic voltmeter (30—18 000 volts); resistance meters (up to 10^{16} ohms); facilities for measuring electrostatic spark sensitiveness of powders.

High Speed Photography

This technique is used to record mechanical and explosive phenomena, to investigate shock initiation of explosives and to determine propagation velocities.

Portable 16 mm ciné camera (100—18 000 frames/sec): framing camera (25 frames at 150 000 — 4 × 10^6 frames/sec), installed in 2·25 kg explosives test facility; streak camera (writing speed 0·7 mm—9 mm/microsec), installed in 4·5 kg explosives test facility. Printing facilities include conversion of 35 mm frames into animated 16 mm film, and colour printing of negatives of explosive phenomena with particular reference to correct colour balance.

Noise Evaluation

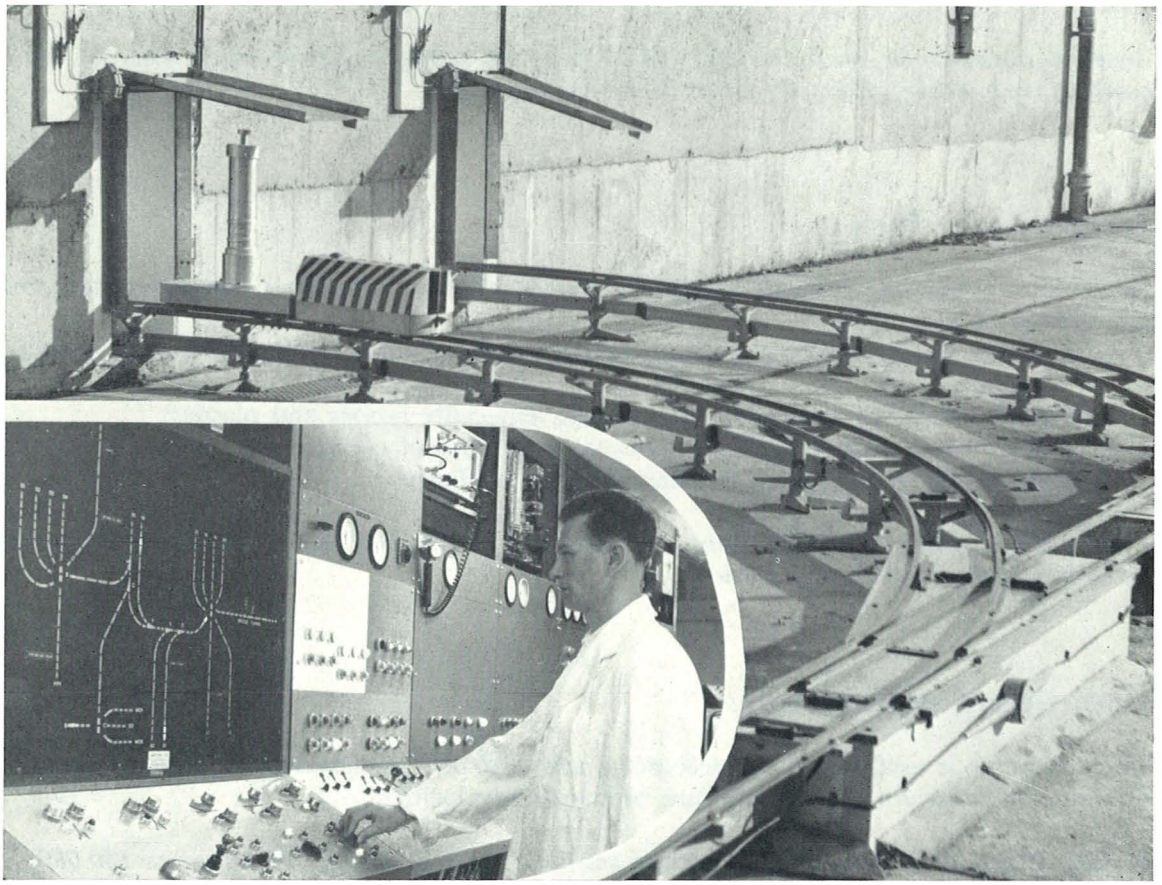
Measurement and analysis of impulsive noises including those of long duration (e.g. sonic booms), and their simulation by explosives. Techniques for generating a wide range of pressure waveforms in air may be applied to studying the behaviour of structures to shocks of this kind.

Apparatus to record shock waves in air down to 5 N/m^2 (0·1 lbf/ft^2).

Remote Control Methods

Development of remote control methods for manufacturing and testing dangerous explosive materials.

Process bays (limit 7·25 kg TNT equivalent) in which hazardous operations can be performed by remote control. Remotely operated mixing, extruding and injection moulding unit (4·5 kg) with temperature, vacuum and shear rate controls on mixer (viscosities 2—3 000 poise). Strong bay (limit 1·35 kg TNT equivalent) with master slave manipulators (3·5 m extended reach), X-ray facility (250 kv), and armoured viewing window. Capability for melt-mixing and moulding, or for pressing explosives, and for carrying out basic machinery operations on explosive charges by remote control. Closed circuit TV available to position all remotely-controlled operations.



723/2 + 3

REMOTE-CONTROL TRANSPORTATION OF HAZARDOUS MATERIALS
A five-inch gauge electric railway system used to transport hazardous materials between manufacturing, testing and storage areas.

Brian Locke

Polymer Technology

Cure chemistry of polyurethane elastomers prepared from di-isocyanates and hydroxy-terminated polyesters and polyethers; optimization of physical properties of heavily-loaded rubbers.

Small scale plant facility for development work; laboratory equipped to study physical properties and ageing characteristics.

PROPELLANTS 1

Head of Branch W G WILLIAMS

Propellants 1 Branch is largely concerned with the development of propellants based on nitrocellulose. Work is undertaken on methods for controlling ballistics, and to devise ballistic assessment techniques. Attention is also given to the quality control of propellants by non-destructive tests involving X-ray or ultrasonic inspection.

ACTIVITIES AND FACILITIES

Propellant Processing

Experimental processing of nitrocellulose-based propellants poses problems similar to those involved in processing plastic materials, especially consideration of viscosity control and particle size.

Plant for rolling and extrusion of incorporated materials; preparation of felted paper tubes with high length/diameter ratios.

Combustion

Investigations of propellant combustion using techniques equally applicable to combustion of fuel oils and gases. High temperature degradation of organic materials, research capable of being extended to flammability and flame-proofing of plastics.

Equipment to measure temperature profiles at burning surfaces, and appropriate instruments (infra-red and ultra-violet spectrophotometers and gas chromatographs) for flame decomposition product analysis.

Ballistic Properties

Burning rates and calorimetric measurements. Experimental techniques are available to study solids, liquids, and gases, and to determine precise heats of combustion, formation and wetting.

Equipment to measure static and dynamic pressures for fractions of a second or longer in ranges up to 31 MN/m^2 (4500 psi). Calorimeters with platinum resistance thermometry systems (precision better than $1 \times 10^{-3}°C$).

Non-Destructive Testing

The integrity and bonding of propellants are inspected by radiographic and ultrasonic test methods which may also be used to investigate conventional plastics and bonded systems.

Radiographic (400 kV) and ultrasonic (375 kc/sec through transmission) inspection equipment.

PRECISION CALORIMETRY
An NPL-pattern bomb calorimeter for determining heats of combustion with an accuracy approaching 1 part in 10^4.

John Littlejair 723/4 + 5
Bob Forbes

PROPELLANTS 2

Head of Branch P R FREEMAN

Propellants 2 Branch is responsible for research and development on composite propellants based on plastic or rubbery binder systems. The facilities include laboratories for quality control, including ballistic and physical property assessment, together with small- and large-scale manufacturing plants.

Basic and applied research on rheology and adhesion is performed to improve the mechanical behaviour of solid propellants and to provide an advisory service on the use of sealants, adhesives and lutings.

ACTIVITIES AND FACILITIES

Composite Propellant Formulation, Manufacture and Assessment

Formulation and manufacture of paste-like and rubbery composite propellants, assessment of ballistic properties by strand burning and static firing of small rocket motors. Compositions of high energy are available covering a wide range of burning rates.

Comprehensive facilities for the manufacture of propellants and filling of small rocket motors. Strand burning bombs and small static proofstand.

Sealants and Adhesives

Development of lutings and cements for threaded joints, etc., and adhesives for metal, plastics, paper, cloth and leather; study of tensile and shear strength, and of stress-strain behaviour of adhesives and joints.

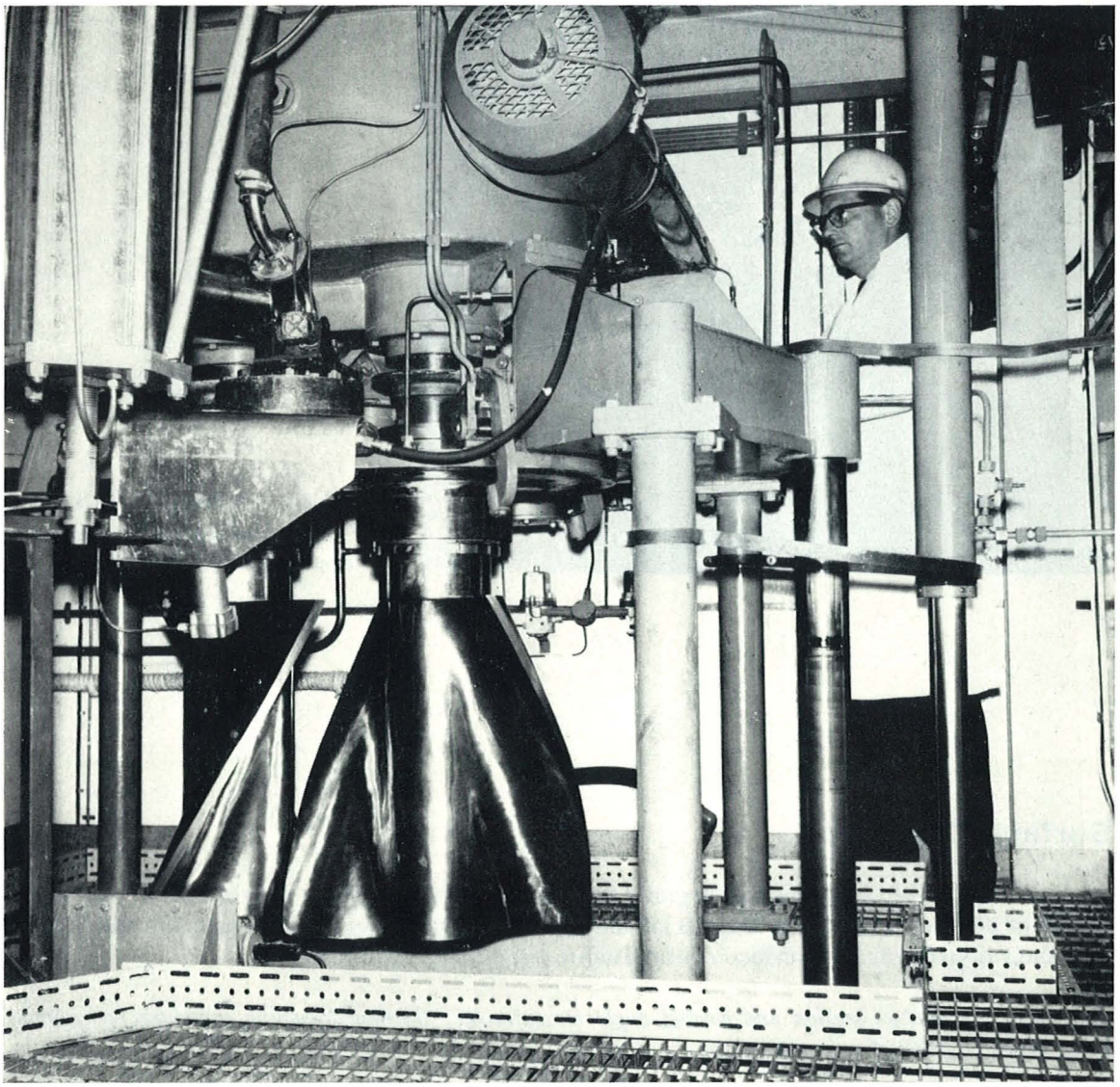
An advisory service is offered on all aspects of bonding and hermetic sealing of joints, and on joint design.

Instron universal testing machine (load, 10^{-3}—5000 kg; cross-head speed, 10^{-3}—10 mm/sec; cross-head travel, 1 m) with thermostatic chamber (—50° to 60°C) and automatic integrator. Hydraulically-operated high-speed test machine (strain rate up to 10 cm/sec); Sanborn twin-channel recorder (10 ms response) and Tektronix oscilloscope. Jigs for the preparation and testing of joints; equipment for preparation of proofed fabrics; viscometers, plastometers; facilities for storage at controlled humidities and temperatures.

Rheology of Stiff Pastes and Highly Filled Rubbers

Dependence of rheological behaviour of highly concentrated solid-in-liquid dispersions on nature of solids, solids loading, magnitude and distribution of particle size, nature and viscosity of liquid, temperature and test methods. Mechanical behaviour of highly filled rubbers by tensile testing over a wide range of temperatures and strain rates. Construction of master curves of mechanical behaviour by time-temperature superposition.

Plastometers to study flow and deformation behaviour including fatigue effect of cyclic compression and extension; fatigue by flexing; effect of imposed hydrostatic pressure; response to biaxial strain. Brittle point apparatus. Tensile testing apparatus.



VERTICAL MIXER FOR RUBBERY-TYPE SOLID PROPELLANTS
The mixing pot has been lowered for removal of the propellant mix.

723/6

MEASUREMENT OF CONTACT
ANGLE OF WATER ON A
CONTAMINATED STEEL SURFACE

Surface Chemistry

Surface tensions of highly viscous organic liquids; effect of molecular weight and temperature. Study of contact angles and interfacial tensions between viscous liquids and inorganic salts, and their dependence on surface contaminants (moisture, surfactants).

Equipment for surface tension and contact angle measurement; thermal siphoning technique for growing large perfect crystals of inorganic salts.

Technology of Pastes and Slurries

Formulation, manufacture, and handling of stiff pastes based on curable and non-curable liquid organic polymers containing a high proportion of solid inorganic filler.

Vertical and horizontal mixers of various capacities capable of processing mixes up to 10^7 poise viscosity; de-aerating pug-mills and pressure extrusion equipment.

NON-METALLIC MATERIALS

Head of Branch B L HOLLINGSWORTH

The Non-metallic Materials Branch undertakes basic and applied research on the chemistry and physics of polymers with particular regard to synthesis, characterization, degradation, and mechanical behaviour under a range of test conditions. The Branch offers an advisory service on the applications of polymers, and supervises long-term environmental testing at the Tropical Research Unit, which is a joint project with Australia.

ACTIVITIES AND FACILITIES

Polymer Physics and Engineering

Study of the physical properties of non-metallic materials and reinforced plastics: stress-strain curve, strength, fracture energy, damping capacity, creep, fatigue, stress relaxation, and dimensional stability. Effects of rate of deformation, temperature and moisture. Stress relaxation tests on rings and beams; dynamic mechanical properties of discs. Compression cell to study effects of dynamic, static, and creep loading.

Hounsfield apparatus (extension rate, 0·0013 — 50·8 cm/min; temperature, — 80° to 80°C); Baldwin machine; Goodbrand machine (fibre test). Avery Izod impact machines (capacity 17 kg.m; maximum loading rate, 18 × 10^2 kN/sec; photographic recording with 35 mm. streak- or 12 000 frames/sec Fastex-cameras). Flywheel machine (fracture energies at impact velocities of 130—1 300 cm/sec). Ultrasonic equipment (150 kc/sec—2 Mc/sec; up to 80°C). Rotating beam machine (fatigue properties).

Polymer Chemistry—Synthesis, Characterization, and Stability

Investigation of novel and potentially useful polymer systems; monomer and polymer synthesis, polymer fractionation, mechanism and kinetics of polymerization, reactions of polymers.

Characterization of polymers by molecular weight (viscometry, osmometry, light scattering, and end-group analysis), spectroscopy (IR, UV and NMR), dilatometry, bulk viscometry, compressibility and thermal expansion measurements, and by optical examination of polymer morphology.

Stability of addition and condensation polymers to heat, ultra-violet light, and high energy radiation; effects of chemical structure, impurities and environment. Mechanism and kinetics of degradation and its effect on molecular weight and physical properties.

MOLECULAR WEIGHT *Hewlett-Packard 502 high-speed membrane osmometer (maximum operating temperature 130°C); Brice-Phoenix Series 2000 Universal light scattering photometer with MSE high-speed centrifuge.*

BULK PROPERTIES *Epprecht Viscometer (0·1—10^6 poise, 0°—180°C); linear expansion apparatus for glass transition temperatures; pressure balance (temperature controlled to ±0·001°C).*

AVERY IZOD PENDULUM IMPACT APPARATUS

A pendulum impact tester modified for tensile and flexural impact tests to investigate the engineering life of non-metals.

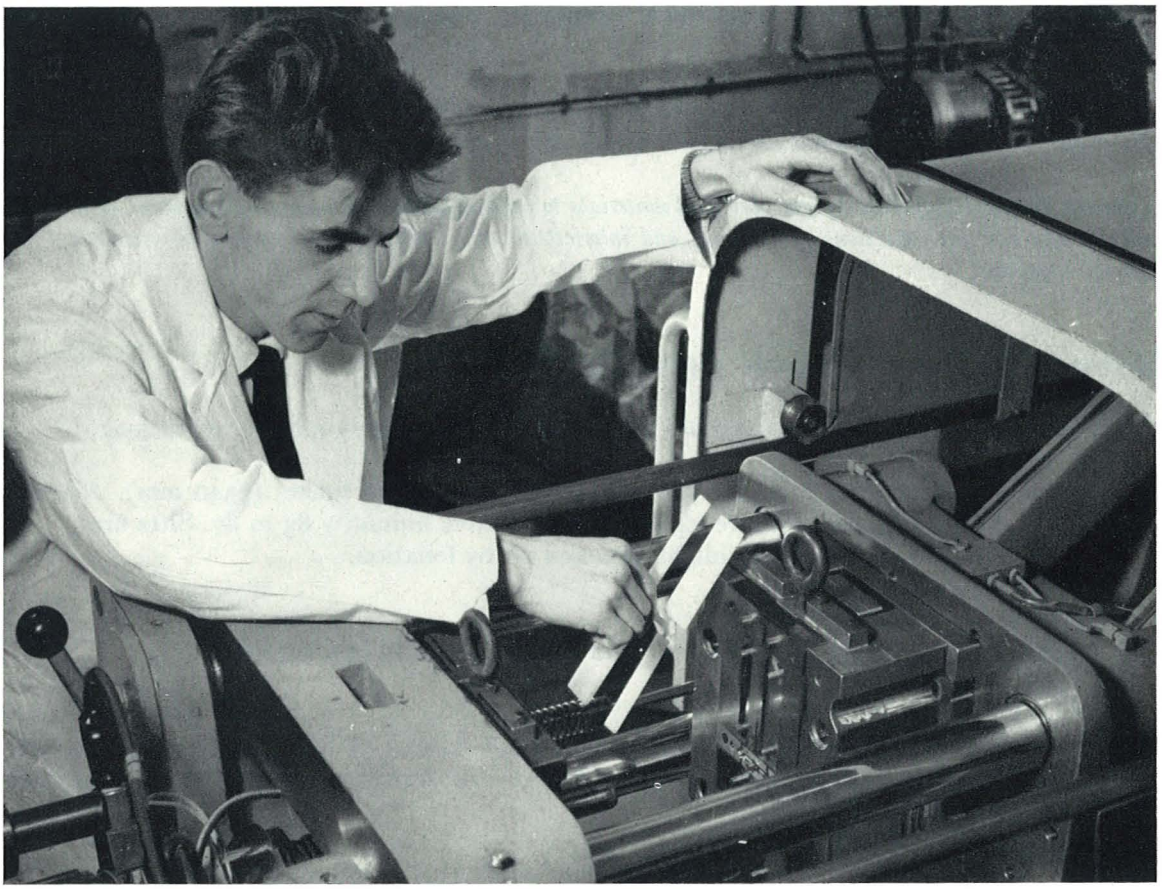
Charlie Munns.

NUCLEAR MAGNETIC RESONANCE MEASUREMENT

This 60 M/c instrument is used for characterization and structure determination of a wide range of organic compounds.

723/9

Pat Fuller.



HORIZONTAL INJECTION MOULDING MACHINE
Test pieces for mechanical property assessment being produced in a constant torque, injection moulding machine.

Keith Ledbury. 723/10

SPECTROSCOPY *PE R10 60 M/c NMR spectrometer (variable temperature probe, spin decoupling unit, probes for ^{1}H, ^{11}B, ^{19}F, and ^{31}P; PE 337 grating spectrometer (4000—400 cm^{-1}, ATR attachment); Unicam SP 500 spectrometer.*

MICROSCOPY *Gilett and Sibert time-lapse microscope (35 mm and 16 mm (ciné) photographic recording).*

DEGRADATION *Mercury lamp, xenon arc, molten salt- and fluidized sand baths.*

GAS CHROMATOGRAPHY *PE Model 801 (dual column analytical instrument, linear programming); Pye Model 105/15 (automatic preparative gas chromatograph, linear programming).*

Polymer Development and Applications

Processing and curing of new rubbers and thermoplastics by injection moulding, extrusion, milling, and compression moulding. Measurement of physical properties, and the effect of contaminants (e.g. explosives, propellants, petrol, etc.). Accelerated and tropical ageing trials to assess useful life. Investigation of failures. Manufacture of special components; antistatic and conducting rubbers.

Proofed fabrics: preparation, mechanical properties, and advice on the design of proofed fabric structures.

PROCESSING *Wide range of mills, mixers, hydraulic presses and injection moulding machines. Facilities for the synthesis of polyester-polyurethane rubbers. Small-scale equipment for preparing proofed-fabric samples.*

TESTING *Physical properties; permeability of materials to organic fluids and water; ageing ovens to simulate hot/dry and hot/wet conditions; continuous and intermittent stress relaxometers. Carbon arc equipment for special exposures.*

Joint Tropical Research Unit, Queensland

Four sites are available for the exposure of small specimens to atmospheric weathering.

(*a*) INNISFAIL Latitude 17° 32′S. Average annual rainfall 140 inches (3540 mm). Average daily mean temperature 74°F (23°C); relative humidity 83 to 87. Sites are
(i) Hot/wet, jungle, i.e. sunlight screened off by foliation.
(ii) Hot/wet, clearing.

(*b*) CLUMP POINT Similar latitude and conditions to Innisfail but the site is
(iii) Marine.

(*c*) CLONCURRY Latitude 20° 43′S. Average annual rainfall 17 inches (430 mm). Average daily mean temperature 78°F (25°C); relative humidity 39. The site is designated
(iv) Hot/dry.

GENERAL CHEMISTRY

Head of Branch I DUNSTAN

The General Chemistry Branch investigates the preparation, properties and reactions of a wide range of ingredients related to explosive, propellant and polymer technology. The Branch offers an advisory service on the stability, compatibility and surveillance testing of propellants, explosives and other hazardous materials. New analytical methods are developed to assist quality control, and a range of specialized techniques and facilities are used to provide an analytical service for the Establishment.

ACTIVITIES AND FACILITIES

Synthesis and Characterization

Synthesis of explosives and ingredients of solid propellants and polymers (fuels, oxidizers, ballistic additives, stabilizers, curing agents, antioxidants, etc.); studies to optimize yield and purity and to reduce hazard (toxicity, thermal decomposition, etc.).

General techniques of preparative chemistry, and supporting facilities: armoured cupboards; PE Model 237 grating spectrometer (4000—650 cm^{-1}); Unicam SP 500 spectrometer; various refractometers and optical microscopes, including Kofler hot-stage instruments; molecular weight determination by semi-micro ebulliometry and micro-cryoscopy.

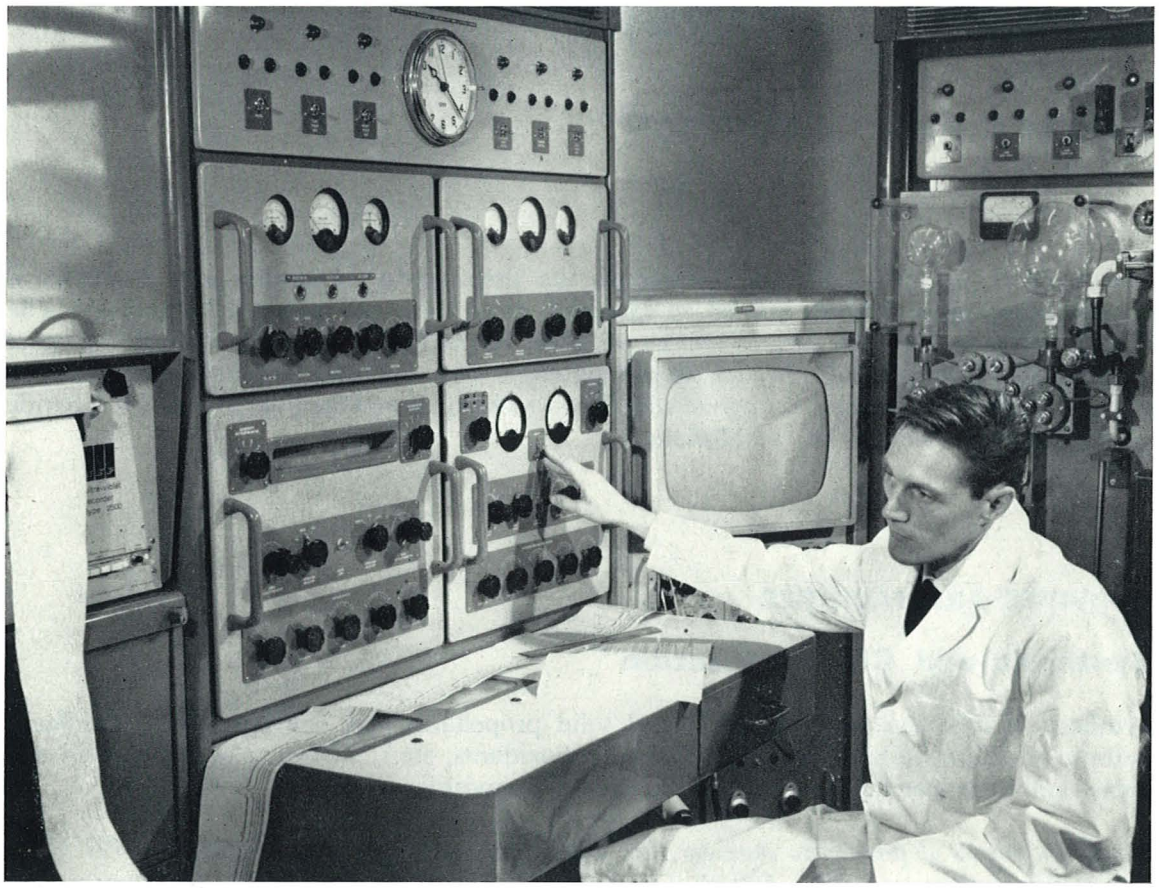
Stability and Compatibility

Kinetics and mechanism of thermal decomposition of explosives and exothermic compositions; ignition phenomena and build-up to low order detonation; compatibility of explosives, propellants, etc. with materials (e.g. polymers, plastics, metals, adhesives, varnishes and paints); effect of severe environmental conditions on storage stability. New techniques to investigate thermal stability.

Environmental testing ovens and standard stability test facilities. Master slave manipulator. Stanton thermogravimetric balance (maximum temperature, 250°C); PE differential scanning calorimeter, Model 1 (−100° to 500°); heat flow calorimeter (sensitivity, 30 μwatts); multirange temperature recording equipment (−200° to 500°C). Photomicroscopy of samples heated in vacuum. Advance Model TC 2A electronic timer counter (1 μsec).

Chemical Analysis and Physical Methods

Separation, identification, and analysis of the constituents of explosives, propellants, polymers, rubbers, etc.; determination of functional groups, elemental composition, and molecular weight; trace metal analysis. Estimation of purity, and investigation of quality control and specification tests. Studies concerned with gas and solvent vapour analysis; molecular and crystal structure; thermochemical characteristics (phase changes, low temperature behaviour and thermal decomposition); cure- and post-cure chemistry of polymeric systems; non-aqueous titration; mass spectrometric and polarographic analysis.



MASS SPECTROMETRY
An AEI Model MS 2H mass spectrometer capable of performing isotopic and chemical analyses on very small quantities of material, including solids.

Norman Paul 723/11

CHROMATOGRAPHY *Wide range of standard equipment for analytical- and preparative-scale column- and thin layer chromatography; Craig counter-current extraction apparatus; Varian Aerograph Model 1522 gas chromatograph (dual column, linear programming); PE F11 gas chromatograph; pyrolysis attachment.*

SPECTROSCOPY *PE Model 257 grating spectrometer (4000—650 cm^{-1}) ATR attachment, micro- and heated cells; modified Grubb Parsons S3A spectrometer (3500—250 cm^{-1}); PE Model 137 UV spectrometer; Unicam SP90 atomic absorption spectrophotometer.*

MASS SPECTROMETRY *AEI Model MS 2H*

MICROANALYSIS *Combustion equipment (C, H, N); Schöniger flask (S, halogens); Mechrolab Model 302 vapour pressure osmometer (molecular weights up to 20 000).*

POLAROGRAPHY *Beckman Electroscan 30 (various electrometric analysis techniques).*

RADIOCHEMISTRY *Tracer laboratory; Panax standard- and low background Geiger counters; Isotope Development Ltd. solid and liquid scintillation counters.*

THERMOCHEMICAL ANALYSIS see *Stability and Compatibility.*

PARTICLE SIZE ANALYSIS *Sharples Micromerograph (humidity- and temperature-controlled); gas adsorption and various types of gas permeability apparatus for surface area measurement.*

Crystallography

Application of optical and X-ray diffraction to identification and characterization of compounds; phase analysis of mixtures, polymorphism, crystal orientation, and crystal structure analysis.

Equipment includes three X-ray generators, one being a high-power rotating anode set, X-ray powder cameras, goniometers (Weissenberg, oscillating crystal and optical), Hilger-Watts 4-circle, single crystal automatic diffractometer, an X-ray powder diffractometer, and polarizing microscope with heating stage.

Mary Best ? becomes Frank Parsers wife

GAS CHROMATOGRAPHY
This technique is particularly useful for identifying and estimating volatile constituents of complex mixtures.

723/12

Gas Kinetics

Kinetics and mechanisms of gas-phase reactions and general free radical chemistry using static and discharge-flow techniques. Reactions of alkyl and alkoxy radicals, nitrogen oxide and nitrogen dioxide. Mechanisms of gas-solid reactions.

High vacuum techniques and product analysis by vapour-phase chromatography, infra-red and mass spectrometry. Emission spectroscopy.

PROCESS RESEARCH

Head of Branch H ZIEBLAND

The Process Research Branch is concerned with means and equipment for processing chemicals on a production scale. Plant and facilities are designed for the manufacture of hazardous compounds and mixtures with particular emphasis on safety, remote-control, and instrumentation. The Branch has special interests in unit operations such as crystallization, mixing, heat transfer, and precision measurements of thermal properties of fluids.

Research and development is being carried out on fibre-reinforced, metallic and non-metallic materials and on the growth of ceramic whiskers.

ACTIVITIES AND FACILITIES

Large-scale Production

Development of laboratory syntheses on to pilot- and full-scale processes; pilot plant operation; manufacture of experimental chemicals and materials, including high explosives, polymer and rocket ingredients, whiskers and aligned inorganic fibres.

Protective enclosures, with remote control, for processing experimental quantities of dangerous chemicals (i.e. fire, explosion, toxicity risks): one for large laboratory-scale glass plant; another for 2·5 kg pilot plant scale, equipped with a closed circuit television loop.

A wide range of pilot-scale plant, including: plant for concentrating nitric acid free from nitrous acid; nitration and sulphonation unit with brine cooling, remote control and acid mixing plant; glass-lined oil heated reactors for polymer manufacture.

Separators such as decanters; pressure-, vacuum- and rotary filters; batch and continuous stainless steel centrifuges; liquid centrifuges; and dry powder sieves.

Dryers, including hot air-, vacuum tray- and rotary-steam tube types.

Grinding plant, including jaw crusher; roll mill; edge-runner mill; hammer mills; and 'micronizer' fluid energy mill.

Mixers: double cone powder blender; medium and heavy paste mixers.

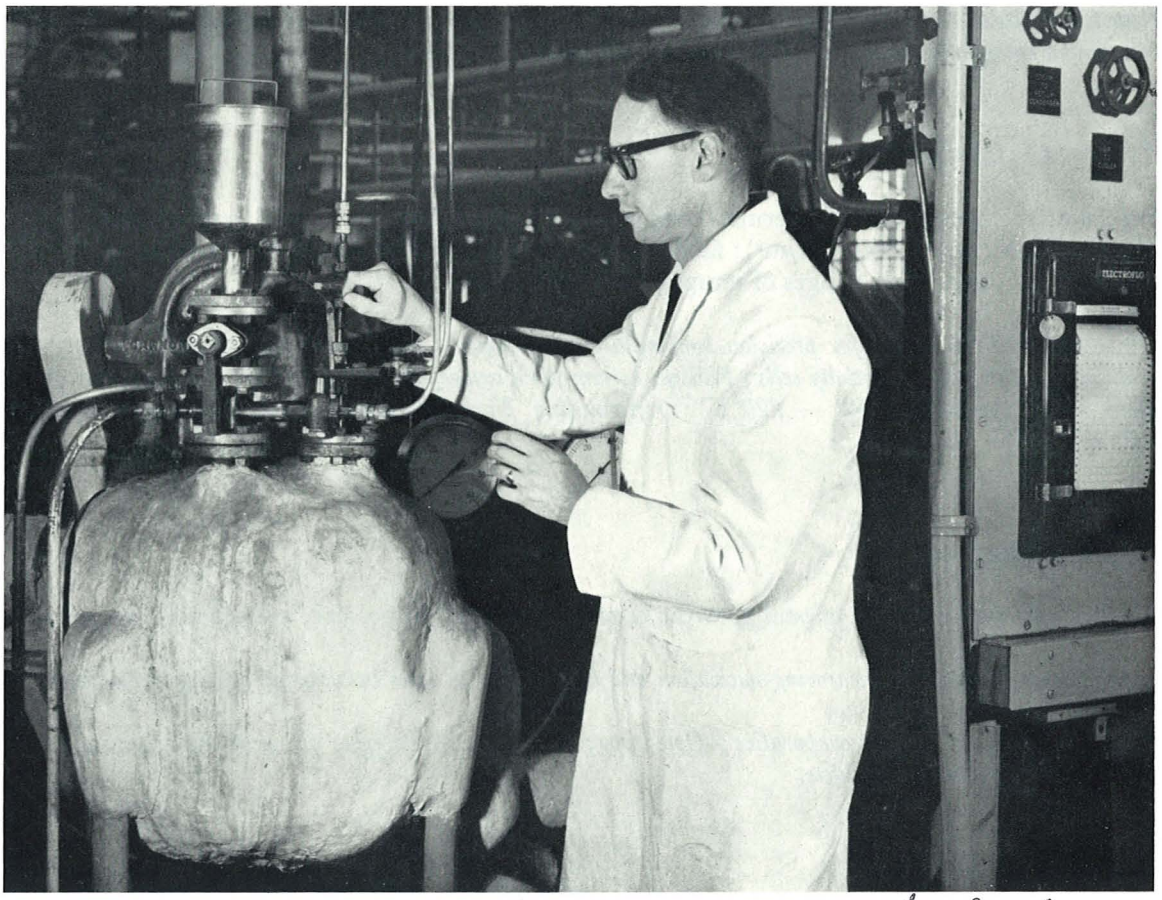
Packed, gas-liquid absorption towers.

Distillation: a 5-cm glass 'molecular' still; a 50-litre glass batch distillation unit; glass distillation column of high efficiency for high vacuum and 150°C; similar unit in stainless steel for pressure distillation up to 1 MN/m².

Intensive Drying or Stripping

The intensive drying (or stripping) of high boiling liquids which may be sensitive to heat or excessive turbulence.

Continuous plant (11·5 kg/h), based on single passage of liquid down a column packed with a battery of vertical helical coils.



PLANT FOR POLYESTER MANUFACTURE
An example of the development of laboratory syntheses on to pilot-scale processes.

Les Dingle
723/13

Convective and Radiative Heat Transfer from Flames and Gases

Studies of convection and radiation from flames and combustion gases (up to 3800°K; 10 MN/m²); radiative emissivity of water vapour (1500°—3500°K; 0·5—10 MN/m²).

Two instrumented test cubicles; water-cooled combustion chambers; black-body furnace to calibrate radiation sources.

Convective Heat Transfer to Liquids

Convective heat transfer from electrically heated surfaces to aviation kerosine and other liquids under sub-cooled, boiling, and supercritical conditions.

Closed-loop apparatus with rectangular flow channel containing heated tube (maximum power, 10 kW; maximum pressure, 10 MN/m²; maximum fluid flow rate, 1·2 kg/sec). Photographic observation using Fastex ciné camera (18 000 half-frames/sec) and 0·2 μsec argon flash lamp.

Convective Heat Transfer to Cryogenic Fluids

Convective heat transfer to fluid hydrogen in the vicinity of the critical point and at supercritical pressures; fluid dynamics of cryogenic fluids.

Remotely-operated test rig in which cryogenic fluids flow through asymmetrically heated rectangular ducts (maximum energy dissipation, 40 kW; maximum pressure, 5 MN/m²).

Thermal Conductivity

Precision measurements of thermal conductivities of liquids, gases, and supercritical fluids (12°— 650°K; up to 300 MN/m²); facilities equally suitable for measuring viscosity, dielectric constant, etc. over wide ranges of temperature and pressure.

Air conditioned laboratory for precision temperature measurement; protected annexe for compressing gases and liquids; thermal conductivity cells: Phillips helium-filled cryogenerator (12° — 90°K); liquid nitrogen-filled metal thermostat (90° — 220°K); recirculating Turbotherm-filled liquid thermostat (300° — 650°K).

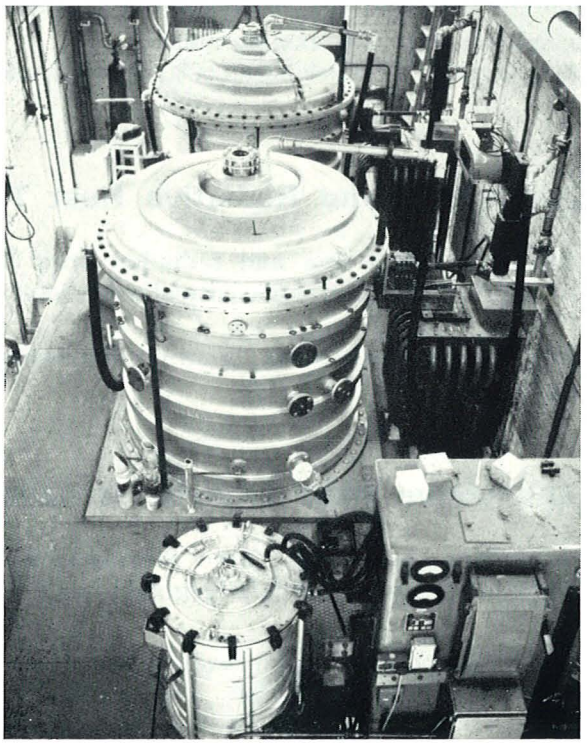
Crystallization

Studies of nucleation and crystal growth; control of crystal shape, size, and size distribution.

Laboratory equipment for measuring nucleation and crystal growth rates in a stirred cooling crystallizer.

Pilot crystallizers: Kestner evaporative; Oslo type; and pulsed tube type, for performance studies and production of crystalline products.

723/1



'BRAN TUBS'
High temperature furnaces for synthesis of silicon nitride whiskers.

High Temperature Equipment

Furnaces of various types for operation up to about 1600°C; high frequency heating equipment; temperature measuring devices.

Fibre Processing Plant

Equipment for sizing whiskers and other short fibres and plants to classify and align asbestos and other whiskers for making composite materials.

Fibre Testing Equipment

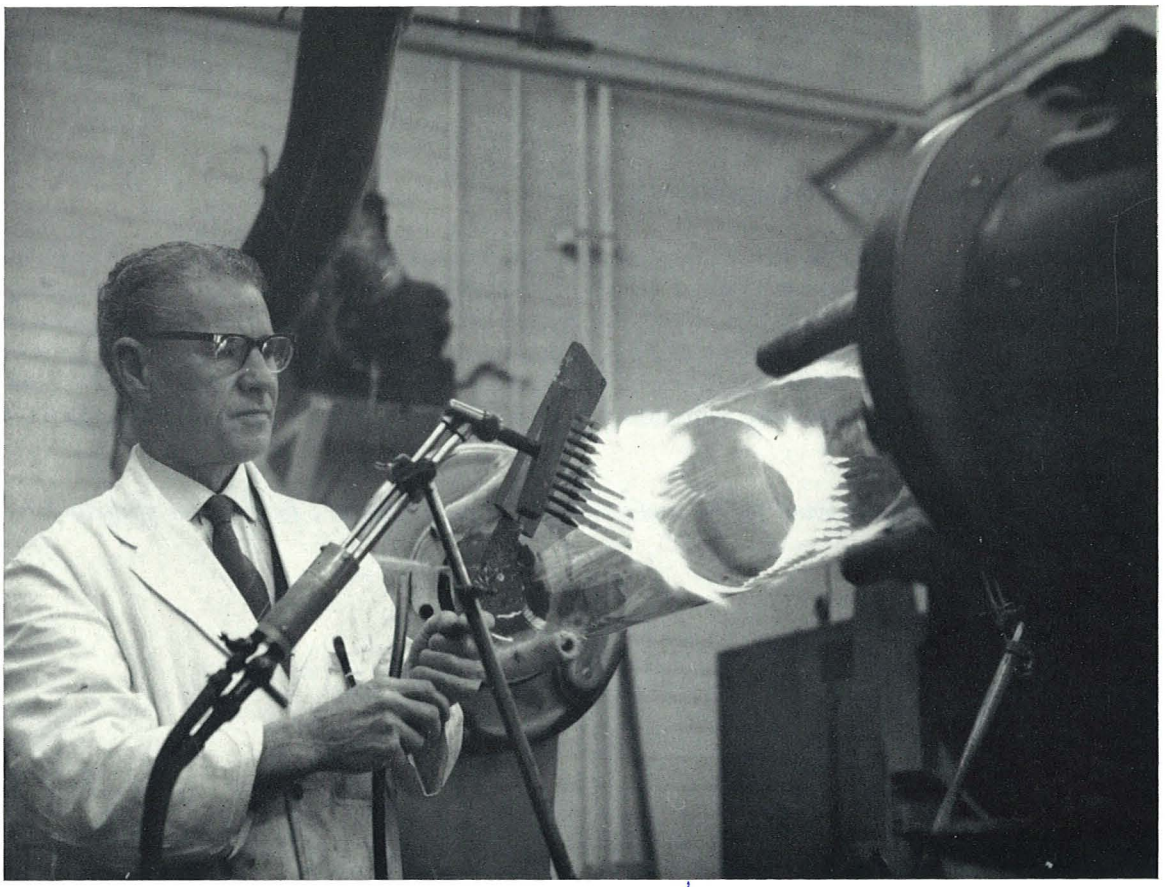
Marsh micro-testing machine and various macro-testing machines.

Microscopes

A range of optical microscopes and a J.E.M. 7 electron microscope.

Instrumentation and Glass Engineering

This Section, part of the Engineering Branch, is responsible for the development and application of instruments and apparatus based on electronic and glass engineering techniques.



723/14

GLASS ENGINEERING
The glass engineering workshop is equipped to undertake construction of scientific glassware ranging from special laboratory articles to the large-scale item shown here.

MISCELLANEOUS RESEARCH ACTIVITIES

In addition to research and development work performed by the Branches described above, certain specialized or exploratory research topics are undertaken by small groups under the direction of Dr. L. J. Bellamy, Mr. G. K. Adams, and Dr. G. H. Young.

Spectroscopy

Studies of factors affecting infra-red absorption spectra of complex molecules; assignment of absorption bands and interpretation of spectra.

Unicam SP 100 spectrometer (3650—300 cm^{-1}); Grubb Parsons GS2 grating spectrometer (4000—650 cm^{-1}); Unicam SP 700 spectrometer (55000—4500 cm^{-1}); attachment to determine emission spectra in the visible region; time-resolved luminescent spectroscopy in the visible region (resolution, 1 μsec).

Flame and Explosion Phenomena

An Elliot 903 computer is in use, and computer programmes are available for calculation of flame and explosion properties, and the thermodynamic properties of two-phase, multi-element systems in chemical equilibrium.

Autoxidation and Antioxidants

Kinetics and mechanism of free radical chain reactions in solution; catalysis of oxidation-reduction reactions by heavy metals; effect of oxidative degradation, light, and ionizing radiation on polymeric materials. Research aimed at preventing or inhibiting oxidative degradation. Design and assessment of new antioxidants; mechanism of antioxidant action, particularly synergistic effects (mixtures of free radical acceptors; free radical acceptor and chelating reagent or S-containing peroxide decomposer); inhibition of autoxidation by metal chelates.

Warburg apparatus and equipment for automatic recording of oxygen uptake; facilities for photochemistry and radiochemistry.

INDEX OF ACTIVITIES

Titles of branches have been abbreviated as follows:

E	Explosives	NM	Non-metallic Materials
P1	Propellants 1	GC	General Chemistry
P2	Propellants 2	Misc. Res.	Miscellaneous Research
PR	Process Research	IGE	Instrumentation and Glass Engineering Section

INDEX OF FACILITIES

THERMOMETERS	
Platinum resistance	P1
Multirange recording	GC
ULTRASONIC INSPECTION EQUIPMENT	
Propellants	P1
Polymers	NM
ULTRA-VIOLET SPECTROMETERS	
General purpose	GC, NM
Continuous scanning	GC, Misc. Res.
VISCOMETERS	
Bulk viscosity	NM, P2
Intrinsic viscosity	NM
X-RAY EQUIPMENT	
Radiographic inspection	P1, E
Crystallographic analysis	GC

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Explosives Research & Development Establishment

Research and Development Activities and Facilities

MINISTRY of DEFENCE

EXPLOSIVES RESEARCH & DEVELOPMENT ESTABLISHMENT

RESEARCH and DEVELOPMENT ACTIVITIES and FACILITIES

ERDE MINISTRY of DEFENCE WALTHAM ABBEY ESSEX

HOW TO CONSULT ERDE

ERDE is able to offer a limited, free consultative service to industrial undertakings on problems related to expertise available in the Establishment.

Problems involving more extensive investigations or the use of equipment and special facilities may be undertaken for a fee, subject to the demands of the Establishment's research and development programme.

Enquiries may be made

(*a*) by letter, addressed to The Director
ERDE
Ministry of ~~Technology~~ DEFENCE
Waltham Abbey, Essex;

(*b*) by telephone, asking for Heads of specific branches or ERDE Industrial Liaison Officer Waltham Cross 23688; (STD) 97-23688 Inner London; (STD) 0992-23688 Outside London.

CONTENTS

INTRODUCTION

The primary function of the Explosives Research and Development Establishment is to undertake research on, and development of, explosives, propellants and related exothermic compositions to meet the present and future requirements of the three Services. The Establishment is also actively engaged on materials work, concerned principally with the chemistry and physics of polymers, and with new engineering materials based on refractory fibres.

To exercise these functions, ERDE maintains a staff of scientific, technical and engineering personnel representing a wide range of disciplines but with particular expertise in chemistry, chemical engineering and physics. Research and development tasks are shared by six technical branches supported by drawing office, machine shop, electronics and glass engineering facilities, and by appropriate library and information services.

It is the purpose of this book to give a brief outline of the work of the technical branches, especially those aspects involving expertise, facilities or equipment which are likely to be of interest to industrial undertakings.

MANAGEMENT ORGANIZATION

Director	Dr. L J Bellamy
Deputy Director	MR G K ADAMS
~~Special Merit 'B' Post~~	~~Mr. G K Adams~~
Heads of Branches	
Explosives	DR C A BECK
Propellants 1	DR C G LAWSON
Propellants 2	Mr. P R Freeman
Non-metallic Materials	Dr. B L Hollingsworth
General Chemistry	DR A R OSBORN
Process Research	Mr. H Ziebland
Chief Engineer	Mr. R Fisher
Chief Safety Officer	Mr. J V Griffiths
Chief Administrative Officer	Mr. S F M Whiteside
Individual Merit Scientists	Dr. A W H Pryde (Chemical Engineering)
	DR D H RICHARDS (POLYMER CHEMISTRY)
	Dr. N Uri (Autoxidation)

EXPLOSIVES

Head of Branch

DR C A BECK

The Explosives Branch deals primarily with the development of sensitive, initiatory explosives and high explosive and propellant compositions of improved performance. Trials are performed to assess sensitiveness and hazards associated with all explosive materials.

ACTIVITIES AND FACILITIES

Explosive Risk

Standard tests designed to evaluate and to compare the explosive risk of materials are based on impact and friction sensitiveness, ease of ignition, susceptibility to burn to detonation, and shock sensitiveness. Results enable recommendations to be made regarding type of hazard, degree of protection and appropriate storage requirements.

Armoured cupboards for small-scale tests (up to 30 g) and instrumented firing site facilities for larger quantities (up to 4·5 kg). Firing site for small-scale underwater tests.

Electrostatic Risk

Electrostatic risks associated with handling explosive powders, vapour/air, and gas/air mixtures are assessed by measuring

(*a*) electrostatic voltages and charges on transferring solids or liquids, or on separating surfaces;
(*b*) comparative electrification of materials, especially fabrics and plastics;
(*c*) electrical resistance of floors, footwear and items of equipment;
(*d*) susceptibility to ignition by capacitor type discharge.

Electrostatic voltmeter (30—18 000 volts); resistance meters (up to 10^{16} ohms); facilities for measuring electrostatic spark sensitiveness of powders.

High Speed Photography

This technique is used to record mechanical and explosive phenomena, to investigate shock initiation of explosives and to determine propagation velocities.

Portable 16 mm ciné camera (100—18 000 frames/sec): framing camera (25 frames at 150 000 — 4 × 10^6 frames/sec), installed in 2·25 kg explosives test facility; streak camera (writing speed 0·7 mm—9 mm/microsec), installed in 4·5 kg explosives test facility. Printing facilities include conversion of 35 mm frames into animated 16 mm film, and colour printing of negatives of explosive phenomena with particular reference to correct colour balance.

Noise Evaluation

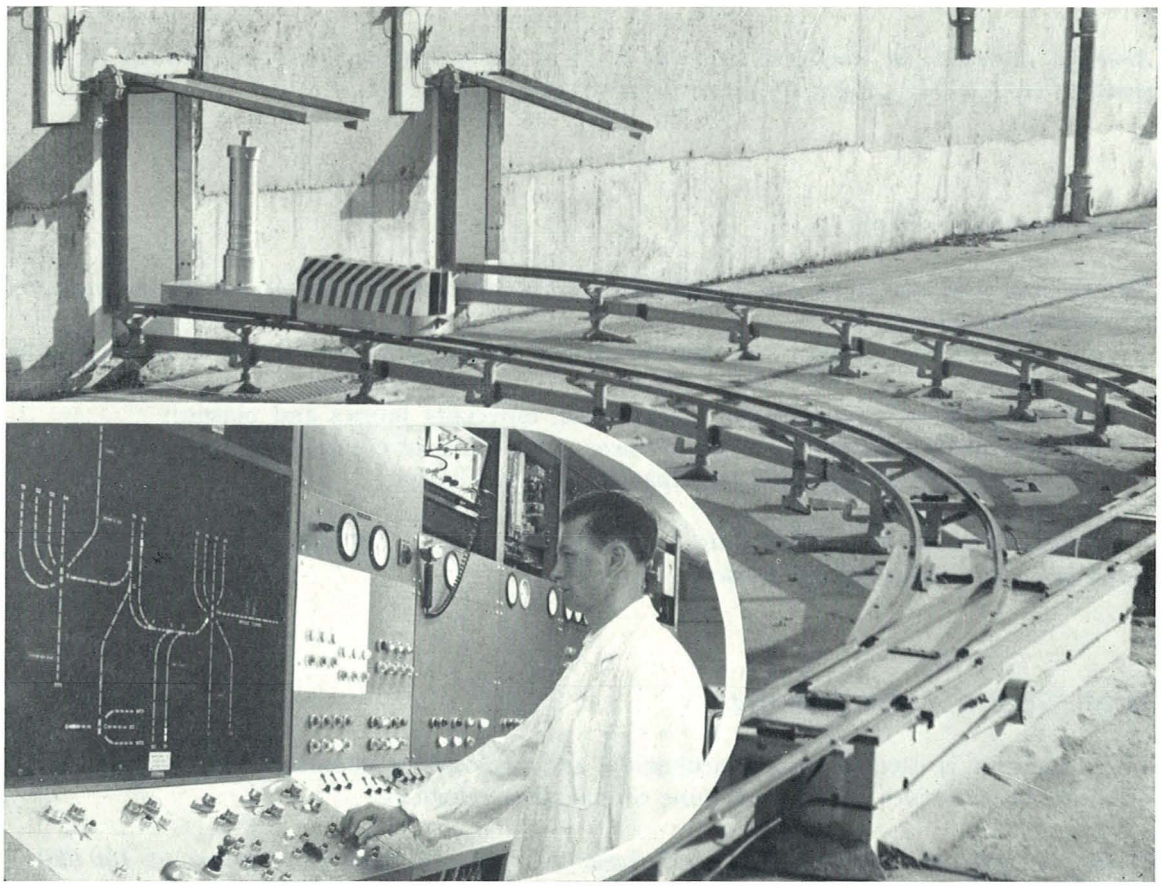
Measurement and analysis of impulsive noises including those of long duration (e.g. sonic booms), and their simulation by explosives. Techniques for generating a wide range of pressure waveforms in air may be applied to studying the behaviour of structures to shocks of this kind.

Apparatus to record shock waves in air down to 5 N/m^2 (0·1 lbf/ft^2).

Remote Control Methods

Development of remote control methods for manufacturing and testing dangerous explosive materials.

Process bays (limit 7·25 kg TNT equivalent) in which hazardous operations can be performed by remote control. Remotely operated mixing, extruding and injection moulding unit (4·5 kg) with temperature, vacuum and shear rate controls on mixer (viscosities 2—3 000 poise). Strong bay (limit 1·35 kg TNT equivalent) with master slave manipulators (3·5 m extended reach), X-ray facility (250 kv), and armoured viewing window. Capability for melt-mixing and moulding, or for pressing explosives, and for carrying out basic machinery operations on explosive charges by remote control. Closed circuit TV available to position all remotely-controlled operations.



REMOTE-CONTROL TRANSPORTATION OF HAZARDOUS MATERIALS
A five-inch gauge electric railway system used to transport hazardous materials between manufacturing, testing and storage areas.

Polymer Technology

Cure chemistry of polyurethane elastomers prepared from di-isocyanates and hydroxy-terminated polyesters and polyethers; optimization of physical properties of heavily-loaded rubbers.

Small scale plant facility for development work; laboratory equipped to study physical properties and ageing characteristics.

PROPELLANTS 1

Head of Branch W DR C/G LAWSON

Propellants 1 Branch is largely concerned with the development of propellants based on nitrocellulose. Work is undertaken on methods for controlling ballistics, and to devise ballistic assessment techniques. Attention is also given to the quality control of propellants by non-destructive tests involving X-ray or ultrasonic inspection.

ACTIVITIES AND FACILITIES

Propellant Processing

Experimental processing of nitrocellulose-based propellants poses problems similar to those involved in processing plastic materials, especially consideration of viscosity control and particle size.

Plant for rolling and extrusion of incorporated materials; preparation of felted paper tubes with high length/diameter ratios.

Combustion

Investigations of propellant combustion using techniques equally applicable to combustion of fuel oils and gases. High temperature degradation of organic materials, research capable of being extended to flammability and flame-proofing of plastics.

Equipment to measure temperature profiles at burning surfaces, and appropriate instruments (infra-red and ultra-violet spectrophotometers and gas chromatographs) for flame decomposition product analysis.

Ballistic Properties

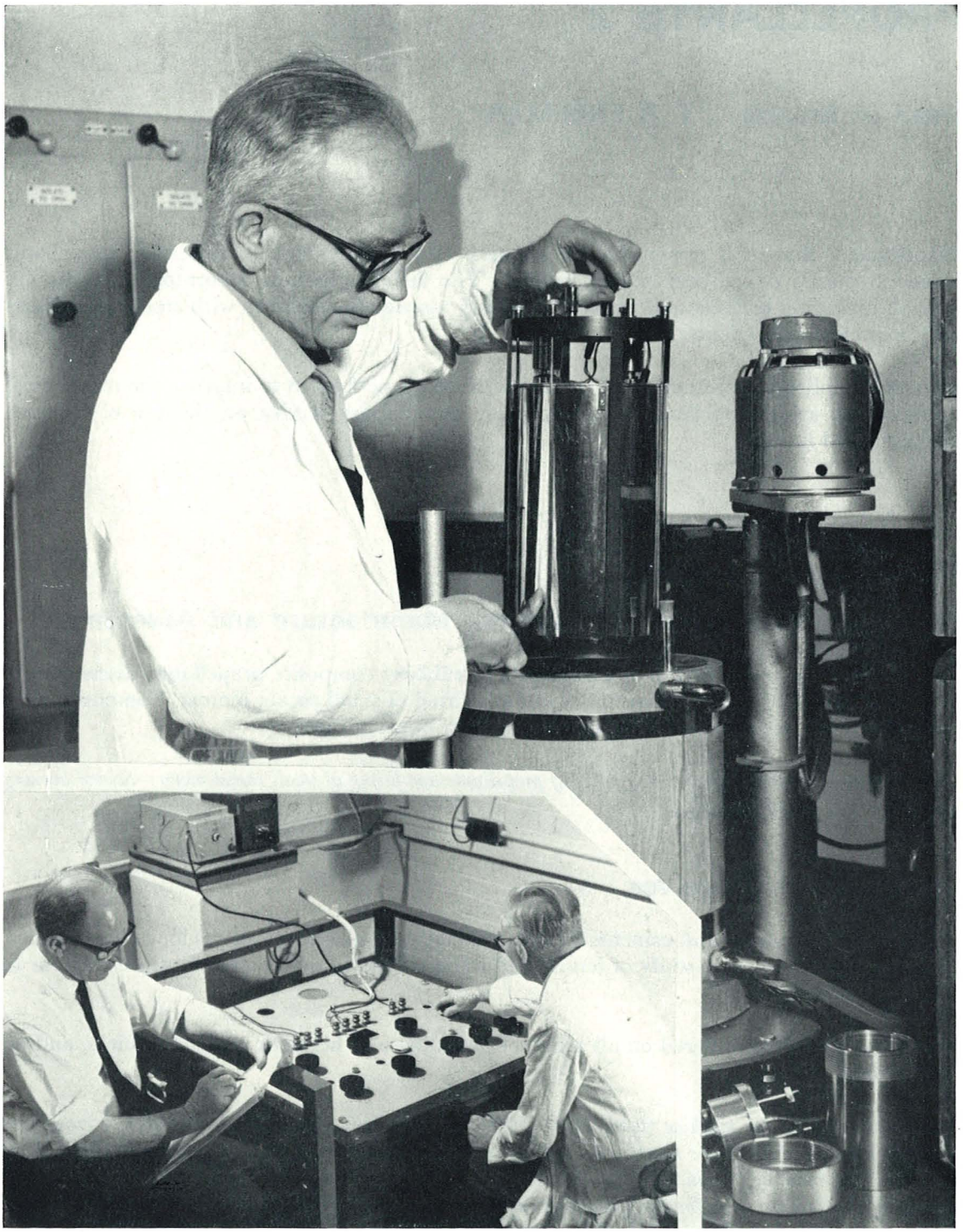
Burning rates and calorimetric measurements. Experimental techniques are available to study solids, liquids, and gases, and to determine precise heats of combustion, formation and wetting.

Equipment to measure static and dynamic pressures for fractions of a second or longer in ranges up to 31 MN/m^2 (4500 psi). Calorimeters with platinum resistance thermometry systems (precision better than $1 \times 10^{-3}°C$).

Non-Destructive Testing

The integrity and bonding of propellants are inspected by radiographic and ultrasonic test methods which may also be used to investigate conventional plastics and bonded systems.

Radiographic (400 kV) and ultrasonic (375 kc/sec through transmission) inspection equipment.



PRECISION CALORIMETRY
An NPL-pattern bomb calorimeter for determining heats of combustion with an accuracy approaching 1 part in 10^4.

PROPELLANTS 2

Head of Branch P R FREEMAN

Propellants 2 Branch is responsible for research and development on composite propellants based on plastic or rubbery binder systems. The facilities include laboratories for quality control, including ballistic and physical property assessment, together with small- and large-scale manufacturing plants.

Basic and applied research on rheology and adhesion is performed to improve the mechanical behaviour of solid propellants and to provide an advisory service on the use of sealants, adhesives and lutings.

ACTIVITIES AND FACILITIES

Composite Propellant Formulation, Manufacture and Assessment

Formulation and manufacture of paste-like and rubbery composite propellants, assessment of ballistic properties by strand burning and static firing of small rocket motors. Compositions of high energy are available covering a wide range of burning rates.

Comprehensive facilities for the manufacture of propellants and filling of small rocket motors. Strand burning bombs and small static proofstand.

Sealants and Adhesives

Development of lutings and cements for threaded joints, etc., and adhesives for metal, plastics, paper, cloth and leather; study of tensile and shear strength, and of stress-strain behaviour of adhesives and joints.

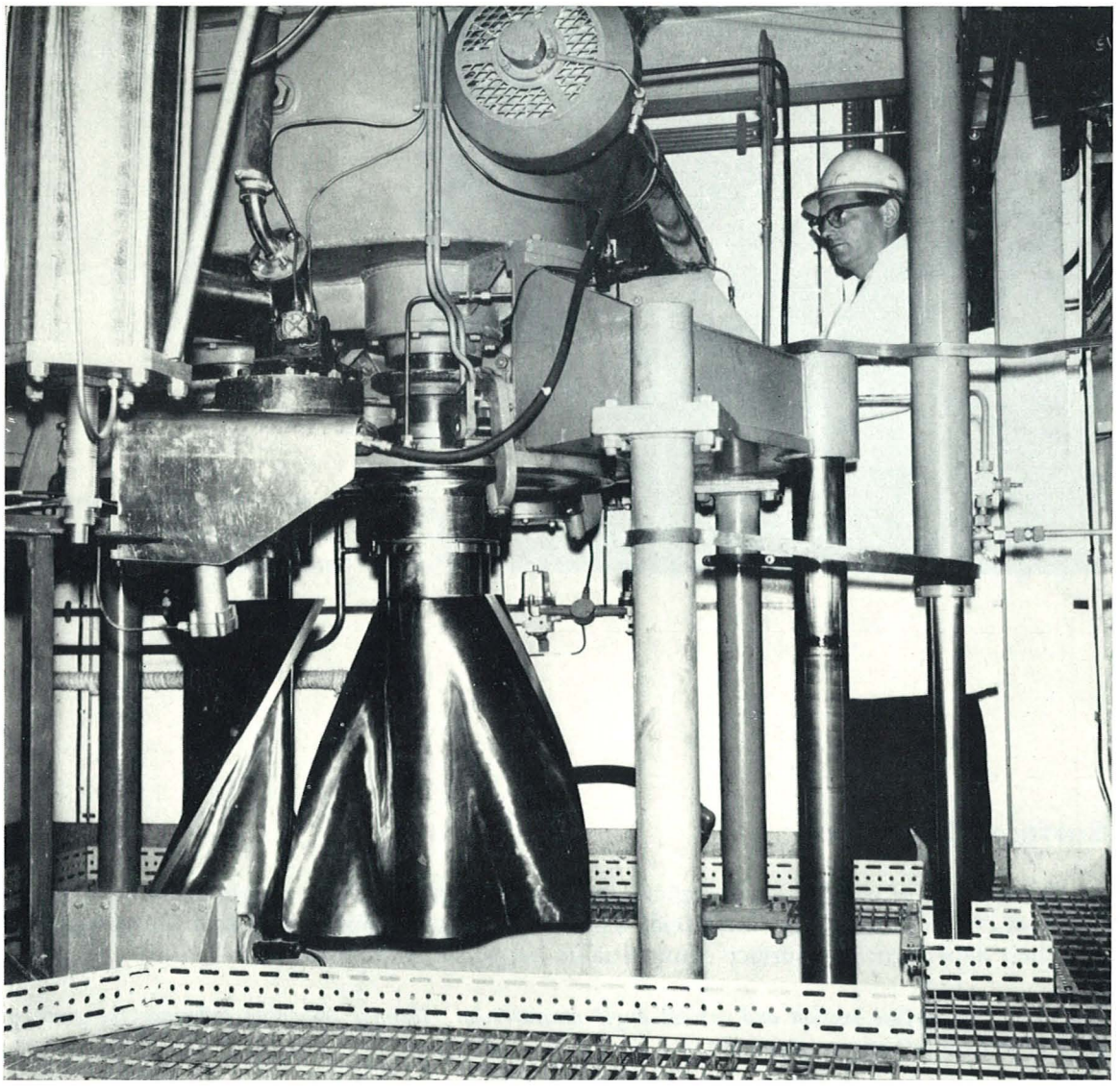
An advisory service is offered on all aspects of bonding and hermetic sealing of joints, and on joint design.

Instron universal testing machine (load, 10^{-3}—5000 kg; cross-head speed, 10^{-3}—10 mm/sec; cross-head travel, 1 m) with thermostatic chamber (—50° to 60°C) and automatic integrator. Hydraulically-operated high-speed test machine (strain rate up to 10 cm/sec); Sanborn twin-channel recorder (10 ms response) and Tektronix oscilloscope. Jigs for the preparation and testing of joints; equipment for preparation of proofed fabrics; viscometers, plastometers; facilities for storage at controlled humidities and temperatures.

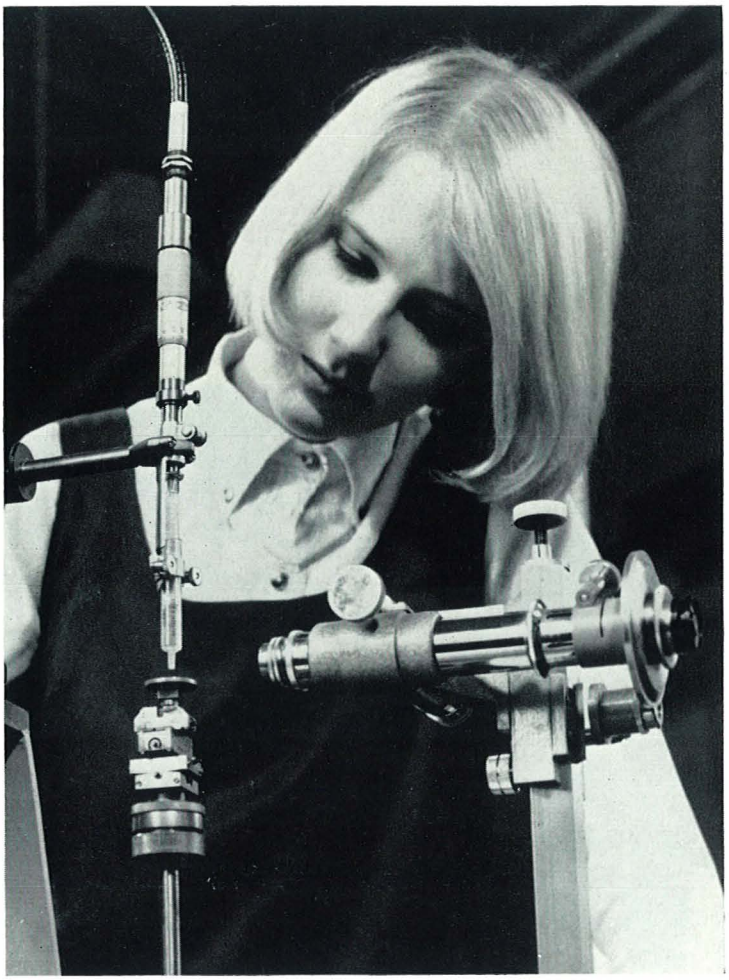
Rheology of Stiff Pastes and Highly Filled Rubbers

Dependence of rheological behaviour of highly concentrated solid-in-liquid dispersions on nature of solids, solids loading, magnitude and distribution of particle size, nature and viscosity of liquid, temperature and test methods. Mechanical behaviour of highly filled rubbers by tensile testing over a wide range of temperatures and strain rates. Construction of master curves of mechanical behaviour by time-temperature superposition.

Plastometers to study flow and deformation behaviour including fatigue effect of cyclic compression and extension; fatigue by flexing; effect of imposed hydrostatic pressure; response to biaxial strain. Brittle point apparatus. Tensile testing apparatus.



VERTICAL MIXER FOR RUBBERY-TYPE SOLID PROPELLANTS
The mixing pot has been lowered for removal of the propellant mix.



MEASUREMENT OF CONTACT ANGLE OF WATER ON A CONTAMINATED STEEL SURFACE

Surface Chemistry

Surface tensions of highly viscous organic liquids; effect of molecular weight and temperature. Study of contact angles and interfacial tensions between viscous liquids and inorganic salts, and their dependence on surface contaminants (moisture, surfactants).

Equipment for surface tension and contact angle measurement; thermal siphoning technique for growing large perfect crystals of inorganic salts.

Technology of Pastes and Slurries

Formulation, manufacture, and handling of stiff pastes based on curable and non-curable liquid organic polymers containing a high proportion of solid inorganic filler.

Vertical and horizontal mixers of various capacities capable of processing mixes up to 10^7 poise viscosity; de-aerating pug-mills and pressure extrusion equipment.

NON-METALLIC MATERIALS

Head of Branch B L HOLLINGSWORTH

The Non-metallic Materials Branch undertakes basic and applied research on the chemistry and physics of polymers with particular regard to synthesis, characterization, degradation, and mechanical behaviour under a range of test conditions. The Branch offers an advisory service on the applications of polymers, and supervises long-term environmental testing at the Tropical Research Unit, which is a joint project with Australia.

ACTIVITIES AND FACILITIES

Polymer Physics and Engineering

Study of the physical properties of non-metallic materials and reinforced plastics: stress-strain curve, strength, fracture energy, damping capacity, creep, fatigue, stress relaxation, and dimensional stability. Effects of rate of deformation, temperature and moisture. Stress relaxation tests on rings and beams; dynamic mechanical properties of discs. Compression cell to study effects of dynamic, static, and creep loading.

Hounsfield apparatus (extension rate, 0·0013 — 50·8 cm/min; temperature, — 80° to 80°C); Baldwin machine; Goodbrand machine (fibre test). Avery Izod impact machines (capacity 17 kg.m; maximum loading rate, 18 × 10^2 kN/sec; photographic recording with 35 mm. streak- or 12 000 frames/sec Fastex-cameras). Flywheel machine (fracture energies at impact velocities of 130—1 300 cm/sec). Ultrasonic equipment (150 kc/sec—2 Mc/sec; up to 80°C). Rotating beam machine (fatigue properties).

Polymer Chemistry—Synthesis, Characterization, and Stability

Investigation of novel and potentially useful polymer systems; monomer and polymer synthesis, polymer fractionation, mechanism and kinetics of polymerization, reactions of polymers.

Characterization of polymers by molecular weight (viscometry, osmometry, light scattering, and end-group analysis), spectroscopy (IR, UV and NMR), dilatometry, bulk viscometry, compressibility and thermal expansion measurements, and by optical examination of polymer morphology.

Stability of addition and condensation polymers to heat, ultra-violet light, and high energy radiation; effects of chemical structure, impurities and environment. Mechanism and kinetics of degradation and its effect on molecular weight and physical properties.

MOLECULAR WEIGHT *Hewlett-Packard 502 high-speed membrane osmometer (maximum operating temperature 130°C); Brice-Phoenix Series 2000 Universal light scattering photometer with MSE high-speed centrifuge.*

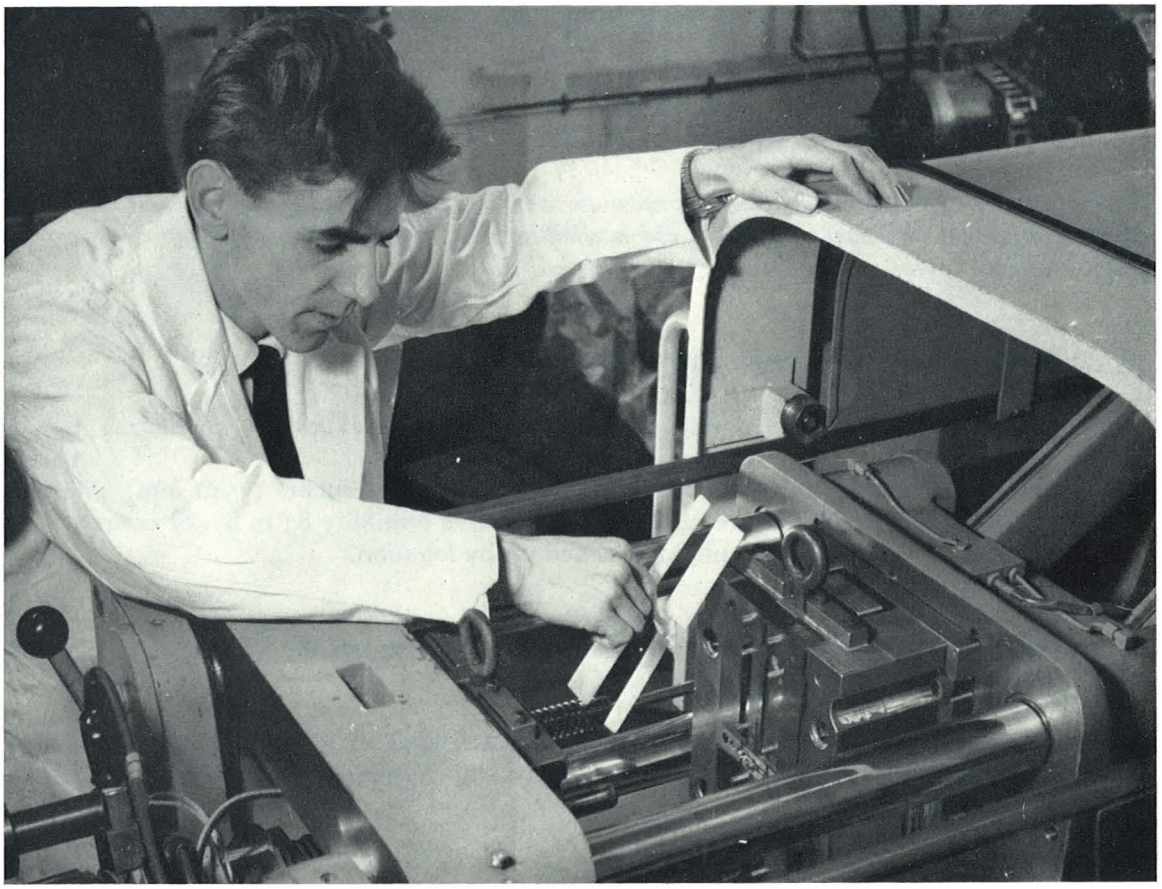
BULK PROPERTIES *Epprecht Viscometer (0·1—10^6 poise, 0°—180°C); linear expansion apparatus for glass transition temperatures; pressure balance (temperature controlled to ±0·001°C).*

AVERY IZOD PENDULUM IMPACT APPARATUS

A pendulum impact tester modified for tensile and flexural impact tests to investigate the engineering life of non-metals.

NUCLEAR MAGNETIC RESONANCE MEASUREMENT

This 60 M/c instrument is used for characterization and structure determination of a wide range of organic compounds.



HORIZONTAL INJECTION MOULDING MACHINE
Test pieces for mechanical property assessment being produced in a constant torque, injection moulding machine.

SPECTROSCOPY *PE R10 60 M/c NMR spectrometer (variable temperature probe, spin decoupling unit, probes for ^{1}H, ^{11}B, ^{19}F, and ^{31}P; PE 337 grating spectrometer (4000—400 cm^{-1}, ATR attachment); Unicam SP 500 spectrometer.*

MICROSCOPY *Gilett and Sibert time-lapse microscope (35 mm and 16 mm (ciné) photographic recording).*

DEGRADATION *Mercury lamp, xenon arc, molten salt- and fluidized sand baths.*

GAS CHROMATOGRAPHY *PE Model 801 (dual column analytical instrument, linear programming); Pye Model 105/15 (automatic preparative gas chromatograph, linear programming).*

Polymer Development and Applications

Processing and curing of new rubbers and thermoplastics by injection moulding, extrusion, milling, and compression moulding. Measurement of physical properties, and the effect of contaminants (e.g. explosives, propellants, petrol, etc.). Accelerated and tropical ageing trials to assess useful life. Investigation of failures. Manufacture of special components; antistatic and conducting rubbers.

Proofed fabrics: preparation, mechanical properties, and advice on the design of proofed fabric structures.

PROCESSING *Wide range of mills, mixers, hydraulic presses and injection moulding machines. Facilities for the synthesis of polyester-polyurethane rubbers. Small-scale equipment for preparing proofed-fabric samples.*

TESTING *Physical properties; permeability of materials to organic fluids and water; ageing ovens to simulate hot/dry and hot/wet conditions; continuous and intermittent stress relaxometers. Carbon arc equipment for special exposures.*

Joint Tropical Research Unit, Queensland

Four sites are available for the exposure of small specimens to atmospheric weathering.

(*a*) INNISFAIL Latitude 17° 32′S. Average annual rainfall 140 inches (3540 mm). Average daily mean temperature 74°F (23°C); relative humidity 83 to 87. Sites are
(i) Hot/wet, jungle, i.e. sunlight screened off by foliation.
(ii) Hot/wet, clearing.

(*b*) CLUMP POINT Similar latitude and conditions to Innisfail but the site is
(iii) Marine.

(*c*) CLONCURRY Latitude 20° 43′S. Average annual rainfall 17 inches (430 mm). Average daily mean temperature 78°F (25°C); relative humidity 39. The site is designated
(iv) Hot/dry.

GENERAL CHEMISTRY

Head of Branch DR A R OSBORN

The General Chemistry Branch investigates the preparation, properties and reactions of a wide range of ingredients related to explosive, propellant and polymer technology. The Branch offers an advisory service on the stability, compatibility and surveillance testing of propellants, explosives and other hazardous materials. New analytical methods are developed to assist quality control, and a range of specialized techniques and facilities are used to provide an analytical service for the Establishment.

ACTIVITIES AND FACILITIES

Synthesis and Characterization

Synthesis of explosives and ingredients of solid propellants and polymers (fuels, oxidizers, ballistic additives, stabilizers, curing agents, antioxidants, etc.); studies to optimize yield and purity and to reduce hazard (toxicity, thermal decomposition, etc.).

General techniques of preparative chemistry, and supporting facilities: armoured cupboards; PE Model 237 grating spectrometer (4000—650 cm^{-1}); Unicam SP 500 spectrometer; various refractometers and optical microscopes, including Kofler hot-stage instruments; molecular weight determination by semi-micro ebulliometry and micro-cryoscopy.

Stability and Compatibility

Kinetics and mechanism of thermal decomposition of explosives and exothermic compositions; ignition phenomena and build-up to low order detonation; compatibility of explosives, propellants, etc. with materials (e.g. polymers, plastics, metals, adhesives, varnishes and paints); effect of severe environmental conditions on storage stability. New techniques to investigate thermal stability.

Environmental testing ovens and standard stability test facilities. Master slave manipulator. Stanton thermogravimetric balance (maximum temperature, 250°C); PE differential scanning calorimeter, Model 1 (−100° to 500°); heat flow calorimeter (sensitivity, 30 μwatts); multirange temperature recording equipment (−200° to 500°C). Photomicroscopy of samples heated in vacuum. Advance Model TC 2A electronic timer counter (1 μsec).

Chemical Analysis and Physical Methods

Separation, identification, and analysis of the constituents of explosives, propellants, polymers, rubbers, etc.; determination of functional groups, elemental composition, and molecular weight; trace metal analysis. Estimation of purity, and investigation of quality control and specification tests. Studies concerned with gas and solvent vapour analysis; molecular and crystal structure; thermochemical characteristics (phase changes, low temperature behaviour and thermal decomposition); cure- and post-cure chemistry of polymeric systems; non-aqueous titration; mass spectrometric and polarographic analysis.

MASS SPECTROMETRY
An AEI Model MS 2H mass spectrometer capable of performing isotopic and chemical analyses on very small quantities of material, including solids.

CHROMATOGRAPHY *Wide range of standard equipment for analytical- and preparative-scale column- and thin layer chromatography; Craig counter-current extraction apparatus; Varian Aerograph Model 1522 gas chromatograph (dual column, linear programming); PE F11 gas chromatograph; pyrolysis attachment.*

SPECTROSCOPY *PE Model 257 grating spectrometer (4000—650 cm^{-1}) ATR attachment, micro- and heated cells; modified Grubb Parsons S3A spectrometer (3500—250 cm^{-1}); PE Model 137 UV spectrometer; Unicam SP90 atomic absorption spectrophotometer.*

MASS SPECTROMETRY *AEI Model MS 2H*

MICROANALYSIS *Combustion equipment (C, H, N); Schöniger flask (S, halogens); Mechrolab Model 302 vapour pressure osmometer (molecular weights up to 20 000).*

POLAROGRAPHY *Beckman Electroscan 30 (various electrometric analysis techniques).*

RADIOCHEMISTRY *Tracer laboratory; Panax standard- and low background Geiger counters; Isotope Development Ltd. solid and liquid scintillation counters.*

THERMOCHEMICAL ANALYSIS see *Stability and Compatibility.*

PARTICLE SIZE ANALYSIS *Sharples Micromerograph (humidity- and temperature-controlled); gas adsorption and various types of gas permeability apparatus for surface area measurement.*

Crystallography

Application of optical and X-ray diffraction to identification and characterization of compounds; phase analysis of mixtures, polymorphism, crystal orientation, and crystal structure analysis.

Equipment includes three X-ray generators, one being a high-power rotating anode set, X-ray powder cameras, goniometers (Weissenberg, oscillating crystal and optical), Hilger-Watts 4-circle, single crystal automatic diffractometer, an X-ray powder diffractometer, and polarizing microscope with heating stage.

GAS CHROMATOGRAPHY
This technique is particularly useful for identifying and estimating volatile constituents of complex mixtures.

Gas Kinetics

Kinetics and mechanisms of gas-phase reactions and general free radical chemistry using static and discharge-flow techniques. Reactions of alkyl and alkoxy radicals, nitrogen oxide and nitrogen dioxide. Mechanisms of gas-solid reactions.

High vacuum techniques and product analysis by vapour-phase chromatography, infra-red and mass spectrometry. Emission spectroscopy.

PROCESS RESEARCH

Head of Branch H ZIEBLAND

The Process Research Branch is concerned with means and equipment for processing chemicals on a production scale. Plant and facilities are designed for the manufacture of hazardous compounds and mixtures with particular emphasis on safety, remote-control, and instrumentation. The Branch has special interests in unit operations such as crystallization, mixing, heat transfer, and precision measurements of thermal properties of fluids.

Research and development is being carried out on fibre-reinforced, metallic and non-metallic materials and on the growth of ceramic whiskers.

ACTIVITIES AND FACILITIES

Large-scale Production

Development of laboratory syntheses on to pilot- and full-scale processes; pilot plant operation; manufacture of experimental chemicals and materials, including high explosives, polymer and rocket ingredients, whiskers and aligned inorganic fibres.

Protective enclosures, with remote control, for processing experimental quantities of dangerous chemicals (i.e. fire, explosion, toxicity risks): one for large laboratory-scale glass plant; another for 2·5 kg pilot plant scale, equipped with a closed circuit television loop.

A wide range of pilot-scale plant, including: plant for concentrating nitric acid free from nitrous acid; nitration and sulphonation unit with brine cooling, remote control and acid mixing plant; glass-lined oil heated reactors for polymer manufacture.

Separators such as decanters; pressure-, vacuum- and rotary filters; batch and continuous stainless steel centrifuges; liquid centrifuges; and dry powder sieves.

Dryers, including hot air-, vacuum tray- and rotary-steam tube types.

Grinding plant, including jaw crusher; roll mill; edge-runner mill; hammer mills; and 'micronizer' fluid energy mill.

Mixers: double cone powder blender; medium and heavy paste mixers.

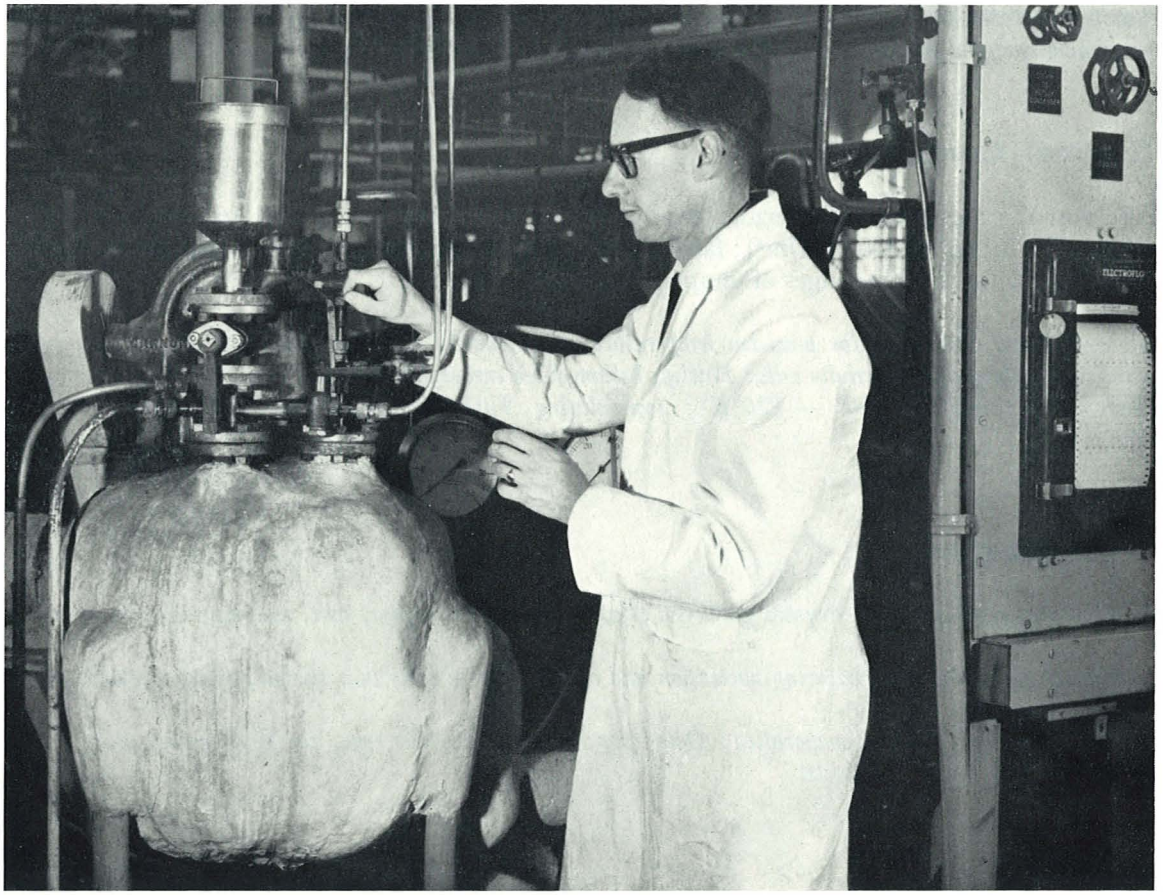
Packed, gas-liquid absorption towers.

Distillation: a 5-cm glass 'molecular' still; a 50-litre glass batch distillation unit; glass distillation column of high efficiency for high vacuum and 150°C; similar unit in stainless steel for pressure distillation up to 1 MN/m².

Intensive Drying or Stripping

The intensive drying (or stripping) of high boiling liquids which may be sensitive to heat or excessive turbulence.

Continuous plant (11·5 kg/h), based on single passage of liquid down a column packed with a battery of vertical helical coils.



PLANT FOR POLYESTER MANUFACTURE
An example of the development of laboratory syntheses on to pilot-scale processes.

Convective and Radiative Heat Transfer from Flames and Gases

Studies of convection and radiation from flames and combustion gases (up to 3800°K; 10 MN/m²); radiative emissivity of water vapour (1500°—3500°K; 0·5—10 MN/m²).

Two instrumented test cubicles; water-cooled combustion chambers; black-body furnace to calibrate radiation sources.

Convective Heat Transfer to Liquids

Convective heat transfer from electrically heated surfaces to aviation kerosine and other liquids under sub-cooled, boiling, and supercritical conditions.

Closed-loop apparatus with rectangular flow channel containing heated tube (maximum power, 10 kW; maximum pressure, 10 MN/m²; maximum fluid flow rate, 1·2 kg/sec). Photographic observation using Fastex ciné camera (18 000 half-frames/sec) and 0·2 μsec argon flash lamp.

Convective Heat Transfer to Cryogenic Fluids

Convective heat transfer to fluid hydrogen in the vicinity of the critical point and at supercritical pressures; fluid dynamics of cryogenic fluids.

Remotely-operated test rig in which cryogenic fluids flow through asymmetrically heated rectangular ducts (maximum energy dissipation, 40 kW; maximum pressure, 5 MN/m²).

Thermal Conductivity

Precision measurements of thermal conductivities of liquids, gases, and supercritical fluids (12°— 650°K; up to 300 MN/m²); facilities equally suitable for measuring viscosity, dielectric constant, etc. over wide ranges of temperature and pressure.

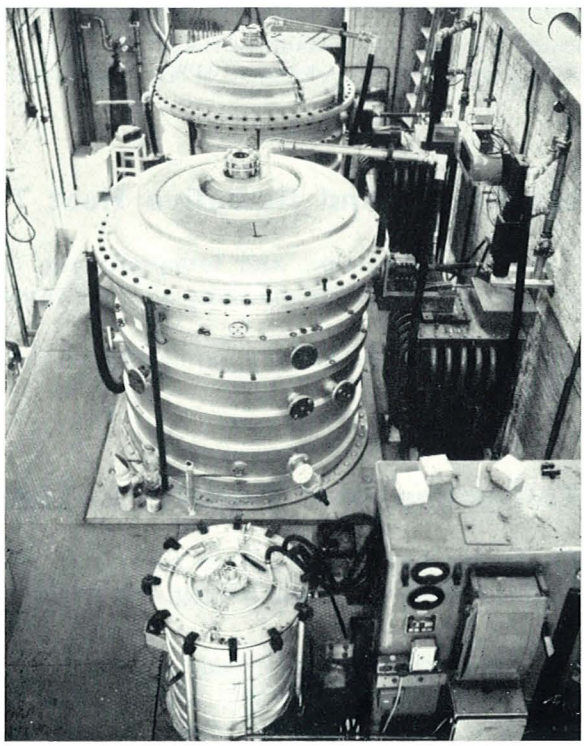
Air conditioned laboratory for precision temperature measurement; protected annexe for compressing gases and liquids; thermal conductivity cells: Phillips helium-filled cryogenerator (12° — 90°K); liquid nitrogen-filled metal thermostat (90° — 220°K); recirculating Turbotherm-filled liquid thermostat (300° — 650°K).

Crystallization

Studies of nucleation and crystal growth; control of crystal shape, size, and size distribution.

Laboratory equipment for measuring nucleation and crystal growth rates in a stirred cooling crystallizer.

Pilot crystallizers: Kestner evaporative; Oslo type; and pulsed tube type, for performance studies and production of crystalline products.



'BRAN TUBS'
High temperature furnaces for synthesis of silicon nitride whiskers.

High Temperature Equipment

Furnaces of various types for operation up to about 1600°C; high frequency heating equipment; temperature measuring devices.

Fibre Processing Plant

Equipment for sizing whiskers and other short fibres and plants to classify and align asbestos and other whiskers for making composite materials.

Fibre Testing Equipment

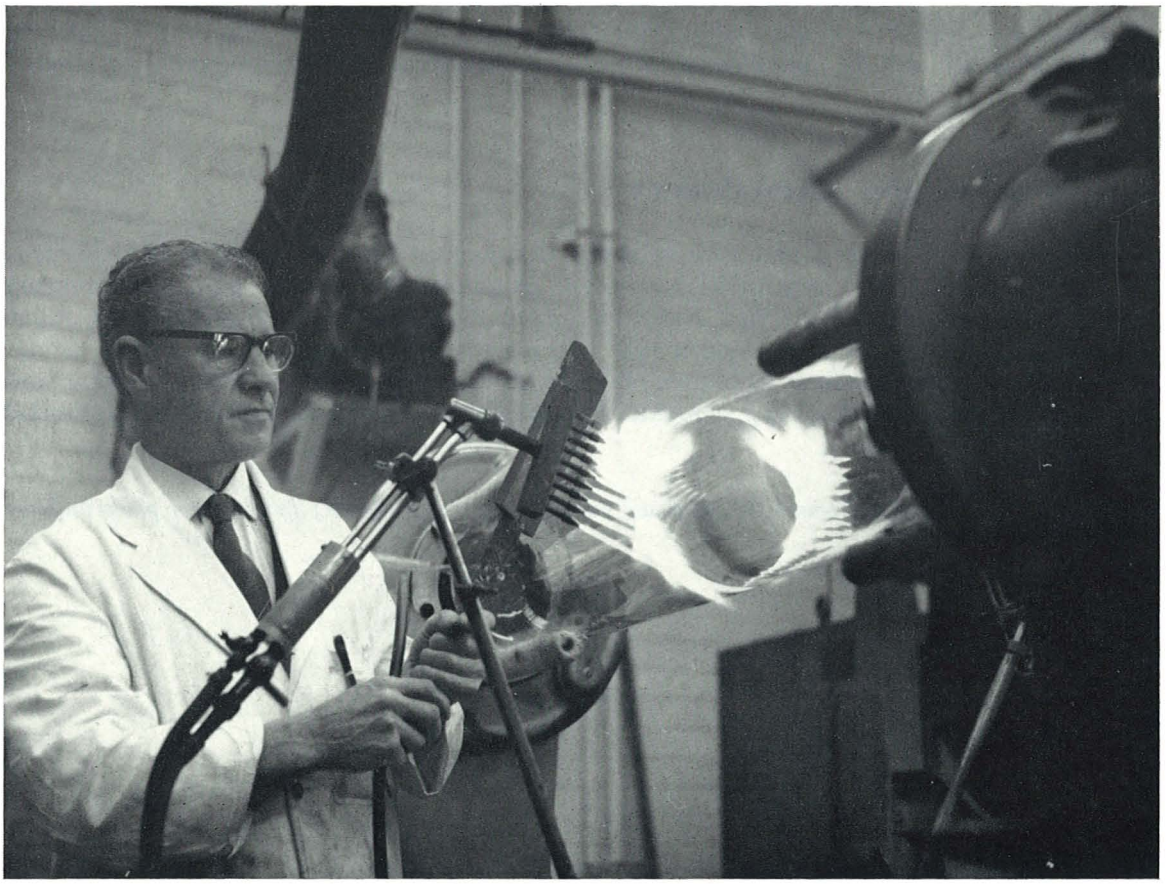
Marsh micro-testing machine and various macro-testing machines.

Microscopes

A range of optical microscopes and a J.E.M. 7 electron microscope.

Instrumentation and Glass Engineering

This Section, part of the Engineering Branch, is responsible for the development and application of instruments and apparatus based on electronic and glass engineering techniques.



GLASS ENGINEERING
The glass engineering workshop is equipped to undertake construction of scientific glassware ranging from special laboratory articles to the large-scale item shown here.

MISCELLANEOUS RESEARCH ACTIVITIES

In addition to research and development work performed by the Branches described above, certain specialized or exploratory research topics are undertaken by small groups under the direction of Dr. L. J. Bellamy, Mr. G. K. Adams,

Spectroscopy

Studies of factors affecting infra-red absorption spectra of complex molecules; assignment of absorption bands and interpretation of spectra.

Unicam SP 100 spectrometer (3650—300 cm^{-1}); Grubb Parsons GS2 grating spectrometer (4000—650 cm^{-1}); Unicam SP 700 spectrometer (55000—4500 cm^{-1}); attachment to determine emission spectra in the visible region; time-resolved luminescent spectroscopy in the visible region (resolution, 1 μsec).

Flame and Explosion Phenomena

An Elliot 903 computer is in use, and computer programmes are available for calculation of flame and explosion properties, and the thermodynamic properties of two-phase, multi-element systems in chemical equilibrium.

Autoxidation and Antioxidants

Kinetics and mechanism of free radical chain reactions in solution; catalysis of oxidation-reduction reactions by heavy metals; effect of oxidative degradation, light, and ionizing radiation on polymeric materials. Research aimed at preventing or inhibiting oxidative degradation. Design and assessment of new antioxidants; mechanism of antioxidant action, particularly synergistic effects (mixtures of free radical acceptors; free radical acceptor and chelating reagent or S-containing peroxide decomposer); inhibition of autoxidation by metal chelates.

Warburg apparatus and equipment for automatic recording of oxygen uptake; facilities for photochemistry and radiochemistry.

INDEX OF ACTIVITIES

Titles of branches have been abbreviated as follows:

E	Explosives	NM	Non-metallic Materials
P1	Propellants 1	GC	General Chemistry
P2	Propellants 2	Misc. Res.	Miscellaneous Research
PR	Process Research	IGE	Instrumentation and Glass Engineering Section

INDEX OF FACILITIES

THERMOMETERS	
Platinum resistance	P1
Multirange recording	GC
ULTRASONIC INSPECTION EQUIPMENT	
Propellants	P1
Polymers	NM
ULTRA-VIOLET SPECTROMETERS	
General purpose	GC, NM
Continuous scanning	GC, Misc. Res.
VISCOMETERS	
Bulk viscosity	NM, P2
Intrinsic viscosity	NM
X-RAY EQUIPMENT	
Radiographic inspection	P1, E
Crystallographic analysis	GC

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Explosives Research & Development Establishment

Research and Development Activities and Facilities

MINISTRY of DEFENCE

Amendments in Blue Made 11 June 1974

EXPLOSIVES RESEARCH & DEVELOPMENT ESTABLISHMENT

RESEARCH and DEVELOPMENT ACTIVITIES and FACILITIES

ERDE MINISTRY of DEFENCE WALTHAM ABBEY ESSEX

HOW TO CONSULT ERDE

ERDE is able to offer a limited, free consultative service to industrial undertakings on problems related to expertise available in the Establishment.

Problems involving more extensive investigations or the use of equipment and special facilities may be undertaken for a fee, subject to the demands of the Establishment's research and development programme.

Enquiries may be made

(*a*) by letter, addressed to The Director
ERDE
Ministry of ~~Technology~~ DEFENCE
Waltham Abbey, Essex; EN9 1BP

(*b*) by telephone, asking for Heads of specific branches or ERDE Industrial Liaison Officer Waltham Cross 23688; (STD) 97-23688 Inner London; (STD) 0992-23688 Outside London.

CONTENTS

INTRODUCTION

The primary function of the Explosives Research and Development Establishment is to undertake research on, and development of, explosives, propellants and related exothermic compositions to meet the present and future requirements of the three Services. The Establishment is also actively engaged on materials work, concerned principally with the chemistry and physics of polymers, and with new engineering materials based on refractory fibres.

To exercise these functions, ERDE maintains a staff of scientific, technical and engineering personnel representing a wide range of disciplines but with particular expertise in chemistry, chemical engineering and physics. Research and development tasks are shared by six technical branches supported by drawing office, machine shop, electronics and glass engineering facilities, and by appropriate library and information services.

It is the purpose of this book to give a brief outline of the work of the technical branches, especially those aspects involving expertise, facilities or equipment which are likely to be of interest to industrial undertakings.

MANAGEMENT ORGANIZATION

Director	Dr. L J Bellamy
Deputy Director	Mr G.K. Adams ~~MR R HERON~~
~~Special Merit 'B' Post~~	~~Mr. G K Adams~~
Heads of Branches	
Explosives	DR C A BECK
Propellants 1	DR C G LAWSON
Propellants 2	Mr. P R Freeman
Non-metallic Materials	Dr. B L Hollingsworth
General Chemistry	DR A R OSBORN
Process Research	Mr. H Ziebland
Chief Engineer	Mr. R Fisher
Chief Safety Officer	Mr. J V Griffiths
Chief Administrative Officer	Mr. S F M Whiteside
Individual Merit Scientists	Dr. A W H Pryde (Chemical Engineering)
	Mr. G W C Taylor (Initiatory Explosives)
	Dr. N Uri (Autoxidation)
	DR D H RICHARDS (POLYMER CHEMISTRY)

EXPLOSIVES

Head of Branch

DR C A BECK

The Explosives Branch deals primarily with the development of sensitive, initiatory explosives and high explosive and propellant compositions of improved performance. Trials are performed to assess sensitiveness and hazards associated with all explosive materials.

ACTIVITIES AND FACILITIES

Explosive Risk

Standard tests designed to evaluate and to compare the explosive risk of materials are based on impact and friction sensitiveness, ease of ignition, susceptibility to burn to detonation, and shock sensitiveness. Results enable recommendations to be made regarding type of hazard, degree of protection and appropriate storage requirements.

Armoured cupboards for small-scale tests (up to 30 g) and instrumented firing site facilities for larger quantities (up to 4·5 kg). Firing site for small-scale underwater tests.

Electrostatic Risk

Electrostatic risks associated with handling explosive powders, vapour/air, and gas/air mixtures are assessed by measuring

(*a*) electrostatic voltages and charges on transferring solids or liquids, or on separating surfaces;
(*b*) comparative electrification of materials, especially fabrics and plastics;
(*c*) electrical resistance of floors, footwear and items of equipment;
(*d*) susceptibility to ignition by capacitor type discharge.

Electrostatic voltmeter (30—18 000 volts); resistance meters (up to 10^{16} ohms); facilities for measuring electrostatic spark sensitiveness of powders.

High Speed Photography

This technique is used to record mechanical and explosive phenomena, to investigate shock initiation of explosives and to determine propagation velocities.

Portable 16 mm ciné camera (100—18 000 frames/sec): framing camera (25 frames at 150 000 — 4 × 10^6 frames/sec), installed in 2·25 kg explosives test facility; streak camera (writing speed 0·7 mm—9 mm/microsec), installed in 4·5 kg explosives test facility. Printing facilities include conversion of 35 mm frames into animated 16 mm film, and colour printing of negatives of explosive phenomena with particular reference to correct colour balance.

Noise Evaluation

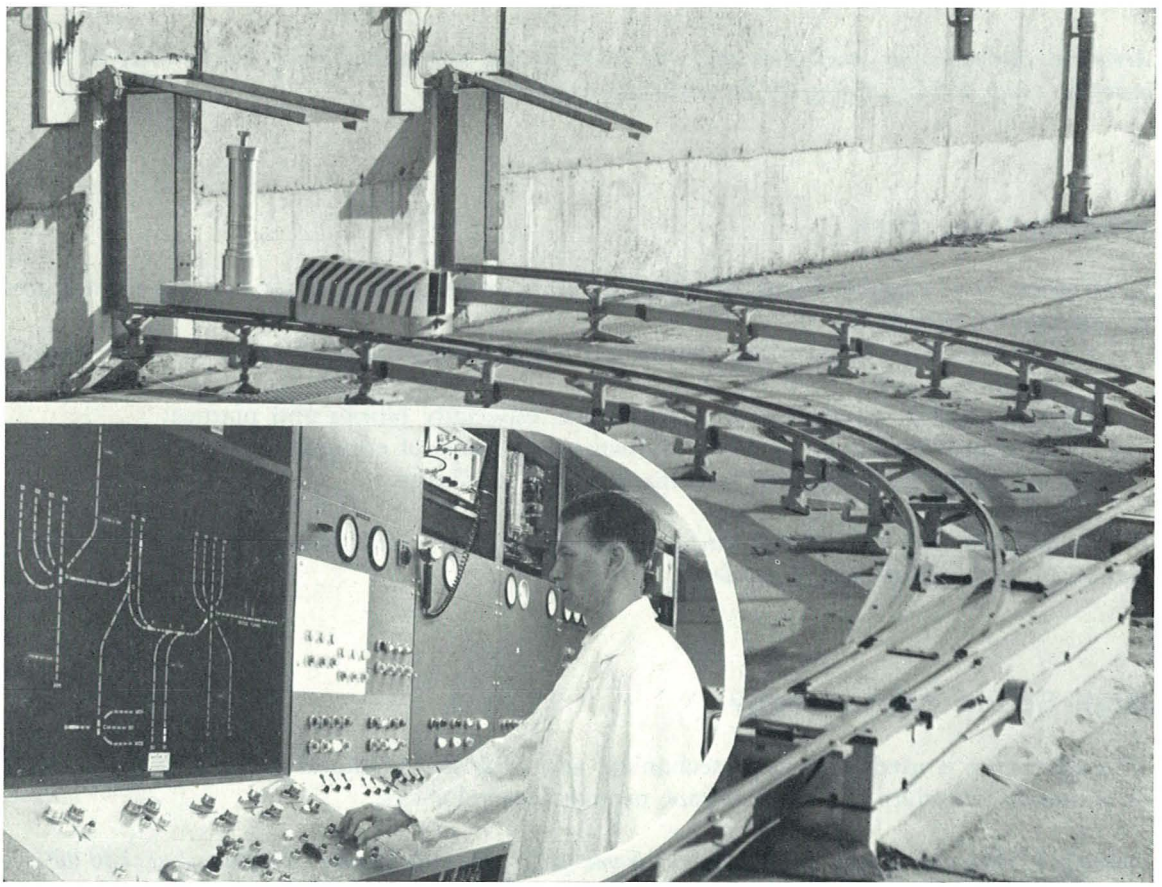
Measurement and analysis of impulsive noises including those of long duration (e.g. sonic booms), and their simulation by explosives. Techniques for generating a wide range of pressure waveforms in air may be applied to studying the behaviour of structures to shocks of this kind.

Apparatus to record shock waves in air down to 5 N/m^2 (0·1 lbf/ft^2).

Remote Control Methods

Development of remote control methods for manufacturing and testing dangerous explosive materials.

Process bays (limit 7·25 kg TNT equivalent) in which hazardous operations can be performed by remote control. Remotely operated mixing, extruding and injection moulding unit (4·5 kg) with temperature, vacuum and shear rate controls on mixer (viscosities 2—3 000 poise). Strong bay (limit 1·35 kg TNT equivalent) with master slave manipulators (3·5 m extended reach), X-ray facility (250 kv), and armoured viewing window. Capability for melt-mixing and moulding, or for pressing explosives, and for carrying out basic machinery operations on explosive charges by remote control. Closed circuit TV available to position all remotely-controlled operations.



REMOTE-CONTROL TRANSPORTATION OF HAZARDOUS MATERIALS
A five-inch gauge electric railway system used to transport hazardous materials between manufacturing, testing and storage areas.

Polymer Technology

Cure chemistry of polyurethane elastomers prepared from di-isocyanates and hydroxy-terminated polyesters and polyethers; optimization of physical properties of heavily-loaded rubbers.

Small scale plant facility for development work; laboratory equipped to study physical properties and ageing characteristics.

PROPELLANTS 1

Head of Branch

DR C G LAWSON

Propellants 1 Branch is largely concerned with the development of propellants based on nitrocellulose. Work is undertaken on methods for controlling ballistics, and to devise ballistic assessment techniques. Attention is also given to the quality control of propellants by non-destructive tests involving X-ray or ultrasonic inspection.

ACTIVITIES AND FACILITIES

Propellant Processing

Experimental processing of nitrocellulose-based propellants poses problems similar to those involved in processing plastic materials, especially consideration of viscosity control and particle size.

Plant for rolling and extrusion of incorporated materials; preparation of felted paper tubes with high length/diameter ratios.

Combustion

Investigations of propellant combustion using techniques equally applicable to combustion of fuel oils and gases. High temperature degradation of organic materials, research capable of being extended to flammability and flame-proofing of plastics.

Equipment to measure temperature profiles at burning surfaces, and appropriate instruments (infra-red and ultra-violet spectrophotometers and gas chromatographs) for flame decomposition product analysis.

Ballistic Properties

Burning rates and calorimetric measurements. Experimental techniques are available to study solids, liquids, and gases, and to determine precise heats of combustion, formation and wetting.

Equipment to measure static and dynamic pressures for fractions of a second or longer in ranges up to 31 MN/m^2 (4500 psi). Calorimeters with platinum resistance thermometry systems (precision better than $1 \times 10^{-3}°C$).

Non-Destructive Testing

The integrity and bonding of propellants are inspected by radiographic and ultrasonic test methods which may also be used to investigate conventional plastics and bonded systems.

Radiographic (400 kV) and ultrasonic (375 kc/sec through transmission) inspection equipment.

PRECISION CALORIMETRY
An NPL-pattern bomb calorimeter for determining heats of combustion with an accuracy approaching 1 part in 10^4.

PROPELLANTS 2

Head of Branch P R FREEMAN

Propellants 2 Branch is responsible for research and development on composite propellants based on plastic or rubbery binder systems. The facilities include laboratories for quality control, including ballistic and physical property assessment, together with small- and large-scale manufacturing plants.

Basic and applied research on rheology and adhesion is performed to improve the mechanical behaviour of solid propellants and to provide an advisory service on the use of sealants, adhesives and lutings.

ACTIVITIES AND FACILITIES

Composite Propellant Formulation, Manufacture and Assessment

Formulation and manufacture of paste-like and rubbery composite propellants, assessment of ballistic properties by strand burning and static firing of small rocket motors. Compositions of high energy are available covering a wide range of burning rates.

Comprehensive facilities for the manufacture of propellants and filling of small rocket motors. Strand burning bombs and small static proofstand.

Sealants and Adhesives

Development of lutings and cements for threaded joints, etc., and adhesives for metal, plastics, paper, cloth and leather; study of tensile and shear strength, and of stress-strain behaviour of adhesives and joints.

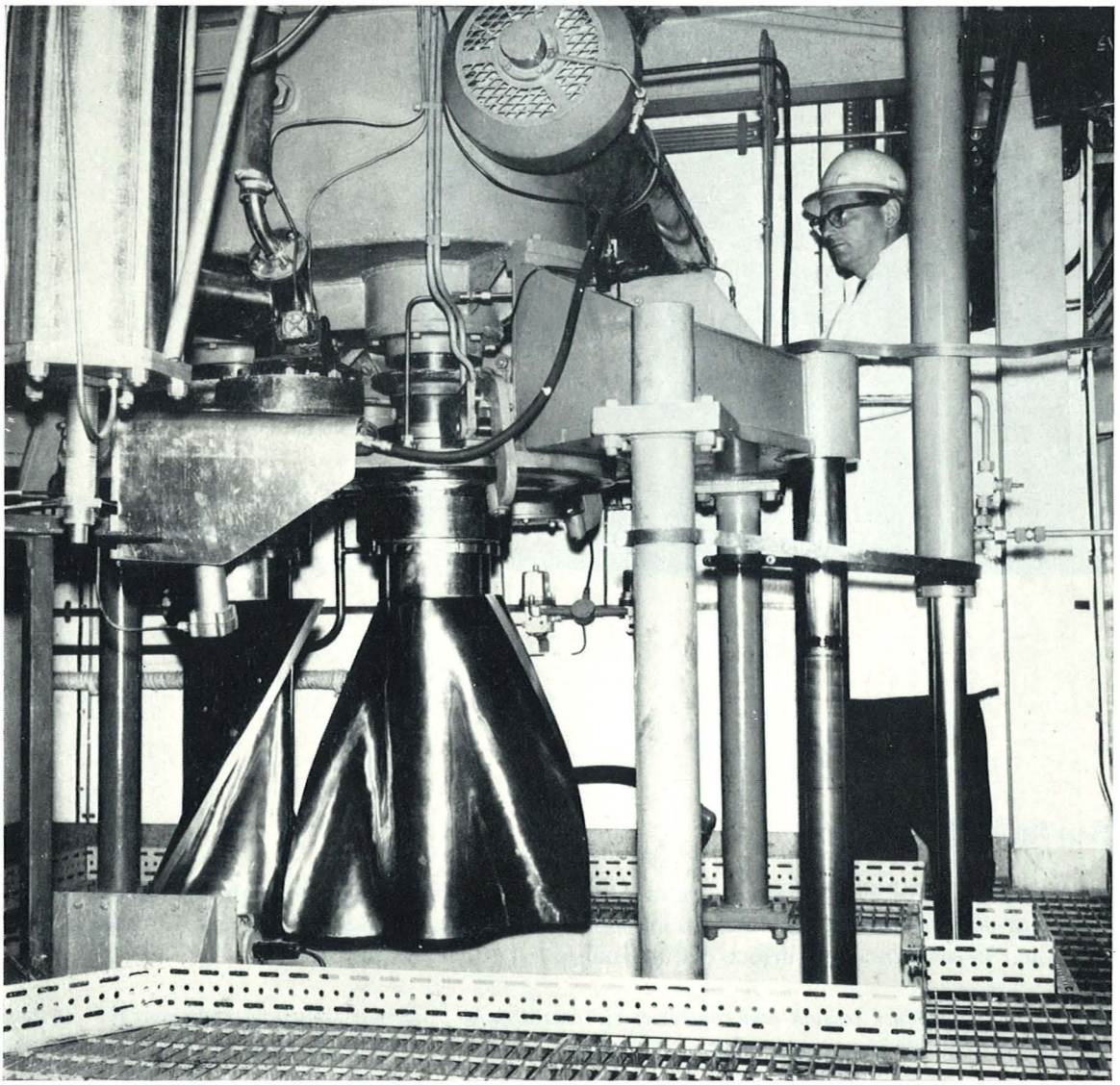
An advisory service is offered on all aspects of bonding and hermetic sealing of joints, and on joint design.

Instron universal testing machine (load, 10^{-3}—5000 kg; cross-head speed, 10^{-3}—10 mm/sec; cross-head travel, 1 m) with thermostatic chamber (—50° to 60°C) and automatic integrator. Hydraulically-operated high-speed test machine (strain rate up to 10 cm/sec); Sanborn twin-channel recorder (10 ms response) and Tektronix oscilloscope. Jigs for the preparation and testing of joints; equipment for preparation of proofed fabrics; viscometers, plastometers; facilities for storage at controlled humidities and temperatures.

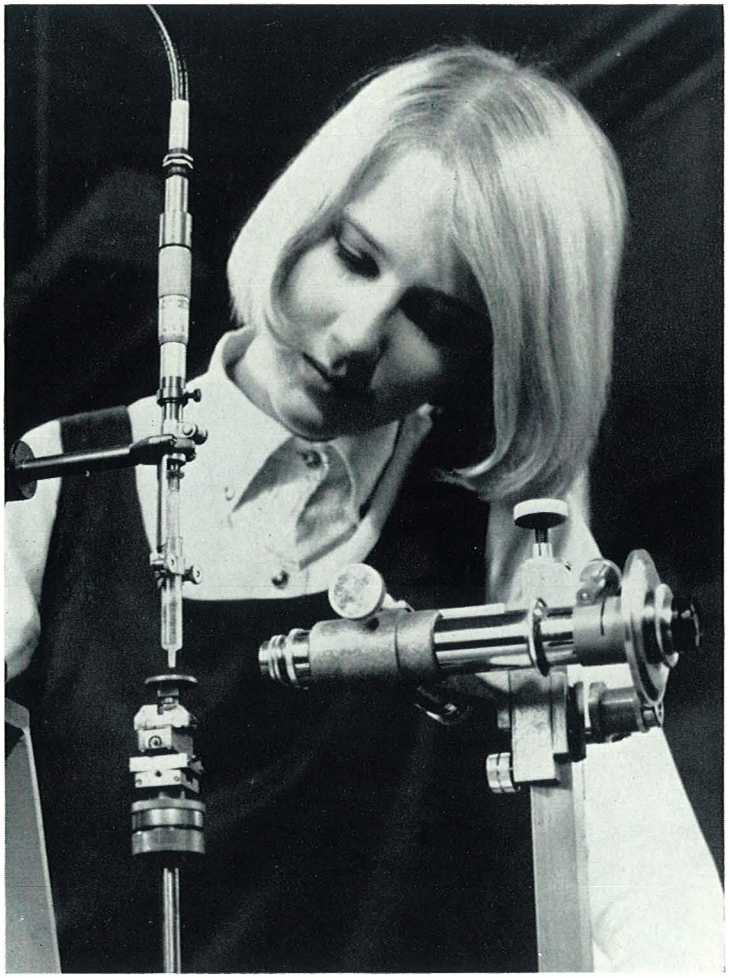
Rheology of Stiff Pastes and Highly Filled Rubbers

Dependence of rheological behaviour of highly concentrated solid-in-liquid dispersions on nature of solids, solids loading, magnitude and distribution of particle size, nature and viscosity of liquid, temperature and test methods. Mechanical behaviour of highly filled rubbers by tensile testing over a wide range of temperatures and strain rates. Construction of master curves of mechanical behaviour by time-temperature superposition.

Plastometers to study flow and deformation behaviour including fatigue effect of cyclic compression and extension; fatigue by flexing; effect of imposed hydrostatic pressure; response to biaxial strain. Brittle point apparatus. Tensile testing apparatus.



VERTICAL MIXER FOR RUBBERY-TYPE SOLID PROPELLANTS
The mixing pot has been lowered for removal of the propellant mix.



MEASUREMENT OF CONTACT ANGLE OF WATER ON A CONTAMINATED STEEL SURFACE

Surface Chemistry

Surface tensions of highly viscous organic liquids; effect of molecular weight and temperature. Study of contact angles and interfacial tensions between viscous liquids and inorganic salts, and their dependence on surface contaminants (moisture, surfactants).

Equipment for surface tension and contact angle measurement; thermal siphoning technique for growing large perfect crystals of inorganic salts.

Technology of Pastes and Slurries

Formulation, manufacture, and handling of stiff pastes based on curable and non-curable liquid organic polymers containing a high proportion of solid inorganic filler.

Vertical and horizontal mixers of various capacities capable of processing mixes up to 10^7 poise viscosity; de-aerating pug-mills and pressure extrusion equipment.

NON-METALLIC MATERIALS

Head of Branch B L HOLLINGSWORTH

The Non-metallic Materials Branch undertakes basic and applied research on the chemistry and physics of polymers with particular regard to synthesis, characterization, degradation, and mechanical behaviour under a range of test conditions. The Branch offers an advisory service on the applications of polymers, and supervises long-term environmental testing at the Tropical Research Unit, which is a joint project with Australia.

ACTIVITIES AND FACILITIES

Polymer Physics and Engineering

Study of the physical properties of non-metallic materials and reinforced plastics: stress-strain curve, strength, fracture energy, damping capacity, creep, fatigue, stress relaxation, and dimensional stability. Effects of rate of deformation, temperature and moisture. Stress relaxation tests on rings and beams; dynamic mechanical properties of discs. Compression cell to study effects of dynamic, static, and creep loading.

Hounsfield apparatus (extension rate, 0·0013 — 50·8 cm/min; temperature, — 80° to 80°C); ~~Baldwin~~ machine; ~~Goodbrand machine (fibre test)~~. Avery Izod impact machines (capacity 17 kg.m; maximum loading rate, 18 × 10^2 kN/sec; photographic recording with 35 mm. streak- or 12 000 frames/sec Fastex-cameras). ~~Flywheel machine (fracture energies at impact velocities of 130—1 300 cm/sec~~). Ultrasonic equipment (150 kc/sec—2 Mc/sec; up to 80°C). Rotating beam machine (fatigue properties).

Polymer Chemistry—Synthesis, Characterization, and Stability

Investigation of novel and potentially useful polymer systems; monomer and polymer synthesis, polymer fractionation, mechanism and kinetics of polymerization, reactions of polymers.

Characterization of polymers by molecular weight (viscometry, osmometry, light scattering, and end-group analysis), spectroscopy (IR, UV and NMR), dilatometry, bulk viscometry, compressibility and thermal expansion measurements, and by optical examination of polymer morphology.

Stability of addition and condensation polymers to heat, ultra-violet light, and high energy radiation; effects of chemical structure, impurities and environment. Mechanism and kinetics of degradation and its effect on molecular weight and physical properties.

MOLECULAR WEIGHT *Hewlett-Packard 502 high-speed membrane osmometer (maximum operating temperature 130°C); Brice-Phoenix Series 2000 Universal light scattering photometer with MSE high-speed centrifuge.*

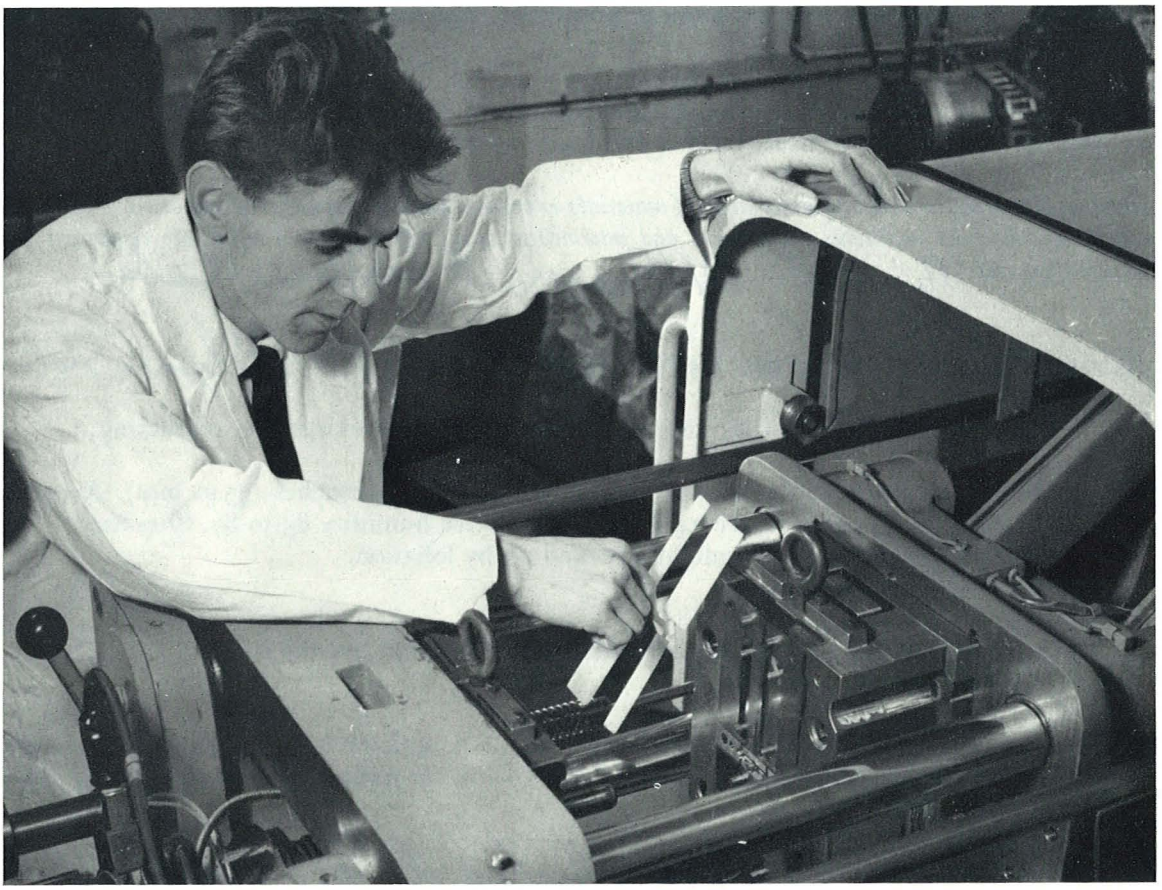
BULK PROPERTIES *Epprecht Viscometer (0·1—10^6 poise, 0°—180°C); linear expansion apparatus for glass transition temperatures; pressure balance (temperature controlled to ±0·001°C).*

AVERY IZOD PENDULUM IMPACT APPARATUS

A pendulum impact tester modified for tensile and flexural impact tests to investigate the engineering life of non-metals.

NUCLEAR MAGNETIC RESONANCE MEASUREMENT

This 60 M/c instrument is used for characterization and structure determination of a wide range of organic compounds. Superseded by JEOL 100 MHz instrument



HORIZONTAL INJECTION MOULDING MACHINE
Test pieces for mechanical property assessment being produced in a constant torque, injection moulding machine.

SPECTROSCOPY ~~*PE R10 60 M/c NMR spectrometer*~~ JEOL 100 MHz *NMR spectrometer (variable temperature probe, spin decoupling unit, probes for* ^{1}H, ^{11}B, ^{19}F, *and* ^{31}P*; PE 337 grating spectrometer (4000—400 cm*$^{-1}$*, ATR attachment); Unicam SP 500 spectrometer.*

MICROSCOPY *Gilett and Sibert time-lapse microscope (35 mm and 16 mm (ciné) photographic recording).*

DEGRADATION *Mercury lamp, xenon arc, molten salt- and fluidized sand baths.* Climatic Weathering Chamber

GAS CHROMATOGRAPHY *PE Model 801 (dual column analytical instrument, linear programming); Pye Model 105/15 (automatic preparative gas chromatograph, linear programming).*

Polymer Development and Applications

Processing and curing of new rubbers and thermoplastics by injection moulding, extrusion, milling, and compression moulding. Measurement of physical properties, and the effect of contaminants (e.g. explosives, propellants, petrol, etc.). Accelerated and tropical ageing trials to assess useful life.* Investigation of failures. Manufacture of special components; antistatic and conducting rubbers.

* Now in Polymer Stability Section.

Proofed fabrics: preparation, mechanical properties, and advice on the design of proofed fabric structures.

PROCESSING *Wide range of mills, mixers, hydraulic presses and injection moulding machines. Facilities for the synthesis of polyester-polyurethane rubbers. Small-scale equipment for preparing proofed-fabric samples.*

TESTING *Physical properties; permeability of materials to organic fluids and water; ageing ovens to simulate hot/dry and hot/wet conditions; continuous and intermittent stress relaxometers. Carbon arc equipment for special exposures.* Climatest UV/Fluorescent weathering Chamber

Joint Tropical Research Unit, Queensland (JTRU) (Polymer Stability Section)

Four sites are available for the exposure of small specimens to atmospheric weathering.

(*a*) INNISFAIL Latitude 17° 32′S. Average annual rainfall 140 inches (3540 mm). Average daily mean temperature 74°F (23°C); relative humidity 83 to 87. Sites are
(i) Hot/wet, jungle, i.e. sunlight screened off by foliation.
(ii) Hot/wet, clearing.

(*b*) CLUMP POINT Similar latitude and conditions to Innisfail but the site is
(iii) Marine.

(*c*) CLONCURRY Latitude 20° 43′S. Average annual rainfall 17 inches (430 mm). Average daily mean temperature 78°F (25°C); relative humidity 39. The site is designated
(iv) Hot/dry.

Small no. of staff are attached to JTRU for 3 year tours
Polymer Stability Section
In addition to the work referred to above under this section's activities, the Section runs a world-wide solar UV radiation monitoring program of more than 20 stations roughly from the Arctic Circle to the equator in both hemispheres. The results enable predictions to be made of the damaging effects of UV on paints, textiles, plastics, rubbers and Human Skin, as well as indicating the location of oil slicks at sea.

GENERAL CHEMISTRY

Head of Branch DR A R OSBORN

The General Chemistry Branch investigates the preparation, properties and reactions of a wide range of ingredients related to explosive, propellant and polymer technology. The Branch offers an advisory service on the stability, compatibility and surveillance testing of propellants, explosives and other hazardous materials. New analytical methods are developed to assist quality control, and a range of specialized techniques and facilities are used to provide an analytical service for the Establishment.

ACTIVITIES AND FACILITIES

Synthesis and Characterization

Synthesis of explosives and ingredients of solid propellants and polymers (fuels, oxidizers, ballistic additives, stabilizers, curing agents, antioxidants, etc.); studies to optimize yield and purity and to reduce hazard (toxicity, thermal decomposition, etc.).

General techniques of preparative chemistry, and supporting facilities: armoured cupboards; PE Model 237 grating spectrometer (4000—650 cm^{-1}); Unicam SP 500 spectrometer; various refractometers and optical microscopes, including Kofler hot-stage instruments; molecular weight determination by semi-micro ebulliometry and micro-cryoscopy.

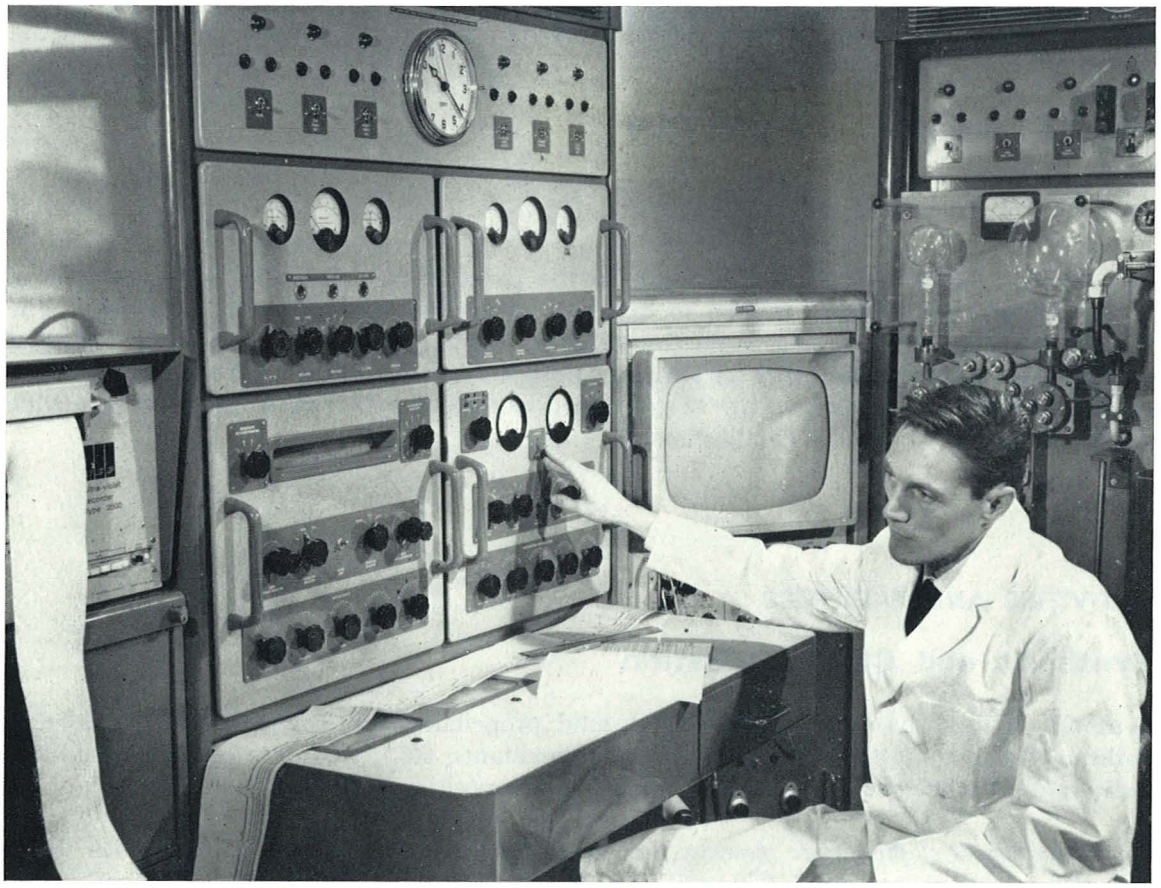
Stability and Compatibility

Kinetics and mechanism of thermal decomposition of explosives and exothermic compositions; ignition phenomena and build-up to low order detonation; compatibility of explosives, propellants, etc. with materials (e.g. polymers, plastics, metals, adhesives, varnishes and paints); effect of severe environmental conditions on storage stability. New techniques to investigate thermal stability.

Environmental testing ovens and standard stability test facilities. Master slave manipulator. Stanton thermogravimetric balance (maximum temperature, 250°C); PE differential scanning calorimeter, Model 1 (−100° to 500°); heat flow calorimeter (sensitivity, 30 μwatts); multirange temperature recording equipment (−200° to 500°C). Photomicroscopy of samples heated in vacuum. Advance Model TC 2A electronic timer counter (1 μsec).

Chemical Analysis and Physical Methods

Separation, identification, and analysis of the constituents of explosives, propellants, polymers, rubbers, etc.; determination of functional groups, elemental composition, and molecular weight; trace metal analysis. Estimation of purity, and investigation of quality control and specification tests. Studies concerned with gas and solvent vapour analysis; molecular and crystal structure; thermochemical characteristics (phase changes, low temperature behaviour and thermal decomposition); cure- and post-cure chemistry of polymeric systems; non-aqueous titration; mass spectrometric and polarographic analysis.



MASS SPECTROMETRY
An AEI Model MS 2H mass spectrometer capable of performing isotopic and chemical analyses on very small quantities of material, including solids.

CHROMATOGRAPHY *Wide range of standard equipment for analytical- and preparative-scale column- and thin layer chromatography; Craig counter-current extraction apparatus; Varian Aerograph Model 1522 gas chromatograph (dual column, linear programming); PE F11 gas chromatograph; pyrolysis attachment.*

SPECTROSCOPY *PE Model 257 grating spectrometer (4000—650 cm^{-1}) ATR attachment, micro- and heated cells; modified Grubb Parsons S3A spectrometer (3500—250 cm^{-1}); PE Model 137 UV spectrometer; Unicam SP90 atomic absorption spectrophotometer.*

MASS SPECTROMETRY *AEI Model MS 2H*

MICROANALYSIS *Combustion equipment (C, H, N); Schöniger flask (S, halogens); Mechrolab Model 302 vapour pressure osmometer (molecular weights up to 20 000).*

POLAROGRAPHY *Beckman Electroscan 30 (various electrometric analysis techniques).*

RADIOCHEMISTRY *Tracer laboratory; Panax standard- and low background Geiger counters; Isotope Development Ltd. solid and liquid scintillation counters.*

THERMOCHEMICAL ANALYSIS see *Stability and Compatibility.*

PARTICLE SIZE ANALYSIS *Sharples Micromerograph (humidity- and temperature-controlled); gas adsorption and various types of gas permeability apparatus for surface area measurement.*

Crystallography

Application of optical and X-ray diffraction to identification and characterization of compounds; phase analysis of mixtures, polymorphism, crystal orientation, and crystal structure analysis.

Equipment includes three X-ray generators, one being a high-power rotating anode set, X-ray powder cameras, goniometers (Weissenberg, oscillating crystal and optical), Hilger-Watts 4-circle, single crystal automatic diffractometer, an X-ray powder diffractometer, and polarizing microscope with heating stage.

GAS CHROMATOGRAPHY
This technique is particularly useful for identifying and estimating volatile constituents of complex mixtures.

Gas Kinetics

Kinetics and mechanisms of gas-phase reactions and general free radical chemistry using static and discharge-flow techniques. Reactions of alkyl and alkoxy radicals, nitrogen oxide and nitrogen dioxide. Mechanisms of gas-solid reactions.

High vacuum techniques and product analysis by vapour-phase chromatography, infra-red and mass spectrometry. Emission spectroscopy.

PROCESS RESEARCH

Head of Branch H ZIEBLAND

The Process Research Branch is concerned with means and equipment for processing chemicals on a production scale. Plant and facilities are designed for the manufacture of hazardous compounds and mixtures with particular emphasis on safety, remote-control, and instrumentation. The Branch has special interests in unit operations such as crystallization, mixing, heat transfer, and precision measurements of thermal properties of fluids.

Research and development is being carried out on fibre-reinforced, metallic and non-metallic materials and on the growth of ceramic whiskers.

ACTIVITIES AND FACILITIES

Large-scale Production

Development of laboratory syntheses on to pilot- and full-scale processes; pilot plant operation; manufacture of experimental chemicals and materials, including high explosives, polymer and rocket ingredients, whiskers and aligned inorganic fibres.

Protective enclosures, with remote control, for processing experimental quantities of dangerous chemicals (i.e. fire, explosion, toxicity risks): one for large laboratory-scale glass plant; another for 2·5 kg pilot plant scale, equipped with a closed circuit television loop.

A wide range of pilot-scale plant, including: plant for concentrating nitric acid free from nitrous acid; nitration and sulphonation unit with brine cooling, remote control and acid mixing plant; glass-lined oil heated reactors for polymer manufacture.

Separators such as decanters; pressure-, vacuum- and rotary filters; batch and continuous stainless steel centrifuges; liquid centrifuges; and dry powder sieves.

Dryers, including hot air-, vacuum tray- and rotary-steam tube types.

Grinding plant, including jaw crusher; roll mill; edge-runner mill; hammer mills; and 'micronizer' fluid energy mill.

Mixers: double cone powder blender; medium and heavy paste mixers.

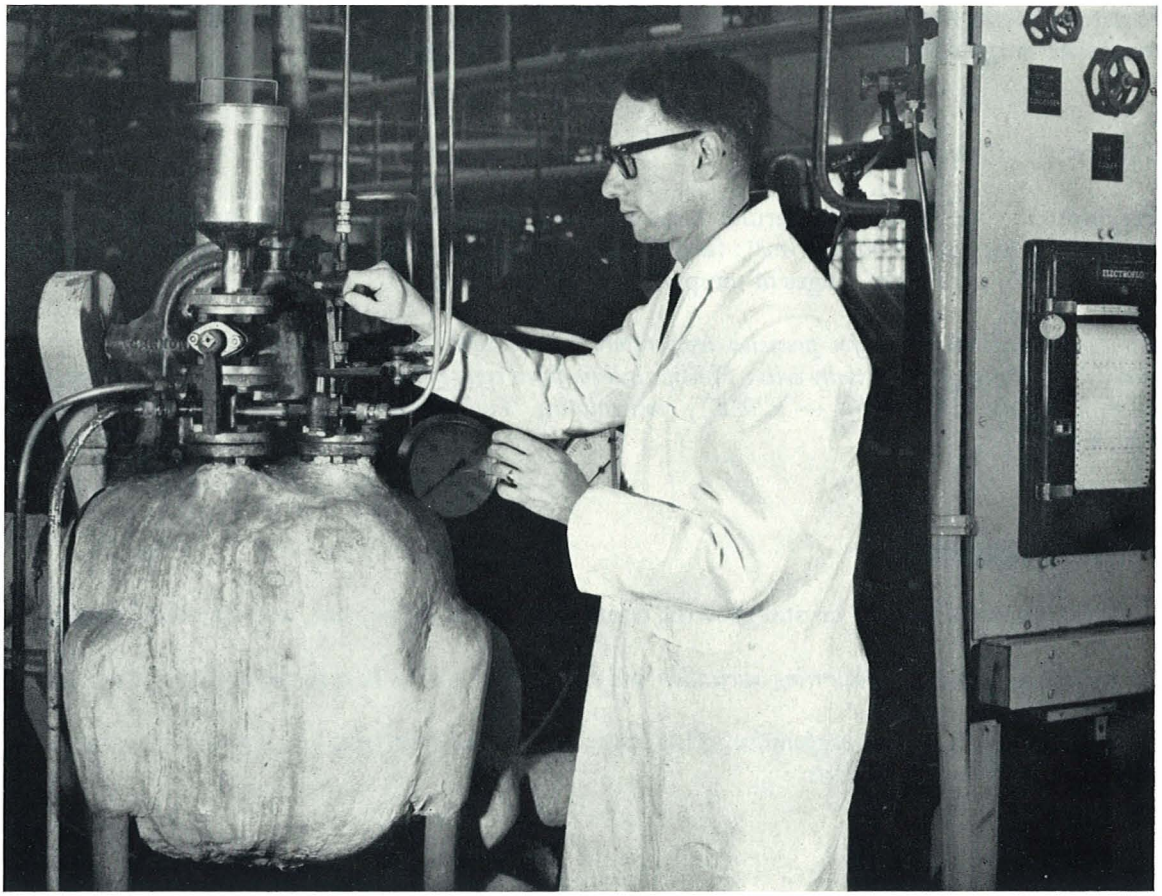
Packed, gas-liquid absorption towers.

Distillation: a 5-cm glass 'molecular' still; a 50-litre glass batch distillation unit; glass distillation column of high efficiency for high vacuum and 150°C; similar unit in stainless steel for pressure distillation up to 1 MN/m².

Intensive Drying or Stripping

The intensive drying (or stripping) of high boiling liquids which may be sensitive to heat or excessive turbulence.

Continuous plant (11·5 kg/h), based on single passage of liquid down a column packed with a battery of vertical helical coils.



PLANT FOR POLYESTER MANUFACTURE
An example of the development of laboratory syntheses on to pilot-scale processes.

Convective and Radiative Heat Transfer from Flames and Gases

Studies of convection and radiation from flames and combustion gases (up to 3800°K; 10 MN/m²); radiative emissivity of water vapour (1500°—3500°K; 0·5—10 MN/m²).

Two instrumented test cubicles; water-cooled combustion chambers; black-body furnace to calibrate radiation sources.

Convective Heat Transfer to Liquids

Convective heat transfer from electrically heated surfaces to aviation kerosine and other liquids under sub-cooled, boiling, and supercritical conditions.

Closed-loop apparatus with rectangular flow channel containing heated tube (maximum power, 10 kW; maximum pressure, 10 MN/m²; maximum fluid flow rate, 1·2 kg/sec). Photographic observation using Fastex ciné camera (18 000 half-frames/sec) and 0·2 μsec argon flash lamp.

Convective Heat Transfer to Cryogenic Fluids

Convective heat transfer to fluid hydrogen in the vicinity of the critical point and at supercritical pressures; fluid dynamics of cryogenic fluids.

Remotely-operated test rig in which cryogenic fluids flow through asymmetrically heated rectangular ducts (maximum energy dissipation, 40 kW; maximum pressure, 5 MN/m²).

Thermal Conductivity

Precision measurements of thermal conductivities of liquids, gases, and supercritical fluids (12°— 650°K; up to 300 MN/m²); facilities equally suitable for measuring viscosity, dielectric constant, etc. over wide ranges of temperature and pressure.

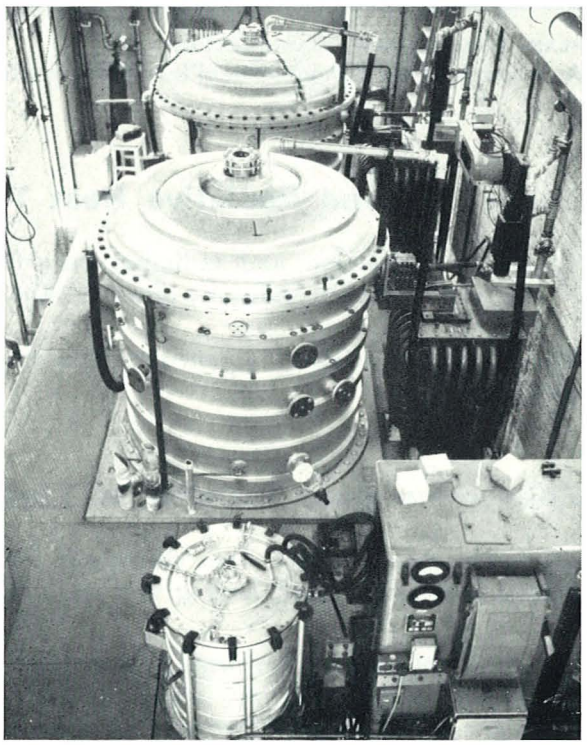
Air conditioned laboratory for precision temperature measurement; protected annexe for compressing gases and liquids; thermal conductivity cells: Phillips helium-filled cryogenerator (12° — 90°K); liquid nitrogen-filled metal thermostat (90° — 220°K); recirculating Turbotherm-filled liquid thermostat (300° — 650°K).

Crystallization

Studies of nucleation and crystal growth; control of crystal shape, size, and size distribution.

Laboratory equipment for measuring nucleation and crystal growth rates in a stirred cooling crystallizer.

Pilot crystallizers: Kestner evaporative; Oslo type; and pulsed tube type, for performance studies and production of crystalline products.



'BRAN TUBS'
High temperature furnaces for synthesis of silicon nitride whiskers.

High Temperature Equipment

Furnaces of various types for operation up to about 1600°C; high frequency heating equipment; temperature measuring devices.

Fibre Processing Plant

Equipment for ~~sizing whiskers and other~~ short fibres and plants to classify and align asbestos and other ~~whiskers~~ for making composite materials.

Fibre Testing Equipment

Marsh micro-testing machine and various macro-testing machines.

Microscopes

A range of optical microscopes and a J.E.M. 7 electron microscope.

Instrumentation and Glass Engineering

This Section, part of the Engineering Branch, is responsible for the development and application of instruments and apparatus based on electronic and glass engineering techniques.

GLASS ENGINEERING
The glass engineering workshop is equipped to undertake construction of scientific glassware ranging from special laboratory articles to the large-scale item shown here.

MISCELLANEOUS RESEARCH ACTIVITIES

In addition to research and development work performed by the Branches described above, certain specialized or exploratory research topics are undertaken by small groups under the direction of Dr. L. J. Bellamy, Mr. G. K. Adams, and Dr. G. H. Young.

Spectroscopy

Studies of factors affecting infra-red absorption spectra of complex molecules; assignment of absorption bands and interpretation of spectra.

Unicam SP 100 spectrometer (3650—300 cm^{-1}); Grubb Parsons GS2 grating spectrometer (4000—650 cm^{-1}); Unicam SP 700 spectrometer (55000—4500 cm^{-1}); attachment to determine emission spectra in the visible region; time-resolved luminescent spectroscopy in the visible region (resolution, 1 μsec).

Flame and Explosion Phenomena

An Elliot 903 computer is in use, and computer programmes are available for calculation of flame and explosion properties, and the thermodynamic properties of two-phase, multi-element systems in chemical equilibrium.

Autoxidation and Antioxidants

Kinetics and mechanism of free radical chain reactions in solution; catalysis of oxidation-reduction reactions by heavy metals; effect of oxidative degradation, light, and ionizing radiation on polymeric materials. Research aimed at preventing or inhibiting oxidative degradation. Design and assessment of new antioxidants; mechanism of antioxidant action, particularly synergistic effects (mixtures of free radical acceptors; free radical acceptor and chelating reagent or S-containing peroxide decomposer); inhibition of autoxidation by metal chelates.

Warburg apparatus and equipment for automatic recording of oxygen uptake; facilities for photochemistry and radiochemistry.

INDEX OF ACTIVITIES

Titles of branches have been abbreviated as follows:

E	Explosives	NM	Non-metallic Materials
P1	Propellants 1	GC	General Chemistry
P2	Propellants 2	Misc. Res.	Miscellaneous Research
PR	Process Research	IGE	Instrumentation and Glass Engineering Section

INDEX OF FACILITIES

THERMOMETERS

Platinum resistance	P1
Multirange recording	GC

ULTRASONIC INSPECTION EQUIPMENT

Propellants	P1
Polymers	NM

ULTRA-VIOLET SPECTROMETERS

General purpose	GC, NM
Continuous scanning	GC, Misc. Res.

VISCOMETERS

Bulk viscosity	NM, P2
Intrinsic viscosity	NM

X-RAY EQUIPMENT

Radiographic inspection	P1, E
Crystallographic analysis	GC

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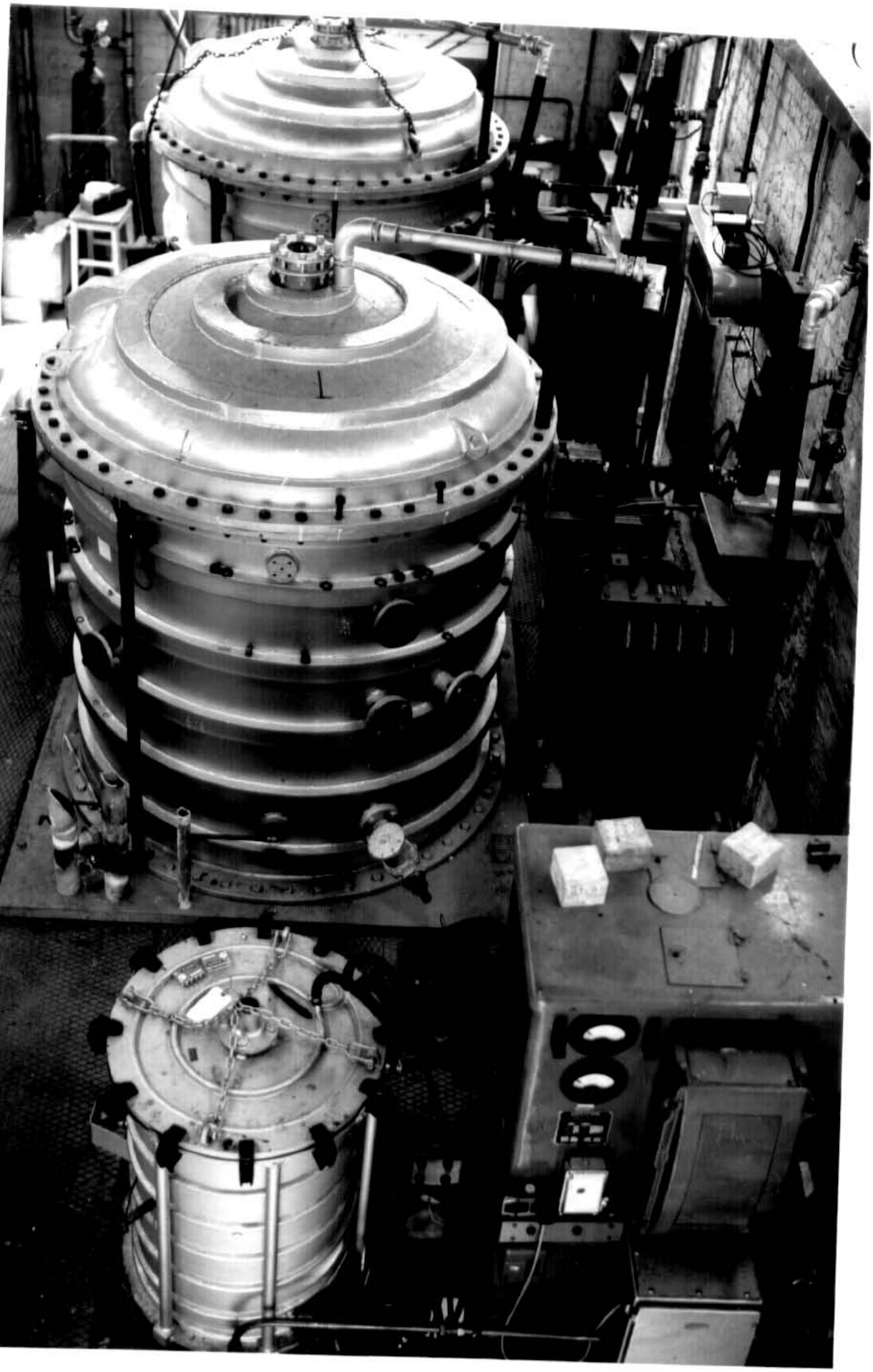

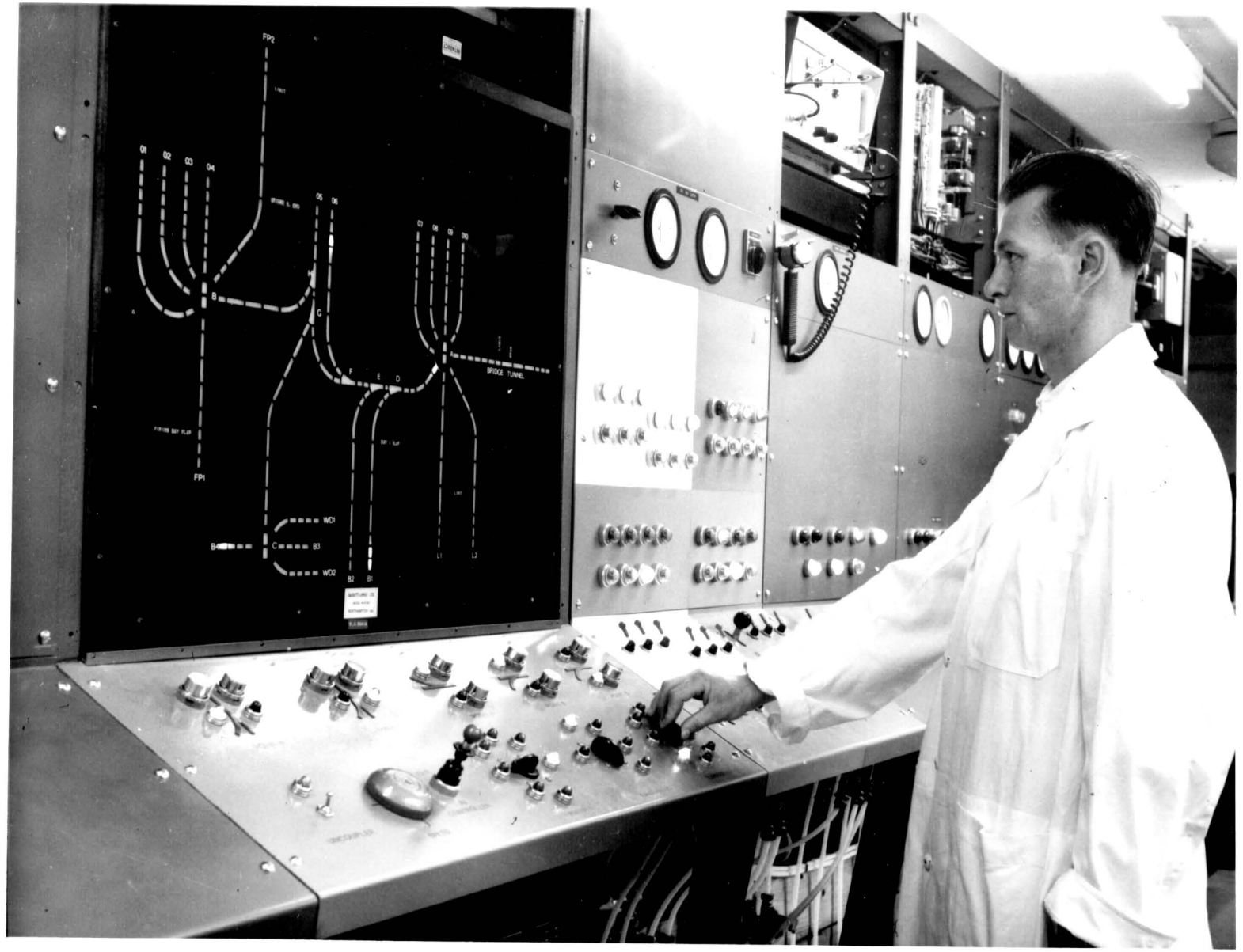
FP2
01
02
03
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06
07
08
09
B
G
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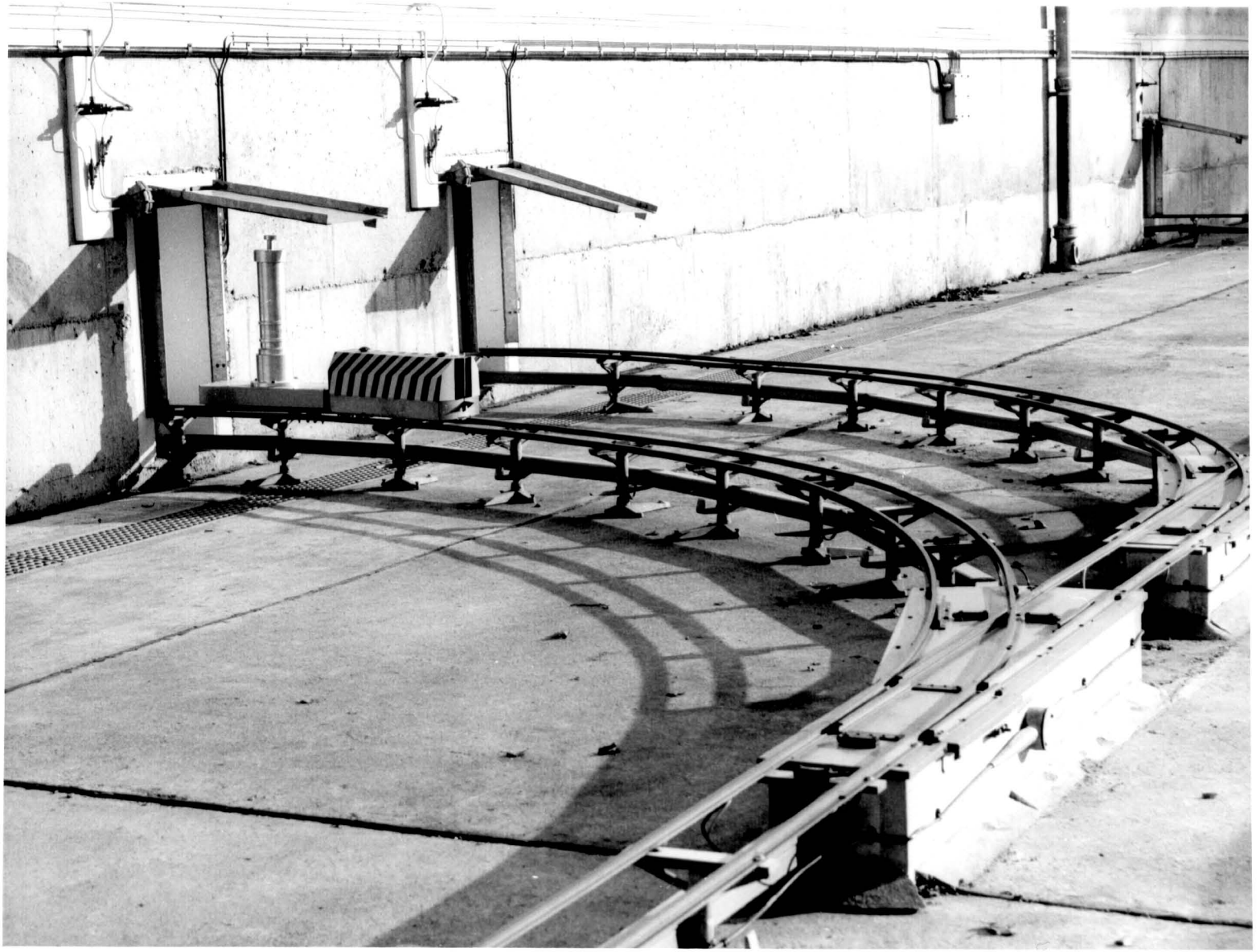
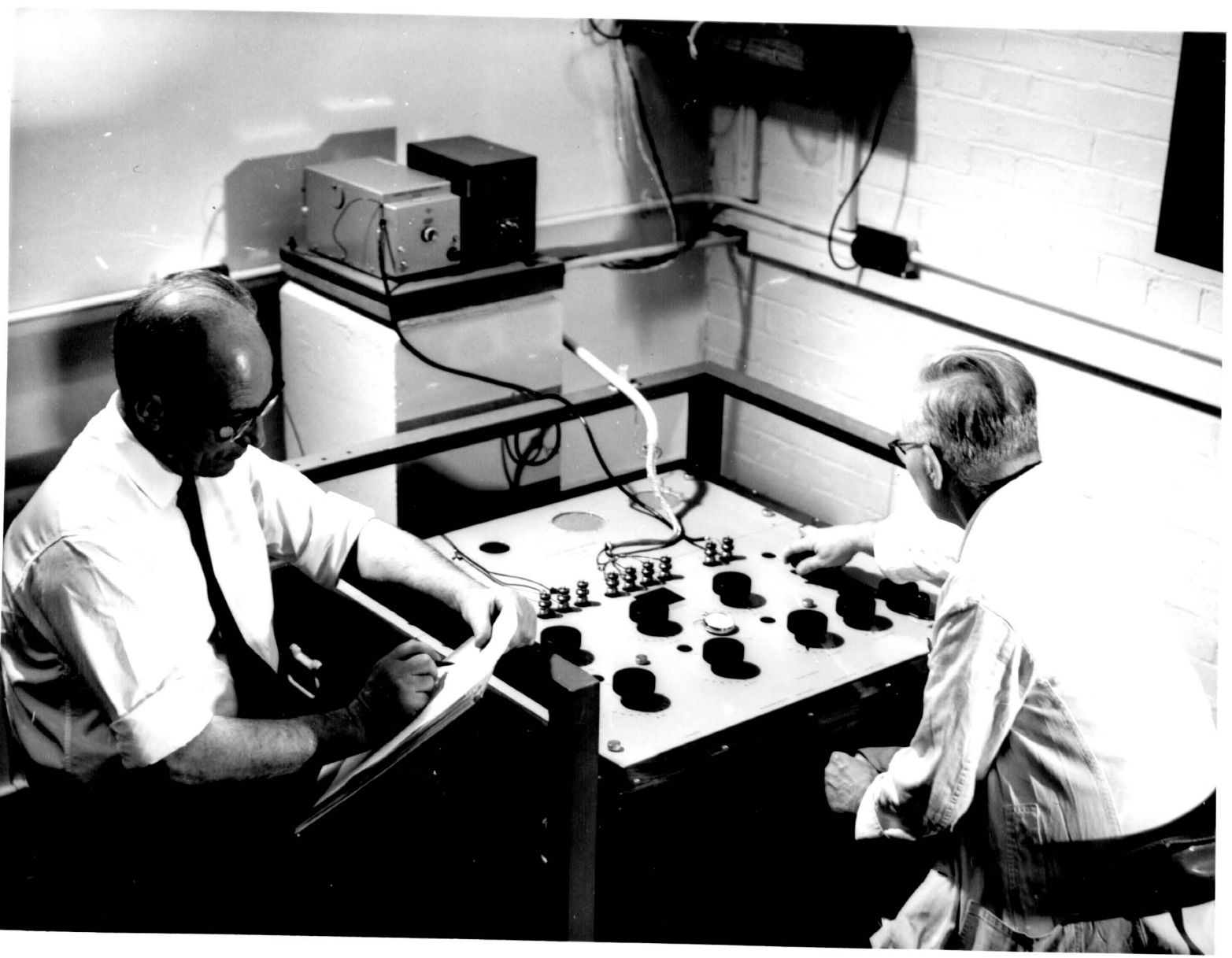
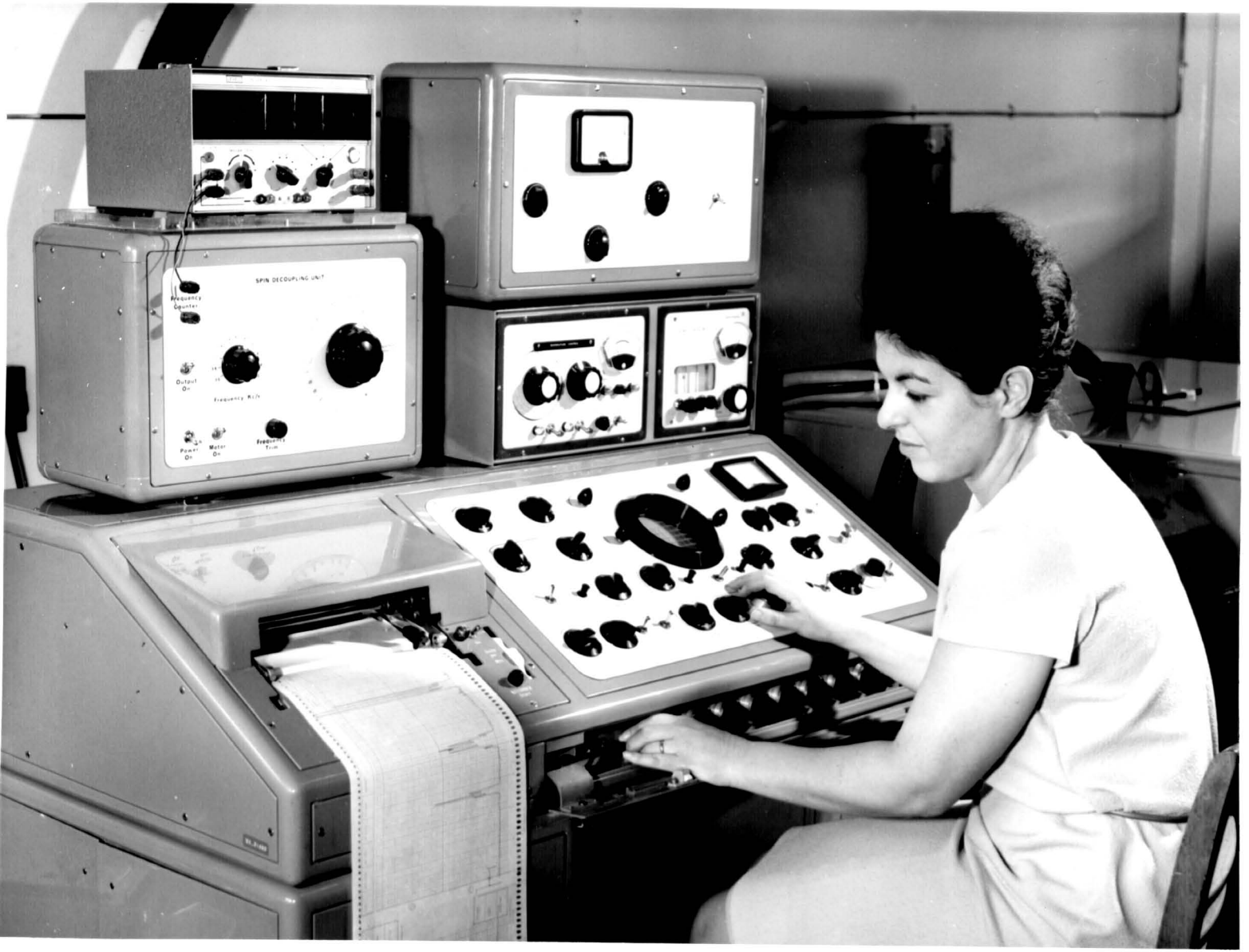
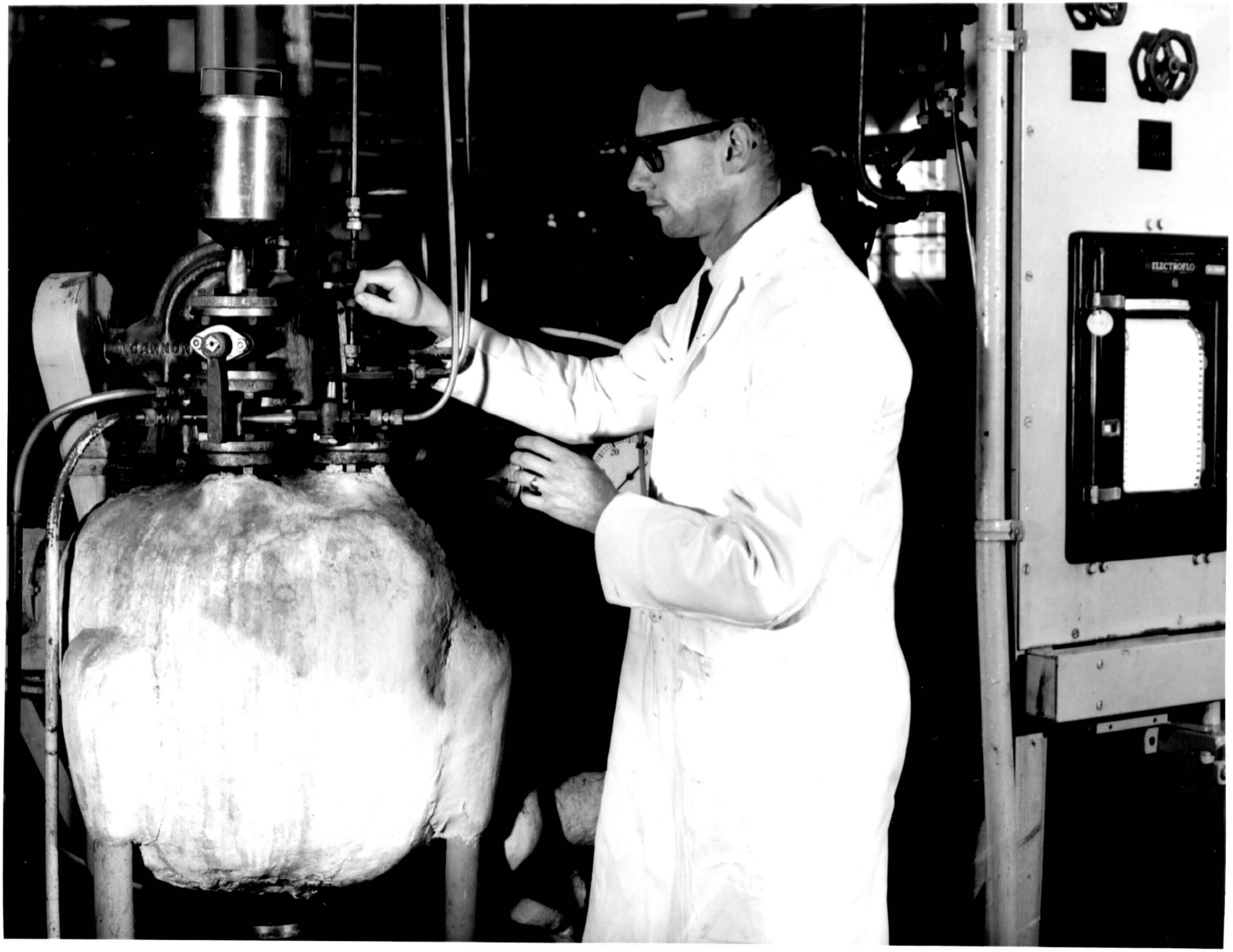
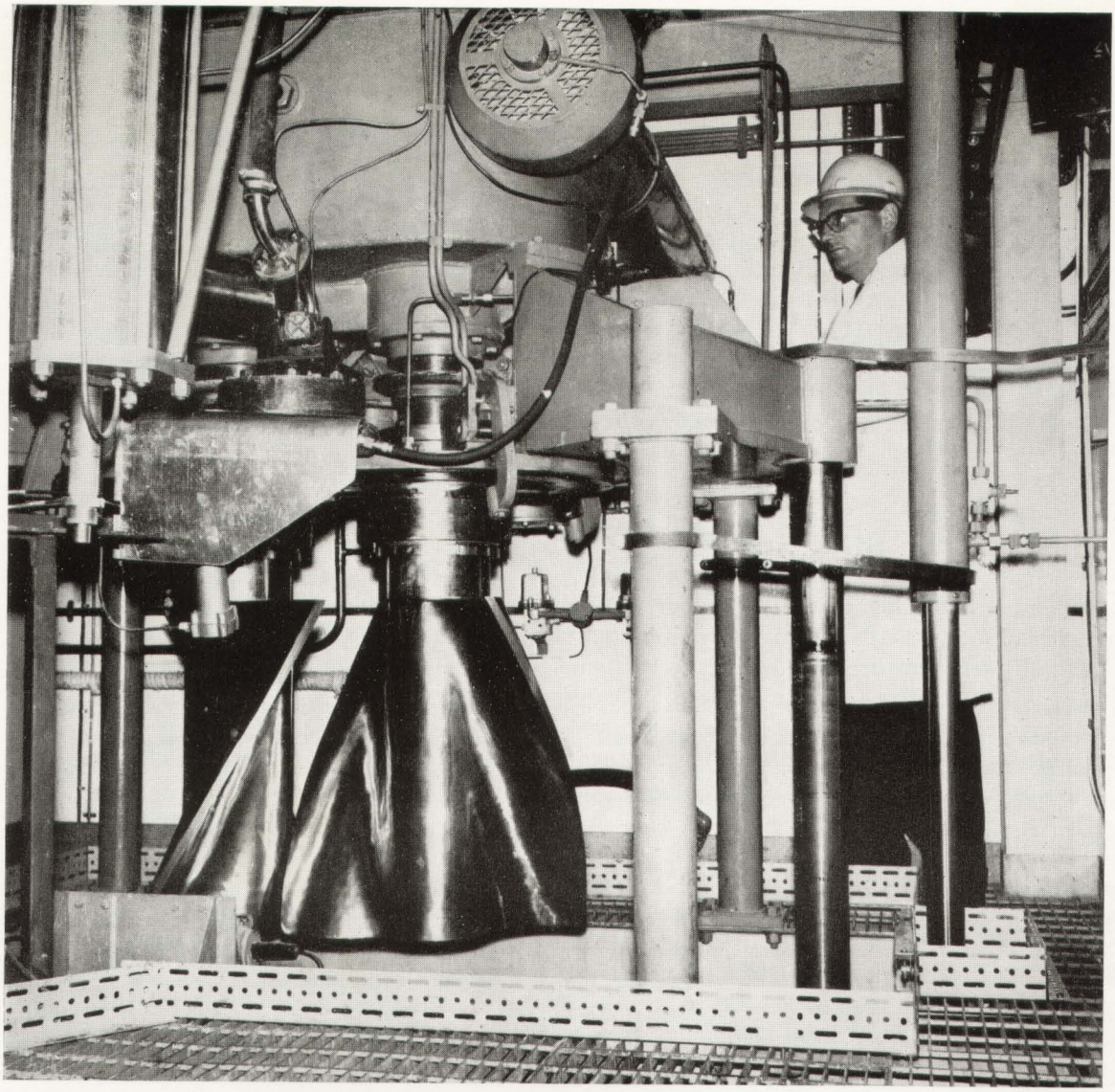
D
BRIDGE TUNNEL
FP1
WC1
B4
C
B3
WC2
B2
B1
L1
L2






SPIN DECOUPLING UNIT
Frequency Counter
Output On
Power On
Meter On
Frequency Trim


ELECTROFLO



VERTICAL MIXER FOR RUBBERY-TYPE SOLID PROPELLANTS
The mixing pot has been lowered for removal of the propellant mix.

Convective Heat Transfer to Cryogenic Fluids

Convective heat transfer to fluid hydrogen in the vicinity of the critical point and at supercritical pressures; fluid dynamics of cryogenic fluids.

Remotely-operated test rig in which cryogenic fluids flow through asymmetrically heated rectangular ducts (maximum energy dissipation, 40 kW; maximum pressure, 5 MN/m²).

Convective Heat Transfer to Liquids

Convective heat transfer from electrically heated surfaces to aviation kerosine under subcooled, boiling, and supercritical conditions.