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MINISTRY OF AVIATION

EXPLOSIVES RESEARCH AND DEVELOPMENT ESTABLISHMENT

WALTHAM ABBEY

PROGRAMME OF RESEARCH AND DEVELOPMENT

APRIL, 1960 - MARCH, 1961

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SECRET

KEY TO ABBREVIATIONS

Priorities - Service

1. So important that in the event of delay, staff and resources should be withdrawn from projects in lower classes.
2. Important, on which staff and resources necessary to meet agreed forecast dates should be deployed.
3. Resources after meeting 1 and 2 to go on these.
4. Risk of not meeting agreed dates may first be taken on these.

Priorities - Research

A. As for Service Priority 1.

B. As for Service Priority 2.

C. As for Service Priority 3.

Effort

Definitions: (See under "Code" in "Effort" column of this R. & D. Programme)

A. Items so fully staffed that progress would not be accelerated by any increase.

B. Sufficient staff has been allocated to the items to ensure satisfactory progress.

C. Progress on this item is retarded by lack of specialist staff.

D. Work to which staff is allocated when work of higher priority is held up for reasons unconnected with staff.

E. No staff can be made available for this item at present.

F. Staff are allocated for short term jobs as the needs and priorities of the moment demand.

Effort is shown as the number in Scientific Officer (S.O.) and Experimental Officer (E.O.) cadres engaged on the items or group of sub-items as ruled off horizontally in the R. & D. Programme. The staff engaged are shown, as a total, at the head of each such division. Totals are taken to the nearest $\frac{1}{4}$ man year (equivalent to three months' work by one man). Obviously they may undergo change during the course of the year.

Extra-Mural Research

For items under extra-mural research contract, the contract number and location are shown in Remarks column.

Deployment Returns; Costing

Costing of the Establishment's work is dependent on quarterly returns of the deployment of White Paper staff on the thirty-odd "Objectives" given in the third column of this R. & D. Programme. The Objectives are grouped under eleven "Fields of Work", three of which, Nos. 5, 7 and 8, are not broken down into separate Objectives.

Reference to Research Programmes of Other Establishments

These references appear in the "Remarks" column, e.g. "v. ARDE 2.2" and indicate the paragraph in the particular establishment's section of the War Office M.G.O. Research Programme 1960/61.

Field of Work	Objective	Investigation	Priority		Effort			ERDE Branch	Remarks
			Service	Resch	Code	S.O.	E.O.		
ROCKET PROPELLANT DEVELOPMENT	.1 Colloidal Extruded					1½	3½	SPRIII	
		(a) Problems in manufacture of platonised compositions.		B	B				
		(b) Suitability of various celluloses for cordite manufacture		B	B				v. 3.1 (a)
		(c) Extrusion techniques for solventless, multiperforated charges (Travelling Charge Gun and Complex Shapes (Snifter))		B	B				v. ARDE 2.2
		(d) Propellants for auxiliary cartridges		B	F				v. ARDE 2.3
		(e) Propellant for Seat Ejector			F				Contract with Messrs. Martin Baker
		(f) Gun assisted rocket charge		B	F				
		(g) Inhibiting coatings. Post design assistance and assessment of alternative materials including polyester resins and fillers for ethyl cellulose							
	.2 Cast Double Base					1½	2¼	SPRIII	
		(a) Investigation of case bonding and casting of composite modified propellants		B	B				
		(b) Co-operation with I.C.I. Ardeer and Summerfield		A	A				E.M.R. Contract No. 6/Gen/1544
		(c) Application of press cutter in production		B	F				
		(d) Processing problems of modified casting powders		B	B				
	.3 Composite, Plastic					1	2	SPRI	
		(a) Improvements in manufacturing processes; new methods of mixing; alternative methods of preparation for mixing; remote control	1		B				
		(b) Study of new compositions; effect of particle size; modification of binder and of high energy ingredients	2		B				Effort also covers 1.5
	.4 Composite, Elastomeric (Polyurethane)					3	5	SPRI	**
		(a) Processing and evaluation of polyurethane compositions		B	B				See also 3.2 (c)
		(b) Design and scaling up for larger scale plant		B	B				See 9.3 (b)

** In the event of E.R.D.E. becoming directly involved in BLUE WATER Mk. 2, Programme Items 1.4 (a) and (b) together with the relevant proportions of the six sub-items of Item 2, Item 9.3 (b) and (c) (part) will be aggregated for the purpose of Costing the Project. (Items 3.1 (f), 3.2 (c) and 9.1 (c) will NOT be included.)

	Field of Work	Objective	Investigation	Priority: Service	Priority: Resch	Effort: Code	Effort: S.O.	Effort: E.O.	ERDL Branch	Remarks
	ROCKET PROPELLANT DEVELOPMENT (contd.)	.5 Charges for Trials								Effort shown under 1.3
			(a) Provision of plastic propellant for various boost and sustainer motors for guided weapons	2	A	B			SPRI	At the time of preparation of this Programme motors include those for Cuckoo, Gosling II and IV, Linnet, Lobster, Raven, Smoky Joe, 5" LAP, 36" Test Vehicles, VR 7&5
			(b) Ordnance Board Programmes for Smoky Joe, Gosling IV, Foxhound, Walkara, Magpie, 2-inch rocket, W1 and W2 Motors	2	B	F			SPRI SPRIII	v. 2.4 (c)
2	ROCKET PROPELLANT EVALUATION	.1 Defect Detection					¼	1	SPRIII	
			(a) X-ray inspection. Acceptance standards for double-base and composite propellants. Assessment using image intensifier		B	B				
			(b) Ultrasonic and alternative techniques for case-bonded charges. Performance of new transducers in Mk.III set for R.O.F.s etc.		B	B				
		.2 Calorimetry and Ballistics						5½	SPRII	
			Calorimetry; strand burning rates; rocket motor ballistics; closed vessel measurements		A	B				
		.3 Chemical Analysis					¼	6	SAS	
			(a) General analytical work for E.R.D.E.		A	A				
			(b) Development of analytical methods for experimental compositions containing new ingredients		A	A				
		.4 Stability; Compatibility; Climatic Testing					1½	2½		
			(a) Development of thermal and chemical methods of stability assessment. Mechanism of stabilisation		A	A			SAS	
			(b) Climatic trials, compatibility and stability studies in aid of E.R.D.E. programme items		A	A			"	
			(c) Climatic trials associated with the Ordnance Board's programme		B	B			"	See 1.5 (b)
			(d) Stability of high energy compositions		A	B			"	
			(e) Factors involved in cracking of colloidal propellants		B	B			SPRIII	

PROGRAMME OF RESEARCH 1960/61 (contd.)

	Field of Work	Objective	Investigation	Priority		Code	Effort		ERDE Branch	Remarks
				Service	Resch		S.O.	S.C.		
	ROCKET PROPELLANT EVALUATION (contd.)	.5 Testing of Mechanical Properties	Design and specification of methods of testing mechanical properties		B	B			SPRI	Effort covered under 3.4
		.6 Sensitivity and Hazards					1¼	1		
			(a) Development of tests for impact, friction and shock sensitiveness, burning to detonation and ignition by adiabatic compression of air bubbles. Trials staged outside E.R.D.E. Detonability of ammonium perchlorate with small proportions of organic binder		B	C			SPRII	v. 6.3 and 6.4 v. ARDE 6.2 (b)
			(b) Composite propellants - Safety measures and protective devices		B	F			SPRI	As required
3	ROCKET PROPELLANT RESEARCH	.1 Synthetic and Preparative Chemistry					3	2		
			(a) Nitrocellulose. Advisory service and incidental laboratory work		B	B			SEI	v. 1.1 (b)
			(b) Preparations required by other branches of E.R.D.E.		B	B			"	
			(c) Hydrides and alkyls of Be and other light metals						"	E.M.R. Contract No. PD/51/02 - Durham University
			(d) Aluminium hydride in solution and products of reaction with solvating and adducting reagents						SPRII	E.M.R. Contract PD/65/03 - Glasgow University
			(e) Preparation and study of certain types of stereoisomers produced by irradiation						"	E.M.R. Contract PD/40/01 - Southampton University
			(f) Synthesis of new polyurethanes and investigation of polyurethane chemistry		A	A			SAS	
		.2 Formulation and Processing					4	5½		
			(a) Fluidised casting procedures with nitrocellulose binders		B	B			SPRIII	
			(b) Improved platonised Colloidal formulations		B	B			"	
			(c) Small scale studies of polyurethane propellants		A	A			SPRI	See also 1.4

PROGRAMME OF RESEARCH 1960/61 (contd.)

	Field of Work	Objective	Investigation	Priority: Service	Priority: Resch.	Effort: Code	Effort: S.O.	Effort: E.O.	ERDE Branch	Remarks
3	ROCKET PROPELLANT RESEARCH (contd.)	.3 Combustion and Flame (solid and liquid combustibles)					6	5½	SPRII	
			(a) Theoretical studies. Flame ignition and propagation. Assessment of propellant performance		B	B				
			(b) Flame propagation; combustion. Role of free radicals in pyrolysis of nitric and nitrous esters and of nitro alkanes. Combustion products of propellants. Reactions in low pressure flames.		B	B				
			(c) Gas phase reactions of nitrogen dioxide							E.M.P. Contract 7/Gen/1603 - Cambridge University
			(d) Influence of halogenated methanes on oxidation mechanisms of acetaldehyde and other organic fuels			A				E.M.P. Contract No. ID/37/06 - London University
			(e) Combustion in solids. Ammonium perchlorate. Thrust efficiency of aluminised propellants		B	B				
		.4 Rheology					1	3	SPRI	Effort includes that under 2.5
			(a) Behaviour of colloidal and composite propellants under various types of shear and strain at differing rates, including the effects of pressure on these properties		A	C				
			(b) Rheological investigations in relation to large charges of propellant		B	C				
4	LIQUID PROPELLANTS	.1 General Chemical Research					4	2		
			(a) Hydrogen peroxide. Stabilisation. Storage still presents problems; study of the interaction between the stannate stabiliser and aluminium to be extended to other polyvalent cations (Fe, Cr and Mn); interaction with phosphates (relevant to inactivation of silver catalyst packs)	1	A	B			SEI	
			Analytical and test procedures	2	A	B				
			Decomposition kinetics. Work incidental to stabilisation and analysis and on 90 to 100% hydrogen peroxide	1	A	B				
			(b) Boranes. Reactivity of simple and substituted boranes in relation to structure, synthesis and thermal decomposition. Displacement reactions of bisacetonitrile decaborane and related compounds.		B	C			SEI	
			Structure of borane compounds.		B	B			SAS	
			(c) Monopropellant for auxiliary power units Requirement for low gas temperatures		C	E			SPRII	

PROGRAMME OF RESEARCH 1960/61 (contd.)

	Field of Work	Objective	Investigation	Priority		Effort			ERDE Branch	Remarks
				Service	Resch.	Code	S.O.	E.O.		
	LIQUID PROPELLANTS (contd.)	.2 Measurement of Thermal Properties					2	3	SPRII	
			Heat transfer							
			(a) Radiation and convection from water vapour (1500 - 3500°K)		A	C				
			(b) Thermal conductivity of ammonia		B	B				
			(c) Heat transfer to liquids at high heat fluxes		B	C				
5	PROPELLANTS FOR ORDNANCE AND SMALL ARMS						½	½		Includes that for Light AA/L70 Gun; 81 mm. Mortar; 105 mm. Tank Gun; QF 20 powder; and other listed Service items
			(a) New equipments	2		F			SPRIII	
			(b) Light guns and rifles. Liaison with I.C.I.						"	E.M.R. Contract No. 6/Gen/2380 - Imperial Chemical Industries
			(c) Ball powder. Double base powders; processing to give improved ballistic stability after storage		B	B			"	
			(d) Weapon performance							
			Picrite cordites - Reproducibility of ballistics and maintenance after storage.		C	D			"	
			Reduction of temperature coefficients. Development of multiperforated grains.		B	F				
			Porous propellants for mortars and igniters.		C	D				
			(e) N.A.T.O. collaboration. Interchangeability of explosives and munitions		B	F			SAS SPRIII	
6	EXPLOSIVE CHARACTERISTICS (HIGH EXPLOSIVES, PROPELLANTS, PYROTECHNICS, INITIATORS.)	.1 Research on Build up and Mechanism of Detonation					1¾	1½	SPRII	
			(a) Basic experimental investigations. Burning to detonation. Minimum propagation diameter and reaction zone length in detonation.		B	B				In co-operation with A.P.D.E.
			Effect of temperature, strain and internal defects on sensitiveness of rocket charges		B	E				In co-operation with A.W.R.E.
			(b) Theoretical investigations							
			(i) Transition from shock to detonation in a one dimensional system							E.M.R. Contract No. PD/65/02 - Glasgow University
			(ii) Unsteady detonation wave theory for three dimensional (cylindrical) system. Generation of shock waves by the accelerating combustion of a porous solid		B	E				

PROGRAMME OF RESEARCH 1960/61 (contd.)

Field of Work	Objective	Investigation	Priority: Service	Priority: Resch	Effort: Code	Effort: S.O.	Effort: E.O.	ERDE Branch	Remarks
EXPLOSIVE CHARACTERISTICS (HIGH EXPLOSIVES, PROPELLANTS, PYROTECHNICS AND INITIATORS.) (contd.)	.2 Functioning of High Explosives; Hazards					¾	1¼	SPRII	
		(a) Service problems Pick up sensitivity of different forms of RDX		B	E				
		Factors affecting sensitiveness of H.E. fillings to set-back in gun ammunition		A	C				
		(b) Basic problems Measurement of Hugoniot compressibilities of solids. Critical pulse shapes for initiation.		B	E				
		Transition from shock to detonation. Phenomena associated with the initiation of explosion.		B	B				v. A.N.D.E. App. II, 14 (d)
	.3 Sensitiveness of Initiator Compounds							SPRII	Effort included in 6.4
		Relationship of spark sensitiveness to other properties of initiators		B	B				v. ARDE App. II, 14 (a) and (c)
		Study of ignition by short arc discharge							
		Sensitiveness to impact; to electrostatic charges; to friction							
	.4 Electrostatic Investigations					1	1	SPRII	Includes effort under 6.3
		Charge generation on polythene and suchlike materials for packaging ammunition etc.		A	C				v. 2.6 (a)
		Charge generation whilst conducting normal operations in a laboratory or ordnance factory							
	.5 Compatibility with Materials and other Explosives					1	3	SAS	
		Studies of the effects of all types of materials on all types of explosives. The range of materials includes component and structural materials, other explosives and other chemical preparations such as insecticides.		A	B				Most of this work is for Service Departments, contractors and other organizations outside the Establishment.
7 CHEMISTRY OF THE INGREDIENTS OF HIGH EXPLOSIVES						2	2½	SEI	
		(a) T.N.T. Advisory service and incidental laboratory work, dark colouration being studied	1	B	C				
		(b) R.D.X. Investigations on the nature of the elementary steps in the nitrolysis and related reactions of hexamine	1	B	E				
		(c) Investigations requested by other branches		C	B				

PROGRAMME OF RESEARCH 1960/61 (contd.)

	Field of Work	Objective	Investigation	Priority: Service	Priority: Resch.	Effort: Code	Effort: S.O.	Effort: E.O.	ERDE Branch	Remarks
	CHEMICAL ENGINEERING (contd.)	.3 Manufacture of Experimental Chemicals required by E.R.D.E.					2	1	SCE	
			(a) Planning and design of S.C.E. sites, buildings and plant		A	C				
			(b) Design of Composite propellant plant		A	C				See 1.4 (b)
			(c) Manufacture of experimental batches of nitric esters, polyesters, isocyanates, lead compounds and miscellaneous materials		A	B				Polyesters for A.W.R.E. shown separately under 9.4
		.4 Manufacture of Experimental Chemicals undertaken for Outside Agencies					$1\frac{1}{2}$	$2\frac{1}{4}$		
			(a) Collaboration with D.O.F.(X) on manufacturing processes		B	C				
			(b) Special polyesters. Synthesis and production as required by A.W.R.E.		A	B			SPRI) SCE)	Contract DA/99/02 - A.W.R.E.
10	RESEARCH ON ANALYSIS	.1 Chemical Procedures; Chromatography					$1\frac{3}{4}$	$2\frac{1}{2}$	SAS	
			(a) Chromatographic methods, particularly vapour phase		B	B				
			(b) Nuclear Magnetic Resonance							E.W.R. Contract No. 7/CSR/1566 - London University
			(c) Basic spectroscopic studies on the mechanism of solution processes		B	A				
		.2 Spectroscopy					$\frac{1}{2}$	$\frac{1}{2}$	SAS	
			Exploitation of new methods. Application to structural problems.		B	A				
		.3 Crystallography					$1\frac{1}{2}$	2	SAS	
			(a) Application of X-ray crystallography to analytical and structural problems		B	B				
			(b) Crystal structure of tetrazene							
11	MATERIALS - NON-METALLIC	.2 Applied research and development					$\frac{1}{2}$	$3\frac{1}{2}$	SMR	
			(a) Polymers with special electrical requirements							
			(i) Preparation of new materials based on styrene; isotactic vinyl polymers							E.W.R. 6/WT/46678 - Yaraley Research Laboratories
			(ii) High temperature ageing on electrical properties of polyethylene							E.W.R. KH/R/0343 - ditto
			(b) [illegible] compositions							E.W.R. 6/PLAS/032 - ditto
			[illegible] of cements and lutings	3	B	B				

PROGRAMME OF RESEARCH 1960/61 (contd.)

Field of Work	Objective	Investigation	Priority: Service	Priority: Resch.	Effort: Code	Effort: S.O.	Effort: E.O.	ERDE Branch	Remarks
MATERIALS - NON-METALLIC	.1 Applied Research and Development (contd.)	(c) Surface coatings Proofed materials; effect of additives; environment; compatibility with explosives. Properties of paint films. Effect of weathering	?	B	B				v. F.V.R.D.E. 13 M.E.X.E. 4 (b)
		(d) Dracone developments Testing methods for proofed fabrics; effect of coatings on strength of fabric; laminar adhesion; endurance of materials and joints under service conditions							Contract with National Research and Development Council v. M.E.X.E. 4 (a)
		(e) Adhesion Adhesives for metal/metal contact compatible with explosives; for collapsible fuel containers; surface catalysed adhesives.	3	B	A				v. ARDE 8 (g)
		Strength of joints; torsional shear of annuli; butt tension and shear; threaded joints; laminar strength of proofed textiles		B	C				
		(f) Packaging materials Development and assessment of both conventional and new materials; effect of storage; environmental degradation.		B	B				
	.2 Materials Evaluation (including development of techniques). Compatibility	(a) Service interests Assessment of plastics and rubbers for various projects. Effect of environment on physical properties of plastics and rubbers (including when in contact with explosives). Physical properties of rubbers under service conditions.	1		A				
		Physical properties of and effect of environment on textiles under service conditions. Compatibility of fibres with explosives.		C	C				
		(b) Test methods (i) Testing with miniature specimens. Tension on surfaces of membranes (theoretical and experimental determinations)		B	B				
		(ii) Processing unit; preparation of special mouldings in rubber and plastics as required							
		(iii) Stress distribution in adhesion; photoelastic examination							
		(iv) Cushioning materials. Properties under shock loading							
		(v) Packaging materials. Behaviour of packaging materials							
						¾	3	SMR	E.M.R. 7/EXPTL/681 and 7/GEN/1327 - Royal College of Science and Technology, Glasgow E.M.R. 7/PACK/76) Printing, packaging and Allied Trades Rsch.Assn. E.M.R. PD/23/03)

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B. As for Service Priority 2.

C. As for Service Priority 3.

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A. Items so fully staffed that progress would not be accelerated by any increase.

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C. Progress on this item is retarded by lack of specialist staff.

D. Work to which staff is allocated when work of higher priority is held up for reasons unconnected with staff.

E. No staff can be made available for this item at present.

F. Staff are allocated for short term jobs as the needs and priorities of the moment demand.

Effort is shown as the number in Scientific Officer (S.O.) Experimental Officer (E.O.) and, in Section 6, Engineer (Eng) cadres engaged on the items as ruled off horizontally in the R. & D. Programme. The staff engaged are shown, as totals at the head of each such division. Totals are taken to the nearest ½ man year (equivalent to three months' work by one man). Obviously they may undergo change during the course of the year.

Extra-Mural Research

For items under extra-mural research contracts the contract number and location are shown in Remarks column. The estimated cost of the contract is shown in brackets beneath the contract number the first figure being the total cost up to 31.3.62, and the second the estimate for 1962/63.

Costing

Costing of the Establishment's work is dependent on quarterly returns of the deployment of White Paper staff on the forty-odd "Objectives" given in the third column of this R. & D. Programme. The Objectives are grouped under eleven "Fields of Work", only one of which (No. 5) is not broken down into separate Objectives.

Abbreviations

SPR I	-	Supt. Propellants Research I
SPR II	-	" " " II
SPR III	-	" " " III
SCE	-	Supt. Chemical Engineering
SEI	-	Supt. Explosives and Intermediates
SAS	-	Supt. Analytical Services
SMR I	-	Supt. Materials Research I
SMR II	-	" " " II
AERE	-	Atomic Energy Research Establishment
ARDE	-	Armament Research and Development Establishment
AWRE	-	Atomic Weapons Research Establishment
C.	-	College
C. of Sc.	-	College of Science
C.S. & M. Fibres Rsch. Assn.	-	Cotton, Silk and Man-made Fibres Research Association
R.C.S.	-	Royal College of Science
R. & P. Rsch. Assn.	-	Rubber and Plastics Research Association
Rsch.	-	Research
U.	-	University.

PROGRAMME OF RESEARCH AND DEVELOPMENT 1962/63.

No.	Field of Work	Objective	Item	Priority		Effort			E.R.D.E. Branch	Remarks
				Service	Rsch	Code	S.O.	N.O.		
1	ROCKET PROPELLANT DEVELOPMENT	.1 Colloidal Extruded. Scaling up of production of experimental compositions. Improvement of processing techniques.	(a) Study of processing factors such as rolling, ageing of paste, which may effect ballistics of compositions VU, BU and AU.		B	B	½	3½	SPR III	
			(b) Ballistic standardisation of additives: lead phthalate, lead stannate, carbon black, etc., and methods for achieving this.		B	B				
			(c) Efficient extrusion procedures for multi-perforated charges applicable to Travelling Charge Gun, etc., and complex shapes for small rocket charges (e.g. Snifter).		C	F				
			(d) Further assessment of silicone and Hypalon rubbers for purposes of inhibition and thermal insulation in rocket motors.		C	F				
		.2 Cast Double Base. Extension of the range of burning rates beyond the present limits. Improvement of mechanical properties and case-bonding of the propellant.	(a) Investigation of burning rate catalysts.		C	F	1½	1½	SPR III	
			(b) Assessment of 'composite modified' propellants for Service use.		C	F				
			(c) Effects of selected nitric esters on rheological properties, stability, and ballistics after storage.		B	B				
			(d) Testing and quality control of complex adhesive systems for binding the propellant to the rocket motor casing.		B	B				
			(e) Cooperation with I.C.I. Ardeer and Summerfield on specific problems, e.g., quality control of casting powder; adjustment of charge ballistics.		A	A				KMR 6/Gen/1544 - I.C.I. Ltd. (£746,000/£82,000)
		.3 Composite Plastic Improved physical properties, especially at low temperatures. Larger specific Impulse. Development of remotely controlled processing plant.	(a) Binder materials in regard to their influence on physical properties; use of ingredients such as aluminium metal or a high explosive to raise performance.			B	2	2	SPR I	Effort also covers items 1.5(a) and 1.5(b)
			(b) Study of variations in the manufacturing process e.g., vertical pugmill; powerful mixers; semi-continuous processes. Better safety devices.			B				
		.4 Composite Elastomeric (Polyurethane) Compositions for the Blue Water II, boost and sustainer motors. (Phoenix) The novel manufacturing and filling process to be tested. Techniques for case bonding to be devised and specifications written.	(a) Construction of remotely operated filling plant will be completed during the current year. Appropriate handling equipment to be designed and installed.	1		A	6½*	2	SPR I	Project Blue Water II. Item (a) is costed under codes 301 and 302 and (b) under code 204. Effort also covers item 1.5(d).
			(b) Examination of case bonding systems for steel, Durestos, Hypalon and aluminium. Provision of equipment for lining and coating of the Phoenix Motor.	1		B	½	1½δ		*Includes 1 Chem II on loan from CROF and 2 Eng II from CE/KRDE. δIncludes 1 EO on loan from SMR/KRDE. See also 3.2(d) and (e)
			(c) Filling programme to determine ballistics, physical properties and storage characteristics of the propellant charges.							

PROGRAMME OF RESEARCH AND DEVELOPMENT 1962/63.

No.	Field of Work	Objective	Item	Priority		Effort			A.R.D.E. Branch	Remarks
				Service	Mach	Code	S.O.	E.O.		
1 (con t'd)	ROCKET PROPELLANT DEVELOPMENT (cont'd)	.5 Charges requested for trials	(a) Provision of tonnage quantities of plastic propellant for various boost and sustainer motors.	2		B	-	-	SPR I	Effort shown under 1.3
			(b) Ordnance Board programmes for Gosling IV, Walkara, Magpie, Linnet and 2" rocket motors.	2	B	F			SPR I (SPR III	
			(c) Filled boost and sustainer motors for the Blue Water programme.	1		B			SPR I	Effort shown under 1.4(a) and (b) Costed under code 204.
			(d) Experimental propellants for seat ejector cartridge.		B	F			SPR III	Contract with Messrs. Martin Baker.
			(e) Propellants in support of work on rocket motors and power cartridges at A.R.D.E.		B	F			"	Effort for items (d) and (e) included under 1.1. These items appeared under 1.1(e) and (d) of 1960/61 Programme. See also 3.2(d) and (e).
2	ROCKET PROPELLANT EVALUATION	.1 Charge Defect Detection Non destructive methods.	(a) Trial of xero-radiography as a method.		C	F	¼	1	SPR III	
			(b) Examination of techniques and acceptance standards for X-ray and ultrasonic inspection.		C	B				
		.2 Calorimetery and Ballistics	(a) Routine calorimetery; strand burning rates; small-motor ballistics; 'closed vessel' P/T measurements.		A	B	¼	6	SPR II	
			(b) Investigation of features determining performance of test motors (i) heat loss and igniter corrections (ii) effect of nozzle design parameters with propellants giving solid particles in exhaust gases.		B	B				
			(c) Development of rotating rotor for determination of instantaneous specific impulse.		B	B				
			(d) Techniques for testing new igniter compositions.		C	B				
		.3 Chemical Analysis	(a) Routine supporting analytical work.		B	A	½	6	SAS	
			(b) Analytical methods for the determination of new ingredients in experimental compositions.		B	A				
		.4 Stability; Compatibility; Climatic Testing.	(a) Assessment of stability: development of thermal and chemical methods. Quantitative studies of NO_2 evolution in propellants and its absorption by stabilisers.		B	A	1½	5	SAS	
			(b) Trials to determine the suitability of NG made by the Glythorp process likely to be adopted at R.O.F. Bishopton.		B	A				
			(c) Stability of high energy compositions		B	B				

No.	Field of Work	Objective	Item	Priority		Effort			R.B.D.E. Branch	Remarks
				Service	Rsch	Code	S.O.	E.O.		
2 (cont'd)	ROCKET PROPELLANT EVALUATION (cont'd)	.4 (cont'd)	(d) Compatability of explosives with all kinds of materials		B	A				
			(e) Climatic trials associated with Ordnance Board programmes.		B	B				See 1.5 (b)
		.5 Testing of Mechanical Properties To devise and standardise mechanical and physical tests for the control of propellant characteristics	(a) Rheological properties of particular propellants studied in relation to their applications. (b) Examination of the effect of temperature, humidity and time on these properties. (c) Selection and specification of physical tests for control of manufacture at R.O.Fs.		B	B	-	-	SPR I	Effort included under 3.4
		.6 Sensitivity and Hazards.	Tests of impact, friction and shock sensitiveness; burning to detonation; ignition in liquids by adiabatic compression of air bubbles.		B	F			SPR II	See 6.3 and 6.4 EMR 61/499/327 - AWRE, Poulness. (£22,000/£15,000) Includes trials staged at other Establishments
3	ROCKET PROPELLANT RESEARCH	.1 Synthetic and Preparative Chemistry Preparation and study of selected types of compound.	(a) Investigations on nitric esters aimed at elucidation and remedying variable stability of propellants associated with by-products of NG, DEGN and TEGN preparations.	1	A	B	½	1	SRI	
			(b) Thermal decomposition of aluminium alkyls.						SPR II	EMR PD/25/03 - U. of Wales (£1,000/£1,000)
			(c) Synthesis of certain types of compound capable of giving stereoisomers by absorption of ultra violet radiation.						SPR II	EMR PD/40/01 - Southampton U. (£2,800/£1,300)
			(d) Investigation of the chemical reactions involved in (a) the curing and (b) the slow degradation of polyurethane elastomers.		B	B	1	1	SPR I	
			(e) Radiochemical study of transesterification of acids for polyurethane preparation.		B	A	1	2	SPR I	
		.2 Formulation and Processing	(a) Slurry casting with nitrocellulose binders. Investigations to improve mechanical properties and extend range of burning rates. Special sizes of ball powder will have to be prepared.		C	B	1	½	SPR III	
			(b) Compositions to exhibit plateauisation at burning pressures exceeding 2 tons p.s.i. Lead additives and others to be tried		C	F				
			(c) Porous propellant having ultra fast burning rate; to assess U.S. claims for latex bonded nitrocellulose propellant.		B	F				
			(d) Preparation of experimental polyester and polyether polyurethane propellants for evaluation.		B	B	1	3½	SPR I	See also 1.4 and 1.5
			(e) Study of crystallisation of polyurethane propellants at low temperatures.		B	F				

No.	Field of Work	Objective	Item	Priority		Effort			E.R.D.E. Branch	Remarks
				Service	Rsch	Code	S.O.	E.O.		
3 (contd)	ROCKET PROPELLANT RESEARCH (cont'd)	.3 Internal Ballistics and Flame Reactions Determination of the mechanism of the physical and chemical processes occurring in the combustion of propellants.	(a) Theoretical studies of flame ignition and propagation. Calculation of propellant performance parameters.		B	B	5½	3	SPR II	
			(b) Investigation of higher than equilibrium hydrogen atom concentrations in hydrogen-oxygen flames.		P	P				
			(c) Study of the kinetics of oxidation by chlorine oxides and oxyacids. Little is known about such reactions, which bear on the burning of propellants containing perchlorates.		B	A				
			(d) Mode of combustion of ammonium perchlorate and binder fuels in composite propellants; measurement of surface temperature of propellants burning at rocket chamber pressures and under transient pressure conditions; pyrolysis of fuels.		B	B				
			(e) Combustion and thrust efficiency of aluminised propellants.							
			(f) The oxidation of halogen compounds (flame inhibitors)							RNE PD/57/06 - Imperial C., London (£2,300/£4,00)
			(g) Thermal decomposition of inorganic perchlorates.							RNR PD/57/122 - Imperial C., London (£500/£1100)
			(h) Oxidation of ammonia and allied compounds.							RNE PD/57/03 - St. Andrews U. (£300/£500)
		.4 Rheology In respect of propellants and their ingredients	(a) Rheological behaviour of all types of solid propellant under a wide range of conditions (e.g. of temperature and humidity). Study of multi axial stressing.			A	2	3	SPR I	Includes effort for 3.5
			(b) Application of data to charge stressing problems			C				
			(c) Effect of ageing on rheological properties.			B				
			(d) Problems associated with large case-bonded charges.			F				
			(e) Particular problems associated with case bonding and insulating liners or boots.			B				
4.	LIQUID PROPELLANTS	.1 General Chemistry Study of specific compounds or of particular classes of compound.	(a) To round off our investigations, the catalytic decomposition of concentrated hydrogen peroxide by ions of V, W, and Os will be studied.	2	B	A	3	3	SEI	
			(b) Work on hydrazine-diborane is nearing completion when boron hydride research will be discontinued.		C	B				Item to be terminated
		.2 Measurement of Thermal Properties Heat transfer data relating to combustion chamber and nozzle cooling problems.	(a) Heat transfer experiments on hydrogen/oxygen combustion products.		B	C	1¾	2	SPR II	Experimental work almost complete
			(b) Measurement of thermal conductivity as a function of temperature and pressure.		B	B				

No.	Field of Work	Objective	Item	Priority		Effort			R.R.D.E. Branch	Remarks
				Service	Rsch	Code	S.O.	E.C.		
4 (contd)	LIQUID PROPELLANTS (contd)	.2 Measurement of Thermal Properties (contd)	(c) Heat transfer phenomena in fluids at high rates of heating in the region of the critical pressure. Heat transfer to kerosine at high heat fluxes and at pressures above and below its critical pressure; the determination of "burn-out" heat fluxes for these conditions. Optical observations by high speed cinematography of the phenomena occurring at super-critical pressures.		B	F			SPR II	
5	PROPELLANTS FOR ORDNANCE AND SMALL ARMS	Improvements to meet service requirements	(a) Reduction of temperature coefficients of rate of burning by use of ballistic modifiers and changes in granule shapes; improvement of ballistic and storage properties by modifications to composition and methods of processing.		C	D	½	½	SPR III	
			(b) Ballistic stability of ball powders. Information on solvent content and processing temperatures gained on small plant may be applicable later at R.C.F. Bishopton.		C	F			SPR III	
			(c) Consumable cartridge cases. Examination of production and Service requirements, and of the qualities of paper and nitrocellulose.		B	F			SPR III	Collaboration with ARDE New item
			(d) NATO collaboration. Interchangeability on explosives and munitions.		B	F			SAS	In collaboration with SPR III
6	EXPLOSIVE CHARACTERISTICS (HIGH EXPLOSIVES, PROPELLANTS, PYROTECHNICS, INITIATORS.)	.1 Research on the Build up and Mechanism of Detonation	(a) Basic experimental investigation on growth of shock waves in condensed phase explosives, to attempt to determine the kinetics of the rate of energy release in the shock wave.		B	B	2½	3	SPR II	
			(b) Measurement of equation of state properties of explosives, explosive products and inert materials at detonation pressures of approximately 10^5 atm.		B	B				
			(c) Theoretical investigations on the growth of detonation waves: two-dimensional flow effects and the prediction of failure diameter.		B	B				New item.
			(d) Investigation of the causes of variability in shock sensitiveness of crystalline explosives.						SEI	Effort included under 7.1
		.2 Functioning of High Explosives. Control of sensitivity, and of properties determining sensitiveness in military explosives.	(a) Certain applications of explosives require close control of pickup sensitivity. The factors affecting this, particularly crystal malformations, are being investigated.		B	B	1	2	SPR II	
			(b) Safety certificate tests; trials of explosive hazards.			F				
		.3 Sensitiveness of Iniator compounds	Investigation and assessment of impact, friction, and spark sensitiveness. Sensitiveness of polymorphs and mixtures of polymorphs.		B	F	1	1	SPR II	See 2.6

No.	Field of Work	Objective	Item	Priority		Effort			R.R.D.E. Branch	Remarks
				Service	Rank	Code	S.O.	E.O.		
6 (contd)	EXPLOSIVE CHARACTERISTICS (contd)	.4 Electrostatic Investigations (contd)	(a) Electrification of personnel; measurement of their capacitance, and evaluation of hazard in relation to minimum capacitance and minimum energy for ignition.		B	B			SPS II	Effort included in 6.3
			(b) Study of adventitious generation of charge on equipment and ammunition containers.			F				
		.5 Compatability with materials and other explosives.	Examination of the effects of all types of materials on all types of explosives as and when requested in R.R.D.E. or by the Services.		B	B	1	3	SAS	
7	CHEMISTRY OF THE INGREDIENTS OF EXPLOSIVES	.1 Organic Chemical Synthesis in Support of Specific Investigations	(a) Nitro aromatic amines and related compounds; resistance to thermal degradation. (for ARDE)	1	A	B	1½	2	SHI	Effort in index 6.1 (d)
			(b) Cyclic and linear aliphatic nitramines. Study of their reactions.							
			(c) Identification and characterisation of compounds derived from nitroresorcinol (7.2(a) and (c)).							
			(d) Hydroxy aromatic quinones and related compounds (10.2(b)).							New item.
		.2 Initiator Compounds and Igniferous Compositions	(a) Examination of lead 4, 6 dinitroresorcinate for A/B detonator, explosive capsules and igniter X2H.	1	A	B	3	3	SHI	
			(b) A composition $KClO_4$/Mg/curable binder, for 2" rocket. Examination of stability, burning rate and ignition effectiveness.							
			(c) Fuseheads for use at temperatures up to 200°C. Examination of suitability of basic lead styphnate.							
			(d) Investigation of lead trinitrophloroglucinate for short length narrow-channel initiation at 150°C or above.							
			(e) Manufacture of lead azotetrazole for particular igniters (wire bridge and conducting composition types).							New item

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No.	Field of Work	Objective	Item	Priority		Effort				S.M.D.E. Branch	Remarks
				Service	Rsch	Code	S.O.	E.O.	Eng		
8	CHEMICAL ENGINEERING	.1 Manufactures	(a) Preparation of polyesters; control of polymerisation.		A	A	1½	3½	-	SCE	
			(b) Lead compounds; effect of processing conditions on the plastonizing properties of the products		A	A					
			(c) Nitric esters for experimental propellants		A	A					Includes effort 8.2(a)
			(d) Compounds required in quantity by ENDE or by other establishments.			F	·		·		Includes requirements for Blue Water II (See Section 1.4)
		.2 New and Improved Manufacturing Processes	(a) Nitration of glycols; safety factors, effects of impurities in the glycols, and intrusive drying of the nitrate esters.		A	A	1	1	-	SCE	
			(b) Recrystallisation, grinding and handling of ammonium perchlorate. (Final stage of the new manufacturing process).		B	C					
			(c) Continuous mixing and casting process for polyurethane propellant substitute (development of safe processing)		C	D					
			(d) Control of crystal size of product from ammonium nitrate plant to minimise caking.		C	C					
			(e) Fractionation of polyesters by distillation, diffusion, or other methods.		C	E					New item.
		.3 Unit Operations	(a) Aggregation and flow properties of powders such as ammonium perchlorate		B	D	½	1½	¾	SCE	
			(b) The Oslo crystalliser								EME 7/Gen/1612 - Birmingham U. (£4,000/£900)
			(c) Solid/liquid mixing; non-Newtonian fluids; propellant pastes.								EME Proposed - Swansea U.
			(d) Factors in the performance and safety of mixing equipment		B	B					
		.4 Instrumentation and Remote Control	(a) Laboratory explosion cupboards		B	B	-	4	1¼		
			(b) Conveying and feeding powders in the fluidized state		B	C					
			(c) Weighing solids and fluids in flow		B	B					
			(d) Service throughout S.M.D.E.			C					

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No.	Field of Work	Objective	Item	Priority		Effort			E.R.D.E. Branch	Remarks
				Service	Rsch	Code	S.C.	E.O.		
9	CHEMICAL ANALYSIS	.1 Chromatography	Liquid/liquid extraction is being added to the range of separative methods in use. It is hoped to develop techniques of comparable power to vapour phase chromatography, but which would be applicable to non-volatile components of mixtures. These may ultimately help the work on polymer degradation and explosives instability.		B	B	1¾	3	SAS	New item.
		.2 Spectroscopy Infra red, visible, and ultra violet	(a) Service (which may involve research) to other sections of E.R.D.E.							
			(b) Primarily, studies on association effects in solution through hydrogen bonds and by dipolar interaction.		B	A	½	1	Dr.L.J. Bellamy	
		.3 Crystallography	(a) Application of X-ray diffraction to general analytical problems.							
			(b) Crystal structure of tetrazene hydrobromide.							
10	MATERIALS NON-METALLIC (Organic)	.1 Relationships between structure and properties of high polymers. Factors determining 'strength'.	(a) A series of polyethers is being prepared for systematic study of the correlation between molecular structure and properties such as glass transition and melting temperatures, specific heat and heat of fusion, co-efficients of expansion and compressibility, and degree of crystallinity.		P	B	4	5	SMR I	New item.
			(b) The control and estimation of 'cure' in resins are largely unsolved problems of technological importance. In this connection the reaction between glycol and dibasic acids is being followed by determinations of bulk viscosity, water evolution, etc.		B	B	-			
			(c) A theoretical study of van der Waal's forces based on measured values of dielectric constant and polarisability.		B	C				
			The phenomenon of electrification of the area of plastic yield of a polymer on impact is being studied to determine the duration of impact. The dynamic modulus so obtained will be compared with that from observations of the free vibration of circularly clamped sheets of polymer.							
			(d) Measurement of compressibilities at constant temperature and of volume thermal expansion at constant pressure for selected solids and liquids. This provides basic data for correlation between molecular and macroscopic forces; e.g. prediction of solvent/solid interactions, such as oils with rubbers.		B	B				

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No.	Field of Work	Objective	Item	Priority		Effort			A.H.D. Branch	Remarks
				Service	Rsch	Code	S.O.	E.O.		
10 (contd)	MATERIALS NON-METALLIC (Organic) (contd)	.1 (contd)	(e) Effect of time of mechanical stressing and of stress-strain behaviour at very high rates and for very long times under constant load. The former is associated with the transition from tough ductile to weak brittle behaviour and the latter is important in investigating the loss of strength with time under load. Both depend to some extent on molecular structure, and the studies of long period stress have been aided by our development of a photoelastic apparatus.		B	C				
			(f) Use of an improved method is being exploited to study the characteristics of solvent transmission through elastomers.		B	C				
			(g) MOR Contracts in support of the above items:-							
			Adhesion							MOR:- (PD/24/067 - Nottingham U. (£500/1000 (PD/24/095 - " (£1000/1800 (7/GEN/1527 - I.C.S. Glasgow (£5700/1100) (7/GEN/1529 - Glasgow U. (£4,64/100)
			Fibre properties at high rates of stressing							(7/Gen/1435 - C.S.M. Fibres (£14,800/3,100) Rsch. Assn.
			Mechanism of Vapour Permeability							(PD/57/09 - Imperial C. London (£3700/£1600) (PD/35/02/B1 - Reading U. (£400/800)
			Crystalline Structure of polymers							Under negot- - Bristol U. iation (£1000/1800)
			Film forming properties of high polymers							(PD/55/02 - Yarsley Rsch. Labs. (£10,100/£10,400)
			Molecular cross linking of polymers							(7/GEN/1675 - C.S. & M. Fibres (£4,00/£1200) Rsch. Assn. In suspense
			The dynamic behaviour of rubbers and plastics							(PD/23/025 - P. & P. Rsch Assn. (£6[illegible]/£1700)
			The breakdown of loaded rubbers							(PD/23/024 - " (£2800/£2300)
			Stress relaxation method as a research tool: study of rubber ageing							(PD/23/123 - " (£2200/£1800)
			Factors influencing the low temperature behaviour of rubber as exemplified in the poly-olefine oxides.							(7/GEN/1690 - Manchester U. (£6500/£2000)
			Properties of chemical bonds for potential use in high temperature polymers							(£500/1000)- U.C. London

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No.	Field of Work	Objective	Item	Priority		Effort			S.R.D.E. Branch	Remarks
				Service	Resh	Code	S.O.	D.C.		
10 (contd)	MATERIALS NON-METALLIC (Organic) (contd)	.2 Degradation of Polymers. To study molecular factors influencing the stability of polymers towards heat, ultra violet and ionising radiations.	(a) Investigation of mechanism of breakdown in polycarbonate polymers.		B	B	2	3	SNR I	(7/GBR/1626 - U.K.E.R.E. Wantage (£2400/£1500) This contract gives New item. access to facilities for high energy irradiation
			(b) Basic studies of oxidative degradation (and its prevention) in (a) nylon and polyethylene, (b) selected hydrocarbons of high molecular weight.				1	1	Dr.Uri	New item.
		.3 New Polymers	Silicone polymers Phosphorus-containing polymers Semi-organic and inorganic polymers containing arsenic, antimony etc. Polymers from polyanhydrides Organic compounds possessing semi-conducting properties						SNR I	At present this Objective is supported entirely extra murally. The primary aim is improved stability at the higher working temperatures demanded of service equipment. (SNR proposed - Westfield C.London (£1700/£2000) ID/44/04 - Manchester C. ofSc. (£1500/£1200) PD/46/03 - Birkbeck C. London (£1500/£1200) PD/55/02 - Yarsley Rsch. Labs. (included in 10.1, q.v.) PD/24/03 - Nottingham U. (£1000/£2000
		.4 Rubbers and Plastics Development of compounds for specific purposes and assessment for service projects.	(a) Effect of environment, including contact with explosives, on the physical properties of new materials.	1		A		3	SNR I	N.B. The work described in Sections 10.4 to 10.7 is related in the main to collaboration with War Office Research & Development Establishments and with the Joint Service R. & D. Committees.
			(b) Statistical evaluation of physical test methods, particularly with miniature specimens.			B				
			(c) Theoretical and experimental study of stress/strain, behaviour of flexible membranes (e.g. rubberised cloth) under biaxial tension.							
			(d) New techniques and new rubber compounds for proofing large woven structures.							
		.5 Adhesives and Sealants Elucidation of factors involved in jointing materials for collapsible tanks.	(a) Surface catalysed adhesives as sealants; an increase in viscosity without premature polymerisation of the monomer is required.	2		C		1	SNR I	
			(b) Silicone and polyurethane rubbers to cure at room temperatures as thread sealants in ammunition.							
			(c) Measurements of adhesion between rubber and fabric in rubber proofed fabrics, and between rubber surfaces cured together, using the direct tension method. Correlation of the forces of adhesion with the weakening of such joints when immersed in selected liquids.							

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No.	Field of Work	Objective	Item	Priority		Effort			M.A.D.E. Branch	Remarks
				Service	Rsch	Code	S.O.	H.O.		
10 (contd)	MATERIALS NON-METALLIC (Organic) (contd)	.5 (contd)	(d) Study of the lack of compatability of strain between adjacent parts of the adherends of composite joints, e.g. in rubberised cloth. (e) Adhesion in pure shear; further development of annular jointed 'napkin ring' specimens. (f) Tape made from polytetrafluoroethylene for hermetically sealing threaded joints. The appropriate physical properties must be determined. (g) Examination of materials and joints for Dreone Developments Ltd.		B	C				Contract
		.6 Surface Coatings	(a) Examination of new polymers and resins for ammunition varnishes. (b) Comparison of the behaviour of paints in the factor of separated coherent films with that of painted surfaces under natural and artificial conditions. (c) Various special applications, including varnishes capable of resisting high temperatures, and for contact with hydraulic fluids or solvents.	2		C		1	SMR I	
		.7 Packaging Materials	(No work being carried out at M.A.D.E.)							SMR PD/21/02 - Printing and Allied (£2300/£700) Trades Rsch. Assn. SMR PD/21/711 - Chalk, Line and Allied Industries Rsch.Assn. The possibility of War Office taking on direct responsibility for these contracts will be explored.
		.8 Environmental Research Study of behaviour of materials in tropical climates.	(a) Determination of temperature contours in materials and 'packages' under tropical conditions. (b) Correlation of deterioration of materials in the tropics with that in accelerated tests and in simulated tropical environments.						SMR I	Programme proposed for the new joint venture of the British and Australian Governments which is expected to begin operations in Queensland in the Autumn of 1962. Effort (1 SO and 2 HO, these 2 HO to be seconded from SMR I). New items.
11	MATERIALS NON-METALLIC (Inorganic)	.1 New materials of great strength.	Work will be concentrated on a suitable 'whisker' material, following the selection (yet to be made) of its possible application to a problem of interest in M.O.A.. The technique may lead to the development of materials having exceptional strength and resistance to shock.			B	2	2	SMR II	A new Branch transferred (1.3.62) from Tube Investments Research Laboratories. New item.
		.2 Chemical aspects of semi-conductor materials	Thermodynamics of epitaxial deposition of gallium arsenide.				1	-	SMR II	New item.
		.3 Potentiality of organic compounds for optical laser action.	Exploratory work to ascertain whether the long fluorescence times of some organic compounds could be exploited				1		Dr.L.J. Bellamy	Although organic materials are concerned, this objective is conveniently grouped in this Field of Work. New item.

SECRET

File Reference: WAC/118/22

MINISTRY OF AVIATION

EXPLOSIVES RESEARCH AND DEVELOPMENT ESTABLISHMENT

WALTHAM ABBEY

PROGRAMME OF RESEARCH AND DEVELOPMENT

APRIL, 1962 - MARCH, 1963

E.R.D.E.
Waltham Abbey
March 1962.

C. H. JOHNSON, C.B.E.,
DIRECTOR

SECRET

EXPLOSIVES RESEARCH AND DEVELOPMENT ESTABLISHMENT

WALTHAM ABBEY

The Materials Branches at Waltham Abbey

M.R. I (under Mr. H. Warburton Hall)

The Materials Group at Waltham Abbey was originally set up to provide laboratory facilities for D.M.X.R.D. It became an integral part of E.R.D.E. about 3 years ago. It was needed because the Land Service side of the then M. of S. had no organisation at all for the basic study of materials. Because of this, and because the Air side was already served by D. Mat. and R.A.E.(Chemistry) the work was - and to some extent still is - heavily biased in favour of Land Service interests. Even now, almost all the 'ad hoc' problems which come to us do so from the War Office, and about half the staff are fully employed on work of this kind. Interdepartmental committees approve the programme of work and arrange liaison. Additionally, R.A.R.D.E.'s and M.E.X.E.'s representatives have formal meetings with M.R. I every six months. Typical of this work is the development of special adhesives for the 'dracones' which will transport oil by sea-towing of large collapsible barges. The N.R.D.C. are directly concerned and they provide some financial support to us because of the potential civil uses; the military requirements of M.E.X.E. for transportable fuel tanks raise similar materials problems.

The remainder of the staff are engaged on longer term work which we hope will anticipate future problems and provide the knowledge which will enable us to deal with them. For example, there are the studies on the measurement of the 'cure' of polymers and on the effects of solvents upon the physical properties of rubbers and plastics. This last work involves the study of interchain forces and of the effects of polymer orientation, but it should lead to better understanding of such practical matters as the swelling and embrittlement of gaskets etc. when exposed to liquids.

Since the branch was incorporated within the M. of A., we have made an effort to reorient their research more in the direction of Aviation interests, but this has had to be done without detriment to the facilities we provide for the Land Service. Wherever we have had a choice of research topics we have therefore selected those of potential use to both sides, and nearly all the basic research items in our programme are of this kind. The work on the physical properties of polymers under high rates of strain is, for instance, useful in the missile field but has many other military design applications. Similarly the new work on the prevention of atmospheric oxidation of polymers is of very general interest and could also have important civil applications (from which, indeed, it had its origin).

We have organised a small group to work on high temperature polymers which is primarily a M. of A. interest. We are studying the nature of thermal and other degradive processes on different types of chemical bonds. In this way we hope to acquire knowledge of the factors which determine the bond strengths formed between different elements under various molecular conditions. This should ultimately enable us to select those elements and linkages in polymers which are most likely to give us the properties required. This topic has been chosen, partly because it covers an important area in which very little systematic knowledge is available, but also because it is complementary to the synthetic work undertaken by R.A.E. and by numerous E.M.R. contractors.

/None ...

None of the activities outlined above overlaps with the work of R.A.E. and good liaison is maintained at working levels. There is a general oversight of the work of both establishments through the Materials working party under D. Mat.'s chairmanship.

M.R. II (under Mr. J.E. Gordon)

The introduction of a new materials branch at Waltham Abbey provides an opportunity for us to make a more direct contribution to Aviation problems, and to extend the spectrum of interesting chemical elements. The group is small and it will concentrate, in the first instance, on the further exploration of the production and applications of non-metallic whiskers. The potentialities of this work have already been dealt with in detail in the correspondence about this branch and they will not be enlarged on here. As a result of enquiries within the M. of A. it would seem that the most likely immediate outlets for reinforced whisker materials lie in the directions of high temperature resistance turbine blades and in raising the working temperature of aluminium. Work has started on the first of these in close collaboration with N.G.T.E. However, it does not seem to us sound to base a new branch entirely on a single type of problem, however important it may be, and we would like to see some small element of diversification introduced at once. The fact that this group has specialised knowledge on the crystal growth of inorganic materials suggests that it could make a valuable contribution in support of the current effort at R.R.E. (and elsewhere) on materials used in solid state physics and we hope to see it expand in this direction. As a first step we have recruited an S.S.O. with specialised experience of the vapour phase growth of inorganic crystals. He is working on the thermodynamics of the chemical reactions leading to the deposition of germanium from the vapour. We have also allocated an S.S.O. for exploratory studies in lasers. At this stage the work is centred on spectroscopy (Dr. Bellamy) but in the event that anything of real promise turns up it would clearly be logical to transfer it to the new branch. Under this heading the possibilities are being explored of organic chemical lasers, and of similar material for which a chemical background is required, so that this also will supplement rather than duplicate the effort at R.R.E.

We would also expect that as this branch grows it will provide a stimulus for our Chemical Engineering branch in the bulk production of specialised materials. The chemical engineering is aligned almost wholly behind the work on propellants and explosives and we would like to see it more broadly based. The new branch should provide an important link between them and Establishments such as R.R.E., with whom they have at present no direct contact.

Waltham Abbey.
21st September, 1962.

EXPLOSIVES RESEARCH AND DEVELOPMENT ESTABLISHMENT

WALTHAM ABBEY

Present Status of 'Whisker' Work

Objectives

Discussions within the M. of A. have suggested two areas in which the application of whisker techniques might pay substantial dividends. These are in raising the working temperature of aluminium and in improving the high temperature properties of turbine blades. The second seems the simpler of the two and we are initially concentrating on this in close collaboration with N.G.T.E. The aim is to incorporate refractory whiskers in an alloy matrix and initially we have studied the incorporation of silicon nitride in nickel. We shall later go on to more refractory matrices.

Work Done

We have concentrated on silicon nitride whiskers as these seem likely to be suitable and we now have a good deal of background information about them. Improvements in methods of growth now allow us to make batches of up to 60 gms which is sufficient for experimental work of this kind. Some 'production' problems still resist solution. The whiskers are incorporated by mixing under water with the powdered metal followed by pressing at 1100°C in refractory dies. The initial results with nickel are promising in that the samples are clearly tough and strong and on removal of the nickel with acid the whiskers are recovered in an undamaged condition. A test rig suitable for high temperature studies is nearly completed, and this, together with detailed hot testing by N.G.T.E. should enable us to make at least semi-quantitative assessment of the results.

The difficulties encountered are (a) some porosity, which may be overcome by improvements in pressing methods, and (b) a tendency towards instability at high temperatures due probably to oxidation of the nickel and subsequent attack upon the whiskers. More resistant materials should be achieved by the use of nickel alloys, and we have also made a few specimens using Ni-Al and Ni-Cr which are a good deal better. However it is not possible to attack the Ni-Cr alloy with acid to examine the state of the whiskers. We shall be in a very much better position to assess all this shortly when quantitative data becomes available.

A small amount of work is also in progress on fibre conversion as an alternative to whiskers. R.A.E. have shown that thin metallic wire reinforcement of matrices gives a useful enhancement of physical properties. We have therefore looked at the possibility of converting thin wires of elements such as Ti and Zr into their nitrides which could be used in similar fashion with the advantage of ability to sustain much higher temperatures. Silicon carbide prepared from carbon fibres has been studied and is quite promising. Although these materials lack the great strength of whiskers their possibly more ready availability makes them worthy of study.

Waltham Abbey.
20th September, 1962.

EXPLOSIVES RESEARCH AND DEVELOPMENT ESTABLISHMENT

WALTHAM ABBEY

Work contemplated at E.R.D.E. in connection with Optical Lasers

We have considered how far the chemical and spectroscopic resources of E.R.D.E. might usefully assist the optical laser programme. Chemical work could help in the improvement of existing materials or in the development of new ones. Both possibilities are being explored in a limited way.

(1) Existing Materials

(a) Crystals.

Improvements in ruby lasers will come through improvements in the homogeneity of the crystals themselves. The present methods of growth almost always result in inhomogeneities which seriously limit the performance. Isothermal growth would give crystals with less strain and we shall therefore look into the possibilities of vapour growth through chemical reaction. The limitation here will probably be in the size of the crystals which can be made in this way, but this can only be found by experiment.

(b) Alterations in the Host Lattice.

Conventional masers in alumina etc. rely on the matrix to keep the active chromium atoms apart. It is possible that this could be done by chemical chelation whereby each active atom would be surrounded by organic chemical groups - as for example in the phthalocyanines. There have been suggestions from the U.S.A. that liquid masers could be obtained in this way and preliminary evidence suggests that this may be done by the use of chelated terbium ions. The possibilities will be examined.

(2) New Materials. Organics.

It is conceivable, but perhaps not very likely, that organic materials can be made to lase. If so the wavelength would be adjustable over quite a wide range by small alterations in chemical composition. Although the chances are perhaps small the rewards would be high and this field should at least be studied in a preliminary manner. Suitable compounds would be those with conjugated double bonds, change transfer systems (for which a claim of laser action has already been made but largely discredited) and compounds with fluorescent lifetimes comparable with ruby. Little is known of fluorescent spectra of such compounds in host lattices and in the first instance it will be necessary to measure the spectra in order to select possible materials for trial.

(3) Light Sources.

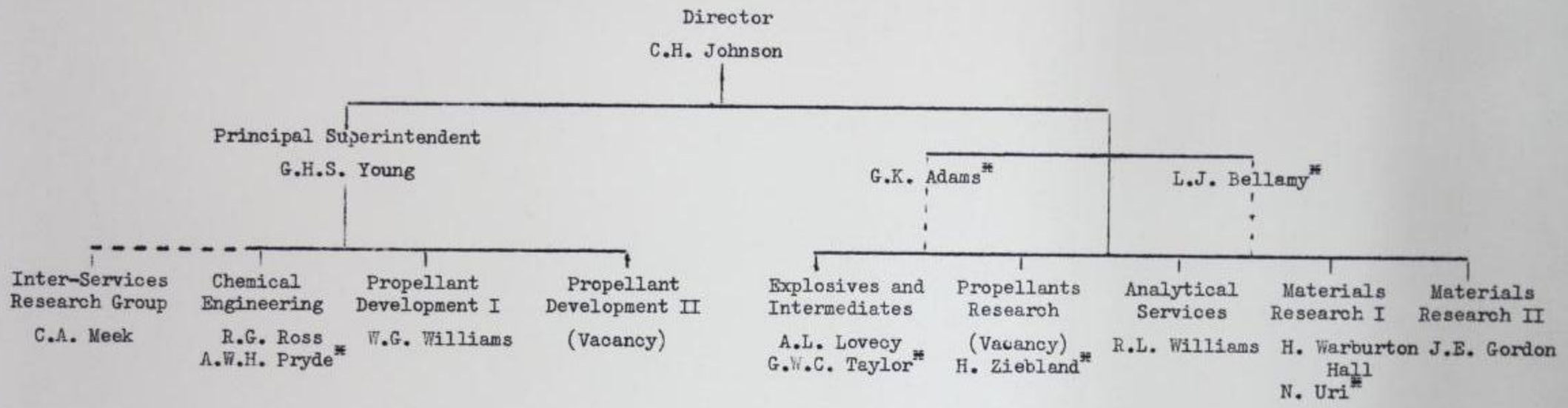
E.R.D.E., with its explosives interests, has already a good deal of experience with, and facilities for, handling explosive light sources of great power - i.e. the argon bomb etc. We are considering how far this might usefully be employed in laser work.

Waltham Abbey.
20th September, 1962.

COVERING SECRET

EXPLOSIVES RESEARCH AND DEVELOPMENT ESTABLISHMENT

The Technical Organisation



Dr. G.H.S. Young is in general charge of 'development' and of the South Site where most of that kind of work is carried on. Dr. L.J. Bellamy, an individual-merit D.C.S.O. (all holders of individual-merit posts are marked with an asterisk) prosecutes his researches in infra-red spectroscopy, acts as adviser to the A.S. and Mats. I and II branches, and is responsible for supervising the Establishment's recruitment of Scientific Officer grades. Mr. G.K. Adams, likewise an individual-merit D.C.S.O., doing theoretical work on detonation phenomena, keeps an eye on the 'explosives' activities, assists Dr. Bellamy in recruitment and is Chairman of the Library committee. Thus, between these two and Dr. Young, the entire R. & D. programme is kept constantly stirred.

The tendency will be to bring all 'propellant' work (R. as well as D.) under one or other of the Propellant Development branches I and II (until recently called Propellants Research III and I respectively). The Propellants Research branch has for some time given increasing attention to the scientific investigation of explosive hazards and to the problems of energy transfer in detonation. A more accurate description of much of the work of this branch would be 'explosives physics', a counterpart to that of the Explosives and Intermediates branch (a title originating in pre-war Woolwich) which could be expressed succinctly as 'explosives chemistry' since its main business is with the preparation and basic chemistry of explosive substances generally.

September, 1962.

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JEP

Reference.....

Director.

The E.R.D.E. Research Programme

Thank you for showing me the minute from Mr. Brewin dated 14th September. I have retained the second copy of the list that Mr. Brewin enclosed.

In regard to items 1 and 2, these are already part of our programme and will continue with the maximum effort that we can reasonably afford. In the case of item 3, the main difficulty here is to recruit a suitably qualified scientist. As far as I know at present there is no-one at E.R.D.E. who is competent in this field and attempts in the past to recruit people for this type of work, or to interest someone in the University in our problems have been largely unsuccessful.

Item 4 is, I am afraid, rather a 'dead duck'. The improvements expected by continuous production of plastic propellant do not seem to be achievable without the expenditure of very considerable effort. A more likely line of attack, on which we are already working, is to improve the present batch mixing process. It seems that we may be able to cut down the mixing time quite appreciably by the use of more powerful machines, and also I think we could now safely increase the size of the batches from about 200 lbs to around 500 or 1,000 lbs. This would, of course, be quite adequate for the present rather limited propellant production at R.O.F. Bridgwater.

Item 5 seems a likely line of development and I intend to get some work started on this in the fairly near future. Item 6 is already being investigated but in my opinion is not an altogether desirable development for plastic propellant.

Item 7 largely depends on our association with R.P.E. Westcott. At the present time the only meteorological rocket is called Bantam and this does not seem to be making very good progress.

Item 8. Some work on this type of system is already in hand, and the feasibility of the idea has in fact already been demonstrated. However, the advantages to be obtained by a complex system of this sort do not seem to be very important at the present time.

Item 9. We have in fact several projects with R.A.R.D.E. in hand at the present time but, as you know, the team at Fort Halstead is now very small and the work is necessarily proceeding rather slowly.

Item 10. I consider sufficient work on pyrotechnics is already in hand and I do not think we could justify increasing our efforts in this field.

Item 11. R.A.R.D.E. have already quite a large contract with Messrs. I.C.I. at Ardeer for this requirement and at the present time I do not think we could justify entering the field seriously, although I did suggest to Mr. Brewin some time ago that we might play a little greater part in the technical supervision of the contract.

Item 12. I understand Dr. Lovecy's Branch is already doing some work in this field and obviously S.C.E. will be brought in when likely compounds emerge.

Item 13. Mr. G.K. Adams and I have already discussed the possibility of extending our activities in the HE field and I think we will shortly have a discussion with Dr. Runnicles of R.A.R.D.E. to see where we can help him. I believe there may be requirements for underwater explosives where aluminized explosives might be very suitable.

Item 14 ...