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PROGRAMME OF RESEARCH FOR E.R.D.E. FOR 1949/50

APPENDIX A

Part I. Liquid Systems

Objective Requirements:

A. Research on the chemistry and operational safety of liquid systems for the production of gas for rocket-propulsion, including their performance and the effect of design factors thereon.

B. Research on the chemistry of HTP for special types of ship-propulsion.

C. Research on the chemistry of liquid systems for the production of gas for mine-clearance by jets, for pressure-operated devices and for other purposes.

Item No.	General Programme	Detailed Investigations	Internal Groups Concerned	Staffing Position	Remarks
	Study of:-				
I(a)	Thermochemistry and kinetics of systems.	Theoretical survey of propellant systems based on:- 1. Nitric acid, hydrogen peroxide, nitrous oxide, tetranitromethane and fluorine compounds. 2. Metals, metal hydrides and covalent metallic compounds as fuels. 3. Ammonia and hydrazine as fuels.	S.P.R. II	A	U.S.A. are working on nitric acid, hydrogen peroxide, nitrogen peroxide, liquid hydrogen, chlorine trifluoride, bromine pentafluoride, fluorine monoxide and borohydrides, and are considering helium hydride and excited hydrogen molecules.
I(b)	Properties of gases at high temperatures.				C.S./R.P.D's requirements are awaited. An E.M.R. contract will probably be placed.
I(c)	Atomisation phenomena of liquids and the characteristics of burners and combustion chambers in relation to propellant performance.	1. Size-distribution study of atomised jets. 2. Effect of different types of injection.	S.P.R. II	A	

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Item No.	General Programme	Detailed Investigations	Internal Groups Concerned	Staffing Position	Remarks
I(f) (contd.)	Jet Phenomena and flow. (Cont'd)	2. Application of these methods to the study of heat transfer from flowing gases.	S.P.R. II	C	
I(g)	Combustion chamber and nozzle cooling and the underlying physico-chemical principles.	1. Measurement of the thermal conductivity of liquid oxygen as a function of temperature and pressure.	S.P.R. II	B	
		2. Study of heat transfer as a function of gas temperature, pressure and rate of flow under rocket conditions.	S.P.R. II	A	
I(h)	Refractories for rocket nozzles and combustion chambers.	1. Means of formation of layers of refractory carbides on graphite nozzles.	S.P.R. II	B	U.S.A. are working on solid refractories and on the formation of layers by additions to fuels, e.g. ethyl orthosilicate.
		2. Behaviour of high melting oxides as combustion chamber linings.	S.P.R. II	B	
I(i)	Properties of flames; temperature, ionisation, spectral absorption and optical discontinuity, with special reference to radio-attenuation.	1. Measurement of attenuation of X and K bands.	S.P.R. II	B	Extensive work in U.S.A.
		2. Measurement of velocity of jets by observing speed of propagation of electrical disturbances by means of radar.	S.P.R. II	B	
		3. Methods for measuring high gas temperature.	S.P.R. II	A	
		4. Spectroscopic survey of molecules and radicles in exhaust jet and combustion chamber.	S.P.R. II	B	

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Item No.	General Programme	Detailed Investigations	Internal Groups Concerned	Staffing Position	Remarks
I(j)	Assessment of performance; proof stand tests on selected mono- and bi-propellants.	1. Improvement of technique of measurement. 2. Combustion chamber geometry as function of pressure, injector characteristics and intrinsic properties of combustion system used. 3. Assessment of atomisers for mono-propellants.	S.P.E. II	A	Division of work on various mono-propellants is as follows: E.R.D.E. Dithekites. E.P.D. Ammonium nitrate solutions. Canada Nitric acid and nitroparaffins. U.S.A. Nitromethane and anhydrous hydrazine.
I(k)	Physical and chemical properties of fuels and oxidants.	Physico-chemical properties of concentrated hydrogen peroxide.			E.M.R. contract with Prof. W.F.K. Wynne-Jones, Durham University.

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Item No.	General Programme	Detailed Investigations	Internal Groups Concerned	Staffing Position	Remarks
I(l)	Physical and chemical stability of fuels and oxidants. Storage of fuels and oxidants.	1. Stability of HTP, with special reference to: (a) Development of satisfactory stability test for use in Service specifications. (b) Relation between conductivity, pH and stability. (c) Effect of dust particles on stability. (d) Study of extraction of chloride ion from plastics by HTP and effect on stability.	S.P.R. II	A	
		2. Study of inorganic and organic stabilisers for HTP, particularly in relation to use of such peroxide with solid catalysts; possible increase of sensitiveness of HTP containing large amounts of organic stabilisers.	S.P.R. II	A	
		3. Compatibility with motor materials.			E.M.R. contract with Laporte Chemicals, Ltd., Luton for H.T.P.
		4. Prevention of freezing of propulsion systems.	S.P.R. II	B	
		5. Prevention of gelling of fuels containing ethyl silicate.	S.P.R. II	C	
		6. Problems of storage of dilute dithekites for monopropellants.	S.E.I. S.P.R. II	B	
I(m)	Safety aspects of the use of liquid systems with special reference to sensitiveness and liability to propagation of detonation.	1. Sensitiveness of liquid systems to impact and friction, including cavity sensitiveness. (see XII(a) and (b)).	S.P.R. I	A	
		2. Development of protective devices; detonation traps etc. (see XII(c)).	S.P.R. I S.P.R. II	A	
		3. Safety of liquid systems under operational conditions. (see XII(a) and XII(d)).	S.P.R. I	A	In collaboration with D.N.O. [illegible].B., R.P.D etc.

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Item No.	General Programme	Detailed Investigations	Internal Groups Concerned	Staffing Position	Remarks
I(o) (contd.)	Development of solid catalysts for hydrogen peroxide. (cont'd)	4. Research on catalysts for the ignition of organic material with HTP products of decomposition - at present Pb-Te stones show promise, but the field must be widened.	S.P.R. II	A	
		5. In conjunction with commercial supplies, evolution of a satisfactory porous porcelain suitable for impregnation with catalytic materials and for use in submarines.	S.P.R. II	A	
		6. Development of laboratory and larger-scale testing of solid catalysts.	S.P.R. II	A	
		7. Development of solid catalysts resistant to high temperature.	S.P.R. II	A	
		8. Fundamental study of the liquid phase reaction of HTP with solid catalysts.	S.P.R. II	B	The vapour-phase reaction is being studied by D.A.E.R. (Admiralty).
I(p)	Solid-liquid and solid-gas systems.	1. Aluminium and magnesium in fine subdivision with water.	S.P.R. II	B	
		2. Ramjet solid fuels.	S.P.R. II	C	U.S.A. are studying emulsions in hydrocarbons and magnesium in coal briquettes for ramjet fuels.
I(q)	General assessment of liquid propellant systems.	Appraisement of all factors, including economics, transport and supply.	S.P.R. II S.E.I.	A	In collaboration with A.D.Amm.P.(X).

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Part II. Plastic Propellants

Objective Requirements: Research on plastic propellant compositions, including methods of manufacture and filling, assessment of performance and influence of physical conditions on performance.

Item No.	General Programme	Detailed Investigations	Internal Groups concerned	Staffing Position	Remarks
	Study of:-				
II(a)	New compositions of maximum performance at minimum flame temperature and of wide operating temperature range.	1. Reduction of flame temperature of NH_4ClO_4 compositions without adverse effect on Force Constant, e.g. substitution of polyisobutylene for polystyrene, addition of coolants.	S.P.R.II	A	Canada is working on propellants based on RDX with rubber, certain polymers and thermo-setting resins. USA are working on compositions based on polysulphide rubber and thermo-setting binders with perchlorates.
		2. Development of compositions with polyisobutylene binders.	S.P.R.II	A	
		3. Study of "Platonisation".	S.P.R.II	A	War Office has agreed to accept two compositions to cover the temperature range if necessary.
II(b)	Rheological properties of propellants in reference to manufacturing processes and widening of the operating temperature range.	Effects of:- 1. Particle size distribution. 2. Particle shape 3. Specific effects of various binders and crystalline substances, wetting agents. 4. Fibrous ingredients. 5. Improvements in methods of measurement and interpretation of results.	S.P.R.II	A	
II(c)	Improvement in the cohesion of the propellant and in the strength and permanence of its adhesion to metal surfaces.	1. Cohesion of propellant.	S.P.R.II	A	
		2. Bond strength of binders between crystalline bodies and metal surfaces.	S.P.R.II	A	
		3. Adhesion of compositions to metal and lacquered surfaces.	S.P.R.II	A	
		See also II(m).			

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Item No.	General Programme	Detailed Investigations	Internal Groups concerned	Staffing Position	Remarks
II(d)	Suppression of flash and smoke.	1. Spectrographic examination of exhaust flames.	S.P.R.II	C	
		2. R.D.X. plastics.	S.P.R.II	C	
II(e)	Supply of ingredients.	1. Survey of manufacturing methods for polystyrene, methyl styrene and polyisobutylene.	S.E.I.	B	
		2. Constitution of lecithin. Identification of active constituent.			E.M.R. contract with Dr. Malkin, University of Bristol.
II(f)	Manufacture of compositions.	1. Effect of variations in incorporation, milling, rolling and de-aeration procedure upon rheological properties and speed of manufacture.	S.P.R.II	B	
		2. Safety of the process at all points (See XII(a)).	S.P.R.II	A	
II(g)	New processes of filling.	1. Vacuum-injection moulding technique.	S.P.R.II	A	The possibility of screw-extrusion is being explored first to avoid, if possible, the expensive installation of the 400 lb. press.
		2. Development of screw-extruder.	S.P.R.II	A	
		3. Development of 400 lb. press.	S.P.R.II	C	
II(h)	Ignition phenomena in relation to reliability and regularity.				No problem exists with current compositions but one may arise with new fillings.
II(i)	Chemical and physical stability.	Evolution of gas on storage.	S.P.R.II	-	Current compositions are satisfactory in this respect, but all batches are examined as a routine.

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II(j)	Sensitiveness to friction, impact etc. and to attack by small arms and fragments.	1. Sensitiveness examination at all stages of manufacture and of finished compositions. (See II(f) 2 and XII(a)).	S.P.R.II	A	
		2. Safety of fillings under operational conditions. (See XII(a)).	S.P.R.II	A	Collaboration with R.A.F.
II(k)	Burning phenomena.	1. Flash radiography of burning charges.	S.P.R.II	C	Collaboration with A.R.E. if work is recommenced.
		2. Charge design for minimal erosion.	S.P.R.II	C	
		3. Correlation of erosion with chemical and physical properties of the propellant.	S.P.R.II	C	
		4. Kinetics of decomposition of NH_4ClO_4.			E.M.R. contract with Dr. Bircumshaw, University of Birmingham.
II(l)	Nozzle erosion.	Suitability of various rocket materials for rocket gases of various compositions and temperatures.	S.P.R.II	B	Dealt with along with I(h)1.
II(m)	Non-destructive testing of filled weapons.	Comparison of supersonic, radiological, acoustic and vacuum methods of test for flaws and completeness of adhesion.	S.P.R.II	B	Collaboration with D.T.R.D., C.S.A.R., and C.I.A.(Air), Harefield.
II(n)	Analysis and general chemistry.	1. Analytical control of raw materials and processing.	S.P.R.I	A	
		2. Climatic deterioration.	S.P.R.I	A	

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Part III. Cordites for Rockets and other Low Pressure Mechanisms

Objective requirement: Research on colloidal propellants of the cordite type for rockets and other low pressure mechanisms so as to improve their performance, serviceability and manufacture and to adapt them to new demands.

Item No.	General Programme	Detailed Investigations	Internal Groups Concerned.	Staffing Position	Remarks
III(a)	Study of:- New compositions of higher performance index for rockets.	Improvement of F.478/148/K (cal.val. 1200) now under test for 6 inch A/T rocket.	S.P.R.I		Staffing depends on results of weapon trials.
III(b)	New compositions for specific low pressure mechanisms.	1. Cool compositions.	S.P.R.I	B	In collaboration with A.R.E.
		2. Compositions with a low temperature correction.	S.P.R.I	A	
		3. Flashless compositions.	S.P.R.I	B	
		4. Compositions with a low pressure index.	S.P.R.I	A	
III(c)	Control of rate of burning.	1. Effect of composition including source and treatment of nitrocellulose.	S.P.R.I	B	
		2. Pressure index; "platonising" ingredients.	S.P.R.I	A	Active work in U.S.A.
		3. Measurements of rate of burning in vented vessel and strand burner.	S.P.R.I	B	
		4. Maintenance of rate of burning at low pressures; effect of special ingredients.	S.P.R.I	C	
III(d)	Improvement of mechanical properties and widening of operating temperature range.	1. Effect of composition on mechanical properties and on their temperature dependence.	S.P.R.I	B	
		2. Deterioration on climatic storage.	S.P.R.I	C	

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Item No.	General Programme	Detailed Investigations	Internal Groups Concerned	Staffing Position	Remarks
III(e)	Methods of producing charges of large diameter.	1. Double-base casting method. (a) Composition and shape of casting materials. (b) Composition of casting solvents. (c) Composition of restrictive containers. (d) Techniques of fabrication of containers and charges. (e) Behaviour of charges.	S.P.R.I	A	Adaptation of U.S. process to suit U.K. conditions.
		2. Direct extrusion; factors affecting consolidation and methods of improving consolidation.	S.P.R.I	B	Work will be extended when the German Mammoth Press has been installed.
		3. Methods of building up charges from segments, discs etc.	S.P.R.I	A	
III(f)	Manufacturing operations.	1. Continuous dewatering of cordite paste.	S.P.R.I	C	Awaiting arrival of plant from Germany.
		2. Screw-extrusion for gelatinisation and pressing.	S.P.R.I	C	
		3. Mechanics of rolling cordite; use of the new research rolling machine for:- (a) fundamental physical and rheological studies. (b) studies for the avoidance of fires during rolling.	S.P.R.I	B	The new research rolling machine is being installed.
		4. Methods of producing patterned sheet for use as casting material.	S.P.R.I	A	

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Item No.	General Programme	Detailed Investigations	Internal Groups Concerned	Staffing Position	Remarks
III(f) (contd.)	Manufacturing operations (cont'd)	5. Fundamentals of die design and the rheology of cordite.	S.P.R.I	B	
		6. Die design and extrusion problems for special shapes.	S.P.R.I	B	Handled as requirements arise.
III(g)	Surface inhibition.	1. Service life of coated charges.	S.P.R.I	B	Carried out as required.
		2. New and improved methods.	S.P.R.I	C	
		3. Interchange of ingredients between coating and basis material; isotony.	S.P.R.I	B	
III(h)	Chemical and ballistic stability.	1. Chemical stability and Service life of new compositions.	S.P.R.I	B	Carried out as required.
		2. Problems connected with large web-sizes (a) study of self-heating. (b) reduction of gas evolution and cracking on storage, in particular study of the effect of stabilisers alternative to carbamite.	S.P.R.I	B	
		3. Study of stability and decomposition of nitric esters.	S.P.R.I	B	E.M.R. contracts with Dr. J.W. Baker, Leeds University and Prof. A.J.Allmand, London University.
III(i)	Sensitiveness and immunity from risk of detonation.	1. Testing of new compositions and new processes to ensure acceptable insensitiveness to impact, friction etc. during both manufacture and use. (See XIIa).	S.P.R.I	B	Carried out as required; A.R.E. gives assistance.
		2. Study of attack by small arms and fragments. (See XIIa).	S.P.R.I	B	Carried out as required in collaboration with O.B. etc.

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Item No.	General Programme	Detailed Investigations	Internal Groups Concerned	Staffing Position	Remarks
III(j)	Manufacture of constituent materials.	1. Mechanical nitration of cellulose.	S.E.I.	C	Plant awaited from Germany. Australia is investigating in relation to wood cellulose.
		2. Stabilisation of nitrocellulose.	S.E.I.	B	Australia is investigating in relation to nitrocellulose derived from wood. E.M.R. contract with Dr. S.M. Neale, Manch. College of Techy.
		3. Direct nitration of wood.	S.E.I. S.C.E.	B	Experiments to check German experience.
		4. Polyvinyl nitrate.			Work being carried out by Canada. Extensive work in U.S.A. on new polymers and other new propellant ingredients.
III(k)	Analysis, calorimetry and general chemistry.	1. Analytical, calorimetric and general chemical services.	S.P.R.I	B	As required.
		2. Climatic trials, in particular of cordite made in Australia and in the curtailed-boiling programme.	S.P.R.I	A	In parallel with ballistic trials by A.R.E.

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Part IV. Cordites for Ordnance

Objective Requirements: Research on cordites for ordnance with particular reference to:-

(i) reduction of gun-erosion,
(ii) elimination of flash and/or smoke on firing,
(iii) improvement of the regularity and stability of ballistics,
(iv) increase of safety in manufacture and use.

Item No.	General Programme	Detailed Investigations	Internal Groups Concerned	Staffing Position	Remarks
IV(a)	Study of:- Reduction of gun-erosion: development of cool propellants of maximum force/flame temperature ratio.	1. Relation between flame temperature and erosion.	S.P.R.I	A	Trials carried out in collaboration wit A.R.E. Confirmatory trials in collaboration with U.S.A.
		2. Relation between propellant gas composition and erosion.	S.P.R.I	A	
		3. Formulation for maximum force/flame temperature.	S.P.R.I.	A	
		4. Effect of free radicles.			E.M.R. contract with Prof.A.R.Ubbelohde Queen's University, Belfast.
IV(b)	Suppression of flash and smoke.	1. Compositions of high nitrogen content.	(S.E.I. (S.P.R.I	B	1 and 2 should require less potassium t ensure flashlessness and so be less smoky in Service charges.
		2. Ultra-cool compositions.	S.P.R.I	B	
		3. Effect of primers and igniters: (a) Smokeless fillings. (b) Venting position in cartridges.	S.P.R.I	B	

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Item No.	General Programme	Detailed Investigations	Internal Groups Concerned	Staffing Position	Remarks
IV(c)	Reduction of temperature coefficient of ballistics.	1. Basic study of erosion of cordites.	S.P.R.I	B	
		2. Cordite erosion as a factor in the temperature coefficient of ballistics.	S.P.R.I	B	
		3. Composition, shape and physical properties of cordites in relation to erosive burning and temperature coefficient.	S.P.R.I	C	In collaboration with A.R.E.
IV(d)	Ignition.	1. Ignition of cool propellants.	S.P.R.I	A	In collaboration with A.R.E.
		2. Means of obtaining a smooth pressure/time relation in burning of cartridges.	S.P.R.I	B	" " " "
		3. Development of cordite-walled igniters	S.P.R.I	A	
		4. Development of smokeless primers.	S.P.R.I	B	
		5. Fundamental studies of ignition.	S.P.R.I	C	
IV(e)	Factors controlling rate of burning.	1. Ballistic trials of a range of cordites made from picrite of various grists.	S.P.R.I	A	In collaboration with C.S.R. and A.R.E.
		2. Surface-moderation for low-pressure, high-velocity guns.	S.P.R.I	C	
		3. Behaviour on burning: tests in the Closed Vessel, Partial Burner and Strand Burner.	S.P.R.I	B	Apparatus being constructed and installed. Extensive work in progress in U.S.A. on the mechanism of burning. E.M.R. contract with Prof.W.E.Garner, Bristol University.
		4. Substitutes for carbamite which do not form a complex with picrite.	S.P.R.I S.E.I.	A	
IV(f)	Ballistic regularity.	Elucidation of reasons for variation of A.C.W. during bulk-production.	S.P.R.I	A	

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Item No.	General Programme	Detailed Investigations	Internal Groups Concerned	Staffing Position	Remarks
IV(g)	Chemical and ballistic stability.	1. Climatic-chemical trials to establish safe life of cordites.	S.P.R.I	A	Will include trials of Australian cordites made from mechanically-nitrated wood cellulose, and cordites from N/C curtailed-boiling programme.
		2. Climatic-ballistic trials to establish regularity life.	S.P.R.I	A	In collaboration with C.S.R. and A.R.E.
		3. Changes in the amount and distribution of volatiles in sealed and unsealed containers.	S.P.R.I	B	
IV(h)	Safety in manufacture and use.	1. Testing of new compositions and new processes to ensure insensitiveness to impact, friction etc. during both manufacture and use. (See XII(a)).	S.P.R.I	B	Carried out as required, with the assistance of A.R.E.
		2. Reduction of liability to cordite fires in tanks.	S.P.R.I	A	In collaboration with F.V.D.E.
		3. "Habitability" trials of cordite containing DEGN.	S.P.R.I	A	In collaboration with Admiralty and M.R.C.
IV(i)	Manufacture and manufacturing technique.	1. Manufacture of new compositions, especially cool cordites, and assessment of new ingredients of cordite.	S.P.R.I	A	
		2. New processes of manufacture (see also III(f)1, 2).	S.P.R.I	B	
		3. Mechanics of rolling cordite (see also III(f)3).	S.P.R.I	B	
		4. Fundamentals of die design and rheology of cordite doughs (see also III(f)5).	S.P.R.I	B	
		5. Improvement of loadability of cordite.	S.P.R.I	B	
		6. Special methods of attaining high density of loading.	S.P.R.I	B	In collaboration with A.R.E.

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Item No.	General Programme	Detailed Investigations	Internal Groups Concerned	Staffing Position	Remarks
IV(i) (contd.)	Manufacture and manufacturing technique (Cont'd)	7. Assessment of the behaviour of picrite of very fine grist during manufacture and performance of cordite.	S.P.R.I	B	
IV(j)	Manufacture of constituent materials.	1. Mechanical nitration of cellulose (see also III(j)1).	S.E.I.	C	Plant awaited from Germany. Work in progress in Australia.
		2. Stabilisation of nitrocellulose (see also III(j)2).	S.E.I.	B	Work in progress in Australia. E.M.R. Contract with Dr.S.M.Neale, Manch. Coll. of Tech.
		3. Direct nitration of wood (see also III(j)3).	S.E.I.	B	
		4. Polyvinyl nitrate (see also III(j)4).			Work in progress in Canada.
		5. New explosive plasticisers.	S.E.I.	B	Work in progress in Canada and U.S.A.
		6. High nitrogen compounds.	S.E.I.	B	Work in progress in U.S.A.
		7. Alternative routes to picrite.	S.E.I.	A	Canada is working on two routes not dealt with by E.R.D.E. E.M.R. contract with Prof. D.M.Newitt, Imperial College, London University under consideration.
		8. Preparation of picrite of very fine grist.	S.E.I.	B	
IV(k)	Picrite-based cordite charges for guns for which they are not already available.		S.P.R.I	B	As required in collaboration with A.R.E.
IV(l)	Analysis, calorimetry and general chemistry.	1. Analytical, calorimetric and chemical services.	S.P.R.I	B	As required.
		2. Climatic trials (see also IV(g) 1 and 2).	S.P.R.I	A	
		3. Calorimetry of cool cordites.	S.P.R.I	A	

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PART V. HIGH EXPLOSIVES

Objective Requirements: A. Research on the synthesis and manufacture of high explosives and of intermediates used in their preparation.

B. Research to devise explosives for stranded line charges for minefield clearance.

Item No.	General Programme	Detailed Investigations	Internal Groups concerned	Staffing Position	Remarks
V(a)	Study of:- Manufacturing processes for explosives and ingredients with a view to more economic use of strategic material, better yields, increased safety etc.				Canada has agreed to be responsible for further development of the acetic anhydride process for R.D.X.
V(b)	Synthesis of new explosives.			C	No particular syntheses are envisaged in this category. Extensive work is in progress in U.S.A. and some in Canada.
V(c)	Study of kinetics of nitration reactions.	Study of kinetics of nitration, in particular the investigation of the active nitrating species in mixed acids in which the H_2O: H_2SO_4 molar ratio is greater than 1.			E.M.R. contract with Prof. Gwyn Williams, Royal Holloway College; work is now proceeding on nitroguanidine.

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Item No.	General Programme	Detailed Investigations	Internal Groups concerned	Staffing Position	Remarks
V(d)	Correlation of molecular structure and energetics with explosive properties.				E.M.R. contract with Dr. A.D. Springall, Manchester University.
V(e)	Nitramines.	Methods of synthesis and structural factors influencing properties			E.M.R. contract with Prof. R.D. Haworth, Sheffield University.
V(f)	Crystallographic work on explosives.				E.M.R. contract with Dr. L.W.H. Small, Birmingham University.
V(g)	Explosives for stranded line charges.	Explosives of the "Nipolit" type:			In collaboration with A.R.E.
		1. Development of manufacturing technique.	S.P.R.I	A	
		2. Modification to use RDX instead of PETN.	S.P.R.I	A	

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Part VI. Initiators

Objective Requirement: Research on the synthesis and manufacture of initiators required for use in detonators, caps and delay systems.

Item No.	General Programme	Detailed Investigations	Internal Groups Concerned	Staffing Position	Remarks
	Study of:-				
VI(a)	Improvements in methods of manufacture of known initiating and delay substances, and evolution of processes for the manufacture of new materials aimed at better performance and safety.	1. Development of production of lead azide of modified properties e.g. compatibility with copper, improved ignitibility and improved binding properties.	S.E.I.	B	
		2. Development of a polymorphic form of lead styphnate less liable to static electrification and to mass-inflammation of large caps.	S.E.I.	B	
VI(b)	Pure chemical substances for use as delays.		S.E.I.	C	
VI(c)	Colloids for the attainment of desired physical properties, e.g. modification of flowing and burning properties, production of non-segregating mixtures.	1. Effect of co-precipitation with colloids.	S.E.I.	B	
		2. Use of surface-active substances for modifying crystal form and size and, hence, the burning properties of initiating substances.	S.E.I.	B	
		3. Surface treatment of initiators to improve flash and/or electrical ignitibility and flowing properties.	S.E.I.	B	

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Item No.	General Programme	Detailed Investigations	Internal Group Concerned	Staffing Position	Remarks
VI(d)	Lead azide substitutes compatible with copper.	1. Research on the preparation of silver azide in a suitable physical form.	S.E.I.	A	
		2. Research on the preparation and properties of lead and thallium salts of nitro-tetrazole, diazo-amino-tetrazole, tetrazolyl azide and nitro-hydroxytriazole.	S.E.I.	C	
VI(e)	Analysis.	Estimation of constituents in freshly manufactured and aged mixtures.	S.P.R.I	B	
VI(f)	Stability.	1. Kinetic studies of thermal decomposition of initiators.	S.P.R.I	B	
		2. Climatic trials.	S.P.R.I	B	
VI(g)	Compatibility with non-explosive ammunition materials.	See item X(d)1.	S.P.R.I	B	
VI(h)	Sensitiveness.	See Part XII.	S.P.R.I	B	
VI(i)	Crystallisation studies.				E.M.R. contract with Dr. W.J. Dunning, Bristol University.

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Part VII. Propellants for Mortars

There is no staff available at E.R.D.E. to carry out research on propellants for mortars. Arrangements have been made for certain research to be undertaken by Australia and Canada.

Part VIII. Propellants for Small Arms

Objective requirements: Research on the preparation of propellants for small arms, in particular for new weapons now under development.

Item No.	General Programme	Detailed Investigations	Internal Group Concerned	Staffing Position	Remarks
VIII(a)	New propellants for existing weapons.				Being done by Australia.
VIII(b)	Propellants for new weapons.	1. Granular nitrocellulose propellants for the 0.270", 0.280" and 0.30/06 calibre weapons. 2. Granular nitrocellulose propellants for the 30 mm. gun "Aden" and for the 20 mm. gun "Aden".			E.M.R. contract with I.C.I. Ltd., Ardeer, in collaboration with A.R.E. E.M.R. contract with I.C.I. Ltd., Ardeer, in collaboration with A.R.E.
VIII(c)	Propellants for higher ballistic performance.		S.P.R.I	C	Under discussion with I.C.I. Ltd., Ardeer. It may be possible for E.R.D.E. to prepare some experimental samples if staff becomes available in the course of the year.

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Part IX. Unorthodox Propellant Systems

Objective Requirement: Research on unorthodox propellant systems for use in rockets, guns, mortars etc.

Item No.	General Programme	Detailed Investigations	Internal Groups Concerned	Staffing Position	Remarks
IX(a)	Study of:- The application of liquid propellants to guns of high muzzle velocity and high rate of fire.	1. Study of rates of burning of mono-propellants at gun pressures.	S.P.R. II	B	In collaboration with A.R.E.
		2. Effect of viscosity of mono-propellants.	S.P.R. II	A	
		3. Ignition systems.	S.P.R. II	B	
IX(b)	The application of plastic propellants extruded "in situ".	Trials of external extrusion apparatus for inserting a plastic charge in the breech of a gun.	S.P.R. II	B	In collaboration with A.D.E. A.D.E. is constructing apparatus for the purpose and E.R.D.E. will supply suitable plastic compositions when the gun is ready for trial and collaborate on safety aspects of design.

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PART X. MATERIALS

Objective Requirement: The application of materials of fabrication, sealing and protection in explosive munitions.

Item No.	General Programme	Detailed Investigations	Internal Groups concerned	Staffing Position	Remarks
X(a)	Sealing Materials - lutings, cements etc.	1. Lutings: Development of compositions retaining plasticity (and therefore satisfactory sealing effect) over increased temperature ranges.	S.P.R.I	B	Arctic and tropical temperature extremes range from -60°F. to + 180°F.; for use with liquid oxygen, temperatures down to - 180°F. are involved. The most promising materials so far encountered are the proprietary "Plaso" waxes.
		2. Cements: Development of improved solventless, self-setting cements.	S.P.R.I	B	Solvent cements dry to porous masses, generally slightly permeable to moisture.
X(b)	Protective materials - special lacquers, varnishes and paints.	1. Lacquers: Development of inert, highly moisture-impermeable lacquers, particularly for use on azide-filled detonators.	S.P.R.I	A.	Recent difficulties in handling corroded fuzes have been ascribed to the formation of copper azide by access of moisture and consequent liberation of hydrazoic acid from lead azide, particularly in presence of shellac. An improved lacquer, based on a stable, inert, filmforming material dissolved in strongly hydrophobic solvents, is an urgent requirement.
		2. Varnishes: Development of highly resistant varnishes from materials other than tung oil, including an "unwettable" varnish for mortar bombs, to decrease loss in range caused by adherent rain-drops.	S.P.R.I	B	

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Item No.	General Progress	Detailed Investigation	Internal Groups concerned	Staffing Position	Remarks
X(b) (Contd.)	Protective materials - special lacquers, varnishes and paints. (Cont'd.).	3. General: Use of corrosion - inhibiting adjuncts in varnishes and paints of all types; study of the mechanism of corrosion inhibition.	S.P.R.I	C	
X(c)	Paper and textile components.	1. Rolled-paper components; development of improved adhesives to impart water-resistance and moisture-impermeability to spirally-wound paper ammunition containers; inter-layering with impermeable foils.	S.P.R.I.	B	In collaboration with Industry and Inter-Services Packaging Panel.
		2. Textile components: treatments of viscose fabrics to render them acceptable alternatives to wool and silk for cartridge bags, igniter bags etc.	S.P.R.I.	B	Considerable progress has been made in developing a rayon (viscose) substitute for silk for cartridge bags, and a corresponding igniter-bag material is now being sought.
X(d)	Compatibility problems.	1. Chemical and physical compatibilities of materials intended for contact with and proximity to explosives.	S.P.R.I.	B	
		2. Study of the suitability of materials for contact with rocket propulsive chemicals:			
		(a) Aluminium alloys with nitric acid.	S.C.E.	A	
		(b) Non-metallic materials with nitric acid.	S.P.R.I	A	
		(c) Metals and non-metallic materials with H.T.P.			E.M.R. contract with Laporte Chemicals Ltd., Luton.

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Item No.	General Progress	Detailed Investigation	Internal Groups concerned	Staffing Position	Remarks
X(e)	Survey and assessment of new materials for application to munitions.	1. Test trials of high melting waxes of British origin in place of imported Carnauba Wax in:- (a) Tracer compositions, (b) Sealing compositions, (c) Compound explosives.	S.P.R.I	A	In collaboration with A.R.E.
		2. Examination of new materials.	S.P.R.I	B	Close collaboration with Design, Industry, and Advisory Services.
		3. Use of polythene as waterproof components of primers.	S.P.R.I	B	The water-proofing of Q.F. primers is especially important
		4. Moulded Bakelised fabric sealing cups for 25 pr. (supercharge) cartridge cases.	S.P.R.I	B	because of the difficulty in water-proofing the case/shell joint.

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Part XI. Chemical Engineering

Objective Requirement: Research on chemical engineering problems in connection with the manufacture of acids, intermediates, explosives and propellants and on chemical engineering problems connected with the use of liquid propellants.

Item No.	General Programme	Detailed Investigations	Internal Groups Concerned	Staffing Position	Remarks
XI(a)	Basic chemical engineering research in connection with plant used in explosives and propellants technology.	1. Theory and practice of drying.	S.C.E.	C	The Chemical Engineering section is in process of recruitment.
		2. Theory of mixing.	S.C.E.	C	
		3. Theory of diffusion and its chemical engineering implications in comparison with distillation.	S.C.E.	C	
		4. Theory of scaling as applied to chemical manufacture.	S.C.E.	B	
		5. Compilation of basic chemical engineering design methods and data.	S.C.E.	B	
XI(b)	Pilot plant design and erection.	Development of plant for alternative picrite syntheses.	S.C.E.	A	
XI(c)	Instrumentation and automatic control as applied to explosives and propellants manufacture; also to liquid propulsion.	1. Application of automatic control to explosives manufacturing processes.	S.C.E.	C	
		2. Methods of metering and proportioning small flows under pressure.	S.C.E.	C	
XI(d)	Materials of construction.	Selection of metals resistant to 98% nitric acid.	S.C.E.	A	
XI(e)	Plant performance tests.	Studies of the concentrating of nitric and sulphuric acids.	S.C.E.	B	

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Item No.	General Programme	Detailed Investigations	Internal Groups Concerned	Staffing Position	Remarks
XI(f)	General engineering services to the Establishment.	1. Design and development of plant and instruments.	S.C.E.	A	
		2. General services as required.	S.C.E.	A	

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Part XIV. Home Office Investigations on Explosives.

Objective Requirements: Research and investigation in connection with explosives submitted by H.M. Chief Inspector of Explosives, including development of methods of examination and assessment.

Item No.	General Programme	Detailed Investigations	Internal Groups Concerned	Staffing Position	Remarks
XIV(a)	Commercial explosives.	1. Control of manufacturers. 2. Suitability and classification of new compositions. 3. Definition of new permitted explosives. 4. Examination of materials from explosives accidents and coal-mine explosions.	H.O.	A	Carried out as required.
XIV(b)	Legal aspects.	1. Examination of samples submitted in connection with offences against the Explosives Act. 2. Examination of materials submitted in connection with Police prosecutions.	H.O.	A	Carried out as required.
XIV(c)	Stability methods.	Investigation into reliability of new methods for estimating stability figure as applied to industrial explosive compositions.	H.O.	A	(i) "A" staffing dependent on supply of suitable staff in 1949. (ii) Continuation of previous work, in particular the assessment of the "Sealed Tube method".

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Item No.	General Programme	Detailed Investigations	Internal Groups Concerned	Staffing Position	Remarks
XIV(d)	Assessment of explosive risk.	Development of method: 1. Communication of main unit explosive charges. 2. Communication of initiating explosive units.	H.Q.	A	Use of vented compartments with pressure/time measurements.
XIV(e)	Friction sensitiveness.	Development of apparatus for estimation of risk with industrial explosive compositions.	H.Q.	A	(i) "A" staffing dependent on supply of suitable staff in 1949. (ii) Chief aim - elimination of personal factor.

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Part XV. Home Office Investigations on Acetylene

Objective Requirements: Research to develop safety methods applicable to acetylene plant and equipment used for chemical synthesis and metallurgical processes both at normal industrial and at high pressures.
Investigation of the causes of explosions in acetylene equipment.

Item No.	General Programme	Detailed Investigations	Internal Groups Concerned	Staffing Position	Remarks
XV(a)	High pressure acetylene: safety requirements.	Explosion characteristics following ignition of acetylene with other reactants at pressures up to 21 atmos., involving measurements of peak explosion pressures and velocities of detonation.	H.O.	A	(i) "A" staffing dependent on supply of suitable staff in 1949. (ii) Effect of addition of specified reactants over range of temperature to 250°C - carried out in special high pressure vessel in course of construction.
XV(b)	Welding gases: design of safety apparatus	1. Measurement of peak explosion pressures. 2. Measurement of velocities of detonation.	H.O.	A	(i) "A" staffing dependent on supply of suitable staff in 1949. (ii) Mixtures with oxygen and air to be investigated over explosive range.
XV(c)	Dissolved acetylene cylinders: safety in use.	1. Investigation of initiation of acetylene decomposition within cylinder.	H.O.	A	Continuation of previous work in specially designed high pressure vessel on porous mass fillings for dissolved acetylene cylinders.
		2. Shock sensitiveness of acetylene in D.A. cylinders.	H.O.	A	
XV(d)	Explosions in industrial acetylene plant.	Elucidation of causes	H.O.	A	

APPENDIX B

Extra-mural Research Contracts relating to the work of the Explosives Research and Development Establishment

File Reference	Title	Subject	Location	Supervisor	Internal Group Concerned	Remarks
7/Chem/58	Physic-chemical problems	(a) Decomposition of acetylene (b) Fundamental theory of nucleation (c) Constitution and synthesis of lecithin (d) Thermal decomposition and vapour-phase burning of liquid explosives, including nitric esters.	Bristol University	Prof. W.E. Garner	S.E.I. S.P.R.I S.P.R.II	
287/Chem/12	Crystallographic work on explosives	(a) Crystal structure studies on high explosives such as RDX (b) Investigations on the anomalons thermal properties of TNT at temperatures near the melting point.	Birmingham University	Dr. L.W.H. Small	S.E.I.	
7/Explosives/4	Kinetics of nitration (nitroguanidine reaction)	Fundamental physico-chemical research on the kinetics of nitration reactions.	Royal Holloway College	Prof. Gwyn Williams	S.E.I.	
7/Chem/73	Mechanism of stabilisation of nitrocellulose	Study by electro-kinetic methods of the sulphuric component of nitrocellulose in relation to the chemistry of stabilisation.	College of Technology, Manchester.	Dr. S.M. Neale	S.E.I.	

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File Reference	Title	Subject	Location	Supervisor	Internal Group concerned	Remarks
7/Chem/16	Methods of synthesis and structural factors influencing the properties of nitramines	A study of the decomposition of primary nitramines in alkaline solution and of synthetical approaches for primary nitramines.	Sheffield University	Prof. R. D. Haworth	S.E.I.	
7/Chem/60	Thermal decomposition of inorganic perchlorates	A study of the thermal reactions occurring during the burning of plastic propellants containing inorganic perchlorates.	Birmingham University	Dr. L.L. Bircumshaw	S.P.R.II	
7/Chem/59	Physico-chemical properties of concentrated hydrogen peroxide	Investigation of some physical, electrical and magnetic properties of concentrated hydrogen peroxide.	King's College, Durham University	Prof. W.F.K.Wynne-Jones	S.P.R.II	
7/Chem/14	Effects of structure on the stability of organic nitrates	A study of the effects of structural and environmental features on the mechanism and the velocity of hydrolysis of organic nitrates in homogeneous media.	Leeds University	Dr. J.W. Baker	S.P.R.I	
7/Chem/60	The production of hydrogen peroxide by photochemical methods	An investigation to explore the possibilities of the production of hydrogen peroxide by photochemical methods.	Cambridge University	Prof. R.G.W. Norrish	S.P.R.II	

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File Reference	Title	Subject	Location	Supervisor	Internal Groups concerned	Remarks
7/Chem/18	Photolysis of nitric esters and nitro bodies		King's College, London University	Prof. A.J. Allmand	S.P.R.I	
6/Chem/562	Research on hydrogen peroxide	(a) Manufacture of HTP of highest attainable purity. (b) Compatibility and corrosion of materials in contact with HTP.	Laporte Chemicals Ltd., Luton		S.P.R.II	
7/Chem/21	Free radicles in the attack of metal surfaces	Investigation of the influence of appreciable concentrations of free radicles in the ambient gases in chemical attack on metal surfaces.	Queen's University, Belfast	Prof. A.R. Ubbelohde	S.P.R.I	
6/Plant & Eq./3711	Mobile liquid oxygen producing plant for rocket propulsion	Advising on the design of a plant to yield oxygen in sufficient quantities for the demands of aircraft rocket motors and projectiles.	British Oxygen Co. Ltd., Morden	-	S.C.E.	
7/Explve/21	Propellant loads for .27, .28 and .30 ammunition	Research leading to the development of ballistically suitable granular powders for the .27, .28 and .30-inch weapons.	I.C.I. Ltd. (Explosives Div.), Ardeer	-	M.X.2	

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File Reference	Title	Subject	Location	Supervisor	Internal Group concerned	Remarks
7/Explve/22	Granular powders for 30 m.m. and 20/30 m.m. aircraft guns	Devising ballistically suitable granular powders for the propellant loads of the 30 m.m. and 20/30 m.m. aircraft guns.	I.C.I. Ltd., (Explosives Div.), Ardeer	-	M.X.2	
7/Explve/23	Molecular structure and energetics investigation	Investigation of the molecular structure and molecular energetics of certain organic compounds, including nitro-compounds, fluorinated hydrocarbons, metallic alkyls and hydrazine derivatives.	Manchester University	Dr. A.D. Springall	S.E.I. S.P.R.II	
7/Chem/25	Oxygen production	Development of ancillary items. Consultation and design of equipment.	Power Jets (R & D) Ltd., London.	-	S.C.E.	
-	Fundamental problems in adhesion	To make a fundamental study of adhesion to metals.	Cambridge University	Dr. C. Kemball	S.P.R.II	Under consideration. To be controlled by D.S.I.R.
-	Fundamental factors affecting adhesion	Development of improved adhesives for Service purposes.	Cambridge University	Dr. F.P. Bowden	S.P.R.II	Under consideration.

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File Reference	Title	Subject	Location	Supervisor	Internal Group concerned	Remarks
-	Sensitiveness of explosives to friction and impact	Increase of fundamental knowledge of the sensitiveness of explosives to friction and impact.	Cambridge University	Dr. F.P. Bowden	S.P.R.I	Under consideration.
-	The conversion of hydrogen sulphide to carbon disulphide	Investigation of the hydrogen sulphide to carbon disulphide reaction in order to promote the thiocyanate process for picrite.	Imperial College, London University.	Prof. D.M. Newitt	S.E.I.	Under consideration.