MINISTRY OF SUPPLY

DIRECTORATE OF MATERIALS AND EXPLOSIVES RESEARCH AND DEVELOPMENT

EXPLOSIVES RESEARCH & DEVELOPMENT ESTABLISHMENT, WALTHAM ABBEY

Programme of Research and Development 1951 - 52

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The Research Programme has been jointly prepared by D.M.X.R.D. and C.S.,E.R.D.E.

SECRET

CONTENTS

INTRODUCTION

Format.

The format of the E.R.D.E. Research Programme has been recast in order to increase its clarity and (it is hoped) its usefulness.

The text is in tabular form. Arbitrary reference numbers are given in the first column, the elements of which refer to the divisions and sub-divisions indicated by the titles in the second and third columns. The information in the fifth and sixth columns amplifies that in the third.

The main sections of the Research Programme have been chosen so as to correspond with the individual responsibilities of the four Superintendents and the head of the Home Office Laboratory. Two of the main sections cover investigations which closely concern two Superintendents jointly.

PRIORITIES.

The projects listed herein are exclusively those on which work will be carried out during the year April 1951 to March 1952. It may be taken for granted, therefore, that a high degree of 'priority' is attached to at least ninety five per cent of them, but owing to the fact that the primary functions of E.R.D.E. are aimed basic research and development - not 'weapons' or 'production' - official Figures of Importance can only rarely be quoted. It should also be borne in mind that official priority classifications are difficult to determine since individual items in the Research Programme may bear upon several applications simultaneously. Columns 4 and 5 should be noted in conjunction. Items regarded by us as of very particular importance or significance are marked with an asterisk (*) in column 4.

Staffing.

No satisfactory method has been found by which the staffing position can be indicated on the Research Programme. Attempts to do so can be very misleading, especially as, in the large majority of cases, small fractions of the individuals' time are involved. The situation must, therefore, be inferred as far as possible from the statements in columns 4 and 5, together with the fact emphasised above that active projects only are listed.

The 'White Paper' strength deployed on this Research Programme in April 1951, including the Superintendents, was approximately 48 Scientific Officers and 90 Experimental Officers.

12. LIQUID PROPELLANT INGREDIENTS (continued)

Main Investigation	Sub-Divisions	Priority	Bearing and/or Origin of Work.	Remarks
Hydrazine 12.3.1. Production (cont.)	12.3.1.2. Dehydration of hydrazine hydrate (EMR).		Future rocket fuel and for liquid propellant gun.	Fisons Ltd.
	12.3.1.3. Reactions of hydrazine and NH_2 radicals in liquid ammonia (EMR).			Prof. M.G. Evans, University of Manchester.
	12.3.1.4. Gas phase catalytic synthesis.			Experimental check on previous work with very short contact times.
12.3.2. Stability.	12.3.2.1. Of hydrazine liquid.			Larger scale tests, samples of about 1 gallon.
	12.3.2.2. Of hydrazine vapour.			
12.3.3. Physical Properties.	12.3.3.1. Of hydrazine.			Will be measured as required.
	12.3.3.2. Of mixtures containing hydrazine.			

/13.1

14. HANDLING RISKS, SENSITIVENESS DETONABILITY (continued).

	Main Investigation	Sub-Divisions	Priority	Bearing and/or Origin of Work.	Remarks
	High-Temperature Stability.	14.8.1. Tests on monopropellants.			Ethyl nitrate, and later propyl nitrate.

21. COLLOIDAL ROCKET PROPELLANTS (Continued)

Main Investigation	Sub-Divisions	Priority	Bearing and/or Origin of Work	Remarks
	21.1.5. Platonised extruded propellant	*	Immediate requirement for 6 sec. Naval ATO unit; also for Seaslug and various large rocket applications.	Compensation for medium performance by low motor tube weight.
Slow-Burning Compositions of High S.I.	21.2.1. Composition for sustainer motors	*	Solid propellants with long burning times and operating at low pressures.	
Improvement of Mechanical Properties and Widening of Operating Temperature Range	21.3.1. Non-cracking equivalent of SU/K	*	SU/K is unsatisfactory in the larger web thicknesses now required.	The use of o-nitrodiphenylamine involves a gelatiniser alternative to carbamite.
	21.3.2. Plasticiser to confer improved low-temperature properties			
	21.3.3. Extrudible high-NC compositions		C.E.A.D. requires hard compositions.	

/21.4

Main Investigation	Sub-Divisions	Priority	Bearing and/or Origin of Work	Remarks
22.2.2. Ammonium perchlorate/ polyisobutylene compositions	22.2.2.1. Ammonium picrate moderant	*	To replace inferior dispolene composition for boost motors	RD.2302, 2304 and 2306 being checked in 5 inch motors in collaboration with R.A.E./R.P.D. for selection of one for larger scale trial.
	22.2.2.2. Oxamide moderant	*	Sustainer motors for D.G.W.R.D.	RD. 2320, 2321 to be checked in 12.5 inch motors in collaboration with R.A.E./R.P.D.
	22.2.2.3. Melamine, picrite and other moderants		General ballistic examination of substances which moderate rate of burning.	
	22.2.2.4. Catalysts to increase rate of burning		Possible C.E.A.D. application to small unguided rockets with high accelerations	Chromic oxide, manganese dioxide, potassium perchlorate, bentonite etc.
22.2.3. Alternative oxidants	22.2.3.1. Ammonium Nitrate	*	E.R.D.E.	Preliminary formulation and temperature cycling
22.2.4. Alternative binders to polyisobutylene	22.2.4.1. Degraded rubber		E.R.D.E.	The supply of British polyisobutylene also under consideration.
	22.2.4.2. Butyl rubber			

23. COLLOIDAL GUN PROPELLANTS.

Main Investigation	Sub-Divisions	Priority	Bearing and/or Origin of Work	Remarks
Development of Charges for New Guns. 23.1.1 Naval Service	23.1.1.1. 3.3" gun for coastal craft.		Requirements for improved weapons specified by Service Departments.	In collaboration with C.S.A.R. and C.E.A.D.
	23.1.1.2. 3"/70 cal.			
	23.1.1.3. 5" Mark N1.	A.10		
23.1.2 Land Service A.A.	23.1.2.1. L.A.A. Bofors Q.F.40 mm.L.70.	A.10+		
	23.1.2.2. L.A.A. Q.F.42 mm.	A.10+		
	23.1.2.3. H.A.A. Short term Q.F.4"/3".	A.9		
	23.1.2.4. H.A.A. Interim Q.F. 4.26"/5.2".	A.9		
	23.1.2.5. H.A.A. Long term Q.F.5".	A.9		
	23.1.2.6. H.A.A. Q.F.5.25" Mk.2 (65 lb. shell)	A.9		

/23.1.3

23. COLLOIDAL GUN PROPELLANTS (continued).

Main Investigation	Sub-Divisions	Priority	Bearing and/or Origin of Work.	Remarks
Charges for High-Performance Guns.	23.3.1. Propellant effects in gun erosion.		Increase of gun life, particularly for new high-performance, high-rate-of-fire A.A. weapons.	In collaboration with C.S.A.R. and U.S. Navy.
	23.3.2. Attack of metal surfaces by free radicals (EHR).		Chemistry of gun erosion.	Prof. A.R. Ubbelohde, Queen's University, Belfast.
	23.3.3. Formulation of optimum propellants.		Increased performance of A.A. and A/T guns.	
Suppression of Flash and Smoke.	23.4.1. Improved flashless propellants for tank guns.	A.10+	To facilitate observation of point of strike .	In collaboration with C.S.A.R.
	23.4.2. Improved non-blinding propellants for Naval guns.			
Bulk Propellant Production.	23.5.1. Lot-to-lot variations of burning rate.	*	Relief of difficulties at proof ranges and filling factories. Reduction of differential ballistic errors.	In collaboration with C.S.A.R, C.C.I., D.O.F(X).
Ignition Problems.	23.6.1. Gunpowder with more regular burning properties.		Control by specification.	In collaboration with C.S.A.R. and I.C.I. Ltd. (Nobel Division).

	propellants.		In connection with N.A.T.O. activities.	

24. CHEMICAL SERVICING AND TESTING OF EXPLOSIVES (continued).

Main Investigation	Sub-Divisions	Priority	Bearing and/or Origin of Work	Remarks
	24.1.2.6. Mechanically nitrated N.C.		Collaboration with Australia.	Climatic-ballistic trials also involved.
	24.1.2.7. Pulp-boiled N.C.		Pulp-boiling reduces time of stabilisation.	
	24.1.2.8. Alternative cellulose supplies.		U.S. and Swedish celluloses.	
24.1.3. Climatic and climatic-ballistic trials (assessment of safe and/or effective lives of propellants).	24.1.3.1. P.Q. - inhibited rocket charges.		Swallow 4", 3" motor.	Climatic trials on samples. Climatic-ballistic trials on finished charges or cartridges.
	24.1.3.2. Rocket charges for 2", 3" and 5" weapons.			
	24.1.3.3. Power cartridges.		Collaboration with D.Arm.D. and industry.	
	24.1.3.4. Picrite-oxamide propellants.			
	24.1.3.5. N.G. substitutes.			
	24.1.3.6. L.S. supplies.			
24.1.4. Analysis and Inspection.	24.1.4.1. Estimation of N.G.			"Round robin".
	24.1.4.2. D.O.F.(X) P2 Analytical Chemists Committee.			

24. CHEMICAL SERVICING AND TESTING OF EXPLOSIVES (continued).

Main Investigation	Sub-Divisions	Priority	Bearing and/or Origin of Work	Remarks
24.2.3. Climatic trials.	24.2.3.1. A.C. bomb detonators.		Collaboration with C.S.A.R.	
	24.2.3.2. Correlation of chemical deterioration with effective life.			
24.2.4. Analytical problems.	24.2.4.1. Tetrazene.		Control by specification.	Present methods unsatisfactory.
	24.2.4.2. Substitutes for Composition A		24.2.1.3.	
Compatibility. 24.3.1. Propellants and H.E. with various materials.	24.3.1.1. Araldite setting cements.		Sealing and jointing of weapons.	
	24.3.1.2. Bostick cements.			
	24.3.1.3. R.D. cements and lutings containing substitute ingredients.			
	24.3.1.4. Rubbers.			
	24.3.1.5. Barrier creams.		Prevention of dermatitis etc.	
	24.3.1.6. Plastics; polystyrene and fromoplast.		Non-metallic A.P. mines.	

24. CHEMICAL SERVICING AND TESTING OF EXPLOSIVES (continued)

Main Investigation	Sub-Divisions	Priority	Bearing and/or Origin of Work	Remarks
	24.4.1.3. Methods for plant control.			General analytical service in E.R.D.E.
24.4.2. C.D.B. Manufacture.	24.4.2.1. Composition of atmosphere over casting powder.		Precautions against "static" ignition of potentially explosive atmosphere.	
	24.4.2.2. Stability of casting liquids.		Safety of liquids in stock.	
General Chemistry.	24.5.1. Fires in A.F.V.		Reduction of possibility and consequences of ammunition fires due to enemy attack.	Collaboration in trials. Compatibility problems arise.
	24.5.2. Micro-Film records.		Safety of Storage	Surveillance trials of celluloid and non-flam films.

25. AMMUNITION SEALING AND PROTECTION (Continued)

Main Investigation	Sub-Divisions	Priority	Bearing and/or Origin of Work	Remarks
25.1.2. Development of new sealing materials	25.1.2.1. Luting serviceable over whole Service temperature range (-80°to +167°F)		Miscellaneous problems on all types of ammunition, referred by Services, O.B. and other branches of E.R.D.E. Often in conjunction with C.S.A.R.	Longer range than, and applicable to many items in 25.1.1.
	25.1.2.2. Improved non-solvent self-setting cements			As possible
25.1.3. Sealing by "cocooning" and sheathing processes	25.1.3.1. Plastic sheaths for fuzes	*		Related to formulation of sensitive azides
	25.1.3.2. Wax dipping of fuzes			
25.1.4. Packaging of ammunition	25.1.4.1. Improvements to rolled paper containers			Handicapped by staff shortage
	25.1.4.2. Sealing of packages			Rubber gaskets
	25.1.4.3. New packaging materials			See 25.1.4.1.

pecial roles | QF cartridges

25. AMMUNITION SEALING AND PROTECTION (Continued)

Main Investigation	Sub-Divisions	Priority	Bearing and/or Origin of Work	Remarks
	25.2.3.2. Adhesives		Miscellaneous problems on all types of ammunition, referred by Services, O.B. and other branches of E.R.D.E. Often in conjunction with C.S.A.R.	A few special applications
	25.2.3.3. Plastics			
25.2.4. Proofing, including rot proofing of cellulose and allied materials	25.2.4.1. Textiles and felts			As possible and as required. Handicapped by staff shortage.
	25.2.4.2. Paper			
	25.2.4.3. Wood			
25.2.5. Lubricants	25.2.5.1. Fuze 208			O.B. trials proceeding
25.2.6. Assessment of new materials				As required e.g. phoryl resins
General Services 25.3.1. Operations ancillary to 25.1 and 25.2	25.3.1.1. Preparation of samples for trial	x		As required. Generally urgent
	25.3.1.2. Formulation of specifications			

26. FINE STRUCTURE OF EXPLOSIVES AND ALLIED SUBSTANCES.

Main Investigation	Sub-Divisions	Priority	Bearing and/or Origin of Work	Remarks
X-Ray Crystallography. 26.1.1. Determination of crystal structure.	26.1.1.1. Initiators: Lead styphnate etc.		Properties of initiators.	Continuation in greater detail of examination of α-, β- and γ-forms of lead styphnate monohydrate.
	26.1.1.2. Oxamide.		Platonising effect in propellants.	Assisted by Hollerith computing installation (EWR arranged by D.W.R.(D))
	26.1.1.3. White compound.		Mechanism of formation of this by-product in the continuous TNT process.	The chemical structure is not known with certainty.
26.1.2. Crystallographic examination.	26.1.2.1. Lead dinitroresorcinate and derivatives.		Manufacture of EDNR (ED 1337 etc.)	To assist in control of production and assessment of product.
	26.1.2.2. Guanidine nitrate and allied substances.		Intermediates in manufacture of picrite.	To assist in control of guanidine nitrate manufacture.
	26.1.2.3. Ammonium perchlorate.		Plastic propellant.	Interpretation of work on thermal decomposition.
	26.1.2.4. T.N.T.		Crystallisation of TNT in poured fillings.	Unusual features in crystallography of TNT being studied further.
26.1.3. Ad hoc problems.				Assistance to other sections.
26.1.4. Crystallographic work on explosions (EWR)				Dr. R.W.H. Small, University of Birmingham.

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31. COMBUSTION STUDIES ON PROPELLANTS AND INGREDIENTS (continued)

Main Investigation	Sub-Divisions	Priority	Bearing and/or Origin of Work.	Remarks
	31.4.1.2. Measurements of rates of burning of selected solid propellants.			To correlate laboratory results with those obtained in rocket motors.
31.4.2. Plastic Propellant.	31.4.2.1. Effect of particle sizes and their distribution.	*	Ballistics of plastic propellants.	
	31.4.2.2. Ignition and burning studies.		Relation between pressure and S.I.	Analysis of gases produced.
	31.4.2.3. Thermal decomposition of inorganic perchlorates (EIR).			Dr. L.L. Bircumshaw, University of Birmingham.
31.4.3. Colloidal Rocket Propellants.	31.4.3.1. Extension of existing facilities and provision of strand burner		Experimental investigation and control of experimental manufacture.	
	31.4.3.2. Effect of platonising agents.		Formulation of compositions.	
31.4.4. Colloidal Gun Propellants.	31.4.4.1. Effect of crystal size of picrite.		Recommendation of an optimum crystal size.	In conjunction with C.S.A.R.
	31.4.4.2. Facilities for closed vessel determination.			Provisi n of apparatus at E.R.D.E. for use in emergency.
31.4.5. Thermal decomposition of crystalline non-ionic compounds.	31.4.5.1. Oxamide (EIR).			Dr. L.L. Bircumshaw, University of Birmingham.

/31.1.5.

40. SUPERINTENDENT, EXPLOSIVES AND INTERMEDIATES.

41. PROPELLANT INGREDIENTS.

Main Investigation	Sub-Divisions	Priority	Bearing and/or Origin of Work	Remarks
Picrite Processes. 41.1.1. The thiocyanate process for guanidine.	41.1.1.1. Materials balance.		To provide an assessment of the process as a basis for future development.	Efficiency of conversion of CS_2 to guanidine.
	41.1.1.2. Direct conversion of H_2S to CS_2 (EMR)			Prof. C.W. Shoppee and Dr. Sykes, University College, Swansea.
	41.1.1.3. Indirect conversion of H_2S to CS_2 (EMR).			Prof. D.M. Newitt, Imperial College of Science and Technology, University of London.
41.1.2. Direct fusion of calcium cyanamide and ammonium nitrate to give guanidine nitrate.	41.1.2.1. Materials balance.		To improve yield of picrite from nitrolim or calcium cyanamide.	Fundamental data for large-scale pilot plant.
	41.1.2.2. Small-scale batch process.			
	41.1.2.3. Small-scale continuous process.			
41.1.3. Nitration of guanidine nitrate.	41.1.3.1. Conditions for continuous process.		Reduction of sulphuric acid usage.	Large pilot plant to be erected and operated.
	41.1.3.2. Kinetics of nitration (EMR).			Prof. Gwyn Williams, Royal Holloway College, University of London.

42. HIGH EXPLOSIVE INGREDIENTS.

Main Investigation	Sub-Divisions	Priority	Bearing and/or Origin of work.	Remarks.
R.D.X. Manufacture.	42.1.1. Control of crystal form for R.D.X./T.N.T., R.D.X./PWX and nipolit.		To improve manufacture, filling and functioning of R.D.X.-rich explosives.	In collaboration with C.S.A.R.
R.D.X.(B) Manufacture.	42.2.1. Nitrator design.			Application of picrite nitration.
	42.2.2. Control of HMX polymorphs.			To assess safety of process.
	42.2.3. Dilution of nitration liquor.			To eliminate dilution.
Methods of Synthesis and Structural Factors Influencing the Properties of Nitramines (EHR).				Prof. R.D. Haworth, University of Sheffield.

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52. CORROSION OF METALS BY CONCENTRATED NITRIC ACID.

No.	Main Investigation	Sub-Divisions	Priority	Bearing and/or Origin of Work	Remarks
52.1	Decomposition and Corrosion in Sealed Tubes		*	D.G.W.R.D.	
52.2.	Closed Vessel Storage Tests			-	
52.3	Corrosion of Welds in Aluminium Alloys			-	
52.4	Stress-Corrosion of Aluminium Alloys			-	

54. DESIGN PROJECTS AND ADVISORY SERVICES.

	Main Investigation	Sub-Divisions	Priority	Bearing and/or Origin of Work	Remarks
	C.D.B. Plant	54.1.1. Design of 24 inch plant at E.R.D.E.	*		Collaboration with S.P.R.I.
	Hydrazine Production Pilot Plant	54.2.1. By ammonolysis of hydrazine sulphate	*		Collaboration with S.P.R.II.
	Mobile Gas Plants	54.3.1. Acetylene production		War Office	Advisory
		54.3.2. Inert gas production			
4.	Boilers	54.4.1. Water Conditioning	*	Engineering services of E.R.D.E.	Advisory

70. HOME OFFICE LABORATORY.

71. INDUSTRIAL EXPLOSIVES.

	Main Investigation	Sub-Division	Priority	Bearing and/or Origin of Work	Remarks
	Examination of Explosives	71.1.1. Control of manufacturers			As required
		71.1.2. Suitability and classification of new compositions			
		71.1.3. Definition of new permitted explosives			
		71.1.4. Materials from explosives accidents and coal-mine explosions.			
		71.1.5. Customs importations			
2	Legal Aspects	71.2.1. Samples submitted in connection with offences against the Explosives Acts.			
		71.2.2. Materials submitted in connection with Police prosecutions.			

INTERNAL DISTRIBUTION

D.N.I.R.D. (4)
C.S.,I.R.D.E. (2)
Dr. Forster
S.P.R.I.
S.P.R.II.
S.E.I.
S.C.E.
Dr. Roberts
Mr. Skelton
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Dr. Lawson
Dr. Williams
Dr. Cooper
Dr. Young
Dr. Pryde
Dr. Walters
Mr. Chard
Dr. Knight
Mr. Munro
Mr. Lester (2)
Registry (1 + stock)

REPORT

11. LIQUID PROPELLANT SYSTEMS.

No.	Main Investigation	Sub-Divisions	Priority	Bearing and/or Origin of Work.	Remarks
11.1	Theoretical Assessment.	11.1.1. Molecular structure and thermochemistry. (EMR)		Fundamental thermochemistry of explosives and propellants.	Prof. H.D. Springall, Univer of Manchester.
		11.1.2. Thermochemistry of fluorohydrocarbons. (EMR)		Possible applications in liquid propellants.	Prof. H.G. Evans, University of Manchester.
11.2	Experimental Assessment.	11.2.1. Nitric acid with selected fuels.		Seaslug.	To determine the effect of p and chemical properties of t fuel on combustion efficienc
		11.2.2. Effect of phosphoric acid in nitric acid on combustion efficiency.	*		Phosphoric acid is a corros inhibitor.
11.3	Monopropellants.	11.3.1. The combustion process in rocket motors.		Monopropellants for A.T.O.	Particular attention to the factor in combustion of mon propellants.
		11.3.2. Ethyl nitrate.	*		Main effort in monopropella
		11.3.3. Dithekite.		E.R.D.E.	Comparison tests as mono- a propellant to assess import mixing process in combustio

No.	Main Investigation	Sub-Divisions	Priority	Bearing and/or Origin of Work.	Remar
11.4	Ignition.	11.4.1. Nitric acid/ kerosine.	*	Seaslug.	Determination of m pressure for satis with pyrotechnic i

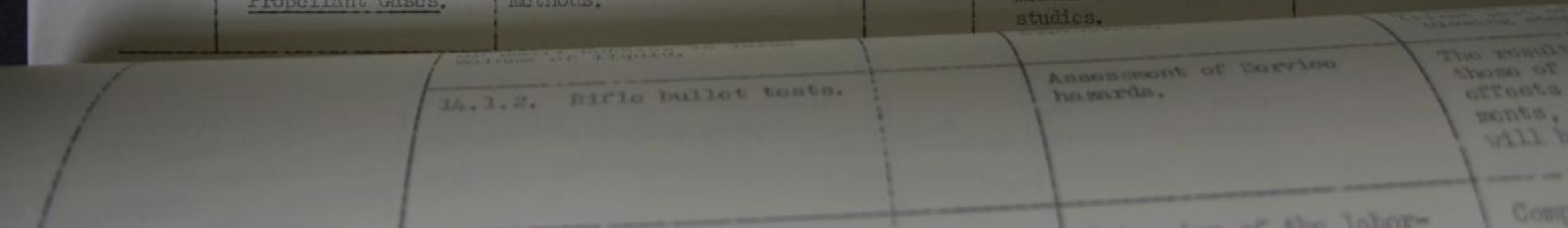
12. LIQUID PROPELLANT INGREDIENTS.

No.	Main Investigation	Sub-Divisions	Priority	Bearing and/or Origin of Work.	Remarks
12.1	Hydrogen Peroxide. 12.1.1. Stability.	12.1.1.1. Bulk storage under tropical conditions.		For Naval requirements.	Completion of work at E.R arrangement of trials at Nigeria.
		12.1.1.2. Mechanism of stabilisation by tin compounds, particularly sodium stannate. (EMR)			Prof. W.F.K. Wynne-Jones, King's College, Universit Durham.
	12.1.2. Compatibility. (EMR)			"Red Shoes" and Admiralty.	Laporte Chemicals Ltd.
	12.1.3. Physical Chemistry of Hydrogen Peroxide Solutions. (EMR)				Prof. W.F.K. Wynne-Jones College, University of D
12.2	Nitric Acid.	12.2.1. Stability.	*	Seaslug.	Mechanism of decompositi vapour and liquid phases
12.3	Hydrazine. 12.3.1. Production.	12.3.1.1. Ammonolysis of hydrazine sulphate.		Future rocket fuel and for liquid propellant gun.	Pilot plant is being des

12.3.1. Production (cont.)	12.3.1.2. Dehydration of hydrazine hydrate (EMR).		Future rocket fuel and for liquid propellant gun.		Pilots [illegible].
	12.3.1.3. Reactions of hydrazine and NH_2 radicals in liquid ammonia (EMR).				Prof. H.G. of Manche

13. PHYSICS OF PROPELLANT GASES.

No.	Main Investigation	Sub-Divisions	Priority	Bearing and/or Origin of Work.	Remarks
13.1	Properties of the Rocket Jet. 13.1.1. Attenuation.	13.1.1.1. Solid and liquid propellants in motors.	*	Guidance of missile.	X band (3.0 cm.)
		13.1.1.2. Fundamental study of effect of propellant constituents and methods of suppressing attenuation.			K band (1.3 cm.) Q band (0.8 cm.)
	13.1.2. Flame Temperature Measurements.			In connection with attenuation and heat transfer work.	Application of line reve methods to rocket jets.
13.2	Heat Transfer. 13.2.1. By Convection and Radiation.	13.2.1.1. In rocket motors.	*		
		13.2.1.2. Spectroscopic measurements of radiation inside rocket motor.			
	13.2.2. Computing Procedures.				Preparation of tabulate calculation of convecti transfer in rocket moto
13.3	Combustion of Propellant Gases.	13.3.1. Spectroscopic methods.		Required for fundamental combustion studies.	Rapid recorder has been constructed.



20. SUPERINTENDENT, PROPELLANTS RESEARCH I

21. COLLOIDAL ROCKET PROPELLANTS

No.	Main Investigation	Sub-Divisions	Priority	Bearing and/or Origin of Work	Remarks
21.1	New Formulations	21.1.1. High-pressure infantry rocket propellant	10 +	To match, dimensionally and ballistically, U.S. propellant for U.S. 3.5. inch H.E.A.T. rocket.	Final production trials p in collaboration with R.O Bishopton.
				To provide charge for C.E.A.D. A/T rocket of greater range and lethality than 3.5 inch	
		21.1.2. Composition with rate of burning intermediate between F565/14/K and F478/148/K.	*	8.4 inch star centred charge for Seaslug boost unit	Must be readily extrudib this large size.
		21.1.3. Slow-burning composition with low flame temperature for liquid propellant ejection (EMR)		Liquid propellant sustainer motor for Seaslug etc.	Compositions F4/3 and F5 produced are ballistical satisfactory but mechani need adjustment. I.C.I. Division) Ltd. (Contrac 6/Gen/1307/C.F.9.a.)
		21.1.4. Extrudible fast-burning compositions similar to F478/148/K.		A number of C.E.A.D. applications similar to the 2 inch air/air rocket.	

/21.1.5

	21.1.5. Platonised extruded propellant	*	Immediate requirement for 6 sec. Naval ATO units also for Seaslug and various large rocket applications.	Compensation by low sensi

21. COLLOIDAL ROCKET PROPELLANTS (Continued)

No.	Main Investigation	Sub-Divisions	Priority	Bearing and/or Origin of Work	Remarks
21.4	Methods of Producing Charges of Large Size.				
	21.4.1. By extrusion	21.4.1.1. The economics of operation of large presses	*		German "Mammoth" press in collaboration with R.N.P.
		21.4.1.2. The back-pressure technique and/or the French long-parallel die.	*	The possibility of extruding charges of a size beyond the capacity of a press cylinder i.e. multi-shot extrusion.	Compositing must be avoid large rocket charges.
	21.4.2. Segmented charge	21.4.2.1. Test of principle in 5 inch motor			
		21.4.2.2. Quest for pourable elastomer			
	21.4.3. Cast double-base propellant	21.4.3.1. Casting powder, casting liquid and restrictive container preparation		Large G.W. boost motor	
		21.4.3.2. Modifications of technique on 6 inch plant for application to full scale plant			Full scale plant to be on South Site at Waltha

22. PLASTIC ROCKET PROPELLANTS

No.	Main Investigation	Sub-Divisions	Priority	Bearing and/or Origin of Work	Remarks.
22.1	Services to other Establishments.				
	22.1.1. Supply of 5 inch light alloy boost motors to R.A.E. for G.W.R.D. trials	22.1.1.1. RD. 2049 (sodium nitrate/dispolene)	*	Mainly for supersonic test vehicles fired at Lark Hill or Aberporth	Manufacture transferred to D.O. Inspection in collaboration wit C.C.I. and C.I.A.
		22.1.1.2. RD. 2201, 2212 (ammonium perchlorate/dispolene)			Manufacture at E.R.D.E. Pressin E.R.D.E. and R.A.E./R.P.D. Transfer of routine work to D.O being arranged.
	22.1.2. Propellants for larger motors	22.1.2.1. RD. 2201 in 8 inch motors	*	R.A.E./R.P.D. development, mainly for D.G.W.R.D.	Larger motor planned
	22.1.3. Supply of rocket motors to C.E.A.D.	22.1.3.1. RD. 2211 in 5 inch motors		Use of plastic propellant in unguided rockets and boosts	
22.2	New Compositions				
	22.2.1. Substitute ingredients for standard compositions	22.2.1.1. American polymethyl styrene	*	To ease supply position of propellants forD.G.W.R.D.	
		22.2.1.2. Alternatives to lecithin			

/22.2.2.

22.2.2. Ammonium perchlorate/	22.2.2.1. Ammonium picrate moderant	*	To replace inferior dispolene composition for boost motors	RD.2302, 2304 and 23 in 5 inch motors in R.A.E./R.P.D. for larger scale tria

22. PLASTIC ROCKET PROPELLANTS (Continued)

No.	Main Investigations	Sub-Divisions	Priority	Bearing and/or Origin of Work	Remarks
22.3	Process Improvements 22.3.1. Particle size of ammonium perchlorate	22.3.1.1. Control of grist	*	Effects of grist on ballistic and rheological properties	Crystallisation and caking wil be studied
		22.3.1.2. Elimination of rolling		E.R.D.E.	Trials of mixtures of controll grists.
	22.3.2. Polyiso-butylene compositions	22.3.2.1. Processing temperatures	*	The use of polyisobutylene of very high viscosity is advantageous	The highest safe operating tem and the processing load requir checking
		22.3.2.2. Load on processing machinery			
	22.3.3. New filling processes	22.3.3.1. Extrusion filling	*	E.R.D.E.	New pugmill to be designed
	22.3.4. Inspection methods	22.3.4.1. Vacuum inspection test	*	C.I.A., C.I.N.O., E.R.D.E., R.A.E./R.P.D.	To be checked with motors larg 12.5 inches diameter.
		22.3.4.2. Web thickness measurements			To be introduced by C.I.A., at E.R.D.E.
	22.3.5. Waterproofing of filled motors		*	E.R.D.E. liaison with R.A.E./ R.P.D. and C.E.A.D.	In collaboration with Material

No.	Main Investigation	Sub-Division	Priority	Bearing and/or Origin of Work	Remarks
22.5	Consolidation and Adhesion 22.5.1. Pressure to consolidate salts compounded with small proportions of binders	23.5.1.1. Salts: inert at first, ammonium nitrate ultimately		Review of field between I.C.I. compositions and plastic propellants. (refer 21.1.3.)	Measurements of density. Rhe of selected pellets. Assessm of safety
		23.5.1.2. Vistac, B.14, graphite			
	23.5.2. Fundamental factors affecting adhesion (EMR)				Dr. F.P. Bowden, University Cambridge.

23. COLLOIDAL GUN PROPELLANTS (continued).

No.	Main Investigation	Sub-Divisions	Priority	Bearing and/or Origin of Work	Remarks
	23.1.3. Land Service T and A/T.	23.1.3.1. A.F.V. 3" gun for A/C.	A.8	Requirements for improved weapons specified by Service Departments.	In collaboration with C.S.A.R. C.E.A.D.
		23.1.3.2. A.F.V. Q.F.120 mm.	A.10+		
		23.1.3.3. Platoon A/T project.	A.10+		
		23.1.3.4. Battalion A/T project	A.10+		
		23.1.3.5. A.F.V. Q.F. 77 mm, 17 pdr. 20 pdr. Improved A.P. performance.	A.10+		
	23.1.4. Small arms and aircraft guns.	23.1.4.1. Propellant loads for .27 .28 and .30 inch ammunition (EHR).			23.1.4.1. I.C.I. Ltd. (Nobel Division) (Contract No.6/Gen/ C.F.9.A).
		23.1.4.2. Granular powders for 30 mm. and 20/30 mm. aircraft guns (EHR).			23.1.4.2. I.C.I. Ltd. (Nobel Division) (Contract No.6/Gen/ C.F.9.A).
23.2	New Charges for Existing Equipments.	23.2.1. L.A. L.A.A. Q.F. 40 mm.		W.O. policy requirement for picrite propellant charges where these are not already approved.	In collaboration with C.S.A.R.
		23.2.2. L.S. T and A/T guns.	A.10+		

23.3.2. Attack of metal surfaces by free radicals (EHR).		Chemistry of gun erosion.	Prof. [illegible], Oxford University, Oxf
23.3.3. Formulation of optimum propellants.		Increased performance of L.A. and A/T guns.	

24. CHEMICAL SERVICING AND TESTING OF EXPLOSIVES.

No.	Main Investigation	Sub-Divisions.	Priority	Bearing and/or Origin of work	Remarks
24.1	Propellant Stability.				
	24.1.1. Effects of storage conditions.	24.1.1.1. Imperfectly sealed S.L. cartridges.		Naval Accuracy Committee.	Trial of Q.F. 4.5" S.L. Cartr
		24.1.1.2. Improved hygrometer for use in Service.		Uncertainty of results of wet and dry bulb measurements.	
		24.1.1.3. Control service to C.S.R. (P. and E.E.).		Effect of volatile matter in propellants as fired on firing results.	Mainly volatile matter estim
	24.1.2. Effects of alternative ingredients and formulations	24.1.2.1. Substitutes for N.G.		Need for greater elasticity in formulating new compositions.	DEGDN and TEGDN being consid
		24.1.2.2. Oxamide, dibutyl phthalate or DEGDN in picrite propellants.			
		24.1.2.3. C.D.B. Compositions.			
		24.1.2.4. Propellants containing potassium perchlorate.		British equivalent to M7 (U.S.) for 3.5" HEAT.	Climatic trials also involve
		24.1.2.5. French and Dutch propellants.		In connection with N.A.T.O. activities.	

	Alkali N.C.		Combustion.
	24.1.2.7. Pulp-boiled N.C.		Pulp-boiling reduces time of stabilisation.
	24.1.2.8. Alternative cellulose supplies.		U.S. and Swedish celluloses.

Climatic-ballist also involved.

24. CHEMICAL SERVICING AND TESTING OF EXPLOSIVES (continued).

No.	Main Investigation	Sub-Divisions	Priority	Bearing and/or Origin of Work	Remarks
		24.1.4.3. 100% surveillance test. Applications and supplies.		Safety of Service stocks, particularly war-time L.S. Inferior stability of some U.S. stocks of N.C. powders.	Collaboration with U.K. and U inspection authorities.
24.2	Initiator Stability.				
	24.2.1. Chemical stability; mechanism and assessment of deterioration.	24.2.1.1. Silver azide.		Substitute for lead azide.	Effects of moisture also invo
		24.2.1.2. Mercury fulminate.			
		24.2.1.3. Substitutions for compositions A and B.		Silver azide is incompatible with antimony sulphide.	
		24.2.1.4. R.D.1650, S9, St3.			
		24.2.1.5. Barium styphnate.			
		24.2.1.6. Manganese/barium peroxide delay composition.		New system proposed by C.S.A.R.	
	24.2.2. Effects of moisture on initiators and initiatory assemblies.	24.2.2.1. Lead azide.			
		24.2.2.2. Fuze 254, unplated and tin-plated.		Formation of copper azide in initiatory assemblies and its prevention.	

		24.2.3.1. A.C. bomb determinations.		Collaboration with C.S.A.R.	
		24.2.3.2. Correlation of chemical deterioration with effective life.			

24. CHEMICAL SERVICING AND TESTING OF EXPLOSIVES (continued).

No.	Main Investigation	Sub-Divisions	Priority	Bearing and/or Origin of Work	Remarks
	24.3.2. Special ingredients.	24.3.2.1. Hydrazine sulphate in propellants.		Rapid-burning propellant.	Some anomalous relations remai to be cleared up.
		24.3.2.2. Potassium perchlorate and common metals.		Use and packing of M7 propellant.	
	24.3.3. Initiators in contact with and proximity to metals plastics sealing materials, varnishes etc.	24.3.3.1. Lead azide.		Continued use of lead azide must be covered.	
		24.3.3.2. Silver azide.			
		24.3.3.3. Substitutes for Composition A.			
	24.3.4. Lead azide with other initiators	24.3.4.1. Substitutes for Composition A.			
		24.3.4.2. R.D.1650.			
	24.3.5. Delay systems with materials listed in 24.3.3.	24.3.5.1. Manganese/barium peroxide; main composition.		New system proposed by C.S.A.R.	
		24.3.5.2. Burster compositions			
24.4	Analytical Control.				
	24.4.1. Ingredients and products made in E.R.D.E.	24.4.1.1. Propellants.			General analytical service in E.R.D.E.
		24.4.1.2. New initiators.			

25. AMMUNITION SEALING AND PROTECTION.

No.	Main Investigation	Sub-Divisions	Priority	Bearing and/or Origin of Work	Remarks
25.1	Ammunition Sealing 25.1.1. Joints in explosive assemblies: sealing materials and methods of application	25.1.1.1. Primers, magazines and bodies		Miscellaneous problems on all types of ammunition, referred by Services, O.B. and other branches of E.R.D.E. Often in conjunction with C.S.A.R.	To be rounded off
		25.1.1.2. Fuzes, including V.T.	*		As required
		25.1.1.3. Detonators, initiators and safety fuzes	*		Related to formation of sensi azides
		25.1.1.4. Mines, grenades, torpedoes etc.			As required
		25.1.1.5. Cartridges QF including SL), A.S. and power cartridges			Recent renewed attention to m closure of A.S. cartridges.
		25.1.1.6. Shell			As required
		25.1.1.7. Igniters and tracers			
		25.1.1.8. Rockets			
		25.1.1.9. Pyrotechnics			

25. AMMUNITION SEALING AND PROTECTION (Continued)

No.	Main Investigation	Sub-Divisions	Priority	Bearing and/or Origin of Work	Remarks
25.2	Materials not Used Primarily for Water-proofing 25.2.1. Protection of exterior and interior surfaces of explosive stores	25.2.1.1. Varnishes and paints for special purposes	*	Miscellaneous problems on all types of ammunition, referred by Services, O.B. and other branches of E.R.D.E. Often in conjunction with C.S.A.R.	Urgent for painting of A/C bo as substitute for RD. 1170,11
		25.2.1.2. Internal lacquering of cartridge cases			As possible
		25.2.1.3. Heat insulating enamel for cartridge cases			As possible
		25.2.1.4. Temporary protectives			As required
	25.2.2. Cartridge bag materials	25.2.2.1. Viscous 25.2.2.2. Box cloth 25.2.2.3. Bonded fabrics			Alternatives to silk. Work t wound up as far as possible o to staff shortage.
	25.2.3. Plastics, rubber and adhesives in special roles	25.2.3.1. Rubber sealing rings and cups in certain	*		

25. AMMUNITION SEALING AND PROTECTION (Continued)

No.	Main Investigation	Sub-Divisions	Priority	Bearing and/or Origin of Work	Remarks
		25.3.1.3. Supervision of bulk manufacture of compositions			Including factory trials
	25.3.2. Advisory service to other Departments				

30. JOINT INVESTIGATIONS, S.P.R.I. and S.P.R.II.

31. COMBUSTION STUDIES ON PROPELLANTS AND INGREDIENTS.

No.	Main Investigation	Sub-Divisions	Priority	Bearing and/or Origin of Work.	Remarks
31.1	Assessment of Combustion Data on Solid Propellants.		*	Formulation of solid propellants for rockets.	
31.2	Calculation of Performances of Solid Compositions.				Particular consideration to m gaseous products in perchlora propellants.
31.3	Theoretical Examination of Solid Propellants.	31.3.1. Systems of consecutive reactions.	*		Especially in relation to plateau and mesa effects. Systems for 31.3.2. to consis of oxidant particles embedded matrix of fuel and vice versa
		31.3.2. Systems in which diffusion rather than kinetics is rate-controlling step.		Mechanism of combustion of plastic and certain U.S. propellants.	
		31.3.3. Theories of burning.			
31.4	Factors Influencing Rate of Burning of Solid Propellants.				
	31.4.1. Basic work on effects of pressure, temperature and particle-size distribution.	31.4.1.1. Oxidants: NH_4ClO_4, NH_4NO_3. Fuels: Paraformaldehyde in the first instance			Fuel is chosen because its behaviour at high temperature known.
	31.4.2. Plastic Propellants.	31.4.2.1. Effect of particle size and their distribution.	*	Ballistics of plastic propellants.	
		31.4.2.2. Ignition and burning studies.		Relation between pressure and S.I.	Analysis of ga
		31.4.2.3. Thermal decomposition of inorganic com-			Dr. L.L. Bir

31. COMBUSTION STUDIES ON PROPELLANTS AND INGREDIENTS (continued).

No.	Main Investigation	Sub-Divisions	Priority	Bearing and/or Origin of Work.	Remarks
31.5	Effects of Platonising Additives on Liquid Systems.		*	Elucidation of plateau and mesa effects.	As more is now known about combustion in liquid systems, e.g. alkyl nitrates, interpretation results should be easier.
31.6	Gaseous Systems.	31.6.1. Rate of burning of NO/CO/H_2 mixtures.		Combustion of colloidal (including CDB) propellants at low pressures.	Methods of catalysing these reactions.
		31.6.2. Combustion in simple $HClO_4$/fuel systems.			Relevant to combustion of plastic propellant.
31.7	Calorimetry.	31.7.1. Facilities for propellant calorimetry		Calorimetric control of experimental manufacture.	
		31.7.2. Thermochemical data on propellant ingredients.		Calculation of gas temperature in plastic and some liquid propellants.	Present data in some cases are unsatisfactory.

for guidance.	41.1.1.2. Direct conversion of H_2S to CS_2 (EMR)		To provide an assessment of the process as a basis for future development.	Prof. C.M. Sheppee, University College
	41.1.1.3. Indirect conversion of H_2S to CS_2 (EMR).			Prof. D.H. Nevil of Science and of London.

41. PROPELLANT INGREDIENTS.
(continued)

No.	Main Investigation	Sub-Divisions	Priority	Bearing and/or Origin of Work	Remarks
	41.1.4. Drying and grinding of fine, sprayed picrite.			To establish processes for large-scale production.	Pilot plants to be erected an operated.
41.2	Nitrocellulose.	41.2.1. Ball powder.		Use in C.D.B. propellant.	Study of U.S. process and alternative procedure.
		41.2.2. Disintegration nitration.		Direct nitration of pulp board.	To be continued to pilot-plan stage.
		41.2.3. Manufacturing trials.			Progressing at factories.
41.3	Nitric Esters.	41.3.1. Ethyl nitrate.		Liquid mono-propellant research.	Preparation as required.
		41.3.2. Effects of structure on stability of organic nitrates (EMR).			Dr. J.W. Baker, University of Leeds.
41.4	Other Materials.	41.4.1. o-Nitrodiphenylamine.		Stabiliser for large colloidal rocket charges.	As required.
		41.4.2. Lead acetylsalicylate.		Mesa effect in rocket propellants.	
		41.4.3. Constitution and structure of lecithin (EMR).			Prof.W.E. Garner, University o Bristol.

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43. INITIATORS.

No.	Main Investigation	Sub-Divisions.	Priority	Bearing and/or Origin of Work	Remarks
43.1	Lead Azide.	43.1.1. R.D.1339, Pure lead azide.	*	Electric detonators for A/T weapons.	For mechanical mixtures with graphite.
		43.1.2. R.D.1335, Lead azide co-precipitated with graphite.		General use in detonators.	
		43.1.3. R.D.1334, Pure lead azide.			To establish manufacture at Ch
43.2	Lead Dinitro-Resorcinate (R.D.1337 etc.)	43.2.1. 30 mm. delay fuze.	*		New compositions to be evolved developed to manufacture.
		43.2.2. Substitute for composition A.		Silver azide is incompatible with composition A.	
		43.2.3. Q.F. primers.			
43.3	Lead Styphnate.	43.3.1. R.D.1318.		Cap compositions.	
		43.3.2. R.D.1303.		Electric cap compositions.	
43.4	Barium Styphnate.			Substitute for composition A for 30 mm. caps.	
43.5	Other Initiators.	43.5.1. Lead azotetrazole.		Low-energy electric initiation.	
		43.5.2. Lead picramate.			

/43.6.

3.6	Sub-Divisions	Priority	Bearing and/or Origin of Work.	Remarks
Crystallisation of Ingredients for Initiator and other Compositions.	43.6.1. Potassium chlorate.		Non-segregating substitute for composition A	

50. SUPERINTENDENT, CHEMICAL ENGINEERING

51. OXYGEN PLANTS.

No.	Main Investigation	Sub-Divisions	Priority	Bearing and/or Origin of Work	Remarks
51.1	Development of Production Plants	51.1.1. Mobile liquid oxygen plants (EMR)	*		British Oxygen Co. Ltd. (Contract No. 6/Gen/1115/C.F.14
		51.1.2. "Air-transportable" oxygen plant (EMR)			British Oxygen Co. Ltd. (Contract No. SB/61767/C.B.39.
		51.1.3. "On site" glider-transportable oxygen plant (EMR)			Ricardo and Co. Ltd. (Contract No. 6/P & Eq./4773/C
		51.1.4. Standard mobile oxygen and nitrogen plant (EMR)	3.		British Oxygen Co. Ltd. (Contract No. 6/P & Eq./7672/C
51.2	Research on Production Plants	51.2.1. Fractionating column packings to give compact air-separation units			
		51.2.2. Assessment of Piazza column as an air-separation unit.			In literature review stage.
		51.2.3. Effect of ships' motion on efficiency of air-separation unit.			British Oxygen Co. Ltd. EMR contract with Admiralty.

52. INHIBITION OF METALS BY CONCENTRATED NITRIC ACID.

No.	Main Investigation	Sub-Divisions	Priority	Bearing and/or Origin	Remarks

53. UNIT PROCESS RESEARCH.

No.	Main Investigation	Sub-Divisions	Priority	Bearing and/or Origin of Work	Remarks
53.1	Plastic Flow in Presses and Extrusion Machines	53.1.1. Flow at solid boundaries and in tubes		Extrusion of solid propellants.	
53.2	Application of Dimensional Similarity to Analysis of Processes				
53.3	Crystallisation	53.3.1 Caking on a cooling surface			
53.4	Absorption of Gases by Liquids	53.4.1. Mixtures of carbon dioxide and ammonia by water			
53.5	Liberation of Gases from Liquids	53.5.1. Foaming			

.1	Main Investigation	Sub-Divisions	Priority	Bearing and/or Origin of Work	Remarks
	C.D.B. Plant	54.1.1. Design of 24 inch plant at E.R.D.E.	*		
	Hydrazine Producti				

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60. JOINT INVESTIGATIONS, S.E.I. AND S.C.E.

61. DESIGN AND OPERATION OF PILOT PLANTS.

No.	Main Investigation	Sub-Divisions	Priority	Bearing and/or Origin of Work	Remarks
61.1	Manufacture of Calcium Cyanamide	61.1.1. Reaction of mixtures of carbon monoxide and ammonia with lime	*	Manufacture of Picrite	Development from laboratory a small scale work (refer 41.1. 41.1.3.1.)
61.2	Manufacture of Guanidine Nitrate, 100 lb./hour	61.2.1. Direct fusion of nitrolim and ammonium nitrate	*		
61.3	Nitration of Guanidine Nitrate	61.3.1. Continuous process with much reduced sulphuric acid usage			

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71. INDUSTRIAL EXPLOSIVES.

			Bearing and/or Origin	Rem

71. INDUSTRIAL EXPLOSIVES (Continued)

No.	Main Investigation	Sub-Divisions	Priority	Bearing and/or Origin of Work	Remarks
71.3	Stability Determination	71.3.1. New methods as applied to industrial explosive composition.			
71.4	Methods of Assessment of Explosive Risk	71.4.1. Communication of main unit explosive charges			Use of vented compartments with pressure/time measurements
		71.4.2. Communication of initiating explosive units			
71.5	Friction Sensitiveness	71.5.1. Apparatus for assessing risk with industrial explosives.			

o.	Main Investigation	Sub-Divisions	Priority	Bearing and/or Origin of Wor	Remarks.

72. COMPRESSED HYDROCARBONS. (continued)

No.	Main Investigation	Sub-Divisions	Priority	Bearing and/or Origin of Work	Remarks
72.5	Decomposition of Acetylene	72.5.1.-Mechanism of thermal decomposition (EMR)			Prof. W.E. Garner, University of Bristol.
72.6.	Industrial Processes Using Compressed Hydrocarbons	72.6.1. Assessment of industrial plant			As required
		72.6.2. Design of safety apparatus			
72.7	Legal Aspects	72.7.1. Control of manufacturers			
		72.7.2. Explosions in industrial plants			
		72.7.3. Examination of samples submitted in connection with offences under the Explosives Acts.			

S.No. 226.
E.No. 305/51.

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