E.15

From: Dr. C.H. Johnson, C.B.E., Director,

EXPLOSIVES RESEARCH AND
DEVELOPMENT ESTABLISHMENT,

WALTHAM ABBEY,

ESSEX.

Ref: WAC/29/020(CHJ/162)

22nd March, 1963.

Dr. B.P. Mullins,
Head of Chemistry, Physics, and
Metallurgy Department,
Ministry of Aviation,
Royal Aircraft Establishment,
Farnborough, Hants.

Dear Mullins,

Panel on Non-Metallic Materials

Herewith my two bits of homework.

As regards the longer, I thought it would be a pity to expand your concluding paragraph (page 24) which was intended to be homogeneous and to strike a resounding final chord. I decided, after consideration, that it could be tacked on appropriately to the end of the previous paragraph on page 23. It makes a very long paragraph but I see no great objection to this.

I am not clear about the "7" stated in Table 1 to be working on Degradation. At the end of last December there were certainly 4 at E.R.D.E. but only 2 are shown - as far as I can see - against R.A.E. If the 7 has to be altered to 6 this part of my paragraph will require revision.

I wish to amend slightly the sentence we decided to insert in the final paragraph on page 24 about the "special situation" existing at E.R.D.E. I would like it to read as follows:-

> A special situation exists at E.R.D.E. were the majority of Materials staff consist of Stone Age men or of individuals transferred en bloc from a moribund Headquarters department (now defunct), or both.

When looking through the debris from yesterday's meeting I found that the last page of Table 2 had become detached. If the separation occurred during the day's discussion I may have omitted to call attention to one or two small corrections, viz. (or namely):-

i) Table 2, Column 1, 4.2 CERAMIC ..... Should read CERAMICS

ii) In the description under 5(1) G & S add "the"; the R.I.P. to read "Breakdown of paints due to climatic or artificial environments studied by the detached film technique".

iii) Are you satisfied with the statement of 4.2(2) M & C? in which reference is made to "..... fuel elements of nuclear reactors".

With kind regards,

Yours sincerely,

It is suggested that the following statement should continue straight on from the end of the existing paragraph on page 23 which ends "... small specialist groups is essential".

It will be seen from Column (4) of Table 1 that out of a total of 34 Work Areas sustained intramurally by R.A.E. or E.R.D.E., or jointly by both the establishments, only in 7 instances does the "Present Effort" exceed 2½ WPG (i.e. two 3s, a 4, a 5, a 6, a 7, and a 13). The team of 4 constitutes J.T.R.U., Australia. The only substantial concentration of effort is to be found in the 13 WPG on "Synthesis of new and model polymers", 1.5(a) G & S, since not only is such work an essential foundation for the advancement of materials as a whole but account must be taken of the necessity to supplement it by extensive characterisation of the products, as was explained in section 5.2.5. The 7 on Degradation (embracing a wide range of important work, mainly long term) is made up of 4 at E.R.D.E. and 3 at R.A.E. The 6 appearing against Ceramics and Refractories, 4.2(b) G & S, represent the entire present strength of the second Materials branch at E.R.D.E. of which the nucleus was recruited from T.I. Ltd. last Spring. It seems unnecessary to comment on the remaining groups which are in excess of 2½ WPG; they are readily identified by reference to Table 1. No fewer than 9 one-man teams exist, and 8 consisting of a half-man which together cover half the total number of intramural Work Areas. It must not be concluded that these represent wasteful dispersion of effort since each main Class of material is sub-divided into several Work Areas and therefore the individual WPG frequently has to divide his time between two or more of them. In other words, a WPG is in most instances a composite man. An interesting feature of Table 3 is its suggestion of a division of labour between the two establishments concerned with Materials research. Thus R.A.E. have Fibres and Lubricants & Hydraulic Fluids to themselves; E.R.D.E. are alone concerned with Adhesives. In the Polymer field the greater part of the effort on Thermosetting Plastics is at R.A.E.; on Thermoplastics at E.R.D.E. This situation is to some extent the result of accidental circumstances, but a conscious effort is being made to exploit it, when possible, in the M.O.A. interest. These lines of demarcation cannot have any degree of permanency since it is often very desirable that closely related work should be carried out in parallel or even

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The appended statement is suggested for inclusion on page 7, second paragraph, following on immediately from "..... attainment on scientific or technical grounds".

We eventually decided, however, that such instances were few and would be best left to ~~emerge~~ arise in the reader's mind from a general appreciation of section 5 of the report. (See, for example, section 5.3 on Adhesives). The small allocation of resources considered adequate for "New transparencies", 1.1(a) M & C, entirely extramural, to some extent reflects doubts about the chances of success). Moreover, the achievability of C & S items, was .....

TABLE 2

~~SCHEDULE~~ LIST OF RESEARCH INVESTIGATIONS ON NON-METALLIC MATERIALS.

The references in column 2 are to items in Departmental Programmes:-

E. means work at ERDE
EE. means extramural work placed by ERDE
C. means work at RAE, C.P.M. Department (numbers are those in Progress Report Chem.2/62 dated Sep
M. means extramural work placed by D.Mat.

The references in the last column are to Work Areas in Table 1.

The symbols (M & C) and (G & S) have the same meanings as in Table 1. (See col.2, Table 1).

REF. NO.	RESEARCH INVESTIGATIONS PROCEEDING	LOCATION		EFFORT	
		INTERNAL	EXTERNAL	W.P.G.	Cost £1000
	(M & C)				
M.2.11	(1) Epoxide resins for transparencies	-	E.M.I.Electronics Ltd.	-	5.0
M.3.12	(2) Mechanical properties of laminates at elevated temperatures	-	Yarsley Research Laboratories	-	2.6
M.3.4	(3) Fatigue and creep characteristics of glass reinforced laminates	-	Bristol Aircraft Ltd.	-	2.7
M.3.14	(4) Fatigue strengths of glass reinforced plastic pressure vessels	-	Bristol Aerojet Ltd.	-	1.4
M.3.15	(5) Short and long-term behaviour of structural plastics	-	Bristol Aircraft Ltd.	-	5.7
M.3.16	(6) Short and long-term behaviour of high temperature resisting materials for radomes	-	Bristol Aircraft Ltd.	-	5.0
C.4.5	(7) Hot tensile strength tests on glass laminates	RAE	-	½	-
M.3.17	(8) Glass fibre reinforced laminates; stress/time/environment relationship	-	Microcell Ltd.	-	8.0
C.41	(9) Rate of loading tests on plastics	RAE	-	½	-
C.4.4	(10) Fatigue investigations	RAE	-	2	-
C.3.1	(11) Winding of glass filament tubes and pressure vessels	RAE	-	2	-
C.3.2	(12) Evaluation of materials for tube winding	RAE	-		
	(G & S)				
C.4.3	(1) Determination of cure of epoxy resins by measurement of insulation resistance	RAE	-	1	-
E	(2) Resin curing investigations of glass fibre laminating resins	ERDE	-	1½	-
M.8.21	(3) Investigation of the glass/fibre interface in glass reinforced plastics	-	RAPRA., Shawbury	-	1.
M.8.23	(4) Investigation of glass finish/resin system by incorporation of glass in particle form	-	Russell House Laboratories	-	2.
	(M & C)				
E	(1) Tensile, shear, compression, creep and other engineering properties	ERDE	-	1	-
M.3.13	(2) Development and evaluation of polyvinyl carbazole foam	-	British Oxygen Ltd.	-	10.
	(G & S)				
E	(1) Thermodynamic, physical and physico-chemical properties in relation to molecular structure	ERDE	-	2½	-
EE.17	(2) Factors affecting the physical properties of polymers	-	University of Manchester	-	2

TERIAL	REF. NO.	RESEARCH INVESTIGATIONS PROCEEDING	LOCATION		EFFORT	
			INTERNAL	EXTERNAL	W.P.G.	Cost £100
		(M & C)				
	M.11.5	(1) Short and long-term behaviour of rubbers for aircraft door & window seals	-	Bristol Aircraft Ltd.	-	1.2
	C.8.2(a)	(2) Non-dermatitic rubbers for face masks	RAE	-	1	-
	E	(3) Ageing	ERDE	-	½	-
		(G & S)				
	EE.21	(1) Stress-relaxation of elastomers and its relation to ageing	-	RAPRA., Shawbury	-	1.0
	C.8.3	(2) Stress-relaxation researches over a wide temperature range	RAE	-	2	-
	E	(3) Deformation behaviour under dynamic and steady loads. Effects of environment	ERDE	-	1	-
	EE.22	(4) Structure breakdown of filler loaded vulcanizates by small deformations	-	RAPRA., Shawbury	-	1.5
	E	(5) Basic studies of solvent/elastomer interactions, swelling and permeability	ERDE	-	½	-
	M.11.2	(6) Correlation of dynamic properties with ability to function as oil sealing materials.	-	J.Walker Ltd.	-	5.0
	M.11.4	(7) Behaviour of rubbers in aircraft fluids	-	RAPRA., Shawbury	-	2.0
	M.11.6	(8) Cross-linking of fluorinated rubbers	-	Yaraley Research Labs.	-	3.0
	C.8.1	(9) Improved cross-linking of high temperature resistant rubbers	RAE	-	2	-
		(M & C)				
	C.13.3, 13.5, 13.6	(1) Degradation of textile materials at high temperatures	RAE	-	2½	-
	C.13.4	(2) Effect of actinic light on physical properties	RAE	-	½	-
NERAL NS)		(M & C)				
	E	(1) Mechanical properties of materials for projectile driving bands and other ammunition components.	ERDE	-	1	-
	EE.4	(2) Assessment of polymers for film forming properties for electronic applications	-	Yaraley Research Labs.	-	2.4
	E	(3) Evaluation of physical properties of materials for R & D Establishments for ammunition and equipment developments.	ERDE	-	½	-
		(G & S)				
	C.1.2	(1) Synthesis of new or model compounds and polymers	RAE ERDE	Various (see below)		
		(A) Compounds containing boron				
	M.1.8	(a) Organoboron-nitrogen compounds and polycondensates containing B-O-C links	-	Northern Polytechnic, London	-	0.8
	M.1.31	(b) Polymers from boron isocyanate	-	Manchester Coll.Sci. & Technology	-	1.8
	M.1.32	(c) Polymers based on substituted	-	Manchester Coll.Sci. & Technology	-	2.0
	M.1.40	(d) Polymers based on borazole	-	Yarsley Research Labs.	-	9.0

F MATERIAL	REF. NO.	RESEARCH INVESTIGATIONS PROCEEDING	LOCATION		EFFORT	
			INTERNAL	EXTERNAL	W.P.G.	Cost £1000
RAL)	EE.8	(B) Compounds containing silicon (a) The development of heat resisting polymers based on inorganic elements.	-	Westfield College, London	-	3.3
	M.1.15	(b) Sil-methylenes and sil-phenylenes	-	ICI.Ltd.,Ardeer.	-	24.0
	M.1.17	(c) Phosphorus-containing silicones.	-	ICI.Ltd.,Ardeer	-	
	M.1.24	(d) Cage compounds containing silicon and nitrogen or oxygen.	-	Birkbeck College, London.	-	1.5
	M.1.35	(e) Cyanosiloxones	-	Man.Coll.Sci. & Technology	-	1.4
	M.1.39	(f) Siloxane-metalloxane derivatives	-	Brit.Resin Products Ltd. Barry.	-	9.6
	C.1.1	(g) Organo-siloxane monomers and polymers	RAE	-	2	-
		(C) Compounds containing phosphorus				
	EE.6	(a) Polymers containing phosphorus–carbon linkages.	-	Man.Coll.Sci. & Technology	-	7.4
	M.1.17	(b) Phosphorus-containing silicones (see silicone - above)	-	I.C.I.Ltd., Ardeer	-	-
	M.1.41	(c) Phosphorus oxynitride	-	Artrite Resins Ltd.	-	10.0
	C.1.2(e)	(d) Phosphorus-nitrogen compounds containing fluorinated groups. (see also fluorine - below)	RAE	-	½	-
	M.1.44	(e) Systems containing phosphonitrilic fluoroalkoxides and phosphimidazolene rings	-	D.Napier & Sons Ltd.	-	6.5
		(D) Compounds containing fluorine				
	M.1.1	(a) Fluorocarbon monomers and polymers	-	Birmingham Univ.	-	3.8
	M.1.2	(b) Metal complexes of fluorocarbons	-	Birmingham Univ.	-	1.6
	M.1.5	(c) Fluorinated polymers containing C - N or C - S linkages	-	Man.Coll.Sci. & Technology.	-	3.3
	M.1.6	(d) Perfluoroalkyl silicon compounds	-	Man.Coll.Sci. & Technology.	-	2.1
	M.1.21	(e) Compounds containing the - N:CF group (see other compounds - below)	-	Man.Coll.Sci. & Technology.	-	2.0
	M.1.22	(f) Perfluorolefin oxides and polymers therefrom	-	Man.Coll.Sci. & Technology.	-	1.8
	M.1.26	(g) Telomerization and polymerization of fluorocarbons by gamma irradiation.	-	Durham Univ.	-	1.3
	C.1.2(d)	(h) Compounds containing fluoroaromatic groups	RAE	-	2	-
	C.1.2(f)	(i) Compounds containing fluoroaliphatic groups	RAE	-	1	-
		(E) Other compounds				
	EE.7	(a) Oligomeric and polymeric compounds of phosphorus, arsenic, antimony and bismuth.	-	Birkbeck Coll. London.	-	1.2
	EE.5	(b) Synthesis of heat resistant polymers	-	Yarsley Res. Laboratories.	-	7.4
	M.1.21	(c) Compounds containing the - N:CF - groups (see fluorine - above)	-	Man.Coll.Sci. & Technology	-	-
	M.1.23	(d) Effect of electric discharges on compounds containing various elements.	-	Birkbeck Coll. London.	-	3.1
	M.1.28	(e) Polymers derived from cyano-derivatives of olefines	-	Man.Coll.Sci. & Technology.	-	1.7
	M.1.29	(f) Polymers derived from nitrogen carbon-oxygen compounds	-	Man.Coll.Sci. & Technology	-	2.6

	REF. NO.	RESEARCH INVESTIGATIONS PROCEEDING	LOCATION		EFFORT	
			INTERNAL	EXTERNAL	W.P.G.	Cos £10
		(E) Other compounds (contd)				
	M.1.30	(g) Metal-carbon polymers	-	Man.Coll.Sci. & Technology.	-	2
	M.1.36	(h) Heterocyclic polymers (see C.1.2.(c) below)	-	Man.Coll.Sci. & Technology.	-	2
	C.1.2(c)	(i) Polymers containing heterocyclic rings (see M.1.36 above)	RAE	-	2	
	C.1.2(b)	(j) Polymers containing aromatic nuclei	RAE	-	3½	
	E	(k) Synthetic work in support of [illegible]	ERDE	-	2	
	EE.	(l) Polymeric organic semi-conductors	-	University of Nottingham	-	2.
	C.2.3 ?	(2) Physical properties of experimental polymers	RAE	-	2	
	EE.	(3) Theoretical study of bond strengths of various inorganic links of interest in the polymer field.	-	Univ.Coll. London.	-	1.
	EE.	(4) Experimental comparison of bond strengths of various inorganic links of interest in the high polymer field.	-	Univ.Coll. London.	-	2.
	EE.22	(5) Effect of crystalline structure on the properties of high polymers.	-	University of Bristol.	-	5.
	EE.13	(6) Permeability of polymer films to water.	-	Imperial College	-	1.
	EE.14	(7) Adsorption of water by polymers	-	University of Reading	-	0.
	E	(8) Fractionation of polymers	ERDE	-	½	-
	E	(9) Degradation by heat, radiation, atomic particles, chemical agencies (e.g. oxygen) or climatic environments	ERDE	-	4	-
	C.2.1	(10) Thermal degradation studies	RAE	-	2	-
	EE.3	(11) Irradiation of explosives and of materials used in explosive stores	-	AERE., Wantage	-	0.7
	E	(12) Dependence of mechanical properties on time-under-stress and temperature; influence of surrounding medium	ERDE	-	2½	-
	EE.19	(13) Dynamic properties of rubbers and plastics	-	RAPRA., Shawbury	-.	1.0
	EE.	(14) Relationship between dynamic properties and molecular structure of high polymers over a wide temperature and frequency range	-	University of Manchester	-	1.0
	EE.1	(15) Effect of temperature, rate of deformation and other variables on the physical properties of fibre-forming polymers	-	CSM/MPRA.,	-	2.5
	E	(16) Development of test methods, including tests for miniature specimens, for research and for obtaining design (e.g. creep) data	ERDE	-	½	-
	M.11.3	(17) Microevaluation of new plastomers and elastomers	-	RAPRA., Shawbury	-	1.6

REF. NO.	RESEARCH INVESTIGATIONS PROCEEDING	LOCATION		EFFORT	
		INTERNAL	EXTERNAL	W.P.G.	Cost p.a £1000
	(M & C)				
EE.	(1) Adhesion of cured rubber surfaces	-	RAPRA., Shawbury	-	0.5
E	(2) Rubber to fabrics and paints to substrates	ERDE	-	1½	-
E	(3) Sealing of ammunition components	ERDE	-	½	-
	(G & S)				
E	(1) Factors in adhesive strength	ERDE	-	1	-
EE.12	(2) Heats of wetting of liquids to solids	-	University of Nottingham	-	1.5
EE.10	(3) Study of electrostatic aspects of adhesion	-	University of Nottingham	-	1.0
EE.9	(4) Influence of design on the strength of a lap-joint	-	Royal College of Science & Technology, Glasgow.	-	1.0
EE.11	(5) Planning of experiments and mathematical interpretation of results of investigations of joints	-	University of Glasgow	-	0.1
	(M & C)				
M.5.10	(1) Greases with improved temperature range	-	Esso Research Ltd.	-	14.0
M.1.45	(2) Synthesis of thermally stable fluids. Arylethers and esters derived from silicon tetrachloride	-	Monsanto Ltd.	-	22.5
	(G & S)				
C.10.1	(1) Lubrication behaviour of molybdenum disulphide systems	RAE	-	1	-
C.10.2 & M.	(2) Lubrication in controlled environments	RAE	University of Cambridge.	1	1.5
	(M & C)				
C.7.1, 7.2	(1) Glass-fibre insulation	RAE	-	1	-
M.2.13	(2) Long-term temperature tests	-	Triplex Safety Glass	-	6.6 (fixed price)
M.2.4	(3) Thermal shock-resisting glass	-	Suntex Safety Glass	-	11.4
M.8.18	(4) Glass fibres of high Young's modulus	-	Deeglass Fibres Ltd.	-	6.0
M.2.1	(5) Strength properties of heat-treated glass	-	Triplex Safety Glass	-	0.5
M.2.14	(6) Silicone K type interlayer for laminated glass	-	Triplex Safety Glass	-	8.0

O.	RESEARCH INVESTIGATIONS PROCEEDING	LOCATION		EFFORT		REFE TO T
		INTERNAL	EXTERNAL	W.P.C.	Cost p.a. £1000	
	(G & S) (1) Strength properties of glass in bulk and fibre form	-	University College, Cardiff	-	1.5	4.1(
	(M & C) (1) Small nose cones for test purposes	-	Plessey Co.	-	11.3	4.2(
.5)	(2) Special graphites for rocket nozzles and fuel elements of nuclear reactors	RAE	-	5	-	4.2(
	(G & S) (1) Strength and resistance to creep at high temperatures	ERDE	-			
	(2) New reinforcing materials; whiskers (silicon nitride) and refractory fibres (titanium nitride); multi-phase systems involving these	ERDE	-	6	-	4.2(
11	(3) Mechanical and electrical properties of ceramics	-	Morgan Crucible Co.	-	1.5	4.2(
10	(4) Development of methods for measurement of dielectric properties at high temperatures	-	Plessey Co.	-	9.9	4.2(
29	(5) High temperature properties of carbides and nitrides	-	Plessey Co.	-	7.0	4.2(
t.) 30	(6) Kinetics of nitridation of silicon	-	BCRA	-	2.0	4.2(
t.) 31	(7) Silicon nitride and silicon carbide	-	BCRA	-	5.8	4.2(
t.) 37	(8) Sintered alumina	-	University of Leeds	-	1.0	4.2(
t.) 44	(9) Physical state of ceramics used in machining processes	-	Manchester College Science and Technology	-	5.0	4.2(
	(M & C) (1) Tests on sub-sonic whirling arm	RAE	-	-	-	5(a)
1.1	(2) Tests on supersonic whirling arm	RAE	-	1	-	5(a)
1.2	(3) Supersonic tests at Pendine	RAE	-	-	1.2	5(a)
1.3	(4) Mechanism of rain erosion	-	University of Cambridge.			
.4			-	2	-	5(b)
.1 .2 .3 .5	(5) Ablation studies relating to high-speed vehicles and rocket nozzles	RAE	-	2	-	5(c)
12.1(a)	(6) Development of white pigments of high refractive index	RAE	-	1	-	5(c)
12.1(c)	(7) Photochemical materials to protect crew	RAE	-	4	-	5(d)
16.2	(8) Measurement of thermal emissivity of painted surfaces for high speed aircraft	ERDE (JTRU)	-	½	-	5(a)
E	(9) Climatic protection	ERDE	-		2.4	5(b)
E	(G & S) (1) Breakdown of paints due to climatic or artificial environments studied by the detached film technique	-	PRS., Teddington	-		
.6.10	(2) Mobility of ions in paint films					

TABLE 1

ASSESSMENT OF RESEARCH INVESTIGATIONS, GROUPED INTO WORK AR

Notes: 1. Assessments in the two sub-columns of column 3 are indicated by n and 0 the lowest (zero markings are inappropriate under "Need")

2. Priorities in column 5 are indicated by letters, A being the high D also indicates probable completion within a ~~short time~~ year.

(1) CLASS OF MATERIAL and Broad Objectives	(2) WORK AREA	(3) ASSESSMENT AREA IN REG NEED	GENE OF INTE
	(M & C) Research undertaken in connection with defined military or civil applications		
	(G & S) ~~Supporting~~ Relevant research to build up scientific and technological capital for ultimate application.		
	(W) For the War Office.		
1. POLYMERIC TYPES			
1.1 THERMOSETTING PLASTICS	(M & C)		
	(a) New transparencies	3	
	(b) Mechanical and physical properties of laminates.	3	
	(c) Glass-reinforced wound tubes.	3	
Aircraft structures; rocket bodies and components; radomes; optical transparencies; ammunition and weapon components (W) boats, vehicles and pontoons (W).	(G & S)		
	(a) Studies of the cure of resins.	2	
	(b) Interfacial studies of glass/resin systems.	2	
1.2 THERMOPLASTICS	(M & C)		
	(a) Tensile, shear, compression, creep and other "engineering" properties.	2	
Optical and electrical transparencies Components of ammunition and weapons (W)	(b) Foamed materials.	2	
	(G & S)		
	(a) Thermodynamic, physical and physico-chemical properties.	2	
1.3 RUBBERS	(M & C)		
	(a) Aircraft and window seals (Short and long-term behaviour)	3	
Aircraft and missile components for use at high and low operational temperatures; flexible oil storage containers and transporters (W); vehicle components (W); face masks.	(b) Non-dermatitic rubbers.	3	
	(c) Ageing (W)	2	
	(G & S)		
	(a) Stress-relaxation phenomena	2 or 3	
	(b) Deformation behaviour under dynamic and steady loads. Effect of environments.	2	
	(c) Basic studies of solvent elastomer interactions, swelling and permeability.	3	
	(d) Cross-linking of fluorinated rubbers.	3	
1.4 FIBRES	(M & C)		
	(a) Degradation of fibres at high temperatures.	3	
Parachutes; arrester gear; inflatable equipment; clothing; towed targets.	(b) Effect of actinic light on physical properties.	1	

(1) CLASS OF MATERIAL and Broad Objectives	(2) WORK AREA (M & C) Research undertaken in connection with defined military or civil applications (G & S) Supporting Research to build up scientific and technological capital for ultimate application. (W) For the War Office.	(3) ASSESSMENT AREA IN RE NEED	GE IN
1.5 POLYMERS (GENERAL INVESTIGATIONS). New and improved plastics, rubbers and fibres, in particular to withstand high and low temperatures and (W) high mechanical stresses, e.g. driving bands.	(M & C) (a) Mechanical and electrical properties. (W) (b) Evaluation of new materials from industry (W) (G & S) (a) Synthesis of new and model polymers. (b) Chemical and physical characterization of new polymers. (c) Molecular and morphological structure, & structure-dependent properties. (d) Fractionation of polymers. (e) Degradation by heat, radiation, atomic particles, chemical agencies (e.g. O_2), or climatic environments. (f) Dependence of mechanical properties on time-under-stress and temperature; influence of the surrounding medium. (g) Development of test methods for research, and for obtaining design data.	3 3 3 3 3 1 3 3 2	
2. ADHESIVES AND SEALANTS Case-bonding of rocket charges; collapsible rubberized tanks and transporters (W); ammunition sealants (W)	(M & C) (a) Adhesion of cured rubber surfaces (W). (b) Rubbers to fabrics (W) and paints to substrates (c) Sealing of ammunition components (W) (G & S) (a) Factors in adhesive strength (b) Distribution of stress in joints, theoretical and experimental (W)	3 3 2 2 2	
3. LUBRICANTS AND HYDRAULIC FLUIDS Aircraft and missile applications, particularly at high temperature; instrument lubrication.	(M & C) (a) Greases with improved temperature range (b) Synthesis of thermally stable fluids. (G & S) (a) Lubrication by solids (b) Lubrication in controlled environments.	3 3 2 3	

(1) CLASS OF MATERIAL and Broad Objectives	(2) WORK AREA (M & C) Research undertaken in connection with defined military or civil applications (G & S) Supporting Research to build up scientific and technological capital for ultimate application. (W) For the War Office.	(3) ASSESSMENT OF WO AREA IN REGARD T NEED	GENERALI OF INTEREST
4. INORGANIC NON-METALLIC MATERIALS	(M & C)		
4.1 GLASSES	(a) Fibrous thermal insulation	3	1
	(b) High temperature testing of sheet	2	0
Reinforced structures for aircraft and missiles; optical transparencies; insulation.	(c) High strength glasses	3	1
	(d) Evaluation of industrial materials.	3	2
	(G & S)		
	(a) Factors affecting strength of glass in bulk and fibre form	3	2
4.2 CERAMICS AND REFRACTORIES	(M & C)		
	(a) Forming techniques.	3	2
	(b) Special graphites.	3	2
Radomes; high temperature applications such as turbine blades, rocket nozzles; nuclear energy applications.	(G & S)		
	(a) Investigations on preparation and properties.	3	2
	(b) Strength and resistance to creep at high temperature; new reinforcing materials; whiskers (silicon nitride) and refractory fibres (titanium nitride); multi-phase systems involving these.	3	3
	(c) Determination of mechanical and electrical properties at high temperatures	3	2
5. PROTECTIVES AND PROTECTIVE AGENCIES (These usually involve more than one of the above classes of materials)	(M & C)		
	(a) Rain erosion	3	0
	(b) Ablation	3	0
	(c) Radiation and thermal protection.	3	0
	(d) Climatic protection	2	2
Radomes and leading edges; rocket nozzles; against nuclear radiation and climatic exposure.	(G & S)		
	(a) Breakdown of paints due to climatic or artificial environments, studied by detailed film technique.	2	1
	(b) Mobility of ions in paint	1	1

December 1961.

Programme of Research 1962/63

Column 1. No. 11

Column 2. Materials Non-Metallic

Column 3. Basic Research

Column 4. Investigation

(a) Chemical and Physical Structure Studies of High Polymers

(i) Model Polymers

A series of model polymers, both liquid and solid, based on the polyethers are being prepared to study the correlation between molecular structure and physical properties. A wide range of properties will be measured, e.g. glass transition and melting temperatures, specific heat and heat of fusion, coefficients of expansion and compressibility, crystallinity etc. Some of the model polymers have now been synthesized.

(ii) Mechanism of Cure

The investigation of the curing mechanism of polyesters continues with a study of the kinetics of the reaction between purified glycol and dibasic acids. The reactions are being followed by determinations of bulk viscosity, water evolution and composition of distillates.

(iii) Molecular Forces

A theoretical study of Van der Waal's forces between the molecules of polymers based on the measured values of polymer dielectric constant at room temperature, the polarisability and density, is being applied to polythene. A technical note has been drafted and the work will be extended to other polymers.

Similarly an attempt is being made to develop a semi-empirical theory correlating the macroscopic room temperature properties of polymers (such as internal pressure, bulk modulus and Young's modulus) with the properties of the individual molecules. This is being applied in the first instance to polythene and a note is being drafted.

/Following

Following the investigation of the novel phenomena of impact resulting in electrification of the area of plastic yield of an impacted specimen of polymer, further work is underway for observing the time of impact. The dynamic modulus obtained by this method is to be compared with values obtained with another novel method viz. from the free vibration of circularly clamped sheets of polymer.

(iv) Compressibility and Thermal Expansion

The work of building up data on the magnitude of intermolecular forces of polymers by measuring compressibilities at constant temperature and volume thermal expansion at constant pressure for solids and liquids is to be continued. Besides providing basic data for a better understanding of the correlation between molecular and macroscopic forces it is hoped this will help in predicting solvent-solid interactions e.g. fuels and lubricating oils with rubber gaskets.

(v) Adhesion

Work will be continued to develop apparatus to study adhesives in pure shear by using an annular jointed "knapkin ring" specimen. The problems to be solved are the elimination of stress concentrations and the variation of apparent shear strengths with joint dimensions.

A preliminary study of the possibility of applying the methods of measuring electrical contact potentials between solids to the case of a polymer film on a metal substrate has been completed. This shows promise and a note has been prepared. An E.M.R. has now been arranged with Nottingham University to continue this study as a means to contribute basic knowledge of adhesion. Supporting studies of adhesion are being pursued by E.M.R.'s at the Royal College Glasgow and the Universities of Nottingham and Glasgow.

/(vi) .....

(vi) Rate of Stressing

A further programme of work is underway to study the effects of time of mechanical stressing and stress-strain behaviour of polymers both at very high rates and for very long times under constant load. The former to give information on the transition from tough ductile behaviour to weak brittle behaviour and the latter to investigate the loss of strength with time under load. Apparatus for applying medium rates of stressing is being constructed in order to complete the spectrum of rates of stressing. Photoelastic apparatus is being used for long stressing time studies of polymers. A supporting study is being pursued extramurally on the behaviour of fibres at high rates of stressing.

(vii) Mechanism of Vapour Permeability

The work of studying the mechanism of water-vapour permeability of polymers by measuring sorption and permeability of polymer films is being progressed at Imperial College, London, and by using other techniques at Reading University.

Similarly an improved method to study the characteristics of solvent (e.g. hydrocarbon liquids) transmission through elastomer materials is being developed.

(viii) Crystalline Structure

Studies of crystalline structure of polymers has made good progress at Bristol University and a new contract is being arranged to extend the work.

(ix) E.M.R. Contracts

Supporting studies being pursued extramurally are:-

(a) Film forming properties of new high polymers.

(b) Investigation of molecular cross-linking of polymers.

/(c) .....

(c) The dynamic properties of Rubber and Plastics.

(d) The carbon black-rubber structure breakdown of loaded rubbers.

(e) The stress relaxation methods as a research technique and for rubber ageing investigation.

(f) Investigation of Polyolefine Oxides - their thermodynamic aspects - and as a means of investigating factors influencing the low temperature behaviour of rubbers.

(b) Polymer Degradation etc.

(1) To study the various molecular factors influencing the stability of polymers to heat, ultra-violet and ionising radiations etc., model compounds which exist as, or are potential, "building blocks" for high polymers, are being prepared for comparative investigations of their stability. The degradation study of polycarbonate is underway. Similarly the investigation of the breakdown mechanism and the influence of molecular grouping on it is being pursued with some of the model compounds already prepared. Also a further programme has been started on high energy irradiation effects on polymers and elastomers. Collaborative facilities to assist in this study are being provided by an E.M.R. with A.E.R.E.

Studies of the efficiency in reducing or preventing the degradation of cellulose in the form of cotton fibres by the application of various metallic compounds including organic metallic compounds to the fibres is continuing. In particular the degradation caused by sunlight is being examined.

(c) New Polymers

The following E.M.R.'s are being continued in the search for new high polymers having improved stability at the higher working temperatures now required in new designs of Service equipment.

(i) Silicone polymers - synthesis and study of properties and factors influencing heat stability.

/(ii) .....

(ii) Phosphorous containing polymers - synthesis and study of properties and factors influencing heat stability.

(iii) Semi-organic or inorganic polymers containing arsenic antimony etc.

(iv) Polymers from Polyanhydrides.

(d) Other supporting studies

(1) Basic exploratory studies of organic semi-conductors at Nottingham University.