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TECHNICAL REPORT No. 71

Handbook of Sealants for Ammunition

R W Bryant

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Handbook of Sealants for Ammunition

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SUMMARY

The many factors influencing the choice of suitable sealing methods for ammunition and allied stores are summarised. The importance of adequate waterproofing is emphasised, in view of the widely varying atmospheric and other conditions to which stores in Service are liable to be subjected.

The properties required in sealing compositions are outlined and performance specifications for lutings and cements are proposed. Details of selected lutings and cements are given on individual data sheets.

The types of joint normally used are considered, and the methods of applying sealing compositions to them are discussed.

A bibliography with abstracts of 24 references is included.

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Reference: WAC/213/012

1 INTRODUCTION

The subject of the waterproofing of ammunition has attracted increased attention in recent years. It has been found that many kinds of ammunition can be rendered useless or even dangerous by ingress of moisture under bad storage conditions; the need for efficient sealing materials and methods is obvious.

A decisive step towards rationalising Service sealing compositions was taken in 1956, when a Manual of Sealing compositions for Ammunition was published,[1] which incorporated information supplied by designers.[2] Five amendments to the Manual were issued at intervals up to 1961, when the pressure of other work became too great for its further continuance. A total of 270 copies have been printed and issued, which confirms the need for such information to be widely disseminated, but it is now out of print, in addition to being out of date.

Since the issue of the Manual, investigations have continued into various aspects of the sealing of joints, and the results of these investigations have been incorporated into this Handbook, which is intended to be an up to date guide to the selection of preferred sealing materials for any of the various types of joint found in ammunition.

The factors which influence the choice of sealing method are described in Section 2, while Section 3 deals with sealing compositions of current importance, including the most useful of the compositions developed and tested in this Establishment. Data sheets for selected cements and lutings are provided in Section 4, and these are indexed (Appendix C). There are other types of sealing

material which are not dealt with in detail. Thus protective coatings and adhesives (seldom used as sealants), rubber O-rings and rubber and plastic washers are excluded.

The situation is continually changing, new compositions being developed and others perhaps becoming unobtainable. In an endeavour to widen the choice of lutings and cements, performance specifications are proposed, laying down criteria against which future sealants may be judged. These specifications are put forward in Appendices A and B, for lutings and cements respectively.

A bibliography with abstracts (in chronological order) is given in Section 6, to enable direct reference to detailed reports and findings. Requests for copies of these reports should be addressed to D/ERDE in the first instance.

Finally, it is hoped that this Handbook, in presenting some of the many factors which must influence the choice of a sealing method suitable for any particular joint, will be of assistance to designers and users. It is emphasised that the Handbook can never be exhaustive nor entirely up to date, and that all users wishing to employ any sealant should seek the latest advice, giving all information relevant to the proposed application.

2 FACTORS CONTROLLING CHOICE OF SEALING METHOD

2 1 Design Considerations

2 1 1 General

Despite a long history of ammunition designs which can only be sealed with difficulty, it remains the fact that many explosives stores are designed primarily to satisfy functioning requirements,

insufficient consideration being given to sealing as an essential element in the design. A frequent result of this approach is a botched-up seal, in which both mechanical seals (washers etc) and sealing compounds are employed. In a well designed joint, one or the other should be sufficient.

2 1 2 Packaging

The waterproofing of any store cannot be fully considered without reference to its package. The ideal is to pack a fully waterproofed store, which may itself consist of an assembly of separately waterproofed components, inside a waterproof package. In emergency it may be necessary to issue incompletely waterproofed stores in waterproof packages, but this is to be deprecated. The user should always be made aware of limitations of this sort. Fully waterproofed stores are sometimes acceptable in non-watertight packages, but care should be taken that the package does not actually promote undesirable effects by entrapping moisture.

Supporting materials enclosed within packages, for example expanded rubbers, plastics, rubberised hair, wood etc, may produce vapours having extremely damaging effects. Protection against these vapours is often essential.

2 1 3 Types of Leak

The following types of leak may occur:

a Leakage of water (or other liquids) under pressure, usually in one direction only, through relatively large holes.

b Diffusion of water vapour through narrow channels; this may result in the special case of c below.

c Breathing - the entry of small quantities of moist air through narrow channels over long periods. This process operates alternately in opposite directions, and is caused by changes of atmospheric temperature and pressure. If the diurnal temperature fluctuation is large, liquid water may condense in the store.

d Permeation of gas, especially water vapour, through materials. This process differs from b above in that the permeating gas dissolves in the external surface of the material, and is regenerated in due course from the internal surface.

The first three conditions can be avoided by proper joint design and the use of suitable sealants. However, permeation through a plastic film can never be wholly prevented, but may be reduced by coating with a relatively impermeable varnish film. The rate of permeation is directly proportional to the area, and inversely proportional to the thickness of the plastic.

Choice of a suitable sealing composition will also depend on the atmospheric and other conditions likely to be encountered, and on the type of joint under consideration.

2 2 Atmospheric and Other Conditions Likely to be Encountered

A store will probably be required to remain serviceable in a wide variety of climatic conditions, ranging from arctic to tropical, at high altitudes in aircraft (either during transport or use), during sea transport and in landing operations (including total immersion). The combination of such factors, if the store is insufficiently sealed and protected, may well render it unserviceable, and possibly unsafe. Some effects of the various conditions are summarised below.

2 2 1 Temperate Climates

The most important characteristic of temperate climates is maintained high humidity, which occurs in spring, autumn and during mild winters. Rain will find its way through an imperfectly sealed joint if exposure is prolonged. Water vapour will gain ingress through channels so narrow that they are impervious to liquid water, and this is accentuated by breathing, as described above (Section 2 1 3). Water vapour will also slowly permeate through plastics.

In every case, moisture is liable to condense on cool internal surfaces and to be retained by hygroscopic explosives and packaging materials. It may result in undesirable chemical reactions such as the formation of dangerously sensitive explosives, or it may support microbiological growth (causing, for example, the rotting of textiles). Further, the failure of electrical circuits may be caused, and indicating or optical instruments may be rendered useless through the formation of a misty film on transparent surfaces.

2 2 2 Tropical Climates

The adverse effects of temperate climates will all

be intensified under tropical conditions. Continued high humidity will be more destructive owing to higher ambient temperatures. The amount of breathing through narrow channels will be increased by large diurnal temperature fluctuations, and permeation is increased both by temperature and by the increase in the quantity of water in the atmosphere.

Tropical climates especially encourage the growth of insects, bacteria and fungi, the attacks by any or all of which on improperly sealed ammunition may render it useless.

Some sealing compositions under maintained high temperatures will be physically or chemically unstable. For example, cements or lutings may soften or even melt, or may react with either the materials of the joint, or atmospheric oxygen, and become hard and brittle.

2 2 3 Desert Climates

Desert regions are characterised by low relative humidities (with a diurnal variation of say 5 to 25 per cent r.h. in the driest season) and high day temperatures (up to 60°C in the shade) falling to -10°C at night in extreme cases. Direct exposure to the sun will give surface temperatures appreciably higher than 60°C. The normal diurnal temperature change is about 40°C and is sufficient to cause considerable expansion and contraction and possibly warping of components. The low relative humidity and high temperatures will cause moisture-containing materials such as wood, textiles and paper to dry out, showing progressive change in size. In addition the sun's direct rays (especially the ultra-violet) may cause rapid chemical deterioration of rubbers, plastics, organic coatings and similar materials.

Dust and sand particles can have an abrasive effect if wind-blown on to exposed sealing compositions

(especially varnishes) and may result in their removal. Dust particles are often hygroscopic and after penetrating very small openings may then cause deterioration due to their absorption of moisture.

2 2 4 Arctic Conditions

The main characteristics of arctic regions are very low temperatures (down to an extreme of about -70°C) and high winds. Although the humidity is low at these temperatures, there may be a high proportion of minute particles of ice. These can penetrate small apertures to the extent of completely filling enclosed spaces, and on thawing cause serious deterioration.

Low temperatures may cause embrittlement of sealing compositions and possibly their fracture due to differential contraction of the materials joined.

2 2 5 High Altitudes

The increasing speed and altitudes being attained by aircraft give rise to special problems since most stores may be transported by air. At an altitude of 60 000 ft (18 000 m) the atmospheric temperature is about -90°C but at supersonic speeds the outside surface of the aircraft may be heated considerably.

The atmospheric pressure at 60 000 ft (18 000 m) is about 1 psi (0.07 bar) which imposes a large pressure differential on a joint and may result in a serious leak, especially if the sealing compound is adversely affected by the low ambient temperature. Such a leak would breathe if the atmospheric pressure varied subsequently.

2 3 Sealing Compositions

Sealing compositions may conveniently be considered under two headings (a) weak (or temporary) and (b) strong (or permanent) sealants. Weak sealants are used when the sealed joint may need to be broken and remade; they do not contribute significantly to the strength of the joint. Examples are washers or O-rings, PTFE tapes, and lutings, which have the consistency of a stiff grease. Permanent sealants, sometimes called cements, are applied to the joint in liquid form and subsequently harden in situ to give joints which are likely to be difficult to undo. However, the mechanical strength of sealing compositions is generally less than that of the constructional materials with which they are used. They should therefore not be called upon to perform more than their legitimate function of sealing gaps between components, which should be fixed to each other by conventional mechanical means (screwing, rivetting, swaging, etc). Grub-screws should be avoided if possible as they may provide a by-pass route for water vapour. If a grub-screw has to be used, both threads should be coated with sealing composition before assembly. An alternative method of sealing is to solder a metal disc into a recess above the top of the grub-screw.

There have been instances where the designer has needed to use cements or adhesives of greater strength than usual for special purposes. Great care should be exercised in selecting compositions of this kind as there are usually explosives compatibility difficulties. For this reason, such materials have been excluded from this Handbook, and it is recommended that requirements to use them in ammunition be referred to the Compatibility Section at this Establishment.

Service sealing compositions are mainly used to seal parallel-threaded joints. They have, to date, been developed in this laboratory, because there are

special requirements more stringent than are normally stipulated in commerce. However, commercial sealants have recently improved in performance, and have been examined in threaded joints. Both temporary sealants (lutings and PTFE tapes and cords) and permanent or setting cements have been assessed and the work summarised.[24] It is discussed below.

2 3 1 Temporary Sealants

PTFE tapes and cord are relatively inefficient in parallel-threaded joints.[22]

One commercial luting (Hylomar SQ 32/S:see Data Sheet No 3) has been found[23] to be comparable as a sealant with the Service materials (Lutings Mk 8 and Mk 9: see Data Sheet No 2), but has inferior low temperature performance, heat stability and water resistance. No temporary sealant tested withstood thermal cycling in heterometallic joints.[22]

These investigations led to statements [19,23,24] of the requirements of a luting. These are that a luting:

i should not slump under its own weight at the highest working temperature,

ii should not be hard and brittle at the lowest working temperature,

iii should remain extensible during application and use,

iv should be tacky and adherent to metallic and other surfaces,

v should be water resistant and have a low water vapour permeability, and

vi should be physically stable and chemically unreactive.

It seems undesirable to restrict the future development of lutings to this laboratory. A performance specification based on the above requirements and on existing specifications, has therefore been drafted (Appendix A). In this, clauses 4 and 6 control slump and consistency at elevated temperature (requirement i); clause 5 controls consistency at low temperatures (requirement ii); clause 7 controls extensibility (requirement iii). Requirement iv is difficult to quantify and is covered in the description (clause 2). To cover water resistance, clause 9 has been drafted, based on work in this laboratory. Water vapour permeability is difficult to measure, although it has been done,[3] and it has been decided to rely on clause 9 to exercise some control of this aspect. The presence of inorganic fillers may lower water resistance, hence the control of ash content (clause 11). Requirement vi is covered by clauses 8 and 10, and indirectly by clause 3 for compatibility with explosives, for which freedom from lead is also a requirement (clause 12).

The design of joints using sealing washers and O-rings has not been investigated here, but grades of rubber and plastic which are compatible with explosives will be recommended on application to this Establishment. The development of washers, O-rings etc is mainly by commercial firms. The British Hydromechanics Research Association carries out research into dynamic seals and is a valuable source of information on mechanical seals in general. The use of such seals in fuzes has been studied.[16]

If a sealant is used in conjunction with a washer, it is advisable to apply it to both sides of the washer before assembly. All joints must be screwed home as firmly as possible without displacing the washer.

2 3 2 Permanent or Setting Cements

Twenty four commercial cements, including polysulphides, polyurethanes, epoxides, silicones, surface-catalysed

compositions and compounds hardened by atmospheric moisture, have been tested here as thread sealants.[24] Several were superior to the Service material (RD 1286) in a stringent thermal-cycling trial. The experience gained permits a statement of the requirements for a general purpose waterproofing cement. These are that the freshly mixed cement should:

i have a viscosity of not less than 1 N s/m^2 (10 poise) and not more than 250 N s/m^2 (2500 poise),

ii have a pot-life not less than 1 hour,

iii have a maximum setting time of 24 hours, and

iv have a contraction not more than 4 per cent by volume while setting.

The set cement should:

v be flexible over a wide temperature range and should not flow at high temperatures,

vi be physically stable and chemically unreactive, and

vii have a cohesive strength, and adhesive shear strength with all the adherends, not less than one-third its rigidity (shear) modulus.

Again, it seems undesirable to restrict the future development of cements to this laboratory. A performance specification based on these requirements has therefore been drafted (Appendix B). In this, clause 3 controls the initial viscosity and pot-life, requirements i and ii. The upper limit of 250 N s/m^2 represents the maximum viscosity for convenient application. Clause 4 controls the

setting time, requirement iii . The contraction on setting (clause 5, requirement iv) is conveniently followed by measuring the change in density with time. Requirement v is covered by clauses 7 (resistance to flow at elevated temperature) and 10 and 12 (by implication - a rigid cement will not comply with these clauses). Requirement vi is covered by clause 6 and by the requirement for compatibility with explosives. Requirement vii (clause 12) arises from the investigation into the maintenance of seals between heterometallic assemblies during thermal cycling,[24] as discussed in Section 2 5 1 below. The implicit requirement for water resistance is met by clause 11.

2 4 Application of Sealing Compositions

2 4 1 General

Many metallic components of stores when manufactured are treated with temporary protectives such as lanoline or grease. Before applying sealant, it is important that they should be thoroughly degreased, since the temporary protective will prevent adequate adhesion of the sealant and may also cause it to deteriorate. Vapour phase degreasing is strongly recommended. The process of degreasing with a solvented rag may sometimes be unavoidable, but this method necessitates regular change of solvent bath and rags, ideally on a counter-current principle, in which a number of solvent containers (each with its rags) are used in sequence, the first (and presumably dirtiest) being discarded at intervals and a clean bath and rags added at the end of the line. The solvent must be removed from the surfaces to be bonded before applying sealant.

Sufficient sealant should be applied for the excess to be extruded all round the joint (the "witness"), which may then be removed by means of a rag damped (not wet) with suitable solvent. Cements must then be allowed a period to set before handling the store.

Difficulty may be experienced in sealing a store in which a threaded plug is finally assembled, if this action considerably compresses the contained air (as is sometimes the case in the assembly of fuzes into filled shell and of magazine into fuzes). In such cases consideration should be given to the provision of a shoulder and a suitable rubber or plastic sealing washer.

Normally visual inspection of an assembled store will be insufficient to determine whether a seal is

perfect. It is recommended that an agreed proportion of the assemblies be subjected to a simple leak test, by the application of a vacuum or air pressure at a differential pressure of about 5 psi (0.3 bar). Such a test need be neither lengthy nor laborious, and has the advantage of promoting efficient sealing techniques in the filling factory.

2 4 2 Application of Lutings

Luting Mk 9 may not be applied molten, because its desirable properties depend critically on the rate of cooling when solidifying. Neither is it suitable for thinning with any solvent. It may be warmed uniformly to about 60°C if this will facilitate application; pressure guns may also be used. The commercial luting Hylomar SQ 32/S, which is unfortunately not generally suitable for Service ammunition applications,[23] is obtainable diluted with solvent, so that it may be applied with a brush. The solvent should be allowed to evaporate before making a joint, however, otherwise a porous joint may result as the solvent escapes.

2 4 3 Application of Cements

Cements setting by loss of solvent are not recommended.[6] Chemically setting cements should be used in the manner recommended by the supplier, Many of these compositions are too viscous to apply by brush,but a spatula or palette-knife may be used. Alternatively apparatus is now commercially available for continuously metering and mixing two-component cements, and the mixed cement may be fed into a suitable applicator.

One part cements, which set without adding catalyst, are now coming into use. Examples are Loctites, which set to rigid solids, and room temperature vulcanising (RTV) silicone rubbers in which the curing reaction is initiated by the water vapour in the air. The one part cements have obvious attractions for

automated assembly lines; a potential disadvantage of Loctites is that they may find their way into the store and lock the mechanism of, for example, a fuze.

2 5 Types of Joint

The majority of joints in ammunition are threaded, but turned-over and swaged, and sleeve joints also occur. These joints are discussed in turn below. Unless otherwise stated, metal/metal joints are intended. Joints in plastics are considered separately (Section 2 5 4).

2 5 1 Threaded Joints

The role of sealants in sealing threaded joints, which form the majority of ammunition closures, is now well defined. The practical experience that joints made with solvented compositions do not remain sealed has been confirmed by systematic experiment.[6] The relative contribution of sealing compositions and joint design to the sealing of threaded joints have been assessed.[8,11]

When components having the same coefficient of thermal expansion are considered,[8] the most important single factor in the sealing of threaded joints is the quality of the sealing composition. The next most important factor is the combination of joint design with mode of application of the sealing composition, as shown in Fig 1, page 17. Application to both threads is preferable, if it is permissible to force composition into the assembly. It is also preferable to apply the sealant to the whole of the threads, so that a complete ring of material is extruded when the joint is closed. If less composition is used, it is then preferable to apply it completely round the periphery of fewer threads, rather than in a series of dabs. Sealing is also improved by screwing on to either (a) an external shoulder if composition is applied to the male threads, or (b) an internal shoulder if composition is applied to the female threads. A joint not screwed on to a shoulder is relatively difficult to seal. Normally, factors such as the metal

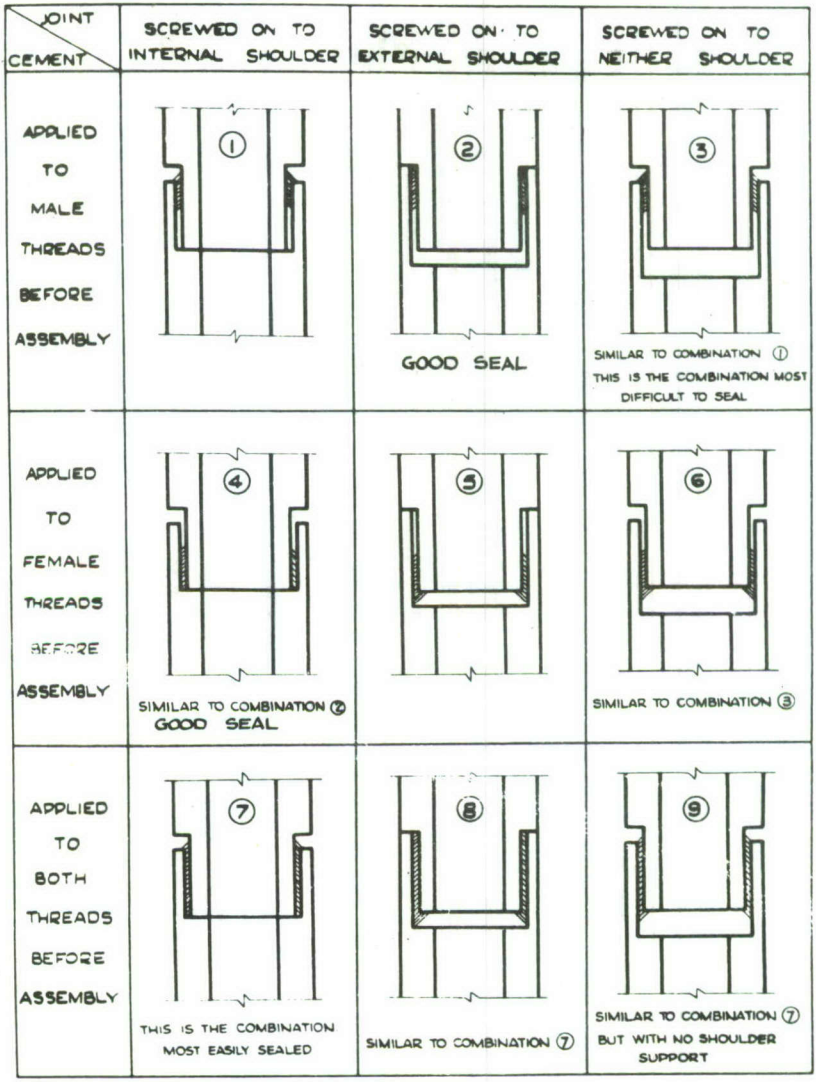


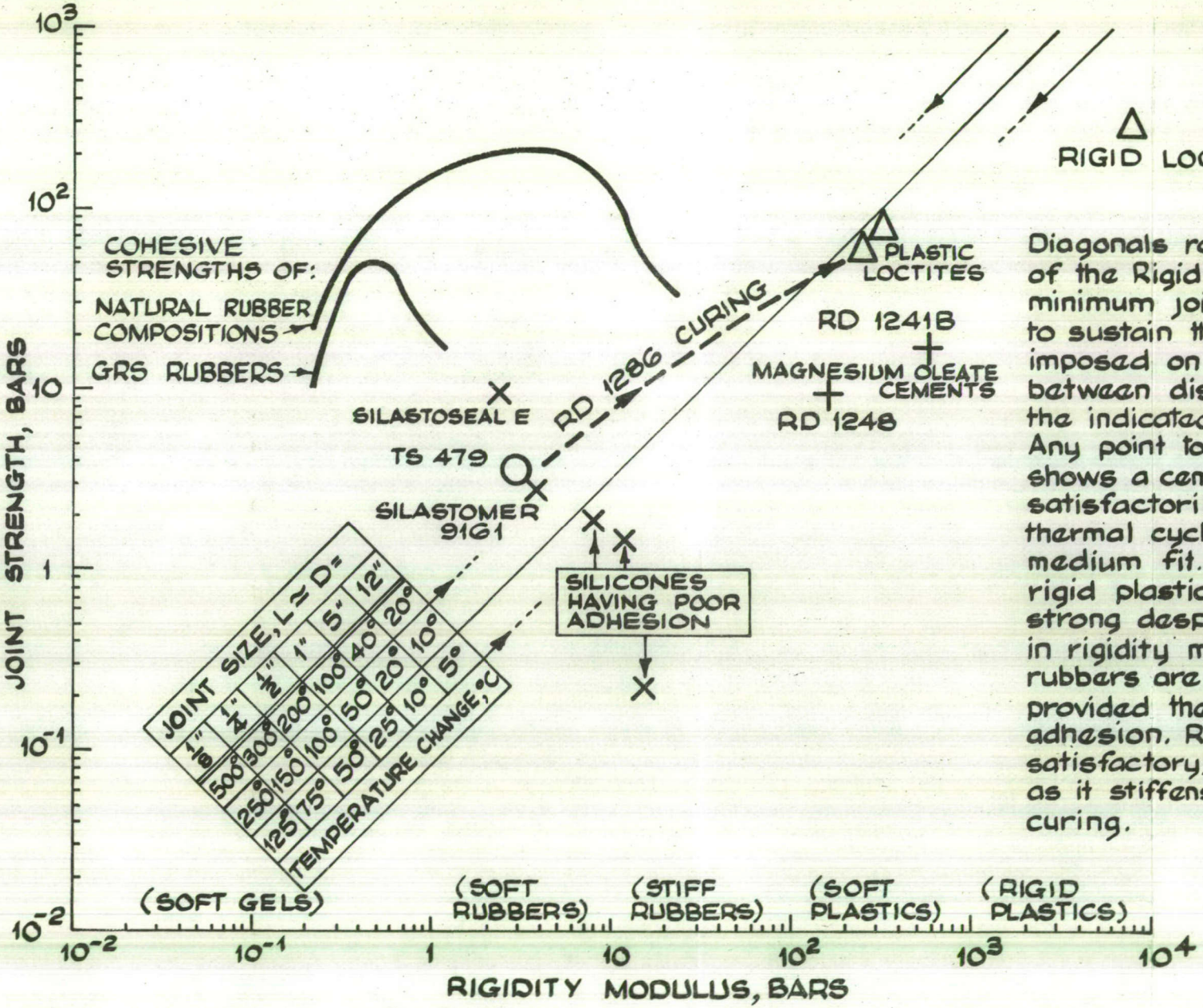
FIG. 1 **THE COMBINATIONS OF THREADED JOINT DESIGN WITH METHODS OF APPLYING SEALING COMPOSITION.**
The final position of sealing composition after assembly is indicated.

used, the dimensions of the joint, and even incorrect application of the sealing composition, are individually of minor importance, although the metal of which the joint is made may affect the quality of sealing when surface-catalysed compositions (eg Loctites) are used.[15]

The effect of mechanical stresses caused either by cyclic changes of temperature, or by impact, on the sealing of various threaded joints has been determined.[11] Thermal cycling does not affect the sealing of joints unless the components are made of dissimilar metals (heterometallic joints). The most important single factor in the resistance of such joints to thermal cycling is the joint design (external, internal, or no shoulder), coupled with mode of application of sealing composition. The next most important factor is the quality of the sealing composition. There is no significant difference between the performance of joints made of different bimetallic combinations of aluminium, brass, and steel. A single axial impact caused by dropping steel threaded assemblies "end-on" through 4 ft 6 in (1.37 m) on to concrete has little effect on the sealing,[11] but the strength may be more seriously affected.[10]

Theoretical analysis[24] of the strain imposed on the sealant by thermally cycling heterometallic joints has led to an understanding of the necessary magnitudes of the adhesive and cohesive strength and the flexibility of a sealing cement. These properties can now be specified as a function of the materials and dimensions of the joint and of the temperature range to be withstood. As shown by the data in Figure 2, page 21, for heterometallic joints of appreciable size [say more than 1 in (25 mm) diameter] the analysis indicates the need to use a rubbery (and necessarily relatively weak) cement if the joint is to remain sealed when thermally cycled over a long period.

The failing torques of joints made with various sealants have been assessed. The failing torque of a cemented threaded joint is the sum of the tightening torque and the contribution of the cement.[10] When the latter is converted into a shear strength, this is found to be equal to the shear strength of a planar joint of the same materials provided the cement layer is of equivalent thickness.[20]



Diagonals represent, as a function of the Rigidity Modulus, the minimum joint strength necessary to sustain the radial strain imposed on threaded joints between dissimilar metals by the indicated change in temperature. Any point to the right of a diagonal shows a cement which will not satisfactorily resist the indicated thermal cycling in BSW joints of medium fit. Both soft gels and rigid plastics are insufficiently strong despite the large difference in rigidity modulus. The intermediate rubbers are the most satisfactory, provided they have adequate adhesion. RD 1286 is initially satisfactory, but fails eventually as it stiffens due to continued curing.

FIG. 2 CEMENTS FOR SEALING THREADED JOINTS OF DISSIMILAR METALS WHEN THERMALLY-CYCLED.

2 5 2 Turned-over and Swaged Joints

Most joints of this kind are now sealed by turning over on to a previously dried layer of rubber latex composition. Liquid chemically setting cements (eg RD 1286) which are rubbery when set usually seal satisfactorily, but tend to contaminate tools. Bituminous compositions (eg RD 1219) preceded rubber latices for such joints.

2 5 Sleeve Joints

Sleeve joints are generally the most difficult to waterproof probably mainly because of the difficulty of fixing the parts relative to one another. Solvent-free cements may be satisfactory; mechanical joints (eg compressing into a groove containing a rubber washer) have been successfully used. Differential thermal expansion of the two components needs to be considered (see above), and is likely to dictate the use of a rubbery sealant in heterometallic joints.

2 5 4 Cementing of Plastics

Most of the preceding sections are relevant to the sealing of plastics/plastics and plastics/metal joints but some special considerations apply to the cementing of plastics components; for example, bonding may be hindered by the presence of mould release agents.

Plastics may be divided for convenience into two classes: (a) readily soluble and (b) insoluble or soluble with difficulty. Class (a) includes for example cellulose acetate and nitrate (celluloid), polystyrene, polymethylmethacrylate, polycarbonate and polyphenylene oxide: class (b), polythene, PTFE, phenolic mouldings, Melinex and Delrin.

The soluble plastics may be cemented together by a solvent if the surfaces to be joined are smooth and close-fitting. For gap joints a bodied cement consisting of a solution of the polymer is preferable. The cemented parts should be held in contact while drying to allow for contraction of the cement. The majority of the plastics in class (b) are difficult to bond, and each joint would have to be considered on its merits.

Thermal cycling causes especially large strains in joints between plastics and metals. Here again it is difficult to generalise, and such joints should be referred to ERDE for individual consideration.

3 CURRENT COMPOSITIONS

In this section, current compositions are classified according to type, ie coating materials, adhesives and cements and lutings.

3 1 Coatings

Coating compounds bearing RD numbers believed to be currently in Service use include RD 1151B, RD 1158G, RD 1170, RD 1176, RD 1177, various RD 1198 compositions, RD 1218, RD 1219, RD 1229, RD 1246B, RD 1272, RD 1276A, RD 1278, RD 1281, RD 1282 and RD 1283.

Particulars of these were included in the original Manual,[1] but their use as sealants is extremely limited. Up to date information about compatibility with explosives is available from this Establishment, and information about specifications from the Inspecting Authorities.

3 2 Adhesives

Similar remarks to those in Section 3 1 above apply to solvented adhesives. These include RD 1221A, RD 1256, RD 1273 and RD 1279. No solvented composition is suitable for maintaining a seal in threaded joints between metallic components.

Solvent-free, structural adhesives form a class which does not lend itself to the data-sheet approach, since no adhesive of this kind, setting at room temperature and compatible with all explosives, has yet been developed. Adhesives compatible with certain explosives are available, but each use has to be considered on its merits, and it is recommended that enquiries about these materials in ammunition be referred to the Compatibility Section at ERDE.

3 3 Cements and Lutings

The remaining category is that of cements and lutings. Of the cements bearing RD numbers, only RD 1200A and

RD 1286 are of current importance. RD 1200A is a glycerine-litharge composition setting to a hard brittle solid with excellent resistance to white phosphorus and mineral oils, but is of only limited use. RD 1286 is a rubbery cement widely used. Superior rubbery compositions from commercial sources[24] include Silastomer 9161 and Silastoseal E (Midland Silicones Ltd) and Thread Sealer TS 479 (Alfred Jeffery & Co). Other commercial sealants which may find uses in certain ammunition are surface-catalysed compositions, eg Loctites (Sealant Grades).

Of the lutings with RD numbers, only RD 1284A and Luting Mk 9 (RD 1287A, which superseded Luting Mk 8, RD 1284) are in current Service use. RD 1284A is a blue-grey stiff plastic material, and Luting Mk 9 is green and of the consistency of a stiff grease. Hylomar SQ 32/S is blue and similar to Luting Mk 9 in consistency. It is the best commercial luting so far examined.

4 DATA SHEETS

Data sheets on each preferred sealant follow in the order tabulated below. Information about compatibility with explosives will be given by the Compatibility Section of ERDE, and specification details are available from the Inspecting Authorities.

Type of Sealant	Composition	Data Sheet Number
Luting	RD 1284A (Sealing Composition, thick)	1
	Luting Mk 9 (RD 1287A)	2
	Hylomar SQ 32/S	3
Cement	RD 1200A	4
	RD 1286	5
	Silastomer 9161	6
	Thread Sealer TS 479	7
	Silastoseal E	8
	Loctite (Sealant Grades)	9

DATA SHEET NO 1

RD 1284A (SEALING COMPOSITION, THICK)

Description	A stiff blue-grey plastic material, similar to Plasticine in consistency, for the sealing of internal crevices in explosive stores. Also used in optical instruments. Recommended in OB Proc 39245 (13 February 1959) as a replacement for all thick Service lutings.	
Composition	Wax Special No 3	70 pts/wt
	Polyisobutylene, low m.w.	30 pts/wt
Reports	References 5, 12	
Application and Handling	To facilitate handling, RD 1284A may be warmed before use, care being taken to avoid local overheating. <u>On no account</u> must it be melted before use or thinned with any solvent.	

DATA SHEET NO 2

LUTING MK 9 (RD 1287A)

Description	A green sticky material, having the consistency of a stiff grease, for use as a general purpose "thin" luting: see OB Procs 39,245 (13 February 1959) and 39,525 (17 June 1960). Remains plastic at -55°C and does not flow at +75°C.	
Composition	Polyisobutylene, medium m.w.	46 pts/wt
	Di-(2-ethylhexyl) sebacate	24 pts/wt
	Polythene (grade 200 or 70)	30 pts/wt
	Monastral Green G.S.	0.5 pt/wt
Reports	Reference 3	
Application and Handling	To facilitate handling, this luting may be warmed before use, care being taken to avoid local overheating. On no account must it be melted before use or thinned with any solvent. A rag damped (not soaked) in white spirit may be used to remove excess luting from the external surfaces of ammunition.	

DATA SHEET NO 3

HYLOMAR SQ 32/S

Description	A blue adhesive material, less sticky than Mk 9 luting, having the consistency of a stiff grease. It is extremely stiff below -10°C, and is inferior to Luting Mk 9 in its stability to heat in the presence of brass, its storage life and water resistance. However, it is superior to Luting Mk 9 in its resistance to petroleum and mineral oils, and it is more extensible. It has another advantage over Luting Mk 9 in that it may be thinned with solvent and applied by brush. It cannot be recommended as a general replacement for Luting Mk 9 in ammunition but may find specialised uses.
Composition	"Polyester-urethane"
Reports	References 23, 24. Hylomar literature from: Marston Lubricants Ltd Rock Ferry Oil Works Birkenhead

DATA SHEET NO 4

CEMENT RD 1200A

Description	A two-part glycerine-litharge cement to be mixed immediately prior to use to give a pale yellow liquid, which has a pot life of at least 90 minutes at 20°C. It sets to a hard brittle solid with excellent resistance to oils and white phosphorus. (Cement C.D. No 2 is essentially similar but may have a shorter pot life.) These cements may not be used in proximity to HEs, due to their lead content.	
Composition	Glycerine, Commercial	15 pts/wt
	Litharge, Yellow	50 pts/wt

DATA SHEET NO 5

CEMENT RD 1286

Description	A two-part cement, forming a dark brown viscous fluid when freshly mixed, which sets to a soft rubber. Its pot life is about 2 hours at 20°C. It is in general use throughout the Services for sealing metal/metal joints except in proximity to Amatol, see OB Proc 38,771, 8 March 1959.	
Composition	Paraformaldehyde	6 pts/wt
	Cashew nut shell polymer (Cellobond H 8160)	100 pts/wt
Reports	References 4, 7, 8, 9, 11, 17, 18, 19, 20, 24.	
Application and Handling	The ingredients must be kept well sealed till used. The proportions must be rigidly adhered to. On no account must there be any dilution with excess of the liquid component or any other liquid. The set cement is weakened by trichlorethylene and solvent (coal tar) naphtha which may be used, where otherwise appropriate, to facilitate the undoing of joints.	

DATA SHEET NO 6

SILASTOMER 9161

Description	A two-part silicone cement, forming a white viscous fluid when freshly mixed, which sets to a soft rubber. Its pot life at 20°C is about 1 hour. It is more resistant to thermal cycling in heterometallic joints than RD 1286, but also more expensive. Silastomer 9161 is one of a number of candidates which might ultimately replace RD 1286, but its use has been proposed only in WP filled shell.	
Composition	Silastomer 9161	100 pts/wt
	Catalyst N 9162	2 pts/wt
Reports	Reference 24	
	Literature from:	
	Midland Silicones Ltd Reading Bridge House Reading Berks	

DATA SHEET NO 7

THREAD SEALER TS 479

Description	A two-part polyurethane cement, forming a grey viscous fluid when freshly mixed, and setting to a soft rubber in about 16 hours at 20°C. TS 479 thus has a longer pot life than either RD 1286 or Silastomer 9161. Like the latter, it is a candidate to replace RD 1286; it is likely to be cheaper than silastomers, but dearer than RD 1286.
Composition	Part A : 50 pts/wt Part B : 50 pts/wt
Reports	Reference 24 Literature from: Alfred Jeffery & Co Marshgate Lane Stratford London E15

DATA SHEET NO 8

SILASTOSEAL E

Description	Silastoseal E is a white, free flowing, one-part silicone rubber sealant which sets at room temperature to a soft rubber. It is ready to use and cures on contact with atmospheric moisture. Preliminary trials have shown it to be a good candidate to replace RD 1286, and it has the advantage that it requires no mixing. It is, however, rather expensive.
Composition	Silicone rubber
Reports	Technical data sheet K51, from: Midland Silicones Ltd Reading Bridge House Reading Berks

DATA SHEET NO 9

LOCTITE SEALANTS

Description	Loctite sealants comprise a family of liquid dimethacrylates (viscosity 10 - 100 poise) which polymerise to plastic materials of various degrees of flexibility in joints between mating metal surfaces. This process occurs chemically when the liquid is in contact with metal and air is excluded. By using a primer, materials other than metals (eg ceramics, glass and some plastics) may be joined. Loctites are very attractive as thread sealants and withstand thermal cycling when the components of the joint have similar coefficients of thermal expansion. Unfortunately, however, joints between components having different coefficients leak on thermal cycling.
Composition	Dimethacrylates
Reports	References 13, 15, 21, 24 Literature from: Douglas Kane (Sealants) Ltd Swallowfields Welwyn Garden City Herts

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5 ACKNOWLEDGEMENTS

Helpful discussions with Mr W A Dukes are gratefully acknowledged. Messrs F S Rayfield and B E Brokenbrow are thanked for assistance in the work leading to the performance specifications.

6 BIBLIOGRAPHY AND ABSTRACTS

1 Bryant R W, Dukes W A, Gooding J — A Manual of Sealing Compositions for Ammunition (Incorporating ERDE Report No 27/R/55) January 1956.

The many factors influencing the choice of suitable sealing methods for ammunition and allied stores are summarised. The importance of adequate waterproofing is emphasised, in view of the widely varying atmospheric and other conditions to which stores in Service are liable to be subjected.

The types of joint normally used are considered, and the methods of applying sealing compositions to them are discussed.

Details of all current compositions are given on individual data sheets; obsolescent and obsolete compositions are described in rather less detail.

2 Webb B L Sealing Compositions: Their Application to Armament Design: Pt 1: Ammunition ADE Technical Information Sheet No TI 5, May 1954.

This information sheet deals with various design aspects of ammunition sealing, including types of leakage, climatic conditions and application of sealing compositions to joints. Typical examples of sealed joints are shown and the sealing compositions used in ADE joint designs are tabulated.

3 Dukes W A Improved Luting Compositions: Part 4: The Development and Trials of RD 1287, a Luting with Improved Low Temperature Performance
ERDE Report No 15/R/55 July 1955.

A new luting, RD 1287, has been developed with improved low temperature performance and unimpaired high temperature performance, when compared with RD 1284 (Luting Mk 8).

Luting Mk 8 was introduced as satisfactory over the "Normal" Service temperature range; subsequently however a particular requirement was published for dynamic functioning at the operating minimum of the "Universal" temperature range [ie 40°F (22°C) lower]. RD 1287 fulfils this requirement and is satisfactory in typical Service applications throughout the "Universal" range [-80°F to +160°F (-62°C to +71°C)].

RD 1287 has a water vapour transmission rate similar to that of other Service lutings, excepting Luting Mk 8, whose rate is exceptionally low. Its water-repellency is greater than, and its water-resistance is equal to, that of Luting Mk 8. It is less reactive towards brass than any other Service luting. Its thermal stability, both physical and chemical, is similar to that of Luting Mk 8, and is satisfactory. RD 1287 is compatible with representative high explosives and propellants, although it causes a slight reduction in the life of propellant N under moist conditions.

4 Dukes W A Cements for Sealing Ammunition: Pt 1: RD 1286, an Improved Solvent-Free Cement Based on Cashew Nut-Shell Liquid DMXRD Report No SEAL/56/1 August 1956

RD 1286, a new cement which has been developed, is based on cashew nut-shell liquid. It is compatible with representative high explosives (except amatol), with single- and double-base propellants, with representative plastic propellants and with gunpowder.

By comparison with Service magnesium oleate cements, such as RD 1241B and RD 124B, RD 1286 has improved characteristics including suitability over the Service temperature range, lower contraction, greater flexibility, higher strength, and more convenient pot life and setting time. It is easier to mix correctly and to apply and it is also a better thread sealer.

5 Dukes W A Improved Luting Compositions: Pt 5: RD 1284A, a Sealing Composition for Filling Crevices
DMXRD Report No SEAL/56/2
August 1956

A new stiff plastic luting, Sealing Composition RD 1284A, has been developed. It is analogous to RD 1284 (Luting Mk 8), and consists of a dispersion of a high melting point synthetic wax in polyisobutene of low molecular weight (provisional British patent specification No 24973/52).

RD 1284A is superior to the stiff Service lutings (Lutings Mks 4 and 6, and Luting, Optical No 1 Mk 1) in that its consistency is much less affected by changes in temperature. In contrast with the Service lutings, it should perform satisfactorily throughout the "Normal" Service temperature range, although in some applications it may become too brittle near the low limit of this range. The water-repellancy, water-resistance and water vapour transmission rate of RD 1284A are better than those of Luting Mk 6 and Luting, Optical No 1 Mk 1 and slightly worse than those of Luting Mk 4.

By analogy with RD 1284, RD 1284A should be satisfactorily compatible with common Service metals, with other typical sealing compositions and varnishes, and with explosives. Presstite Elastic Compound No 155, a proprietary composition manufactured in USA, has also been examined. It has many desirable properties.

6 Bryant R W, Dukes W A Cements for Sealing Ammunition: Pt 2: The Inadequacy of Cements Containing Solvent in Threaded Joints DMXRD Report No SEAL/56/3 October 1956

The properties which directly affect the functional efficiency of a cement for sealing threaded joints in ammunition are considered. The most important physical requirements are (a) rapidity in setting, (b) high ultimate strength and (c) efficient sealing (waterproofing).

With minor exceptions, all the cements tested which contain solvent are unsatisfactory, in that they set very slowly, have low ultimate strengths and fail to waterproof a standard metallic threaded joint. In contrast chemically setting cements are shown to set very much more quickly, to be generally stronger, and to be considerably more efficient in sealing.

Cements containing solvents should therefore not be used to seal or rapidly secure metallic threaded joints.

7 Bryant R W, Dukes W A — The Effect of Solvents on Cements RD 1241B and RD 1286
DMXRD Tech Note No SEAL/57/1
November 1957

Samples of cements RD 1241B and RD 1286, after various periods and temperatures of cure, were immersed in various solvents at 25°C and the effects noted. The resistance of RD 1241B to all the solvents tested (except ethylene glycol) was poor. RD 1286 was unaffected by liquids of high solubility parameter (eg, water), and was superior to RD 1241B in its resistance to solvents of low solubility parameter. RD 1286 was rapidly disintegrated by those solvents with solubility parameters about 9, ie trichlorethylene, carbon tetrachloride, acetone and coal tar naphtha.

8 Bryant R W, Dukes W A The Sealing of Threaded Joints: Pt 1: Sealing Compositions and Joint Design
DMXRD Report No SEAL/57/3
January 1958

The most important single factor in the sealing of threaded joints is the quality of the sealing composition. Cements which dry merely by evaporation of solvent are greatly inferior to solvent-free cements and to lutings. RD 1151B is the least, and RD 1286 the most, satisfactory cement tested.

The next most important factor is the combination of joint design with mode of application of the sealing composition. Application to both threads is preferable, if it is permissible to force composition into the assembly. Sealing is also improved by screwing on to either (a) an external shoulder if composition is applied to the male threads, or (b) an internal shoulder if composition is applied to the female threads. A joint not screwed on to a shoulder is relatively difficult to seal.

The metal and dimensions of the joints, and even incorrect application of the sealing composition, are individually of minor importance.

9 Bryant R W, Dukes W A Hot storage Trials of the Ingredients of Thread-Sealing Cements, RD 1241B, RD 1248 and RD 1286
DMXRD Report No SEAL/57/4
February 1958

Variations in properties during storage at elevated temperatures of the ingredients of three current thread-sealing cements have been determined.

The liquid ingredient of each cement becomes more reactive on storage, causing a reduction in the pot life (or period of use) of the cement. RD 1241B is inferior to the other cements in this respect, as storage rapidly results in an inconveniently short pot life. The originally very long pot life of RD 1248 is greatly reduced, but never becomes inconveniently short. Except on storage at 75°C, the useful lives of the liquid ingredients of RD 1286 and RD 1248 are similar. The solid ingredient of RD 1286 however becomes less reactive on storage.

No serious change is likely to occur in the pot life or strength in threaded joints of RD 1286 after prolonged storage of the ingredients at temperatures up to 40°C (104°F).

10 Bryant R W, Dukes W A The Strength of Threaded Joints: Pt 1: Resistance to Mechanical Shock
DMXRD Report No SEAL/58/1
May 1958

The strength (that is, the failing torque) of a cemented threaded joint is the sum of the tightening torque and the contribution of the cement.

The resistance of steel threaded joints [assembly weighing 2 lb (0.91 kg); thread 1 inch (25.4 mm) in diameter] to a single axial impact when dropped 4 ft 6 in (1.37 m) on to concrete has been investigated. For joints screwed on to the external shoulder: (i) a tightening torque of 30 ft lb (40 J) is necessary to resist one impact if there is no sealing composition in the joint, (ii) a tightening torque of 10 ft lb (14 J) is necessary if the joint is luted and (iii) less than 10 ft lb (perhaps nil) is necessary if the joint is cemented. Similar, but perhaps higher, tightening torques are required if the joint is screwed on to the internal shoulder.

11 Bryant R W, Dukes W A The Sealing of Threaded Joints: Pt 2: Thermal Cycling and Mechanical Shock
DMXRD Report No SEAL/58/2
July 1958

The effect of mechanical stresses caused either by cyclic changes of temperature, or by impact, on the sealing of various threaded joints has been determined. Thermal cycling does not affect the sealing of joints unless the components are made of dissimilar metals. The most important single factor is the joint design (external, internal, or no shoulder), coupled with mode of application of sealing composition. The next most important factor is the quality of the sealing composition. RD 1286 is the best cement and RD 1284 (Luting Mk 8) the best luting, examined. There is no significant difference between the performance of joints made of different bimetallic combinations. A single axial impact caused by dropping steel threaded assemblies "end-on" through 4 ft 6 in (1.37 m) to concrete has little effect on the sealing.

12 Dukes W A

Optical Lutings
DMXRD Tech Note No SEAL/58/3
February 1959

Some physical properties of RD 1284A, a stiff luting which has been introduced recently, have been compared with those of optical lutings (ie, Luting, Optical No 1 Mk 1 and Luting, Wax Renax) and of a few similar proprietary compositions.

The consistency of RD 1284A was much the least affected by changes in temperature: it softened least at 75°C and stiffened least at -30°C.

RD 1284A was not inferior to the Service material, Luting Optical No 1 Mk 1, in adhesion to glass and metals, neither did it smear glass more.

A Service trial of RD 1284A as an optical luting is suggested.

13 Bryant R W, Dukes W A The Bonding of Threaded Joints: Pt 1: Loctite Cements
DMXRD Report No ADH/58/1
February 1959

Three grades (D, C and E) of Loctite thread-bonding cement have been examined. The strengths (that is, the failing torques) of steel threaded joints of various dimensions cemented with Loctite have been measured. It has been shown that the failing torque M (in ft lb) may be calculated from the following equations:

for Loctite grade D, $M = 130\ L.D_E^2$

for Loctite grade C, $M = 40\ L.D_E^2$

for Loctite grade E, $M = 30\ L.D_E^2$

where L is the length of engagement (or nut thickness) and D_E is the effective diameter of the thread, both in inches.

A variation of ± 30 per cent is usual in the strength of replicates even when the joint is completely filled with cement.

14 Bryant R W, Dukes W A Nomogram for Deriving Failing Torques of Steel Threaded Joints Cemented with RD 1286 DMXRD Tech Memo No TM/59/1 October 1959

RD 1286 is a cement, based on cashew nut-shell polymer, which has been found effective for sealing and bonding screw-threaded joints. It is applied as a fluid which sets to a rubbery gel: this subsequently strengthens to a degree governed by the temperature and period of storage. Consequently, threaded joints cemented with RD 1286 have strengths (or failing torques) dependent not only on the geometry of the joints but also on their history. The nomogram relates the mean failing torques of steel threaded joints to these parameters.

It covers periods of storage up to 10 years at temperatures ranging from 15 to 75°C, and components having nominal thread diameters from $\frac{1}{8}$ in to 16 in, with lengths of engagement from $\frac{1}{8}$ in to 8 in.

A variation in strength of ± 30 per cent of the mean is normal for joints completely filled with cement.

15 Bryant R W

The Sealing of Threaded Joints: Pt 3: Surface Catalysed Compositions
DMXRD Report No SEAL/59/1
November 1959

The sealing efficiency of surface-catalysed compositions has been examined in brass, aluminium and steel threaded joints.

These compositions differ from conventional chemically-setting cements because their setting rate depends on the metal of the adherends and setting is inhibited at air interfaces. They are less efficient than conventional chemically-setting cements as thread-sealers and this is probably because they are much less viscous. Grade AV, the most viscous tested, seals the best.

Some of the conclusions reached in Part 1 of this series of reports, about sealing with conventional cements, are not valid for these recently introduced compositions. For example, brass assemblies are easier to seal with surface-catalysed compositions than are aluminium, which are in turn easier to seal than steel. Also, a joint is more easily sealed if so disposed that a fillet of composition open to the air can act as a reservoir to fill holes in the joint.

16 Dove E E

Improved Waterproofing of Fuzes
Report ROF/DOF/AMM/No 35
February 1960

This report gives a survey of the investigations and development of new methods of hermetic sealing for fuzes. No attempt has been made to develop chemical sealing methods such as lutings, cements etc, since a great deal of work has been carried out by Establishments specialising in this type of work. The investigations as such have therefore been confined to mechanical type sealing. The following processes have been considered:

(i) Cold welding - considered unsatisfactory for fuze assembly.

(ii) Application of Seals in Latex form - satisfactory sealing obtained by this method.

(iii) Swaged Joints - a satisfactory method of assembly giving good seals together with economy of machining and assembly time.

(iv) Metal Injection - satisfactory seals can be obtained but the use of this process probably could not be justified on conventional fuze work. Swaged joints with conventional O-seals or with moulded on seals are recommended.

17 Bryant R W, Dukes W A The Kinetics of Cross-linking of a Polyphenol/ Formaldehyde Rubber DMXRD Report No RU/59/2 April 1960

The chemical kinetics of the reaction between formaldehyde and a polyphenol derived from cashew nut-shell liquid have been investigated by measuring gelation times and by measuring the Young's modulus of the rubbery product at intervals.

The reaction leading to gelation is first-order with respect to formaldehyde, and has an activation energy of 20 kcal/mole (84 kJ/mole). The post-gelation cure is also first-order with an activation energy of 23 kcal/mole (96 kJ/mole). On prolonged heating the rubber continues to stiffen, up to a maximum modulus. This "overcure" reaction is also first-order, and very much slower at elevated temperatures than the formaldehyde crosslinking reaction. The specific reaction rates, k_1 for the curing reaction, and k_2 for the over-cure reaction, are given by the following Arrhenius equations:

$$k_1 = 5 \times 10^9 \quad \exp(-23 \times 10^3/RT) \quad s^{-1}$$

$$k_2 = 2 \times 10^{-2} \quad \exp(-8 \times 10^3/RT) \quad s^{-1}$$

18 Bryant R W, Dukes W A The Physical Properties of a Polyphenol/Formaldehyde Rubber at Various Degrees of Crosslinking DMXRD Report No RU/59/3 May 1960

"Cellobond H 8160", a polyphenol derived from cashew nut-shell liquid, when crosslinked with paraformaldehyde yields a rubber-like material of which the physical changes during polymerisation can be followed more conveniently than in ordinary rubber vulcanizates. Immediately after gelation it shows Hookean behaviour in simple extension. As further crosslinking occurs the stress-strain curves at first conform with the statistical theory of rubber elasticity; then the phenomenological (Mooney-Rivlin) theory is apparently obeyed. Finally the relation again appears Hookean. The modulus increases through the range 1 to 10^5 lb/in^2 (0.07 to 6900 bars). The particular composition containing six parts by weight of paraformaldehyde per hundred of resin (cement RD 1286) is probably fully cured when there is one crosslink per phenolic nucleus. Its change in tensile strength during cure conforms with the theory of F Bueche. The tensile modulus, strain energy and elongation at break, and the density, all show inflexions corresponding to complete cure with methylene links. The solubility parameter does not very appreciably with the degree of polymerisation; the experimental value agrees with that calculated from molar attraction constants.

19 Bryant R W, Dukes W A Some Sealing Materials for Threaded Joints Paper B3, the 1st B.H.R.A. International Conference on Fluid Sealing April 1961

The development of special sealing compositions, both lutings and cements, for parallel threaded joints is summarised, and their performance is described. The most important single factor in the sealing of threaded joints is the quality of the composition. Desirable qualities are discussed. Cements which dry merely by evaporation of solvent are greatly inferior to solvent-free cements and to lutings.

20 Bryant R W, Dukes W A The Bonding of Threaded Joints: Pt: 5 The Failing Torque Relative to the Shear Strength of the Corresponding Planer Joint
ERDE Report No 19/R/61
November 1961

Previous measurements of the failing torques of bonded threaded joints have been converted into shear strengths, assuming that there are no stress concentrations and that the cement over the whole of the threaded surface is sheared. The strengths so obtained have been compared with the shear strengths of standard planar joints of the same materials. It has been shown to be necessary to take into account the glue-line thickness.

There is no significant difference between shear strengths measured in threaded or planar steel joints of the same glue-line thickness, whether the cement is brittle or rubberlike, strong or weak.

This is not true, however, if the cement is capable of viscous flow. In this case, and perhaps generally if the adherends are light alloys or plastics, threaded joints appear a few times weaker than comparable planar joints.

21 Bryant R W, Dukes W A, Long Mrs J V — The Increase in Strength with Time of Metal-Metal Joints Bonded by Surface-Catalysed Compositions
ERDE Tech Memo No 19/M/61
November 1961

The rates of setting of various commercially available surface-catalysed adhesives, based either on dimethacrylates or on a cyano-acrylate, have been investigated. The shear strengths of planar joints of brass, steel and aluminium alloy were measured after various periods of cure at room temperature. The rates of accretion of strength are shown graphically. Of the substrates, the aluminium alloy was the least efficacious as a catalyst. Brass always gave the least period of inhibition of solidification. Similar ultimate strengths were found on brass and steel, and lower strengths on aluminium alloy.

In general, the lower the ultimate strength, the longer was the time taken to attain it. The cyano-acrylate composition was by far the strongest and quickest setting material tested.

22 Dukes W A, Long Mrs J V The Sealing of Threaded Joints: Pt 4: Polytetrafluorethylene Tapes and Cord
ERDE Tech Memo No 16/M/62
January 1963

The sealing efficiency of commercial grades of PTFE tape and cord has been examined in brass, aluminium and steel parallel-threaded joints. These materials can only be applied to the male component. The weakest and softest grade was the most satisfactory, but if it was not carefully wrapped over the whole thread before assembly it was less successful. The loss of efficiency due to application over only a fraction of the thread was less for material in the form of cord than in the form of tape. However it is comparatively expensive, laborious and time-consuming to wrap a yard of cord round the complete thread of a joint, although the process is cleaner than applying luting. In general, the cord was more efficient than the lutings, which were more efficient than the best PTFE tape.

Between heterometallic components, neither the PTFE materials nor the lutings provided seals which could withstand thermal cycling.

Neither the metal of the joint nor the degree of compression of the enclosed air at assembly has any important effect on the ease of sealing threaded joints with PTFE.

23 Bryant R W, Dukes W A, Long Mrs J V — Commercial Lutings
ERDE Memo No 10/M/63
January 1964

Twenty firms specialising in sealing compounds were sent a performance specification for soft lutings (with which the Service compositions, Lutings Mk 8 and Mk 9 comply), and were asked to submit samples for evaluation. Eight materials were submitted, but only one, Hylomar SQ 32/S is likely to find Service applications. It is superior to the existing lutings in its resistance to petroleum products and is more extensible. It is as good as the existing lutings in its resistance to flow at 75°C (167°F) and in its compatibility with explosives. It is intermediate between the two Service compositions in respect of its embrittlement temperature and in its sealing efficiency in screw threads. However, it is inferior in its consistency at low temperatures, heat stability in contact with brass, and water resistance. It could not be recommended as an alternative to the existing Service Lutings Mk 8 and Mk 9 for general use, but it has potentially valuable properties which may find use in specialised applications.

24 Bryant R W, Dukes W A, Long Mrs J V — The Sealing of Threaded Joints: Pt 5: A Review of Commercial Sealants ERDE Report No 10/R/66 August 1966

Commercial lutings and thin polytetrafluorethylene (PTFE) tapes and cord have been assessed as sealants for parallel-threaded joints. One luting is comparable with the Service materials and may find specialised uses. The relative inefficiency of PTFE tapes will often outweigh the advantage of cleanliness, unless resistance to extreme temperatures and to a variety of solvents is required.

Twenty-four commercial cements, including polysulphides, polyurethanes, epoxides, silicones, surface-catalysed compositions and compounds hardened by atmospheric moisture, have been assessed as thread sealants. Several were superior to the Service material in a stringent thermal-cycling trial.

Theoretical analysis of the imposed strain has led to an understanding of the necessary magnitudes of the adhesive and cohesive strength and the flexibility of a sealing cement. These properties can now be specified as a function of the materials and dimensions of the joint and of the temperature range to be withstood.

APPENDIX A

OUTLINE OF A PERFORMANCE SPECIFICATION FOR SOFT LUTINGS FOR AMMUNITION

1	Scope	This specification relates to soft lutings for ammunition, particularly for waterproofing and sealing threaded joints. The luting is intended for applications where a high degree of compatibility with explosives is required but its compatibility with all explosives in all environments has not been established. Advice on compatibility requirements in particular applications should be sought from ERDE or other competent authority. It may be compounded from any materials provided the product complies with the requirements of this specification.
2	Description	The luting shall be an homogenous mass, free from foreign matter and visible impurities, having the consistency of a stiff grease. It must wet, and adhere strongly to, metal surfaces. It may be required to be coloured by means of an approved pigment or dyestuff.
3	Compatibility with explosives	a The luting must be type-tested for compatibility with explosives,

		b Samples may be taken at any time to check that compatibility with explosives remains unchanged.
		c The manufacturer must disclose in confidence to the Inspecting Authority the composition and method of preparation of the luting and must undertake to notify the Inspector in advance of any proposal to change either composition or method of preparation.
4	Behaviour on heating (flow test)	When tested by the method described in Annex 1, the luting shall show no appreciable flow, neither shall there be any sign of syneresis nor separation of any of the ingredients.
5	Low Temperature penetration	When tested as described in Annex 2, no value of the penetration shall be less than 30 units.
6	High Temperature penetration	When tested as described in Annex 3, no value of the penetration shall exceed 250 units.
7	Elongation	When tested as described in Annex 4, the mean elongation shall be not less than 60 mm.

8	Non-corrosive properties	The luting shall not cause corrosion of copper, brass, aluminium or mild steel surfaces when tested as described in Appendix A of BS 3245 : 1960.
9	Water resistance	When tested by the method described in Annex 5, the luting shall show good water repellency, shall not change appreciably in appearance, and shall show no evidence of penetration of water from the exposed edges of the luting.
10	Heat stability	When tested by the method described in Annex 6, the luting shall not change appreciably in consistency nor shall it be discoloured or show any evidence of cracking or separation of any ingredient.
11	Ash content	The ash content, determined by the method described in IP 4/61, shall not exceed 0.1 per cent.
12	Lead content	The luting shall not contain lead or lead compounds together exceeding 0.03 per cent by weight, calculated as metallic lead.

METHOD FOR DETERMINATION OF BEHAVIOUR ON HEATING

Use a metal container of rectangular section with the following internal dimensions:

Base	25 mm x 25 mm
4 sides	25 mm x 12.5 mm

The nature of the metal from which the container is made is not critical.

Fill the container at 75°C with the material at the same temperature. Level off the surface of the material with a warm knife.

Maintain the assembly on one side, with the exposed surface of the material vertical, at 75°C for 24 hours.

ANNEX 2 of
Appendix A

METHOD FOR DETERMINATION OF LOW TEMPERATURE PENETRATION

Determine the low temperature penetration of the material by the standard method of the Institute of Petroleum serial designation 49/63, but ignore references to a water bath and a transfer dish, and use the following method for preparation of the sample and procedure.

PREPARTION OF SAMPLE AND PROCEDURE

Fill the specified container at room temperature with the material to be tested taking care to avoid entrapment of air. Smooth flat the surface of the material, using a knife at room temperature.

Cool the filled container to -45°C and maintain at that temperature for two or more hours, then quickly transfer to the stand on the penetration machine and determine the penetration within 30 seconds. Make three determinations, cooling the sample container for at least two hours at -45°C immediately prior to each determination, or alternatively use three separate filled containers. Except where specified otherwise, follow all details of the test method as laid down in IP 49/63.

METHOD FOR DETERMINATION OF HIGH TEMPERATURE PENETRATION

Determine the high temperature penetration of the material by the standard method IP 50/62 but ignore reference to a grease worker and a constant-temperature bath, and use the following method for preparation of the sample and procedure.

PREPARATION OF SAMPLE AND PROCEDURE

Use a container as specified in IP 49/63 for the determination of low temperature penetrations exceeding 225 units. Fill it with the material to be tested in the manner described in Annex 2.

Heat the filled container to 75°C and maintain at that temperature for two or more hours, then quickly transfer to the stand on the penetration machine and determine the penetration within 30 seconds. Without smoothing the surface make two more determinations, heating the sample container for at least 2 hours at 75°C immediately prior to each determination. Alternatively use three separate filled containers. Do not maintain the sample at 75°C for more than a total period of 24 hours. Except where specified otherwise, follow all details of the test method laid down in IP 50/62 using the procedure for 'Unworked Penetration'.

METHOD FOR DETERMINATION OF ELONGATION

Press the material to be tested into two brass tubes 51 mm (2 in) long and 19 mm (¾ in) in internal diameter, co-axially butt-jointed together to form a single tube. Take care to avoid inclusion of air into the cylindrical test specimen. Maintain the assembly in an incubator for 6 hours at 25°C. Pull the brass tubes vertically apart along the axis at 500 mm/minute (20 in/minute) and observe the extending thread of material. Note the separation of the tubes at the moment of rupture and report as the elongation of the material.

Prepare three separate test specimens from each sample and take the mean of three determinations.

METHOD FOR DETERMINATION OF WATER RESISTANCE

Degrease with ethyl methyl ketone two flat glass microscope slides each 25 x 75 mm. Stick these together at right angles in the form of a cross by means of a film of the luting about 1 mm thick and 25 mm square, removing any excess of luting extruded during the preparation. Immerse the assembly in tap water at 60°C and maintain these conditions for 4 days. Then allow the assembly to cool to room temperature without removing it from the water. When at room temperature, remove the assembly and shake off excess water. Inspect the free surface of luting for water repellancy and for signs of degradation (eg whitening) or other changes in appearance. Examine the luting/glass interface through the glass for any evidence of water penetration.

DETERMINATION OF HEAT STABILITY

Prepare clean glass and brass surfaces as follows:

a Glass: Wash well with hot water containing a detergent, rinse thoroughly under running tap water and allow to drain and dry at room temperature.

b Brass: Abrade the surface uniformly with 0 grade emery cloth, wipe and degrease with ethyl methyl ketone.

At room temperature, spread the luting evenly to a depth of approximately 1 mm on to glass and brass surfaces prepared as above, and place the coated specimens in an oven at 75°C. Maintain these conditions for 3 months, then cool to room temperature. Compare the coating of luting with a similar, freshly prepared, specimen for discolouration or any change in consistency. Inspect the surface for evidence of cracking or separation of any ingredient.

OUTLINES OF A PERFORMANCE SPECIFICATION FOR GENERAL-PURPOSE AMMUNITION CEMENTS

1	Scope	This specification relates to general-purpose cements for ammunition. These materials are applied as fluids and subsequently set to become rubbers in the joint. They are intended for applications where a high degree of compatibility with explosives is required, combined with resistance to thermal shock. Their compatibility with all explosives in all environments has not been established. Advice on compatibility requirements in particular applications should be sought from ERDE or other competent authority. They may consist of any materials which will comply with the requirements of this specification.
2	Description	The mixed cement shall be free from lumps and shall have the wetting properties necessary for adhesion to metal surfaces.
3	Consistency and Pot-life	The freshly prepared cement shall have a viscosity not less than 1 $N s/m^2$ (10 poise) at 25^oC, and, when maintained at this temperature for one hour, the viscosity shall not be greater than 250 $N s/m^2$ (2500 poise).

4	Gelation Time	The gelation time at 20°C, measured with a Techne Gelation Timer (Techne (Cambridge) Ltd) shall not exceed 24 hours.
5	Contraction on setting	The contraction on setting shall not exceed 4 per cent by volume.
6	Non-corrosive properties	The composition shall not cause corrosion of copper, brass, aluminium or mild steel surfaces when tested as described in Appendix A of BS 3245 : 1960.
7	Resistance to flow at elevated temperatures	Cast a 10 mm cube of the material and cure it for 3 days at 100°C. Place the unsupported cube in a suitable air oven at 75°C. The cube shall retain its shape under these conditions for 24 hours.
8	Compatibility with explosives	a The cement must be type-tested for compatibility with explosives. b Samples may be taken at any time to check that compatibility with explosives remains unchanged. c The manufacturer must disclose in confidence to the Inspecting Authority the composition of the cement and must undertake to notify the Inspector in advance of any proposed change in composition.

9	Preparation of sheet material	Cast a uniform sheet of cement 1 to 3 mm thick and cure for 3 days at 100°C. This sheet is used for the tests in clauses 10, 11 and 12 below.
10	Stiffness at low temperatures	Measure the apparent rigidity modulus of the fully cured sheet material (clause 9 above) at -45°C by the method described in ASTM D1043/61T. The apparent rigidity modulus at -45°C shall be not greater than 3100 bars (45 000 psi).
11	Water absorption	Weigh a portion of the cured cement (clause 9 above) and wholly immerse it in distilled water at 60°C. Maintain these conditions for 4 days, then remove the sample, wipe off the excess water with filter or blotting paper and reweigh. The gain in weight, calculated as a percentage of the original weight, shall not exceed 3 per cent.
12	Strength and adhesion	The cement, cured for 3 days at 100°C, shall have a tensile cohesive strength, and adhesive shear strengths with aluminium, brass and mild steel adherends, not less than one-third its rigidity (shear) modulus, all measured at 20°C.

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Technical Report No 71
Explosives Research and Development Establishment
HANDBOOK OF SEALANTS FOR AMMUNITION
R W Bryant
September 1971
75 pp, no tabs, 2 figs

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The properties required in sealing compositions are outlined and performance specifications for lutings and cements are proposed. Details of selected lutings and cements are given on individual data sheets.

The types of joint normally used are considered, and the methods of applying sealing compositions to them are discussed.

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