



Magnesium Elektron

SERVICE & INNOVATION IN MAGNESIUM

Surface Treatments for Magnesium Alloys in Aerospace & Defence

Datasheet : 256

Magnesium Elektron UK,
P.O. Box 23, Rake Lane, Swinton, Manchester, M27 8DD, England.
Tel: 0161 911 1000 Fax: 0161 911 1010
Web: www.magnesium-elektron.com VAT No: GB 668 2142 26

A Division of MAGNESIUM ELEKTRON LIMITED. Registered in England No. 3141950.
Registered Office: The Victoria, 150-182 Harbour City, Salford Quays, Salford, M50 3SP
A Luxfer Group Company

Surface Treatments for Magnesium Alloys in Aerospace & Defence

Introduction

This booklet will be of value to all personnel involved in the various aspects of magnesium surface treatment, including materials engineers and technical staff concerned with workshop practice. In addition it will assist those responsible for the design and use of magnesium alloy components to ensure that all magnesium parts behave satisfactorily in operational service. The recommendations are directed to applications that operate in conditions common to aerospace and military use which range from moderate to very aggressive environments.

The booklet describes specific surface treatments and discusses other aspects of corrosion prevention, including the need for good design practice, workshop assembly practices, procedures for repair of protective coatings where local damage has occurred and the use of preventive maintenance.

Detailed operating instructions covering the various stages of protection are given in the form of appendices and reference is made to appropriate military or aerospace specifications.

| CONTENTS | PAGE |
|--|-------|
| Introduction | 2 |
| Corrosion behaviour of unprotected magnesium alloys | 3/4 |
| The behaviour of magnesium components in service | |
| Surface contamination | |
| Unprotected magnesium surfaces | |
| Galvanic contacts | |
| The principles of successful protection | 5/6 |
| 1. Selection of a suitable protection scheme | |
| Protection scheme 1 | |
| The minimum recommended standard | |
| Protection scheme 2 | |
| For aggressive environments | |
| Protection scheme 3 | |
| For very aggressive environments | |
| 2. Design considerations | |
| Need to specify required protection | |
| The position of a component in service | |
| The effect of dissimilar metals | |
| The effect of sharp edges | |
| Identification of parts | |
| 3. Correct application of the chosen protection scheme | |
| 4. In-service inspection and maintenance | |
| Appendices | |
| i Chemical cleaning treatments | 7 |
| ii Electrochemical cleaning treatment | 8 |
| Fluoride Anodising | |
| iii Chromate conversion coatings | 8/9 |
| iv Chemical Pre-treatment of the Yttrium containing Magnesium Alloys | 9/10 |
| v Hard anodising treatments | |
| HAE and Dow 17 | 10/11 |
| Magoxid and Tagnite | 11 |
| vi Surface sealing | 12 |
| vii Assembly | 12/13 |
| viii Painting | 13 |
| ix Temporary protection | |
| x Repair and maintenance | 14 |
| xi Examples of good/poor design practice | 15 |
| xii Related specifications | 16 |

Corrosion behaviour of unprotected magnesium alloys

In common with most metals, magnesium is oxidised when subjected to atmospheric exposure but the resulting corrosion rates are significantly less than those obtained with similar tests on mild steel.

Magnesium is also very slightly attacked by water and the degree of attack depends mainly on the purity of the water. For example, the corrosion rate of clean magnesium alloys in distilled water is approximately 0.04 mm penetration per year, whereas in potable water the rate would be approximately double this figure.

The effect of aqueous solutions on magnesium varies considerably depending upon the nature of the solute. Magnesium is resistant to attack by alkalis but is attacked by most acids; two notable exceptions being hydrofluoric and chromic acids. Similarly, common acidic salts, again with the exception of fluorides and dichromates/chromates, attack magnesium. Probably the most damaging solutions, and also the most prevalent, are chloride solutions usually found in the form of seawater.

Magnesium alloys are not prone to intergranular attack due to the fact that the grain boundaries are cathodic compared with the actual grains and would therefore be cathodically protected if exposed to a corrosive environment. In addition, most magnesium alloys, with the exception of the magnesium-aluminium alloys, are not susceptible to stress corrosion cracking under normal conditions and at stresses up to 0.2% Proof Stress values.

The presence of cathodic impurities (eg, iron, nickel, copper) can have a significant effect on the corrosion behaviour of unprotected magnesium alloys. Cathodic impurity levels in alloys specified for aerospace and defence applications are controlled at low levels to minimise corrosion effects. Reducing some impurities to ultra low levels can have a further beneficial effect (eg, the corrosion resistant high purity alloys AZ91D, AZ91E, Elektron WE54 and Elektron WE43) provided other factors, such as dissimilar metal couplings or fasteners, do not have an overriding effect.

Conversely, the surface contamination of magnesium alloys can increase their corrosion rate considerably. For example, the abrasive blasting of a magnesium alloy casting with cast iron or steel shot results in minute cathodic particles becoming embedded in the metal surface. This produces a very reactive surface and may result in high corrosion rates. This effect is galvanic corrosion. It occurs when two metals having different electrode potentials are in electrical contact and are wetted with a common electrolyte. A similar set of circumstances arises at dissimilar metal attachments, such as nuts, bolts, rivets, etc. and here severe corrosion may occur in corrosive environments if the necessary precautions are not taken.

In practical applications, these latter effects have a

greater influence on corrosion behaviour of magnesium components than the basic metal purity.

From the above information it is possible to identify particular problem areas and therefore detail the protective treatments necessary to ensure components behave satisfactorily in service. These are as follows:

The behaviour of magnesium components in service

In most applications, the presence of other metals in assembly with magnesium and the general operating environments preclude the use of magnesium in the unprotected condition, regardless of basic corrosion resistance. The prime consideration is then to define protective coating systems and techniques which can prevent or minimise the initiation of corrosion breakdown rather than minimise corrosion after breakdown has occurred.

From consideration of the corrosion characteristics of magnesium alloys and the operating requirements in aerospace applications, it is possible to identify particular problem areas and detail the protective treatments necessary to ensure that components behave satisfactorily in service. These are as follows:

a) Surface contamination

The contamination of magnesium surfaces resulting from the use of ferrous abrasives can be removed by a combination of acid pickles (see Appendix i) or by Fluoride Anodising (see Appendix ii).

The use of high purity alumina or glass beads in place of ferrous abrasives is preferable, but care should be taken to ensure that pick-up of heavy metal contamination, eg. from the equipment, table or blasting nozzle, is avoided.

b) Unprotected magnesium surfaces

Unless a magnesium component is to function in an innocuous environment, it should not be used in service without some form of protective treatment.

Note:

A chromate conversion coating, although essential for the good adhesion of subsequently applied resins or paints, should always be considered as having no protective value in its own right. Protection of magnesium may be necessary during the time a component is being manufactured if it is left untreated for extended periods of time. Factors such as temperature changes, humidity, and the types of dust present in the machine shop are very important and influence the choice of the temporary protective treatment employed. (See Appendix ix).

Probably most corrosion damage encountered in service occurs at unprotected mating faces when these are left in the as-chromated condition with their edges open to the atmosphere. Corrodent is able to gain access to the joint by capillary action and, because of the very slow rate of evaporation from within the joint, remains in

contact with the unprotected magnesium for long periods. Techniques aimed at eliminating this form of corrosion are given in Appendices vii and viii.

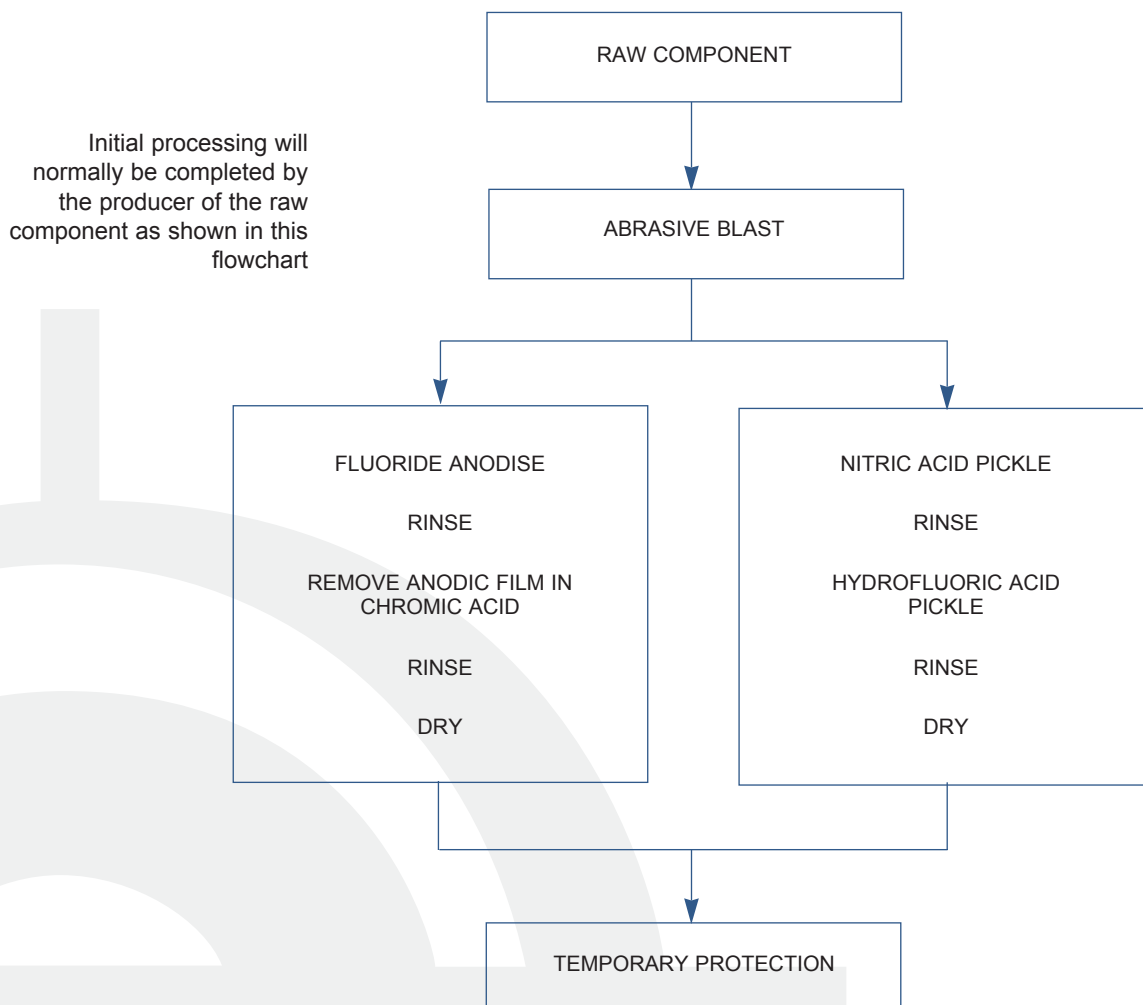
Consequently, all surfaces of a magnesium component should, prior to going into service, be protected by the complete scheme necessary for the particular application.

Finally, unprotected magnesium surfaces may occur in service due to mechanical damage removing the applied protective scheme. In these instances the re-application of the original scheme, or its equivalent, should ideally be carried out immediately. If this is not practicable, then a water displacing oil, protective oil, grease or wax, should be applied liberally over the affected area until a thorough refurbishment is possible. (See Appendix x).

c) Galvanic contacts

A dissimilar metal in contact with magnesium will not by itself result in corrosion. As stated previously, for corrosion to occur the two metal surfaces must be wetted with a common electrolyte. This most often occurs at mating faces, where the unprotected faces have connecting bolts passing through them.

Obviously, any technique aimed at removing the necessary conditions for corrosion to occur will eliminate galvanic corrosion. (See design considerations and Appendices vii and viii).



The principles of successful protection

There are four main principles of surface protection which dictate the behaviour of any component, in any material, during its service life.

1: SELECTION OF A SUITABLE PROTECTION SCHEME

The protection given to a particular component must be considered very carefully since the unnecessary application of a complex protection scheme can be costly. Similarly, the application of an inadequate scheme can be even more costly if it results in the premature breakdown of a component necessitating its replacement. Consequently, a judgement has to be made taking into account several factors relevant to each application. The most important of these is undoubtedly the operational environment. However, other factors such as the required component life, the frequency of inspection, the cost of the component, its replacement and refurbishment must also be considered.

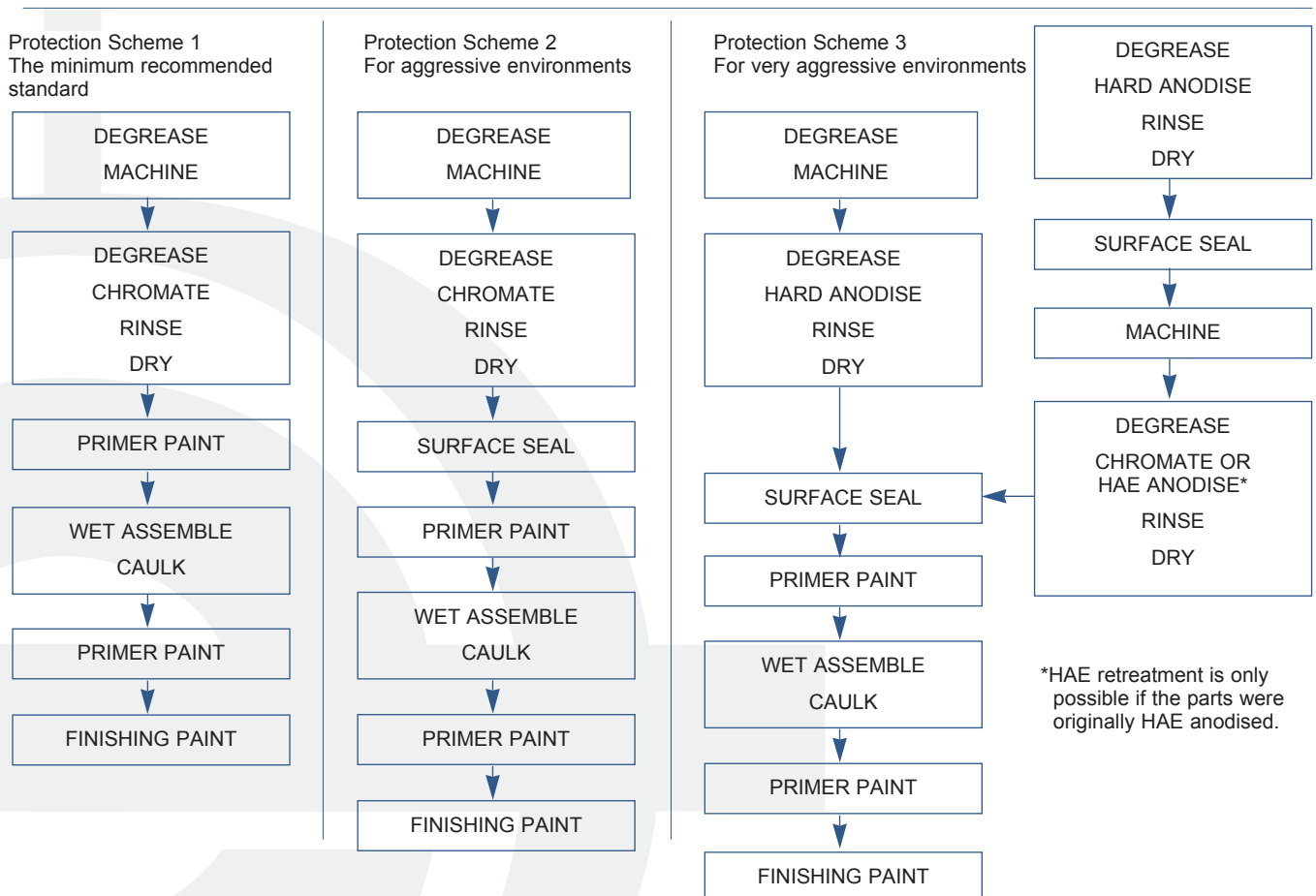
When considering the operational environment of a component it is essential to take into account the conditions prevailing at all times in the component's life. For example, a component may operate intermittently and while working be warm and dry, but when idle be subjected to a very corrosive environment. An example of this could be an engine component on a carrier-based aircraft. Similarly, the conditions prevailing within a component may differ considerably from those prevailing on its outer surfaces. For example, an aircraft gearbox that is vented may have a mild external environment since water can readily evaporate from its outer surfaces,

whereas condensation occurring within the gearbox could result in pockets of warm acidic water collecting below the oil, and high humidity conditions above the oil level.

With the above factors in mind the following three schemes, numbered 1, 2 and 3, are given as indications of the protection necessary for military and aerospace applications operating in moderate, aggressive and very aggressive environments respectively. While it is not possible to be definitive in terms of applications, these can probably be equated to civil, land-based military and sea-based military aircraft respectively. Details of the schemes are given in the appendices.

One of the following finishing schemes is normally applied by the manufacturer of the finished components. However, the raw component producer may be requested to supply parts in the chromated and Surface Sealed condition in order to improve their overall protection and optimise storage life.

The schemes should not be considered as exclusive. Other schemes have and are being used very successfully in service. One such scheme is based on nylon coating and satisfactory primers have been developed to optimise adhesion. Whilst protection schemes 1, 2, and 3 may be used up to 200°C, alternative schemes may be employed for higher temperature applications.



2: DESIGN CONSIDERATIONS

The satisfactory in-service performance of any component begins at day one on the drawing board. The following factors are those which a designer must consider when designing a component in magnesium, or indeed, most other metals.

Need to specify required protection

A designer should, after having collaborated with the material engineer, specify on all drawings the protection scheme decided upon and make dimensional allowance for it, where applicable. If it is necessary, for any reason, to restrict the scheme anywhere on a component, eg. on mating faces, then the designer must specify some additional protective measures to compensate. (See Appendix vii).

The designer should also specify that all assembly should be carried out wet, i.e. using a sealing compound, and that dissimilar metals are overpainted after assembly. (See Appendix vii).

The position of a component in service

Components in service should be free draining. Consequently a designer must know in which position, or positions, a particular component will operate when in service in order to ensure that corrosives are not retained in recesses etc. (See Appendix xi).

The effect of dissimilar metals

The area of dissimilar metal present on a magnesium alloy component should be kept to a minimum. For example, the use of studs in place of bolts will, if acceptable, reduce the dissimilar metal area/contacts by up to 50%. In this case however, the captive ends of the studs should be in blind holes and not in ones that break through. If the latter is inevitable the resulting hole should be plugged with sealing compound.

The degree of attack resulting from galvanic corrosion is, among other things, proportional to the difference in potential between the two metals. With magnesium assemblies all dissimilar metals should be coated, or plated, with zinc, cadmium or aluminium, in order to minimise attack if the protection scheme should break down.

The effect of sharp edges

The application of conventional paints to surfaces having sharp edges or rapid changes in contour results in the "drawing-back" of resins or paints due to surface tension effects. The resulting thickness of paint on an edge can be reduced to virtually zero. In addition, sharp edged components are more likely to suffer premature breakdown due to the ease and increased likelihood of sharp edges being damaged in service. Consequently designers should specify on all drawings that corners and edges, particularly those produced by machining, are radiused to 0.75 mm minimum.

A similar situation arises on sand castings that have an

unduly rough surface, and here designers should specify that such roughness is mechanically removed i.e. by scurfing.

Identification of parts

This should ideally be by embossing but scribing or stamping is acceptable if carried out prior to the application of the protection scheme. Painting is the only acceptable technique of identification after the protection scheme has been applied.

3: CORRECT APPLICATION OF THE CHOSEN PROTECTION SCHEME

The protective value of a fully protected component is only as good as that at its weakest point. Consequently it is futile to treat 99% of the area of a component with an excellent protection scheme and then leave 1% of its area in the chromated only condition. This situation often arises where there is a mismatch of close tolerance mating faces leaving the exposed surfaces inadequately protected. Such sites are potential problem areas due to the presence of crevices and dissimilar metal contacts, and severe corrosion may occur when the parts are exposed to corrosive environments.

It is important that production supervision and quality assurance departments ensure that all components are treated in accordance with the relevant specifications. This will entail the routine inspection of procedures and components at all stages of manufacture.

Important points to verify on assemblies are that there are no open crevices around mating edges, nuts, bolts and washers and that all surfaces are adequately coated.

4: IN-SERVICE INSPECTION AND MAINTENANCE

Aerospace and military equipment should be inspected regularly during service and if there are signs that the protective coating has been damaged or in any way degraded, then remedial action should be taken as soon as possible. In this respect, magnesium is no different to most other materials.

The exact form the remedial action will take for any particular component will vary depending upon several factors. However the aim should be to re-protect the component to a level at least as good as that provided by the original finish. (See Appendix x).

If, for any reason, the remedial action cannot be carried out immediately, the affected area should receive a liberal application of a water displacing oil or wax. This helps prevent further deterioration before the complete repair is effected.

An overall application of a protective oil or wax to all components will also considerably extend their service life.

Appendices

Appendix i Chemical Cleaning Treatments

| Name | Bath Composition | Procedure | Container | Resulting Appearance | Typical Metal Removal | Remarks |
|---|--|---|----------------------|--|--|---|
| Solvent Degrease | Paraffin or White Spirit. | 5 mins immersion in liquid at room temperature. | Steel | – | Nil | Removal of heavy deposits of oil or grease. Vapour degreasing will be necessary for complete cleaning. |
| Vapour Degrease | Trichloroethylene or Trichloroethane. | 5 mins immersion in vapour. Repeated if necessary. | Steel | – | Nil | Removal of oil or grease. |
| Caustic Soda | 2–5% NaOH in water. | 5–30 mins immersion in boiling solution. | Steel | – | Negligible | Removal of oil or grease. Paint removal. |
| Mild Alkaline | 2.5% Na ₃ PO ₄ .12H ₂ O 2.5% Na ₂ CO ₃ .10H ₂ O 0.06% Soap in water. | 5–15 mins immersion in boiling solution. | Steel | – | Negligible | Removal of oil or grease. |
| Nitric Acid Pickle | 5–10% HNO ₃ in water. | Repeated brief dips at room temperature until clean. | Rubber or Polythene. | Clean and bright with black smut on some alloys. | 0.05 mm | General cleaning of rough castings. |
| Sulphuric Acid Pickle | 2–5% H ₂ SO ₄ in water. | Repeated brief dips at room temperature until clean. | Rubber or Polythene. | Clean and bright with black smut on some alloys. | 0.05 mm | General cleaning of rough castings. |
| Chromic Acid | 10–15% CrO ₃ in water. | 15 secs to 30 mins immersion in boiling solution. | Aluminium or Steel. | Clean grey. | Negligible unless contaminated with e.g. Chloride. | Removal of corrosion products and conversion coatings. A subsequent immersion in HF or alkali to reactivate the surface may be necessary prior to chromating. |
| Chromic / Sulphuric Acid | 10% CrO ₃ 0.1% H ₂ SO ₄ in water. | Swab until clean. | – | Clean grey. | Negligible | Removal of superficial corrosion products. |
| Nitric Acid / Hydrofluoric Acid Treatment | a. 5–10% HNO ₃ in water. b. 10% HF in water. | Up to 2 mins in HNO ₃ , rinse and 15 mins immersion in HF. | Polythene | Bright grey. | 0.05 mm | Removal of heavy metal contamination from surface of rough castings. This treatment is not as effective as Fluoride Anodising. See Appendix ii. |

Note: Vapour degreasing in trichloroethane or trichloroethylene may result in degradation of some resin films if they are not subsequently baked at 120°C for 15 minutes.

Appendix ii Electrochemical Cleaning Treatment, Fluoride Anodising

Fluoride anodising is a cleaning treatment applicable to all magnesium alloys and is recommended as a pretreatment for all components prior to the first application of protective finishes.

The treatment removes contamination resulting from abrasive blasting, polishing or other operations involving the use of some abrasives, wire brushes, steel wool or files, themselves contaminated with metallic debris from previous use.

Pretreatment

Parts should, if necessary, be cleaned of residual paint using a suitable paint stripper and degreased. (See Appendix i).

If tolerances permit, such as with the treatment of rough castings, a pickle for 1–2 minutes in nitric acid is recommended in order to remove surface contaminants such as loosely held sand, metal/mould reaction products etc.

Chromic acid cleaning will also remove previously applied conversion coatings or corrosion product when necessary.

Container

A hard rubber or plastic lined tank resistant to acid fluorides fitted with normal bus bars and fixing connectors.

Electrolyte

15–25% ammonium bifluoride (NH_4HF_2) solution in water.

Power source

A source capable of providing a progressively increasing AC voltage up to a maximum of 120V.

Current requirements are dependent on the maximum processing load, but 150 amps/square metre of surface area on one electrode is suggested as a minimum.

Procedure

Parts to be anodised are mounted on magnesium alloy clamps and positioned at least 250 mm below the surface of the electrolyte with approximately equal surface areas connected to each electrode.

Parts should be positioned so that gas formed during treatment vents freely. If this is not possible, it is essential to change the suspension point of parts at some stage of the process to ensure complete treatment.

AC voltage is applied and gradually increased, depending upon the current limitations of the equipment, until 90–120 volts is reached. (Some alloys, such as AM503, may be slightly etched at 120 volts and it is sometimes necessary to limit the terminal voltage to 90). Current flow is heavy at first but diminishes rapidly as impurities are removed and an insulating film of magnesium fluoride is formed on the surface. Treatment

is complete when the current has fallen to below 50 amps/square metre and this is usually within 10–15 minutes of achieving maximum voltage. When the treatment is complete, the power is switched off, the parts removed, rinsed and dried thoroughly.

Appearance of treated parts

A uniform grey-white colour.

Dimensional change

Negligible.

Post treatment

The fluoride film produced by Fluoride Anodising is a poor paint base and must be removed in chromic acid. (See Appendix i).

Stripping of the fluoride film is not necessary when parts are subsequently to be given the thick HAE or Dow 17 treatments.

Appendix iii Chromate Conversion Coatings

Chromate conversion coatings are applied to magnesium alloys to act as a key for subsequently applied resins or paints. They should not be considered as protective finishes in their own right.

The Chrome Manganese, Hot Half Hour and Dow 7 treatments result in negligible metal loss and produce films that are excellent paint bases.

The Acid Chromate or Dow 1 treatment results in dimensional loss of approximately 0.025 mm and cannot therefore be used on finely machined parts. In addition, the resulting comparatively thin film is an inferior paint base compared with the thicker darker coloured films.

When chromated parts are accidentally damaged they are best retreated in the bath used originally. However, it is permissible to treat small areas of components with the Dow 19 or Alocrom 1200 touch up solutions.

Note

It is not usually necessary to remove inserts from components treated in the Chrome Manganese, Hot Half Hour or touch up solutions. However, care should be taken during rinsing and drying to ensure no moisture is retained between inserts and magnesium.

| Name | Bath Composition | Procedure | Container | Resulting Appearance | Control |
|------------------------------------|---|--|---|---------------------------------------|---|
| Chrome Manganese | 10% Na ₂ Cr ₂ O ₇ .2H ₂ O 5% MnSO ₄ .5H ₂ O 5% MgSO ₄ .7H ₂ O in water. | 2 hours immersion at room temperature. (Proportionately less at higher temperatures). Rinse and dry. | Steel or Aluminium. | Dark brown to black. | Working range of pH is 4–6. Maintained within the range by additions of H ₂ SO ₄ or CrO ₃ |
| Hot Half Hour Bath. (R.A.E. Bath). | 3% (NH ₄) ₂ SO ₄ 1.5% (NH ₄) ₂ Cr ₂ O ₇ 1.5% Na ₂ Cr ₂ O ₇ .2H ₂ O 0.27–0.43% NH ₄ OH (SG.880) in water. | 30 mins immersion in boiling solution. Rinse in warm water and dry. | Steel or Aluminium. | Brown to black. | Controlled by pH:- Alloy pH .880 NH ₄ OH Mg–Zr 5.90–6.00 0.27% Mg–Al 5.90–6.05 0.27% Mg–Mn 6.05–6.18 0.34–0.4% Mg–Zn–Mn 6.00–6.10 0.34% |
| Acid Chromate (Dow 1) | 15% Na ₂ Cr ₂ O ₇ .2H ₂ O 25% HNO ₃ (SG. 1.42). | 10 secs to 2 mins immersion at room temperature – Drain 5–15 seconds, rinse in cold or luke warm water and dry. | Stainless Steel or Aluminium. | Golden yellow often with iridescence. | Controlled by specific gravity 1.20–1.24. Rejuvenated by nitric acid additions. |
| Dow 7 | a. 20% HF (60%) b. 12–18% Na ₂ Cr ₂ O ₇ .2H ₂ O 0.25% MgF ₂ or CaF ₂ . | 1/2–5 mins immersion in bath (a) at room temp. Rinse thoroughly then 30–45 mins immersion in bath (b) at boiling point. Rinse and dry. | a. Polythene or Synthetic Rubber. b. Steel or Aluminium. | Light to dark brown. | Bath (a) by analysis. Bath (b) by analysis plus control of pH between 4.1 and 5.5. |
| Dow 19 Touch Up | 1% CrO ₃ 0.5% CaSO ₄ in water. | Apply by swab for 1–3 mins. Rinse and dry. | | Light to dark brown. | |
| Alocrom1200 Touch Up. | 3% Alocrom 1200 in water. (ICI product). | Apply by swab for 2–3 mins. Rinse and dry. | | Brassy. | |

Appendix iv Chemical Pre-treatment of the Yttrium Containing Magnesium Alloys

In common with some other Rare Earth containing magnesium alloys eg. EK41, HM31, HK31; the yttrium containing alloys ELEKTRON WE43 and WE54 do not respond to certain chemical treatments, notably some of the chromate conversion coating baths. The following identifies some of the precautions and alternative chemical pre-treatments that are applicable when processing ELEKTRON WE43/54 alloy components.

Acid Pickling

A normal response to mineral acid cleaning baths is obtained, resulting in a relatively smut free surface.

Fluoride Anodising

Fluoride Anodise cleaning can be used but precautions are required to avoid pitting and metal loss. The composition of the bath must be maintained in the range 25–30% ammonium bifluoride (NH₄F.HF) and anodising voltages limited to 90 volts A.C. maximum.

Chromic Acid Cleaning

A normal response to hot chromium trioxide (CrO₃) solutions for the removal of surface oxide films, corrosion products and previously applied conversion coatings is obtained.

Dow 17 and HAE Anodising

Thick and thin anodic conversion coatings can be routinely applied by both the above hard anodising processes.

(See MEL Data Sheet 201).

Tagnite and Magoxid (KEPLA)

The chromate free anodic coatings may be satisfactorily applied.

Chromate Treatments

1. The following standard chemical treatments do not produce satisfactory chromate conversion coatings under standard conditions.

Dow 7/Dichromate Treatment

(MIL-M-3171C TYPE III)

Dow19/Chromic Acid Brush-on Treatment

(MIL-M-3171C TYPE VI)

Iridite 15 Mag-Coat

(MIL-M-3171C TYPE VIII)

RAE Hot Half Hour Chromate Treatment

(DTD 911C Bath III)

Chrome Manganese Treatment

(DTD 911C Bath V)

2. The following standard chemical treatments can be used under certain specified conditions to produce satisfactory chromate conversion coatings.

Dow 1/Chrome Pickle/Acid Chromate

(MIL-M-3171C TYPE I)

Chrome Manganese

–pH 4.0–5.5; 10–20 mins at 100°C

–pH 4.5–5.5; 30–60 mins at 50°C

–pH 5.25–5.75; 60–120 mins at ambient temperature.

(pH adjustment with sulphuric acid or sodium hydroxide solutions as required).

Chrome Manganese – galvanic application mode
(See MEL Data Sheet 203).

RAE Hot Half Hour

–pH 5.5–6.0; 15–45 mins at 50°C

–pH 5.5–6.0; 45–90 mins at ambient temperature.

(pH adjustment with sulphuric acid or ammonium hydroxide solutions as required).

3. The following standard chemical treatment can be used to produce a satisfactory chromate conversion coating.

Dow 9/Galvanic Chromating Treatment

(MIL-M-3171C TYPE IV).

4. Alocrom 1200/Alodyne 1200 (ICI Product) prepared as a 1–2% solution with deionised water can be used as an effective ‘brush-on’ or ‘touch-up’ treatment for the localised repair of damaged conversion coatings.

Appendix v

Hard Anodising Treatments

HAE and Dow 17

Hard anodising is applicable to all magnesium alloys and the treatments result in the formation of thick abrasion-resistant coatings. However, the corrosion protective values of the coatings are minimal due to their inherent porosity, though when sealed with a water-impermeable unpigmented resin (see Appendix vi) the resulting duplex films have excellent corrosion and abrasion resistance.

Pretreatment

Parts should be degreased using normal techniques and have dissimilar metals (eg. inserts), removed, masked or suitably blanked off. Parts having been Fluoride Anodised need not be stripped prior to hard anodising.

Power source

A source capable of providing a progressively increasing AC voltage up to a maximum of 110V.

Current requirements are dependent on the maximum load processed, but 150 amps/square metre of surface area on one electrode should be considered a minimum.

Procedure

Parts to be anodised are mounted with good electrical contact on magnesium alloy clamps and positioned at least 250 mm below the surface of the electrolyte with approximately equal surface areas connected to each electrode.

Parts should be positioned so that gas formed during treatment vents freely, or alternatively re-positioned as necessary to ensure overall treatment. Good electrical contact between parts and clamps must be maintained at all times.

AC voltage is applied and gradually increased to maintain the desired current density. When the terminal voltage has been achieved, the parts are removed and inspected. Parts should have a uniform colour, but if not, they should be returned for a further 3–5 mins at the terminal voltage, and then re-inspected.

When the treatment is judged complete, either by colour or thickness of the coating, the parts should be rinsed thoroughly and dried at 120°C.

Post treatments

The HAE solution is highly alkaline and therefore parts must be thoroughly rinsed after treatment. A post treatment in dilute hydrofluoric acid or ammonium bifluoride is recommended in order to neutralise any retained alkali but this must also be followed by thorough rinsing and drying. Post treatments that leave water-soluble reactive inorganic chemicals in the pores of the anodic films are not recommended.

Notes

1. The processes as described produce films giving approximately 0.04 mm build up.

However, by varying the treatment times and conditions, films upwards from 0.003 mm build up are attainable.

The protective value and abrasion resistance of the extremely thin films are only comparable with chromate conversion coatings and consequently their use is not recommended. The protective value of resin sealed anodic coatings increases with increasing thickness and where tolerances permit a coating resulting in a minimum increase in dimension of 0.025 mm should be applied.

2. Metal is consumed during the treatments which result in a true film thickness approximately double the film build up.

3. A detailed record should be kept of operating parameters, particularly current density and treatment times necessary for the treatment of each component. Use of this information permits similar components to receive the same coating thickness within close limits.

4. The anodic films are extremely hard but somewhat rough, and therefore tend to have an abrasive effect on parts coming into contact with them. This can be overcome by honing the film after resin impregnation to give a smooth bearing surface.

5. The throwing power of the HAE anodic treatments is good but that of Dow 17 is exceptional in that it can fully treat an 8 mm diameter bore for at least 150 mm depth without recourse to ancillary electrodes.

6. The hard anodising of magnesium giving a dimensional increase of 0.04 mm/surface cannot always be tolerated. In instances where this is the case alternative techniques are required and these will vary depending upon the component. For example, the masking of fine threads is usually necessary and this is easily achieved by using magnesium or non-metallic threaded screws or plugs. On the other hand, the masking of open areas is more difficult and usually requires the use of rubber-gasketed blanking plates.

However, some success has been achieved with paint-on maskants.

Having fully treated the components and removed the masks, some treatment of the bare areas is then necessary. It is quite permissible to return the component to the bath and to retreat until the desired film thickness on the machined areas has been achieved. (In the case of threaded holes it is usual not to carry out any further treatment as long as assembly is carried out using sealing compounds).

It should be noted that the Dow 17 treatment of machined parts previously Dow 17 and Surface Sealed will result in damage to the sealing resin. This technique is, however, possible with the HAE treatment.

| Name | Bath Composition | Container | Temp (°C) | Typical Current Density (amps/m ²) | Approximate Treatment Time (mins) | Maximum Voltage | Resulting Appearance |
|--------|---|---|------------------|--|-----------------------------------|-----------------|----------------------|
| HAE | 12% KOH 1.0% Al 3.5% KF 3.5% Na ₃ PO ₄ .12H ₂ O 2.0% K ₂ MnO ₄ . | Mild Steel (Preferably Rubber or Plastic Coated). | Room (30°C max). | 600 | 60 | 90 | Dark brown |
| Dow 17 | 24% NH ₄ HF ₂ 10% NaCr ₂ O ₇ .2H ₂ O 9.0% H ₃ PO ₄ (85%) | Mild Steel (Preferably Rubber or Plastic Coated). | 70–80°C. | 350 | 20 | 90 | Dark green |

Tagnite and Magoxid

These are two new proprietary hard anodised coatings which have been developed in the USA and Europe respectively. Both coatings are white/grey in appearance and do not contain chromates. They provide excellent corrosion resistance with

performances similar to that of HAE coatings in the surface sealed condition. With no post treatment they provide a good degree of protection as the coatings are less porous than alternative anodising treatments.

Appendix vi Surface Sealing

Surface Sealing is a technique developed to produce a thin, flexible, extremely water-impermeable resin coating on all suitably treated magnesium alloy surfaces. This technique should not be confused with “impregnation” to seal surface porosity.

Pretreatment

Surface Sealing must be applied to clean chromated, or hard anodised, preheated surfaces. Ideally the resin should be applied to freshly produced coatings since contamination absorbed into chromate films or the pores of hard anodised films is extremely difficult to remove.

Recommended Resins

Any surface sealing resin which meets DTD 5562 is suitable for surface sealing of Magnesium.

Two major suppliers of resins in the UK are:–

Courtaulds Aerospace, Shilden, County Durham DL4 2QP.

Indestructible Paint Company Limited,
25, Pentos Drive, Sparkhill, Birmingham B11 3TA.

If required a resin may be formulated as follows:

| | |
|-------------------------|---------------------|
| Araldite HZ985 Hardener | 100 parts by weight |
| Araldite PZ985 Resin | 300 parts by weight |
| Ethyl Acetate | 240 parts by weight |
| Toluene | 136 parts by weight |
| Diacetone Alcohol | 24 parts by weight |

This formulation has been found by Magnesium Elektron to be satisfactory and is suitable for dip application, but additional solvents in the above ratio may be added for application by spray. A 25% addition is usually sufficient but more may be added for spray application to close tolerance areas.

The Araldite resin and hardeners are available from Ciba-Geigy (U.K.) Limited, Duxford, Cambridge.

Coating procedure

1. Preheat the component at 200–220°C for 30 minutes or until this temperature has been maintained for at least 10 minutes.
2. Allow to cool to 60°C then spray with, or preferably dip in, surface sealing resin.
When dipping, allow the components sufficient time in the resin to cool and absorb the resin.
3. Allow to air dry for 15–30 minutes. Ensure uniform drainage and remove any tears that form with a small brush.
4. Bake at 200–220°C for 10–15 minutes.
5. Remove drips or tears that may have formed with a sharp knife or glass paper taking care not to damage the chromate or anodic film.
6. Repeat steps 2, 3, 4 and 5 twice more making 3 coats in all.
7. Bake final coat to manufacturer’s recommended temperature for 45–60 minutes.

The complete resin coating so formed is approximately 0.025mm thick.

Notes

1. Preheating the component is essential in order to ensure all surface moisture is completely removed.
2. Dipping is preferred to spraying since this ensures the complete coverage of all surfaces.
3. Dipping components while still warm assists the resin to permeate and fill surface irregularities and the porosity of hard anodic films.
4. The full treatment is usually applicable to all surfaces, including machined areas; however when tolerances do not permit this, the coating can be reduced to 2, or in extreme circumstances to 1 coat of resin. The protective value of the thinner coatings is obviously reduced.
5. Surface Sealing being extremely thin is prone to damage in use and consequently should, in general, be classed only as a foundation for subsequent painting.
6. Surface sealing resins are extremely resistant to most chemicals and therefore very difficult to remove.
7. Epoxy resins are recommended although phenolic resins have also been used successfully.
8. Vapour degreasing in trichloroethane or trichloroethylene may result in degradation of some resin films if they are not subsequently baked at 120°C for 15 minutes.

Appendix vii Assembly

The method of assembly employed and the efficiency with which it is carried out considerably influences the behaviour of magnesium components in service.

All assemblies incorporating magnesium components should include wet assembly which involves the application of a sealing compound between all contact areas. These include mating faces, nuts, bolt heads and washers etc. The sealing compound may be of a setting or non-setting variety, but the latter is generally used on parts which are to be disassembled regularly. However, it should be recognised that the different compounds will have differing properties and only those with proven corrosion resistance should be used.

Additional protection provided by the application of sealing compound to form fillets or overlays at the exposed edges of joints is also beneficial. The protective value is further increased if the fillets are over-painted with the full paint scheme. Sealing compounds used for caulking must always be the polymerising, or setting, type of compound.

If, for any reason, mating faces have to be left unprotected, caulking and overpainting of joint edges is essential.

Sealing compounds are usually chromate pigmented to provide chromate inhibition, although non-chromate pigmented compounds, eg silicone rubbers, have been used successfully.

The practices of wet assembly, caulking and overpainting effectively eliminate the possibility of corrodent gaining access to crevices and causing corrosion, often unnoticed for long periods.

An additional problem area, often not appreciated until after assembly, occurs when areas on adjacent components (mating faces), are given minimal protection and these areas do not match exactly when assembled. When this occurs, overpainting after assembly to ensure all areas receive the full protective scheme is essential.

Appendix viii Painting

The painting of magnesium alloys for protection is basically no different to the painting of any other metal. The basic requirements for a high degree of surface cleanliness, a good pretreatment and the proper application of a good quality paint are all important. These factors play a large part in determining how well a paint scheme will perform in service.

Pretreatment

Paint is normally applied onto chromate conversion coatings directly, or on Surface Sealed chromate conversion or hard anodic coatings. It should never be applied to bare magnesium.

When paint is to be applied directly on a chromate film it is advisable for the film to be freshly applied and baked to ensure complete drying. Renewal of the chromate film ensures that any contamination of the old film is completely removed.

The paint scheme

The individual coats of a paint scheme must, of course, be compatible with each other and also with pretreated magnesium. Good alkali resistant and moisture impermeable epoxy paints are preferred. For some applications, a polyurethane finish, which is more resistant to UV degradation and hence less likely to suffer from "chalking," is often used.

In general, baked paints have a greater protective value than cold curing paints. Similarly, the baking of cold curing paints often improves their performance but may render them more difficult to strip.

Paint may be applied by dipping, spraying or brushing, but whichever technique is used, the aim should be to apply a uniform coating of the desired thickness over all surfaces.

Primer should contain in the dry film not less than 15% by weight of chromate pigment. This should be either strontium chromate or strontium chromate containing up to 10% of barium chromate.

Compounds of mercury and lead must not be used in the primer.

An intermediate filler coat, if desired, and finishing coats should be applied to give a total organic coating thickness of at least 0.1mm and preferably 0.13 mm to 0.15 mm.

The finishing coat is normally chosen to have the colour and texture required by the particular application.

When to paint

Ideally a primer coat should be applied prior to assembly and should cover all surfaces including internal and mating faces. This is particularly important if the part has not been Surface Sealed. It may be necessary to restrict the coating thickness in certain areas but it should not be omitted completely.

At least one coat of primer and one coat of finish should be applied after wet assembly (see Appendix vii) to produce the desired overall thickness. Painting after assembly ensures the joints between adjacent components are adequately covered to stop ingress of moisture. In addition, the painting of bolt heads, nuts etc. isolates them from corrodent and effectively eliminates galvanic corrosion.

If, for any reason, painting cannot be carried out after assembly, the parts should be masked as necessary and the full paint scheme applied. After assembly the joints between components and dissimilar metals should be hand painted with cold curing primer and finish.

Whatever the sequence, all exposed surfaces should receive applications of primer and finish.

Appendix ix Temporary Protection

Magnesium components should generally be given some form of temporary protection between machining stages if delays in excess of 24 hours are likely to be encountered.

The degree of protection will vary depending upon the condition of the component, the environment in which the component is stored and the duration of the storage.

The following information should therefore be considered as a guide only.

Note:

The sealing of components in polythene bags without dessicant may lead to corrosion if condensation occurs within the bag due to temperature changes.

| Storage time | Surface condition of component | | | |
|--------------|--------------------------------|-------------------|-----------------|---------------------------|
| | Cleaned | Machined | | Fully Protected* |
| | Unheated/ heated store | Unheated store | Heated store | Unheated/ heated store |
| 1-7 days | A | B | B | A |
| 1-4 weeks | B | C | C | A |
| 1-12 months | C | E | D | D |
| 1-5 years | C | E | E | D |

Key

- A. No treatment.
- B. Coated with oil, grease or wax.**
- C. Coated with oil, grease or wax** and protected from dust.
- D. Sealed in dry polythene bag with dessicant.
- E. Oiled and sealed in dry polythene bag with dessicant.

* Fully protected assumes all the component has received full organic protection. If some parts are only machined and chromated, treat as for machined.

** All materials must be compatible with magnesium.

Appendix x Repair and Maintenance

Repair

The treatment a damaged magnesium alloy component receives will vary depending upon various factors.

These include:

- The stage at which the component becomes damaged, i.e. during manufacture or in service.
- The complexity of the component.
- The environment to which the damaged component is exposed.
- The time interval between the damage and its rectification.
- The feasibility of carrying out the preferred treatments.

If components become damaged during manufacture they must be retreated to the original specification.

Although it is also preferable to treat components damaged in service to the original specification, this is not always practicable. In such circumstances, the aim should be to re-protect to a level at least as good as the original finish.

The following flow charts illustrate typical repair schedules. Where appropriate, degreasing with a paraffin wash or solvent swab may be necessary.

Maintenance

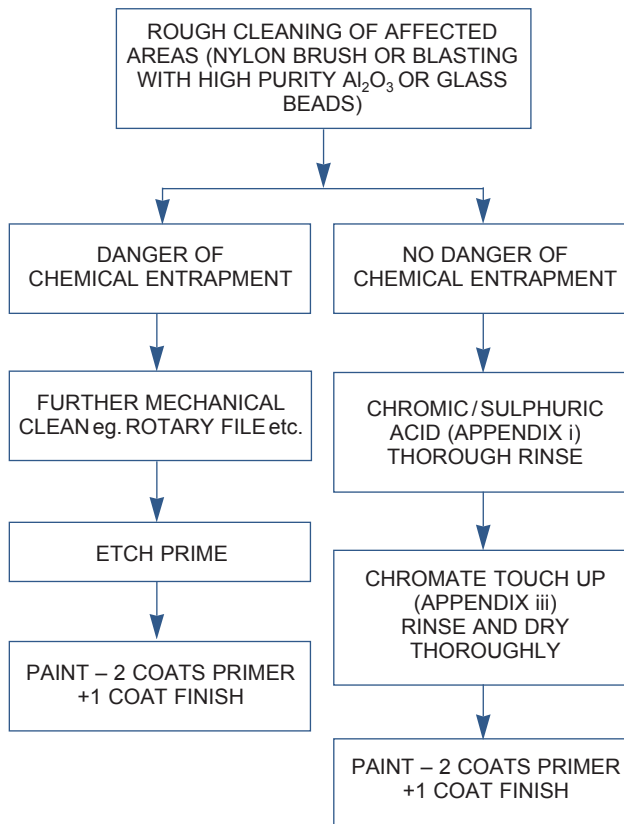
Magnesium components should be inspected regularly during service for signs of breakdown and degradation.

The necessary treatment should be actioned as soon as possible.

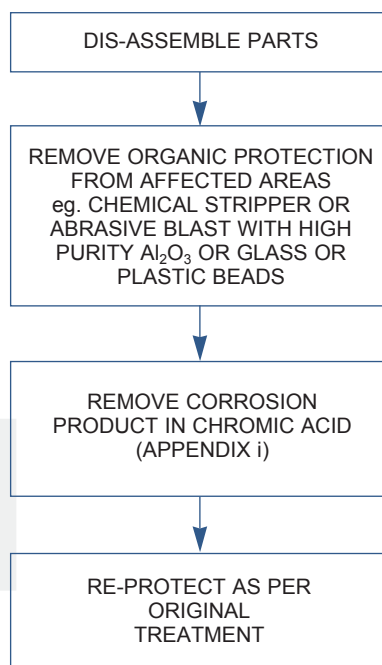
The build up of contamination, eg. salt, present on components should be removed by brushing and washing with fresh water. This should be followed by thorough drying, eg. with a hot air blower, and finally by the application of a fine spray of dewatering oil or similar protective oil, grease or wax.

The routine application of such dewatering materials to components in service will considerably prolong their service life.

- In-situ repair of superficially corroded parts
The processing route selected needs to take into consideration whether or not there is a potential danger due to the entrapment of aqueous solutions, eg. crevices, proximity of other sensitive equipment, etc.



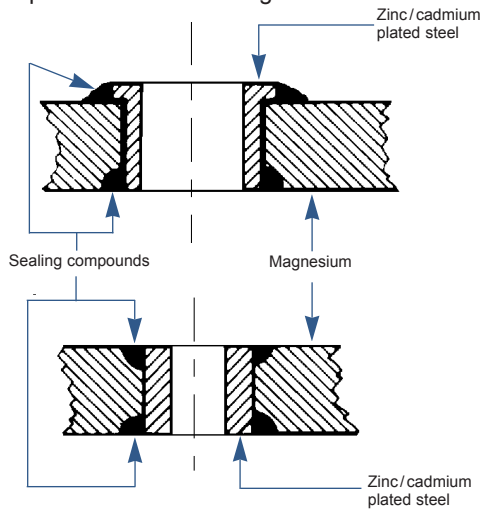
- General retreatment of corroded parts



Appendix xi
Examples of Good/Poor Design Practices

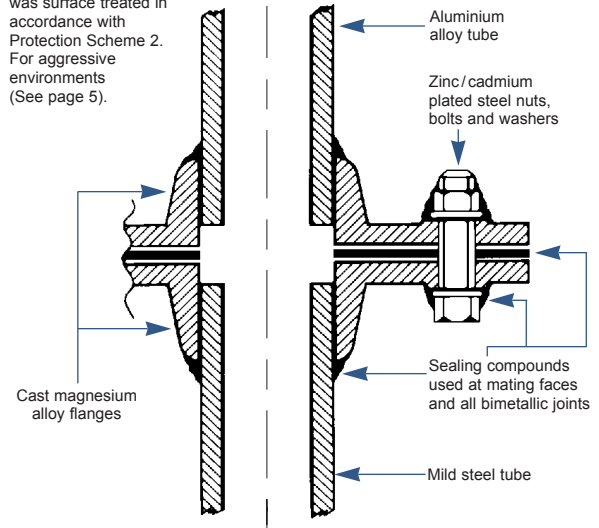
Design practice in relation to potential corrosion hazards.

Good practice for bush fittings

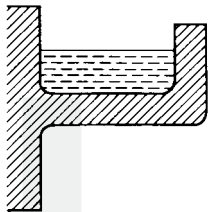


MEL test assembly for evaluating paint and assembly schemes

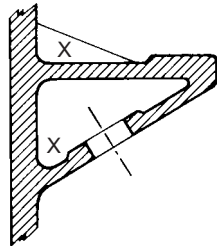
This test assembly was surface treated in accordance with Protection Scheme 2. For aggressive environments (See page 5).



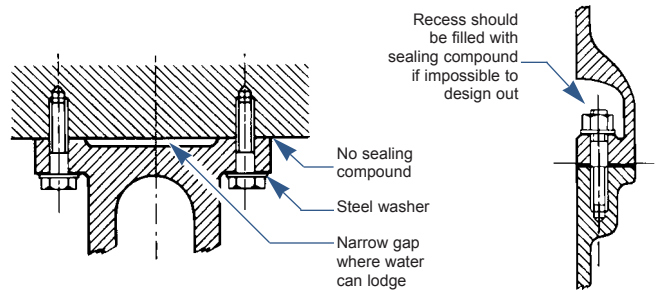
Poor practice



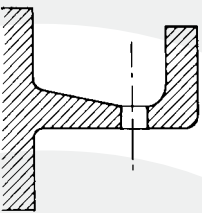
Liquid trap



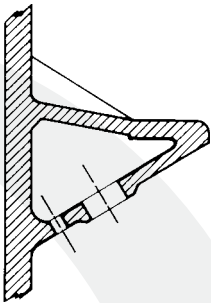
Water can be trapped at (X)



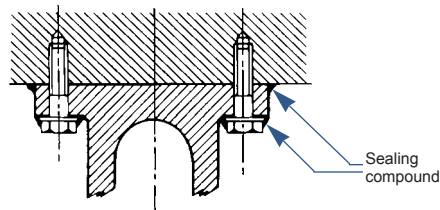
Better/good practice



With provision of taper and drain hole

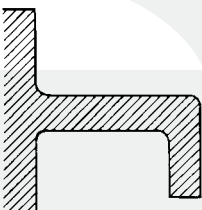


With taper and drain holes

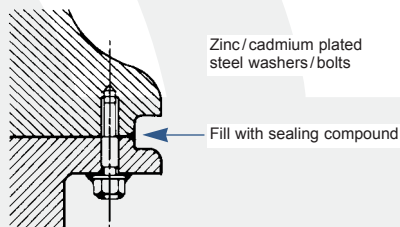


With no gap

Recommended practice



No recess where water can collect



For use when direct metal to metal contact is required for electrical reasons

Appendix xii
Related Specifications and
Magnesium Elektron Data Sheets

| | |
|---------------------|--|
| DTD 911 | Protection of Magnesium Rich Alloys Against Corrosion. |
| MIL-M-3171 | Magnesium Alloy, Processes for Pretreatment and Prevention of Corrosion on. |
| MIL-M-45202 | Magnesium Alloys, Anodic Treatment of. |
| Form No. 141-479-82 | Magnesium: Operations in Magnesium Finishing (Dow Chemical Company Publication). |
| DTD935 | Surface Sealing of Magnesium-Rich Alloys. |
| DTD5555/5567 | Exterior Glossy Finishing Schemes (Cold Curing Epoxide Type). |
| DTD5562 | Clear Baking Resin for Surface Sealing Magnesium. |
| DTD5580 | Exterior Glossy Finishing Schemes (Cold Curing Polyurethane Type). |



Certificate No. FM12677