CATEGORY 3

Magnesium Elektron Limited

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SALT SPRAY PERFORMANCE OF HAE, Dow 17 AND TAGNITE COATINGS

REPORT BY: H. KARIMZADEH

ISSUED BY: J F KING

Magnesium Elektron Inc
Reade Manufacturing Division
100 Ridgeway Blvd
Lakehurst
N J 08733
USA

Magnesium Elektron
P O Box 23 Rake Lane
Swinton
Manchester
M27 8DD

Copy No:

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Summary

The corrosion protection characteristics of TAG 8200, TAG 8500, HAE and Dow 17 anodic coatings without post-treatments were evaluated on Elektron QE22 and Elektron ZE41 alloys in a ASTM B117 salt spray test.

Two coating types were tested; type I approximately 8μ thick and type II approximately 17-21μ thick.

Both Tagnite coatings in the thin or thick form performed very well in the salt spray test and their performance was far superior compared to HAE and Dow 17 coatings.

The performance of HAE type I and type II coatings was generally superior to Dow 17 equivalent, but the difference was less significant.

Generally, the protection provided by the thicker coatings (type II) was superior to thinner coatings (type I).

It is evident that Tagnite coatings without any post-treatment provided far superior protection compared to any of the other coatings evaluated. This is of great significance for real applications, since the post-treatment of certain parts of a component may not be permitted.

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1. Introduction

Anodising of magnesium components, particularly for aerospace applications, has been carried out for several decades.

In recent years, due to health, safety and environmental legislations, demand for chromium free and environmentally friendly coatings has risen.

Technology Applications Group Inc (TAG) have developed two chromate free anodic coatings for magnesium alloys. The coatings are produced by an electrochemical process during which magnesium oxide is created through an anodisation process, while inorganic silicate (TAG 8200) or vanadate (TAG 8500) species from the electrolyte are fused to the surface. These coatings are claimed to exhibit improved corrosion resistance over the currently used HAE and Dow 17 treatments.

The corrosion protective values of HAE and Dow 17 without any post-treatment are minimal due to their inherent porosity level, though when sealed with a water impermeable resin, the resulting duplex films have excellent corrosion resistance.

During this work, the corrosion performance of HAE, Dow 17 and Tagnite coatings without any post-treatment are directly compared.

2. Experimental Details

2.1 Sample Preparation

24 QE22-T6 and 24 ZE41-T5 test panels nominally 125 x 100 x 5mm were received from TAG.

The alloys were cast by Fansteel Wellman Dynamics and received in the machined condition.

8 QE22 and 8 ZE41 test panels were coated with TAG 8500 and TAG 8200, respectively. The remaining 32 panels were HAE or Dow 17 treated at Magnesium Elektron in accordance with MEL's procedure (Appendix I) to obtain similar thickness to type I and type II Tagnite coatings.

Throughout this report, the coating thicknesses 8-10μ are referred to as type I and coatings 17-21μ are referred to as type II coatings.

The surface treatment and the average film thickness for all the test panels are given in tables 1 and 2.

2.2 Visual Inspection

Before exposure to the salt spray test, all the test panels were visually inspected for defects, colour and surface texture. After inspection, the top end of each test panel bearing the suspension hole and the panel identity were masked off using a polymer masking tape.

One test panel from each treatment was retained as a standard.

2.3 Corrosion Test

Triplicate test panels were placed on polypropylene racks at 15-30 degrees to vertical and exposed to ASTM B117 salt spray test for the following durations:

Type I coatings	-	168 hours, see Table 3
Type II coatings	-	336 hours, see Table 4

After the test the masking tape was removed, the test panels were thoroughly rinsed in warm water to remove loose corrosion product from the surface and dried in an oven at 110°C.

3. Results and Discussion

3.1 Visual Inspection

Prior to salt spray test the panels were visually examined. All test panels appeared free from defects and showed good overall coverage. Tagnite coatings, as expected, had a much smoother finish than HAE and Dow 17 coatings. The typical appearance of the coatings on QE22 and ZE41 panels are shown in figures 1-2 and 3-4, respectively.

3.2 Corrosion Test

Due to the large number of coating combinations, the results on QE22 and ZE41 are reported separately.

Although corrosion had occurred on both sides of the test panels, the corrosion assessment was carried out on the top face of the panels which had suffered most corrosion attack.

3.2.1 Corrosion Characteristics of the Coatings on QE22 Panels

Detailed results are shown in tables 5-6 and figures 5-6.

Type I Coatings

Test panels coated with TAG 8500 appeared good with very little corrosion. The pits were generally very fine. Several larger pits were randomly spaced on each test panel (Fig. 5a). There was very little corrosion spread from the pits and the general performance of all three test panels was very similar.

The HAE treated panels showed significantly more corrosion that the Tagnite treated panels. The corrosion points were randomly spaced and the corrosion attack was in the form of pitting and growth (Fig 5b). This was consistent for all three test panels.

The Dow 17 treated test panels showed severe corrosion. The corrosion was in the form of pitting and growth with extensive spread in some areas (Fig. 5c). The corrosion attack on one of the test panels (QF1781) was much more extensive, covering approximately 70% of the exposed face. The reason for that is not clear.

Type II Coatings

Test panels coated with TAG 8500 appeared good with very little corrosion (Fig. 6a). Although the test panels were exposed for 336 hours (twice as long as for type I), there were significantly fewer fine pits present, indicating the good degree of protection provided by this type of coating. Several larger pits were also present but they were not considered extensive.

Significantly more corrosion attack was evident on the HAE treated test panels (Fig 6b) than the Tagnite treated ones. Corrosion spread on to the masked area indicated the very porous nature of the coating, allowing moisture penetration beneath the masking tape.

Significant corrosion attack had occurred on the Dow 17 treated test panels (Fig. 6c). Similar to HAE coated panels, the corrosion attack on the masked area is due to the very porous nature of the coating.

3.2.2 Corrosion Characteristics of the Coatings on ZE41 Panels

Detailed results are shown in tables 7-8 and figures 7-8.

Type I Coatings

Very little corrosion had occurred on the test panels coated with TAG 8200. The test panels appeared very similar and contained randomly spaced fine pits and one or two large corrosion points (Fig. 7a).

Severe corrosion had occurred on the HAE treated panels covering up to approximately 70% of the exposed face. It appeared that the corrosion points had linked and spread, leaving parts of the exposed areas unattacked (Fig. 7b).

Dow 17 treated panels also suffered severe corrosion attack (Fig.7c). The level of corrosion attack varied between the panels ranging approximately 40-90%of the exposed face.

Type II Coatings

Test panels coated with TAG 8200 appeared very good after 336 hours exposure to salt spray. Although very fine pits were present on all test panels, only one corrosion point was notable on each panel (Fig 8a).

Significant amount of corrosion had occurred on the HAE treated panels. The corrosion points were large and appeared interlinked, while most of the exposed face was unattacked (Fig. 8b). The corrosion attack on the masked area was notable and this is considered to be due to high porosity level of the coating allowing the moisture to penetrate beneath the masking type.

Severe corrosion of Dow 17 treated panels had occurred covering approximately up to 70% of the exposed face (Fig 8c). The corrosion attack had extended on to the masked area. This is considered to be due to the porosity level of the coating.

4. Conclusion

1. The corrosion performance of QE22 test panels coated with type I or type II TAG 8500 was far superior to HAE or Dow 17 treated equivalent.

2. QE22 test panels coated with type I HAE performed better than Dow 17 equivalent, but when coated with type II, the performance was similar.

3. The corrosion performance of ZE41 test panels coated with type I and type II TAG 8200 was far superior to HAE or Dow 17 equivalent.

4. The HAE treated ZE41 test panels performed better than Dow 17 equivalent.

5. Type II coating provided far superior protection to type I, bearing in mind the test duration for type II was twice as long.

6. The salt spray performance of both TAG 8200 and TAG 8500 without any post treatment is considered very good.

TABLE 1

Details of the Coatings on QE22 Test Panels

Alloy	Sample ID	Coating	Coating thickness μ (Ave)
QE22	QF161-QF164	TAG 8500	7.7
QE22	QF165-QF168	TAG 8500	17
QE22	QF169-QF172	HAE	8
QE22	QF173-QF176	HAE	17
QE22	QF177-QF180	Dow 17	8
QE22	QF181-QF184	Dow 17	17

TABLE 2

Details of the Coatings on ZE41 Test Panels

Alloy	Sample ID	Coating	Coating Thickness μ (Ave)
ZE41	ZF224-ZF227	TAG 8200	21
ZE41	ZF228-ZF231	TAG 8200	10
ZE41	ZF232-ZF235	HAE	10
ZE41	ZF236-ZF239	HAE	21
ZE41	ZF240-ZF243	Dow 17	10
ZE41	ZF244-ZF247	Dow 17	21

Table 3

Test Panels Exposed to ASTM B117 Salt Spray Test for 168 Hours

Alloy	Sample ID	Coating	Coating Thickness μ
QE22	QF161-QF163	TAG 8500	7.7
QE22	QF169-QF171	HAE	8
QE22	QF177-QF179	Dow 17	8
ZE41	ZF228-ZF230	TAG 8200	10
ZE41	ZF233-ZF234	HAE	10
ZE41	ZF240-ZF242	Dow 17	10

Table 4

Test Panels Exposed to ASTM B117 Salt Spray Test for 336 Hours

Alloy	Sample ID	Coating	Coating Thickness μ
QE22	QF165-QF167	TAG 8500	17
QE22	QF173-QF175	HAE	17
QE22	QF181-QF183	Dow 17	17
ZE41	ZF224-ZF226	TAG 8200	21
ZE41	ZF236-ZF238	HAE	21
ZE41	ZF244-ZF246	Dow 17	21

Table 5

Appearance of QE22 Panels with Type I Coatings after 168 hours ASTM B117 Salt Spray Test

Panel ID	Coating	Appearance
QF162	TAG 8500	Generally good with very little corrosion. Approx. 80 very fine pits and several large pits 2-4mm in diameter.
QF163	TAG 8500	Generally good with very little corrosion. Approx. 80 very fine pits and several larger pits 2-5mm in diameter.
QF164	TAG 8500	Generally good with very little corrosion. Approx. 60 very fine pits and several larger pits 2-3mm in diameter.
QF170	HAE	Extensive corrosion. Approx. 70 large pits up to 10mm in diameter.
QF171	HAE	Extensive corrosion. Approx. 100 large pits up to 10mm in diameter.
QF172	HAE	Extensive corrosion. Approx. 70 large pits up to 10mm in diameter.
QF178	Dow 17	Severe corrosion covering approx. 70% of the exposed face. Some corrosion spread on to the masked area.
QF179	Dow 17	Extensive corrosion. Approx. 80 large pits up to 15mm in diameter covering approx. 25% of the exposed face.
QF180	Dow 17	Extensive corrosion. Approx. 80 large pits up to 12mm in diameter covering approx. 25% of the exposed face. Some corrosion attack on the masked area.

Table 6

Appearance of QE22 Test Panels with Type II Coatings after 336 hours ASTM B117 Salt Spray Test

Panel ID	Coating	Appearance
QF166	TAG 8500	Generally good with very little corrosion. Approx. 25 very fine pits and 10-15 larger pits 2-4mm in diameter.
QF167	TAG 8500	Generally good with very little corrosion. Approx. 20 very fine pits and 10 larger pits 2-6mm in diameter.
QF168	TAG 8500	Generally good with very little corrosion. Approx. 30 very fine pits and 10-15 larger pits 2-6mm in diameter.
QF174	HAE	Extensive corrosion covering approx. 30% of the exposed face. Corrosion attack on the masked area.
QF175	HAE	Severe corrosion covering approx. 50% of the exposed face. Corrosion attack on the masked area.
QF176	HAE	Extensive corrosion covering approx. 25% of the exposed face. Corrosion attack on the masked area.
QF182	Dow 17	Extensive corrosion in the form of large pits covering approx. 25% of the exposed face. Corrosion attack on the masked area.
QF183	Dow 17	Extensive corrosion in the form of large pits covering approx. 25% of the masked area. Corrosion attack on the masked area.
QF184	Dow 17	Extensive corrosion in the form of moderate to large size pits covering approx. 10% of the exposed face. Corrosion attack on the masked area.

Table 7

Appearance of ZE41 Test Panels with Type I Coatings after 168 hours ASTM B117 Salt Spray Test

Panel ID	Coating	Appearance
ZF229	TAG 8200	Generally good with very little corrosion. Approx. 25 very fine superficial pits. Small amount of corrosion on the lower edge and one corrosion point approx. 6mm in diameter.
ZF230	TAG 8200	Generally good with very little corrosion. Approx. 25 very fine superficial pits. Small amount of corrosion on the lower edge and two corrosion points spreading up to 11mm.
ZF231	TAG 82500	Generally good with very little corrosion. Approx. 15 fine superficial pits. Small amount of corrosion on the lower edge and two corrosion points spreading up to 8mm.
ZF233	HAE	Severe corrosion covering approx. 50% of the exposed face.
ZF234	HAE	Severe corrosion covering approx. 70% of the exposed face.
ZF235	HAE	Severe corrosion covering approx. 50-60% of the exposed face.
ZF241	Dow 17	Severe corrosion covering approx. 90% of the exposed face.
ZF242	Dow 17	Severe corrosion covering approx. 80% of the exposed face. Corrosion spread on to the masked area.
ZF243	Dow 17	Severe corrosion covering approx. 40% of the exposed face. Some corrosion spread on to the masked area.

Table 8

Appearance of ZE41 Test Panels with Type II Coatings after 336 hours ASTM B117 Salt Spray Test

Panel ID	Coating	Appearance
ZF225	TAG 8200	Generally good with very little corrosion. Approx. 70 very fine pits. One corrosion point spreading up to 8mm.
ZF226	TAG 8200	Generally good with very little corrosion. Approx. 70 very fine pits. One corrosion point spreading up to 10mm.
ZF227	TAG 8200	Generally very good with very little corrosion. Approx. 70 very fine pits. One corrosion point spreading up to 6mm.
ZF237	HAE	Significant amount of corrosion. Approx. 35 large deep pits spreading, similar to filiform type corrosion, covering approx. 15% of the exposed face. Several large pits on the masked area.
ZF238	HAE	Significant amount of corrosion. Large deep pits spreading, similar to filiform type corrosion, covering approx. 25% of the exposed face. Several large pits on the masked area.
ZF239	HAE	Significant amount of corrosion. Large pits spreading, similar to filiform type corrosion, covering approx. 15% of the exposed face. Some corrosion attack on the masked area.
ZF245	Dow 17	Severe corrosion covering approx.70% of the exposed face. Some corrosion attack on the masked area
ZF246	Dow 17	Severe corrosion covering approx. 40% of the exposed face. Severe corrosion of the masked area.
ZF247	Dow 17	Severe corrosion covering approx. 60% of the exposed face. Significant amount of corrosion on the masked area.

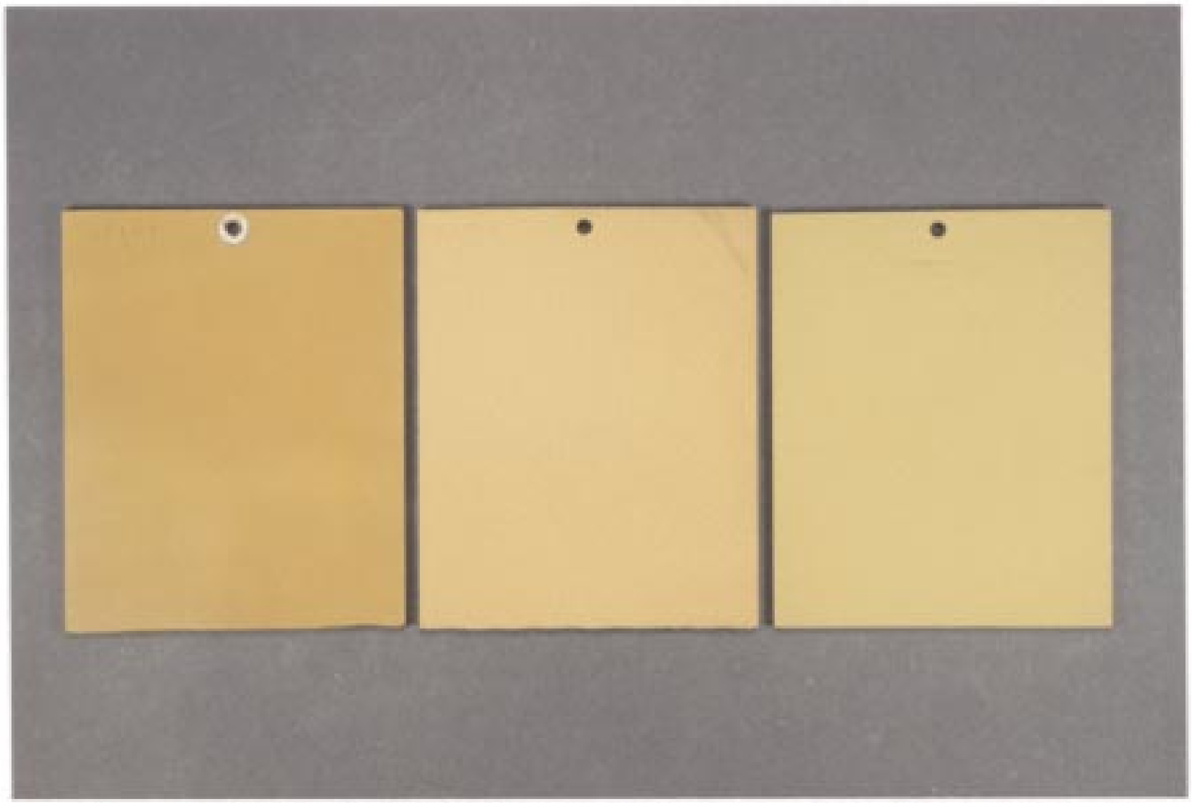

Figure 1 QE22 Test Panels coated with type I coating, TAG 8500 (left), HAE (centre) and Dow 17 (right)

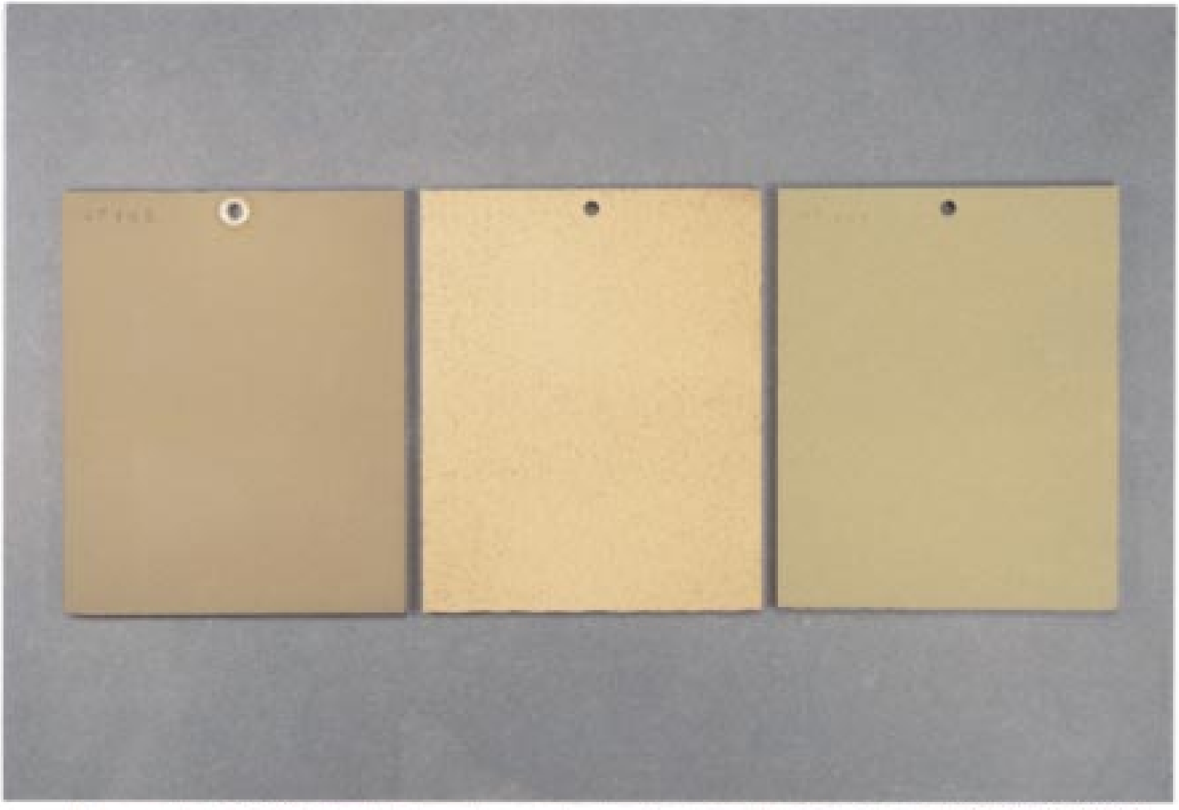

Figure 2 QE22 Test Panels coated with type II coating, TAG 8500 (left), HAE (centre) and Dow 17 (right)

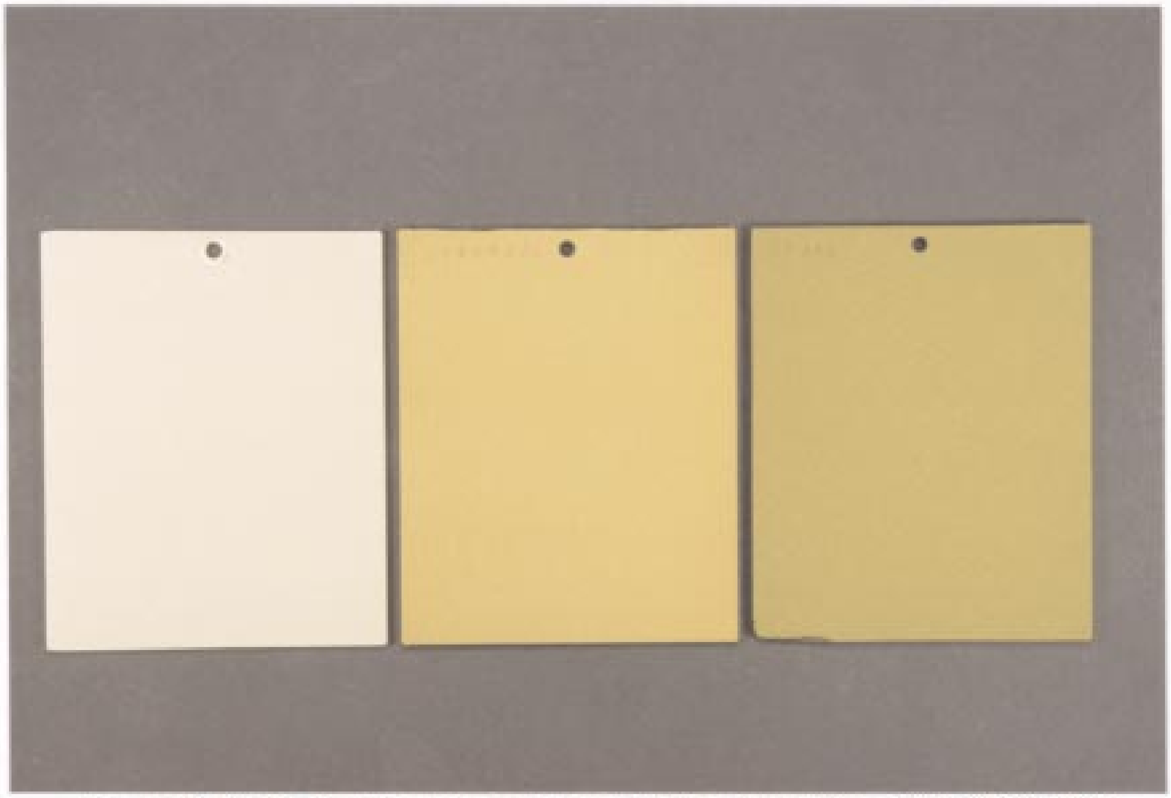

Figure 3 ZE41 Test Panels coated with type I coating, TAG 8200 (left), HAE (Centre) and Dow 17 (right)

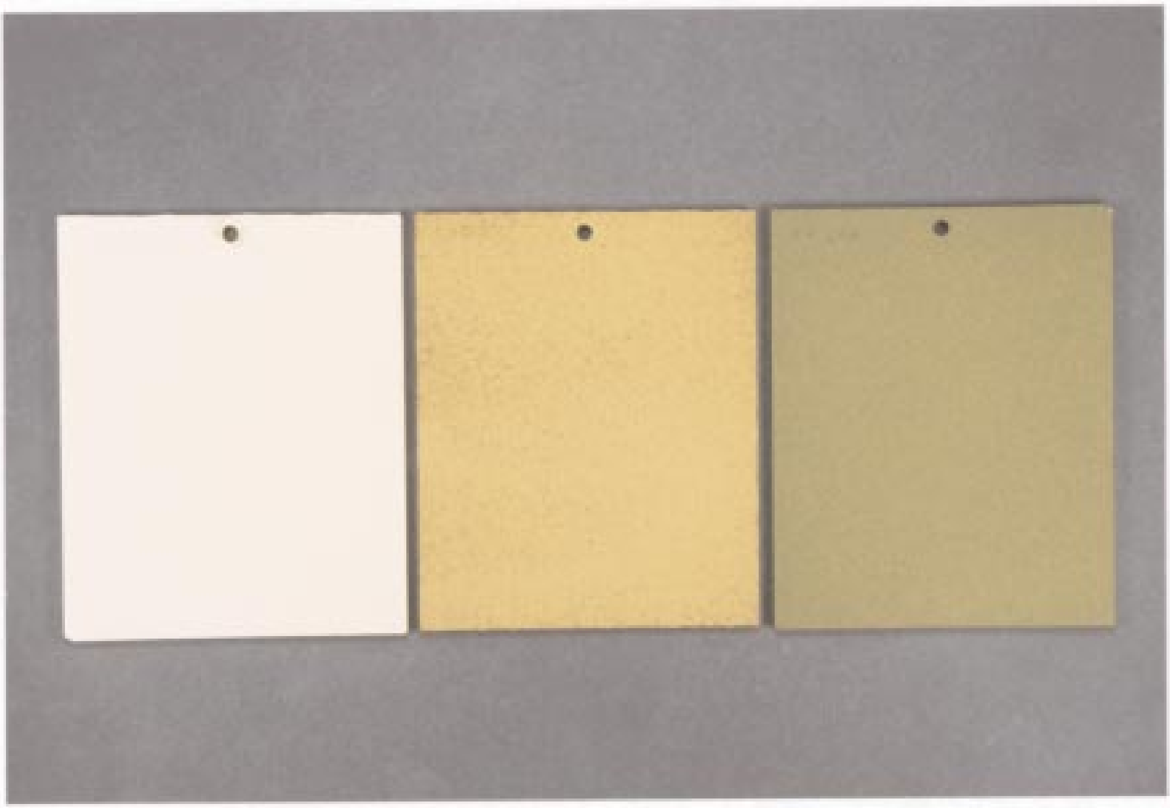

Figure 4 ZE41 Test Panels coated with Type II coating, TAG 8200 (left) HAE (centre) and Dow 17 (right)

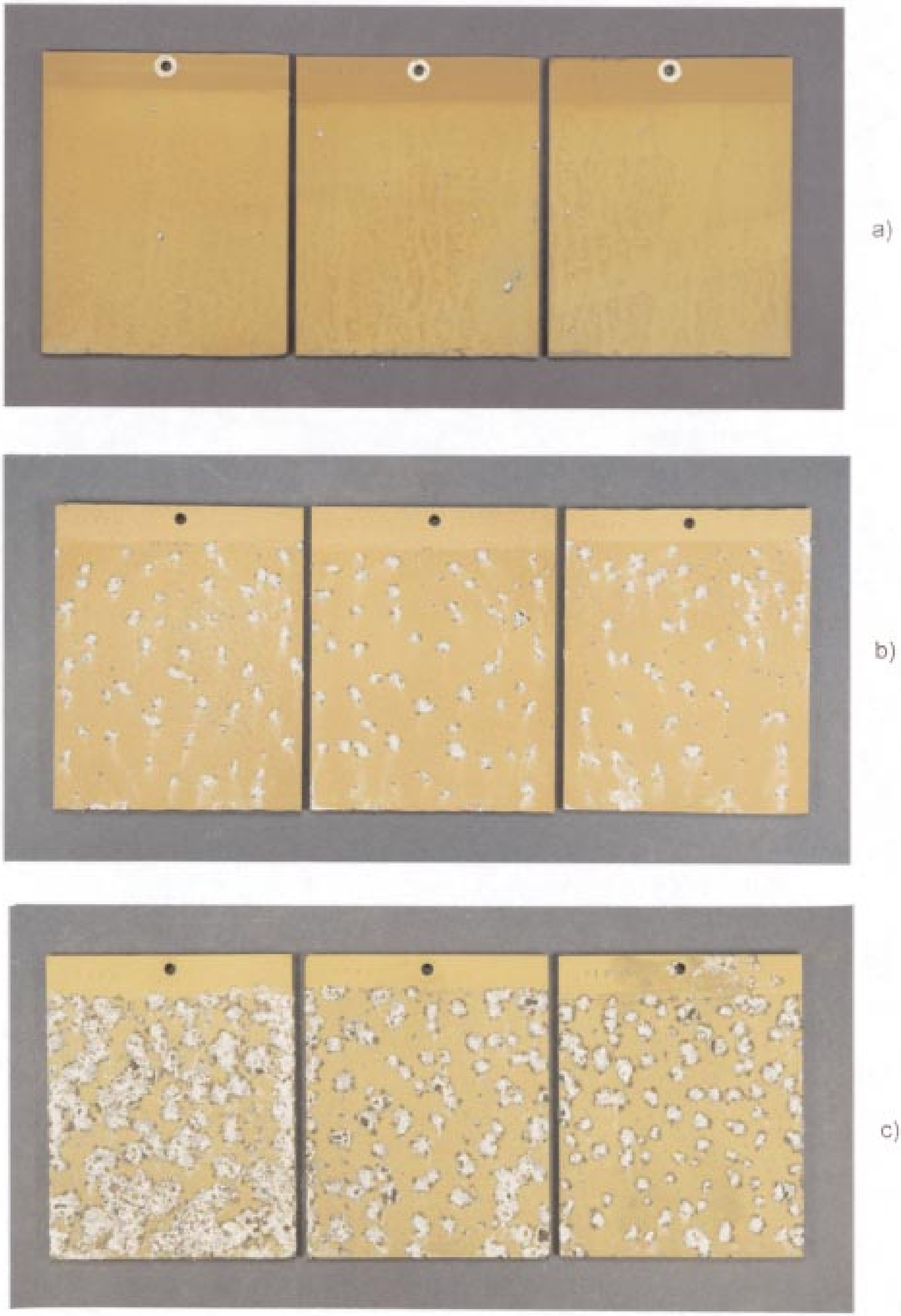

Figure 5 QE22 Test Panels coated with type I coating and exposed to ASTM B117 salt spray test for 168 hours a) TAG 8500, b) HAE, c) Dow 17

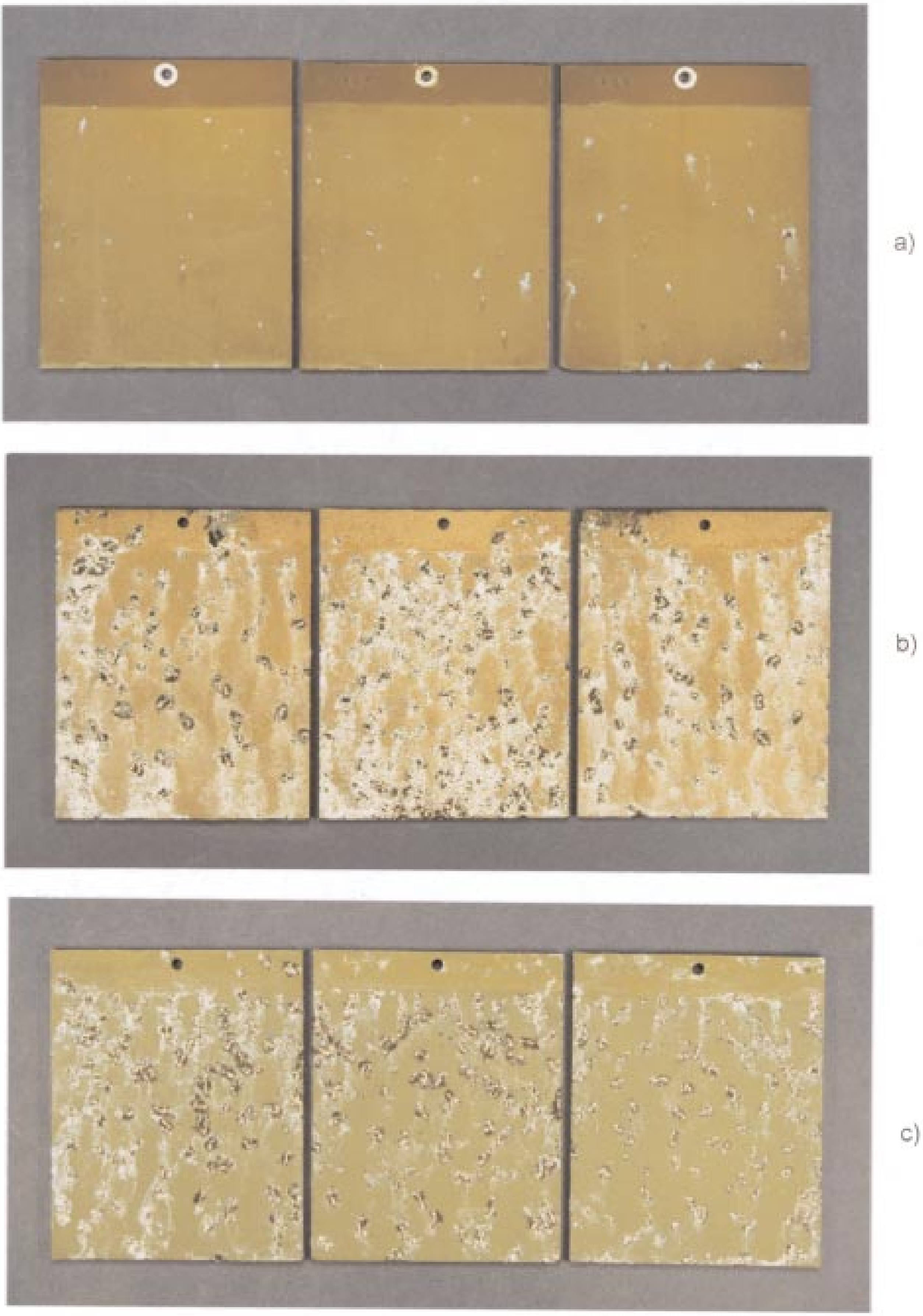

Figure 6 QE22 Test Panels coated with type II coating and exposed to ASTM B117 salt spray test for 336 hours a) TAG 8500, b) HAE, c) Dow 17

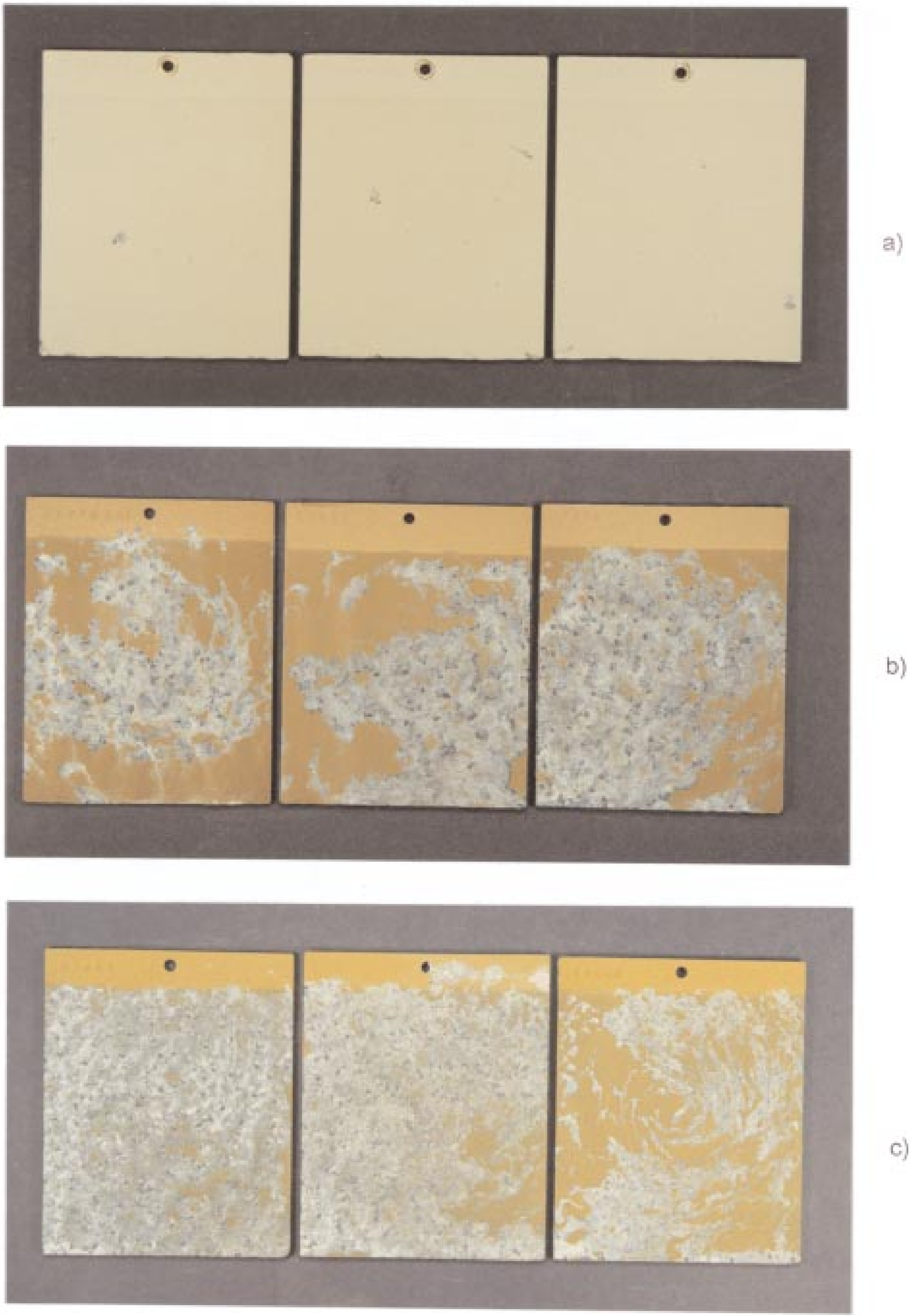

Figure 7 ZE41 Test Panels coated with type I coating and exposed to ASTM B117 salt spray test for 168 hours a) TAG 8200, b) HAE, c) Dow 17

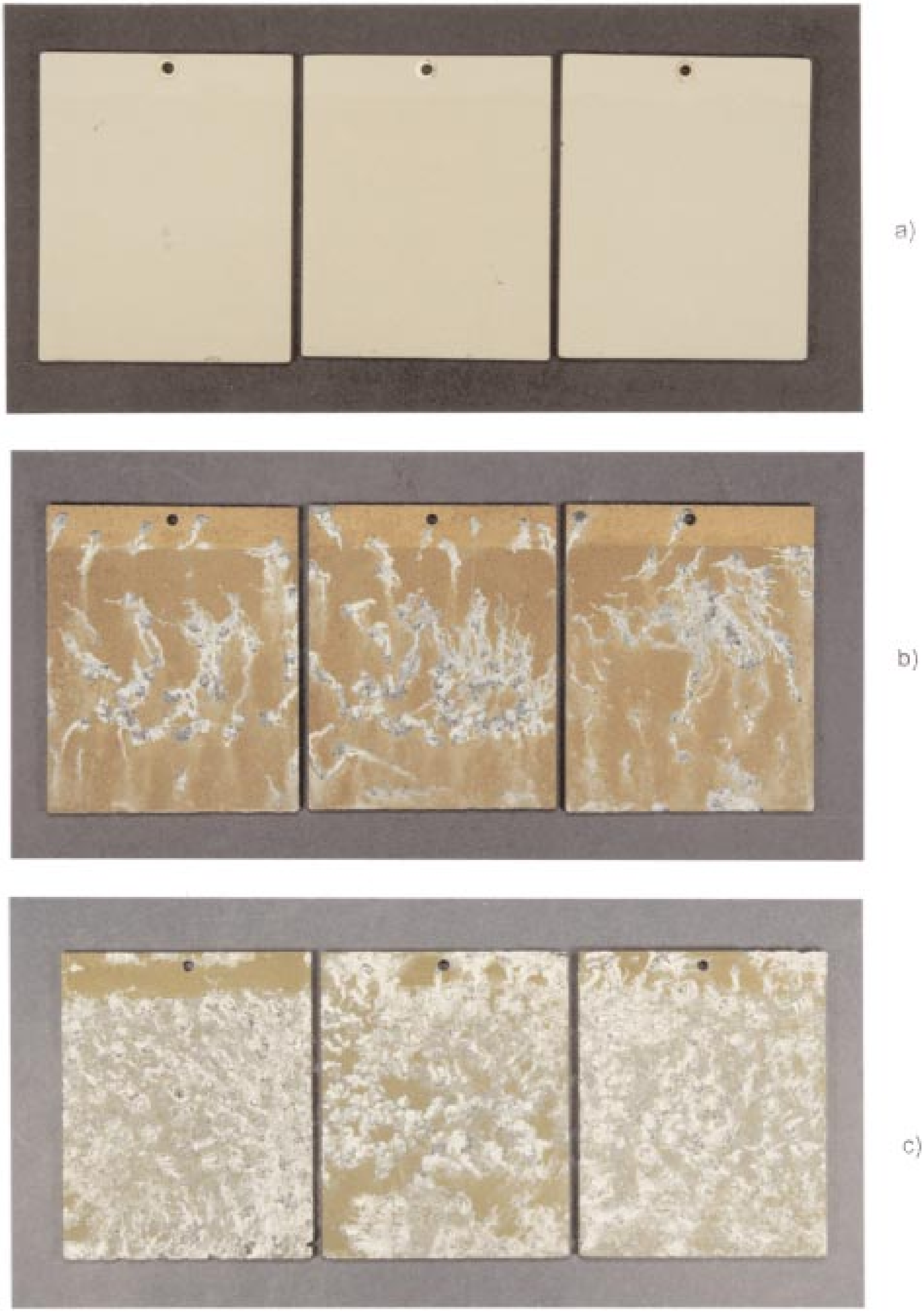

Figure 8 ZE41 Test Panels coated with type II coating and exposed to ASTM B117 salt spray test for 336 hours a) TAG 8200, b) HAE, c) Dow 17

APPENDIX I

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HAE and DOW 17 Hard Anodising of Magnesium Alloy Components

MEL

Magnesium Elektron Ltd

Regal House London Road
Twickenham TW1 3QA
ENGLAND

Telephone 01-892 4488
Telex 8811765 MELLDN G

Printed in England by Cavalier (Anglia) Printers Ltd.

HAE and DOW 17 Hard Anodising of Magnesium Alloy Components

Magnesium alloy components may be designed for use in very corrosive environments and/or where abrasion of the applied surface treatment is likely to occur. Under these conditions the protection afforded by conventional corrosion protection schemes, based on chromate conversion coatings with paint or resin films, may be inadequate and a more durable surface treatment required. HAE or Dow 17 hard anodic coatings provide excellent abrasion resistant bases for further treatment.

HAE and Dow 17 anodic coatings are porous and by themselves will not protect magnesium in corrosive environments. To achieve the best possible protection anodic coatings must be sealed with epoxy or other suitable resin systems to ensure complete impregnation of the coating down to the metal surface. This is achieved using the technique described in MEL Data Sheet 200 — Surface Sealing of Magnesium Alloy Components. The complete three coat resin impregnation technique results in minimal resin film build up above the surface of thick anodic coatings. Conventional painting does not fully impregnate anodic coatings and could permit rapid lateral corrosion spread from a point of damage if exposed to corrosive environments. Surface Sealing further improves the abrasion resistance of anodic coatings and reduces any spalling tendency. Conventional paint schemes may then be applied for additional protection.

Although HAE anodic coatings are harder and more abrasion resistant, the Dow 17 process offers superior "throwing power" and is capable of treating long and narrow bores, as may be present in complex aerospace components, without recourse to ancillary electrodes. For example, bores 8 mm diameter can be fully treated to a depth of at least 150 mm. Both processes can be used to apply thick or thin coatings but the Dow 17 process is more flexible and can be used to produce intermediate coatings if required. The abrasion and corrosion resistances of the thin films are little better than those obtained with conventional chromate conversion coatings whereas the full anodic treatment offers significantly improved protection.

Electrolyte Compositions

Dow 17

The Dow 17 electrolyte has the following make up composition:-

Ammonium Bifluoride ($NH_4F\text{-}HF$)	265 gm
Sodium Dichromate ($Na_2Cr_2O_7.2H_2O$)	100 gm
Phosphoric Acid (85% H_3PO_4, S.G. 1.69)	90 ml
Water to make	1 litre

Approximately half of the total volume of water is heated to 70°C and the ammonium bifluoride added slowly with care. The other chemicals are added in order, followed by the balance of the water to make up the required volume. The solution is then heated to the operating temperature, 70° to 80°C, and stirred vigorously for 5 to 10 minutes. Undissolved solids should be allowed to settle before use.

Bath composition should be controlled to within ± 15% of the above individual constituents on the basis of chemical analysis.

HAE

The HAE electrolyte has the following make up composition:-

Potassium Hydroxide (KOH)	165 gm
Aluminium (99.9%) (A1)	11 gm
Potassium Fluoride (KF)	34 gm
Trisodium Phosphate ($Na_3PO_4.12H_2O$)	34 gm
Potassium Manganate (K_2MnO_4)	19 gm
Water to Make	1 litre

The aluminium addition is best made by first reacting the metal, in a separate container, with part of the potassium hydroxide solution until dissolved. Dissolution must be performed in a well ventilated area to safely remove the flammable hydrogen gas evolved. Any undissolved residue should be separated by decantation and discarded.

If potassium manganate is not readily available, advice on its preparation is obtainable from MEL.

The above individual constituents should be controlled to within ± 10% by chemical analysis of the bath. The free alkali content should be maintained between 10–12% KOH. Fluoride and phosphate deplete very slowly.

Equipment

The Dow 17 electrolyte can be contained in an unlined steel tank to which direct heating is applied. Electrical heaters bolted to the tanks should be isolated to prevent earthing of anodising currents. Alternatively a tank lined with or composed of a suitable plastic material, resistant to hot acidic fluoride solutions, can be used in which case heating may be by an external water bath or suitably protected immersion heaters. To minimise heat loss the Dow 17 tank should be effectively insulated and the bath operated with a floating ball blanket to reduce evaporation and fuming. A forced extraction system must be provided over/around the tank to remove emission gases and the resultant fine mist of electrolyte during anodising. When not in use the tank should be covered with a suitable lid.

The HAE electrolyte is preferably contained in a steel tank lined with synthetic rubber or suitable plastic material resistant to strong alkali solutions. The electrolyte becomes heated in use and a refrigeration unit may therefore be required to maintain the temperature below 30°C. Adequate ventilation over the HAE tank is also required during anodising.

Both anodising treatments require a power source capable of providing a progressively increasing voltage up to a maximum of 100 volts A.C. (See note 3). The current requirement for the power source will vary depending on the size of the installation. As a guide, 150 amps/square metre of surface area on one electrode when the bath is working to capacity should be considered a minimum requirement.

Power is applied to the components being anodised via normal busbars and holders. All parts of the holders immersed in the electrolyte must be of magnesium alloy and preferably of similar alloy type as the components being treated. Surfaces of the holders at the electrolyte/air interface must be masked, e.g. with plastic insulation tape, to avoid local attack.

In view of the high electrical voltage employed and possible "no earth" conditions, access to the tank must be prevented whilst the current is switched on.

Pretreatment

All components should be in a clean condition, free of dirt or swarf and should be degreased by solvent vapour or alkali cleaning solutions prior to immersion in HAE or Dow 17 anodising baths. All dissimilar metals, e.g. inserts, should be removed, masked or blanked off to prevent contact with electrolyte. During the anodising process metal is consumed and it is therefore necessary to mask any fine threads present. This is best achieved using magnesium or non metallic threaded screws or plugs. If raw sand cast surfaces are present it is beneficial, although not essential, if components are first Fluoride Anodised (see M.E.L. Data Sheet 202 – Fluoride Anodising of Magnesium Alloy Components). Fluoride Anodising is more effective in removing surface contamination from cast surfaces and assists in producing a more uniform hard anodic coating. The fluoride film does not have to be removed prior to hard anodising (see note 1).

Anodising Procedures

Dow 17

The Dow 17 process can be used to produce thin films, light green in colour or darker green thicker films depending on design requirements. Dimensional increases of approximately 0.007 mm and 0.035 mm are typical for the thin and thick films respectively. However the full protective potential of the coating is not realised below an increase per surface of 0.025 mm. Increases above 0.050 mm should be avoided because of the increased risk of spalling of the anodic coating. The actual thickness of the Dow 17 film is greater than the measured increase per surface due to penetration and conversion of base metal during the anodising process.

The Dow 17 bath should be at the operating temperature (70° – 80°C) and if reheated from cold should be stirred and settled prior to use. Components to be treated are fixed in good electrical contact to magnesium alloy clamps, rods or bows and located in the tank to give approximately equal surface areas on each electrode. Components should be immersed at least 150 mm below the electrolyte surface and should be positioned to allow free venting of evolved gases. When this is not possible, components should be repositioned one or more times during the treatment to ensure overall coverage.

Current is applied and the voltage progressively increased to maintain the chosen current density. The time taken to produce a satisfactory coating will depend on the thickness of the coating required, the current density used and to some extent the chemical composition and temperature of the electrolyte. As an approximate guide, Figure 1 gives the total ampere-minutes per square metre required to produce various dimensional increases per surface. For the thicker coatings, treatment times of approximately 30 minutes are typical. When the desired coating has been applied, as determined by visual appearance and measurement, components should be thoroughly rinsed and dried at around 120°C. Removal of clamps may release trapped electrolyte in which case the component should be rinsed again otherwise subsequent resin sealing may be affected.

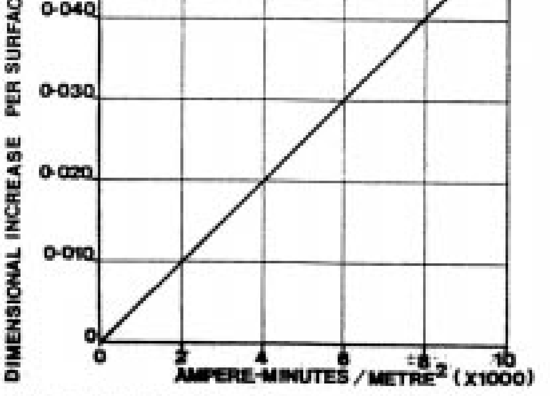

FIGURE 1: DIMENSIONAL INCREASE PER SURFACE 'V' TOTAL AMPERE MINUTES CONSUMED DURING DOW17 ANODISING.

HAE

The HAE process can be used to produce a thin tan coloured film or the full chocolate brown coating. Unlike the Dow 17 process, HAE film build up beyond the initial thin film is not an even process. Development of the full coating is by outcrop formation, initially near component edges and then the gradual filling in of general surfaces. This method of film build up serves as a useful visual guide in determining when the treatment is complete. Dimensional increases of approximately 0.005 mm and 0.040 mm are typical for the partial and complete coatings respectively. The actual thickness of the full HAE film is approximately double that of the measured increase due to conversion of base metal during the anodising process.

Components to be treated are fixed in good electrical contact to magnesium clamps, rods or bows and located in the tank to give approximately equal surface areas on each electrode. They should be immersed at least 250 mm below the electrolyte surface to avoid local overheating and ion depletion. Components should be positioned to allow free venting of evolved gases. When this is not possible, it is necessary to re-position the components one or more times during the treatment to ensure overall coverage.

Current is applied and the voltage progressively increased to maintain the chosen current density. A voltage of 65 – 70 volts is normally sufficient to produce the thin tan film and 85 – 90 volts the full coating. HAE anodising can be performed at current densities ranging from 150 to 3000 amps/square metre, however, the optimum current density is around 650 amps/square metre. At this density the treatment is complete in approximately 1 hour and the danger of over treatment resulting in spalling of the film is minimised. When 85 – 90 volts has been reached the components are taken from the bath, rinsed and examined. If the coating is a uniform brown colour the treatment is complete. A lighter coloured "speckling" indicates too short a treatment time and the components should be returned to the bath for a further short period of anodising, e.g. for 5 minutes not exceeding 90 volts and then re-examined. When the treatment is judged complete the components should be thoroughly rinsed and dried at 120°C.

The HAE electrolyte is highly alkaline and an optional dip post treatment in dilute hydrofluoric acid or ammonium bifluoride solution is recommended in order to neutralise any retained alkali. The post treatment will cause a lightening in colour of the brown HAE coating. Following this treatment components must be thoroughly rinsed again before drying. Post treatments that leave water-soluble reactive inorganic chemicals in the pores of the anodic film are not recommended.

Processing

For maximum protection the application of thick, resin impregnated hard anodic coatings on all surfaces including mating faces etc. is desirable. Ideally a component should be machined prior to anodising and the effect of dimensional change due to the process taken account of at the design stage. Where this is not possible or critical tolerances are involved then alternative processing techniques may be employed.

For example: –

(a) High tolerance areas on machined components may be masked using rubber-gasketted blanking plates, rubber or nylon plugs etc. (Some success has been achieved with paint-on maskants but the very searching nature of hard anodic processes tends to undercut these maskants at edges).

Having fully anodised the component 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 apply a thin partial anodic coating to the previously protected areas. (In the case of threaded holes only, it is usual not to carry out any further treatment so long as component assembly is performed using jointing compounds). The component can then be Surface Sealed, limiting critical areas to two or, in extreme circumstances, to 1 coat of resin if the full 3 coat application cannot be tolerated. The protective value of the thinner coatings is obviously reduced.

(b) An alternative to the above is to fully hard anodise a rough or part machined casting, to machine and then apply a thin partial anodic coating on the machined areas. Great care must be taken to reduce the risk of absorbing contaminants into the porous anodic film during machining as this would interfere with subsequent resin-sealing.

(c) A better alternative is to fully hard anodise a rough or part machined casting, to Surface Seal the anodic film and then complete machining operations. With the pores of the anodic film fully impregnated, handling of the casting during final machining is eased and machined surfaces can now be conventionally chromate pretreated and then Surface Sealed. If required, HAE treatment of machined areas on parts previously HAE anodised and Surface Sealed may also be performed. This technique is not possible with the Dow 17 process as the sealing resin is damaged by immersion in the Dow 17 electrolyte.

Notes

(1) Partial HAE and Dow 17 treatments are sometimes used which result in dimensional increases of the order of 0.006 mm on all surfaces. The abrasion and corrosion resistances of these thin films are little better than that of chromate conversion coatings and consequently are not recommended. Where thin films are stipulated, prior Fluoride Anodising, if performed, should be removed before Dow 17 treatment.

(2) Anodic treatments can reduce the fatigue strength of magnesium components. Fatigue loss will vary with alloy type. The effect on actual fatigue performance should be determined for critical applications.

(3) Although it is customary to use an A.C. power source, D.C. can be used for Dow 17 anodising. For D.C. use the ammonium bifluoride content should be increased to 360 gm per litre of electrolyte and anodising performed using a steel plate or steel tank walls as the cathode

(4) A detailed record should be kept of operating parameters particularly current density, time, temperature and terminal voltage for the treatment of each component. Use of this information will facilitate the similar treatment of components within close limits and together with visual and physical examination of suitable test panels will also indicate when bath replenishment is required.

(5) Thick anodic films are extremely hard but somewhat rough and can therefore have an abrasive effect on parts coming into moving contact with them. This can be overcome by honing the film after resin impregnation to give a smooth bearing surface. Honing can also be employed to restore original critical dimensions because the true thickness of full anodic coatings is approximately double that of the measured increase per surface.

(6) With additional quality controls the HAE and Dow 17 treatments described are generally in compliance with the U.S.A. specification MIL – M – 45202.

(7) Many of the chemicals and processes associated in applying the HAE or Dow 17 treatments are hazardous. The suppliers of chemicals should always be consulted as to any necessary safety precautions. Health and Safety awareness should be paramount when designing suitable plant for hard anodising.

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FURTHER INFORMATION CAN BE OBTAINED FROM: –

MEL
Magnesium Elektron Ltd
Regal House London Road
Twickenham TW1 3QA ENGLAND
Telephone 01-892 4488 Telex 8811765 MELLDN G
Facsimile 01-891 5744

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