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The President Writes

There I am, quietly driving along minding my own business and at some level at least fulfilling my role as President of the Institute of Corrosion, when all of a sudden my dashboard lights up with a range of unnecessarily disturbing messages and accompanying bleeping, warning me to stop immediately before my engine overheats and automotive life as I know it ceases to be. I’m sure you used to just get a little red light blink on rather than this multimedia extravaganza. Anyhow, turns out my radiator header tank was a little low (after all that flashing and bleating I had at least expected flames), so I happily topped it up and went on my merry way.

Next day, the same son-et-lumière palaver. A quick check found a gentle dripping from the bottom of the radiator. Damn thing had rusted through. I thought all that sort of unpleasantness was long gone in modern cars, but I was wrong. Apparently I shouldn’t park near trees (at least, deciduous ones) as the dead leaves get stuck under the radiator and...well, you know the rest. And this in a relatively modern car made by a reputable manufacturer (ten letters, commonly initialise using consecutive letter of the alphabet, one across).

They certainly got one across me. Being a modern car you have to essentially dismantle the whole front end to access the radiator so it was no simple (or cheap) matter to get it replaced. And there was me thinking such splendid design features went out with good old BMC who bravely maintained the concept of built-in obsolescence by crafting as many traps for water, mud and of course leaves as pre-CAD design could muster. Perhaps I should think of my radiator as a sort of tribute act to the golden age of dissolving vehicles, when you could allegedly get more electrical current from a Lancia’s bodywork than you could from its battery.

So, to this edition’s photograph. In partial recognition of Italy’s contribution to initially soluble and now largely durable cars, this one features a rather ropey bridge in northern Italy suffering from a myriad of bridge strikes and a sign that ought to say ‘non guidare veicoli alti sotto questo ponte’ but doesn’t. They have at least used stainless steel guttering and pipework to carry the water away from the failed joint. Can’t help but admire their attention to detail.

As I decide whether to move house from the edge of a wood just to make my radiator (and goodness knows what else) deliver a longer, corrosion free life, it’s worth making a small mental note that we still haven’t satisfactorily sorted out all the basic stuff in this corrosion control malarkey. Still, I suppose it keeps someone in a job – principally me, so I can earn enough to pay for my blessed radiator to be replaced!

The Institute of Corrosion and the British Institute of NDT (BINDT) take their relationship to the next stage by signing an MoU

The Institute of Corrosion and the British Institute of NDT (BINDT) take their relationship to the next stage by signing a Memorandum of Understanding (MoU) to document the special relationship that exists between the two Institutes and to lay down a commitment to the ongoing process.

It is noted that the relationship that has developed between ICorr and BINDT since 2007 is one of mutual respect and trust. This relationship is unique and there is a desire to protect it by articulating its key features within this MoU.

The overriding principle in working together shall be respectful and complementary collaboration. Thus, ICorr will always work in the best interests of BINDT and it will when possible promote BINDT and its products & services and likewise, BINDT will always work in the best interests of ICorr and it will when possible promote BINDT and its products & services.

Paul Lambert, President of ICorr said “We have worked hard for three years to get to where we are. There is a lot of synergy between ICorr and BINDT and we are already considering a number of collaborative projects to pursue”.

As constituted, the Joint Policy Group is the focal point for inter-Institute discussions; it will meet on a regular basis to discuss progress and to propose new opportunities. From time to time, and as-required, there may be a need to convene Working Groups that report to the Joint Policy Group. The nature of the business discussed shall be on a “best fit for both Institutes” basis; neither Institute should feel threatened by the other or compelled to agree to something that is not in the best interest of their members.

George Georgiou, President of BINDT said “This is an historic moment, instead of being absorbed by larger organisations and losing identity, our Institutes have developed a collaborative process which will provide a unique opportunity to secure our future, maintain our identities and increase membership value”.

This MoU is based on the principle that the synergies gained by working together will enable ICorr and BINDT to have a greater impact than if the two Institutes were to work separately and alone. It enshrines the long term future independence of both ICorr and BINDT whilst providing a framework for collaborative activity. There is no take over of one Institute by the other.

A summary of the MoU will be placed on the Institutes web site shortly but if in the meantime if you require more information on the MoU please contact Paul or the Institute office.
I have attended a couple of corrosion related conferences recently. The first was the Corrosion Science Symposium. For members who don’t know too much about these CSSs, they are organised each year by the Corrosion Science Division of the Institute (one of the two main divisions that the Institute has, the other being the Corrosion Engineering Division). As a past Chairman of CSD and someone who served on the committee for ten years (1996-2005), I like to keep a foot in the CSD camp as well as the CED. This year’s CSS, the 51st, was held in Southampton and very ably organised by Julian Wharton. The meeting is designed to give young researchers the opportunity to present their work in a friendly atmosphere. In Southampton there were 28 such presentations (23 oral and 5 nice posters). The highlight is normally the U R Evans award and lecture and this year was no exception with the recipient being Professor Philippe Marcus from ENSC, Paris, France. Hopefully a longer report on the symposium including a synopsis of Professor Marcus’s lecture (maybe the full lecture!) will appear in the next issue of CM. Suffice to say here that the part of the conference that I attended was very good and included a most enjoyable banquet. The only downside with a CSS is that no full papers are required so no publication ensues. However, this means that work in progress is encouraged. The other conference which I have attended recently (Eurocorr 2010 in Moscow) was rather different. It was a gamble by the EFC running a conference at such a “foreign” (not too many people speak English! and the city is still some way from being internationalised) location. It is also expensive and a long trek from many parts of Europe. Nonetheless the conference went very well and attracted some 650 delegates. I will write a longer report myself on this for the next issue of CM. In terms of dissemination of the 300 odd papers (given in about 30 different sessions), these (well most of them anyway) are put on a ROM which is put together by DECHEMA. After one year they are then made available on the EFC website. As ICorr as a body belongs to the EFC, we are entitled to access these archived papers (I will find out how an individual member can do this and report in my next TT).

So conferences are one way of getting ones work disseminated. And conversely someone interested in a particular area can find out more by either attending or getting hold of the conference proceedings (the Eurocorr one is equipped with an excellent search engine). Then there are journals. Just a selection of the more academic ones are; Corrosion Science, Corrosion Engineering Science and Technology (CEST) and Corrosion: somewhat more practically orientated are: Materials Performance, Anti-Corrosion Materials and Methods, Journal of Protective Coatings and Linings: and a couple of good “paint” ones are; Progress in Organic Coatings (POC) and Surface Coatings International. Most journals are now on line (in the case of CEST back issues are being gradually digitised - I think so far that has been done back to 1990). One must not forget specific corrosion books. Every body has their favourites (I like D (Denny) A Jones) and plenty of useful information lies within these. Then there is the Internet. Specific sites like Corrosion Doctors can help with queries. If all else fails though you can always ask the Technical Secretary!

Finally to my corrosion snaps in the last issue of CM (two out of the three appeared on the front cover!). The answers were: Ai - weathering steel and the cause of the rusting is just the lack of protection (in theory it should rust fairly slowly and uniformly with copper in the steel, produce pleasant colour with minimal run off); Aii - blackening of stainless steel on a statue overlooking the Baltic. This is not so clearcut (I saw something very similar several years ago on stainless steel plate for nuclear use). It appears that the thin protective chromium oxide does not always form as well as it should and some form of thicker black chromia/iron oxide forms. The third example (B) looks to be galvanised or zinc plated steel where the latter did not cover the whole area and/or the throw has not been sufficient. It is possible the threads were more active as well due to residual stresses! Any further or alternative explanations please let me know. The address as usual is: Douglas@harbridge.freeserve.co.uk
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Correx Ltd are starting the planning for the UK Corrosion Conference 2011 to be held alongside the Correx Exhibition, together with Surface World 2011, which will be held at the NEC Birmingham on the 1-3 November 2011.

At the time of a world recession, which has hit the UK, resulting in major government cuts for savings, members of ICorr will not need reminding that corrosion losses account for over 3.5% of the gross national product (GNP), literally billions of pounds a year on corrosion wastage.

The original government DTI report on the cost of corrosion stated that, “at least 25% savings could be made with more awareness of the specification and control of the application of protective coatings”. It is important for the public to know that the companies, organisations and individuals involved in corrosion control products and services have all of the answers to preventing this staggering cost to the nation.

The re-launch of the corrosion exhibition last year, Correx 2009, held in conjunction with Surface World 2009 demonstrated that there is a real need for a focal point in the UK to draw in specifiers, structure owners and all those who are able to influence the control of this wastage. The many exhibitors and conference delegates were able to mingle in 2009 and make so many people aware of the help that is available.

The Correx Board are in the process of setting out the structure and details of the conference and intend to build on the initial re-launch of the successful 2009 event.

Full details of the 2011 event will be announced in the next issue of Corrosion Management, together with the formal call for papers for this event, obviously preference will be given to the quality papers submitted, but staff from any Exhibiting companies will be considered favourably.

It is important that companies and individual members put the dates in their diaries for 2011 (1-3 Nov 2011) now and take advantage of the significant discounts to be given to ICorr members to attend this conference, so that they can either learn from other presentations, or to present their papers, extolling the benefits of their products and services available.

The detailed theme of the conference will be announced with the call for papers, but the organising committee, currently being reformed, are going to major on some of the significant developments likely to be featured over the next 10 to 15 years with wind turbines, both on and offshore, flood defence systems including piling, flood/sluice/lock gates as well as bridges and the infrastructure of both railway and road networks.

If any member feels they could contribute to the national conference in 2011 please contact David Deacon at the ICorr office on admin@icorr.org

For details of the remaining stand spaces at the Correx/Surface World Exhibition contact the Exhibition Organizers, Nigel Bean at Hill Media on 01442 823400 or nigelbean1@aol.com

Midlands branch meetings in the winter and spring of 2010 had been well attended by a cross section of delegates from corrosion practitioners through to consultants and end users. Attendances were certainly helped by the excellent presentations on offer.

Due to the relative success of branch meetings, the branch committee felt it was time to move on to bigger things, leading to a half day event held on the 14th September. This ICorr/NACE GB co-hosted event went down a treat and was a huge success, requests for places for next year have already been received, all this without even setting a date or theme.

The venue at Coalbrookdale certainly did not disappoint with the exhibition and food hall sited within an 18th century building, original cast iron machinery being intertwined with innovative state of the art equipment on the exhibition tables making a good contrast.

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Brief interludes to visit the Museum of Iron and the world renowned Iron Bridge attracted a good level of support from the delegates.

Barry Lamb of BAC provided an interesting presentation on LATreat™ an innovative method to combat ALWC in Harbours. After the aforementioned interludes, John Broomfield gave an informative presentation on corrosion of concrete reinforcement, highlighting the evolution of a modelling programme and its application to give more understanding of optimum repair activities, if any.

After the dust settled, a brief joint meeting was held to discuss future co-operation between ICorr Midlands Branch and NACE GB – UK Division.

Many Thanks to sponsors BAC Corrosion Control Ltd and NACE GB – UK Division, Exhibitors and delegates.
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CORROSION BEHAVIOUR OF MG/AL ALLOYS IN HUMID AND SALINE ATMOSPHERES

By R. Arrabal1, A. Pardo1, M.C. Merino1, P. Casajús1, M. Mohedano1, S. Merino2, E. Matykina3

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Summary

The influence of temperature, relative humidity and chloride concentration on the corrosion behaviour of AZ31, AZ80 and AZ91D magnesium alloys was evaluated in high humidity and salt fog environments. In high humidity environment, the degree of corrosion increased with increasing relative humidity and temperature and was influenced by the aluminium content and alloy microstructure for relative humidity values above 90%. Under the salt fog test, corrosion attack increased with decreasing aluminium content in the alloy and increasing Cl– concentration and temperature. In both environments, corrosion attack was initiated around the Al–Mn inclusions for the AZ31 alloy, whereas aluminium segregation and β-phase distribution were the main controlling factors for the corrosion behaviour of the AZ80 and AZ91D alloys, the latter revealing lower corrosion resistance than the AZ80 alloy in saline environments.

Keywords: Magnesium alloys; Atmospheric corrosion; Salt fog.

1. Introduction

The atmospheric and saline corrosion studies of magnesium alloys are receiving more attention in the recent years because of their excellent combination of low density and mechanical properties and, therefore, potential use for lightweight transport component applications. Heavier aluminium or steel components can be replaced by magnesium alloys, which turns into reduced fuel consumption and harmful emissions in the transport sector [1]. However, the use of magnesium alloys for structural applications has limited success due to their poor corrosion properties in humid and saline environments [2,3]. Aluminium is the most important alloying element for magnesium. In general, immersion tests of Mg–Al–Zn (AZ series) alloys in chloride aqueous solutions show better corrosion behaviour with increasing aluminium content [4]. For the majority of Mg–Al alloys, aluminium is partly in solid solution and partly precipitated along the grain boundaries in the form of Mg17Al12 (β-phase), which greatly influences on the corrosion behaviour of these alloys. Thus, if the β-phase forms a finely divided and continuous network, it acts as a barrier to inhibit the overall corrosion of the alloy and if the volume fraction of β-phase is small, it serves as a galvanic cathode and accelerates the corrosion process of the α-matrix [5]. Also, if there is an increase in the relative size of the β-phase at the expense of the Al–rich–α area, the cathode to anode area ratio increases resulting in greater localized corrosion [6].

In high humidity environments, moisture can lead to rapid surface degradation of magnesium alloys, which is much more noticeable in the presence of Cl–ions [7]. The temperature and ambient concentrations of CO2 also have an effect on the atmospheric corrosion resistance of magnesium alloys. Normally, corrosion rate increases as temperature increases, whereas CO2 has a beneficial effect due to the formation of slightly protective films consisting of magnesium carbonates [6].

In the present study the influence of Al content, alloy microstructure, chloride concentration, temperature and relative humidity on the corrosion behaviour of the AZ31, AZ80 and AZ91D magnesium alloys was evaluated by accelerated laboratory tests in salt fog and climatic cabinets.

2. Experimental

2.1 Tests materials

The studied materials were AZ31, AZ80 and AZ91D magnesium alloys and commercially pure or “low–purity” Mg as the reference material (Table 1). All the materials were supplied by Magnesium Elektron, UK. Mg and AZ31 materials were fabricated in wrought condition and AZ80 and AZ91D alloys were manufactured by a casting process.

2.2 Microstructural characterization

The specimens were wet ground through successive grades of silicon carbide abrasive papers from P120 to P2000, followed by 0.1 μm diamond finishing. Two etching reagents were used: a) 5% Nital, to reveal the constituents and general microstructure of Mg, AZ80 and AZ91D materials and b) Acetic–picral mixture, to reveal grain boundaries in the AZ31 alloy. The constituents were examined by scanning electron microscope (SEM) using a JEOL JSM–6400 microscope equipped with Oxford Link energy–dispersive X–ray (EDX) microanalysis hardware. The corrosion products were removed in boiling chromium trioxide (200g L–1) solution during 1 min for characterization of the initial stages of corrosion of the Mg–Al alloys. For low angle X–ray diffraction (XRD) studies, a Philips X Pert diffractometer (Kα=1.54056 Å) was used.

Table 1: Chemical compositions of the tested magnesium materials

<table>
<thead>
<tr>
<th>Material</th>
<th>Elements (wt.%)</th>
<th>Al</th>
<th>Zn</th>
<th>Mn</th>
<th>Si</th>
<th>Cu</th>
<th>Fe</th>
<th>Ni</th>
<th>Ca</th>
<th>Zr</th>
<th>Others</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mg 99.9%</td>
<td></td>
<td>0.006</td>
<td>0.014</td>
<td>0.03</td>
<td>0.019</td>
<td>0.001</td>
<td>0.004</td>
<td>&lt;0.001</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AZ31</td>
<td></td>
<td>3.1</td>
<td>0.73</td>
<td>0.25</td>
<td>0.02</td>
<td>&lt;0.001</td>
<td>0.005</td>
<td>&lt;0.001</td>
<td>&lt;0.01</td>
<td>&lt;0.001</td>
<td>&lt;0.30</td>
</tr>
<tr>
<td>AZ80</td>
<td></td>
<td>8.2</td>
<td>0.46</td>
<td>0.13</td>
<td>0.01</td>
<td>&lt;0.001</td>
<td>0.004</td>
<td></td>
<td></td>
<td></td>
<td>&lt;0.30</td>
</tr>
<tr>
<td>AZ91D</td>
<td></td>
<td>8.8</td>
<td>0.68</td>
<td>0.30</td>
<td>0.01</td>
<td>&lt;0.001</td>
<td>0.004</td>
<td>&lt;0.008</td>
<td></td>
<td></td>
<td>&lt;0.30</td>
</tr>
</tbody>
</table>
Extraction of carbon replicas was used for characterization of Al–Mn particles imbedded in the studied Mg–Al alloys. The carbon extraction replicas were examined in a JEOL 2000–FX transmission electron microscope (TEM) operating at 200 kV and equipped with Oxford link EDX microanalysis hardware. Surface potential maps of polished specimens were obtained using a Nanoscope III MultiMode scanning probe microscope (Veeco–Digital Instruments) working in tapping mode and using a silicon tip with a platinum–coating of 20 nm thickness as the reference electrode. All measurements were made at room temperature with a relative humidity in the range of 40–65%.

2.3 Gravimetric tests
Prior to the corrosion tests, specimens with a working area of 15 cm² were wet ground to a P1200 SiC finish, followed by rinsing with isopropyl alcohol in an ultrasonic bath and drying in warm air. The specimens were hung in a climatic cabinet with a nylon thread and exposed to salt fog according to ASTM B 117 standard. Tests cycles were performed at 20 and 35 ºC. Additionally, the influence of saline concentration (2, 3.5 and 5 wt.% NaCl) was evaluated. At the end of the tests, the specimens were washed with hot water (< 38 ºC) in order to remove saline deposits formed on the material surfaces. High relative humidity tests consisted of 24 h cycles performed in a saturated water vapour at various relative humidity values (80–90–98% RH) and temperatures (25–50 ºC ± 1 ºC) during 672 h (28 days) simulated by a humidity condensation cabinet CCK 300 (Dycometal). Temperature and humidity were verified using digital thermometer and hygrometer. At the end of the tests, the specimens were rinsed with deionized water and dried in warm air. The specimens were weighed before and after the tests using a Sartorius BP 211D scale with an accuracy of 0.00001 g. Mass changes per unit of surface area were calculated according to the expression \( \frac{M_f - M_i}{A} \), where \( M_f \) is the final mass, \( M_i \) the initial mass and \( A \) the exposed surface area. In all cases, tests were performed in duplicate to guarantee the reliability of the results.

<table>
<thead>
<tr>
<th>Material</th>
<th>Particle types</th>
</tr>
</thead>
<tbody>
<tr>
<td>AZ31</td>
<td>( \text{Al}_{19}\text{Mn}<em>4, \text{Al}</em>{11}\text{Mn}_4, \text{Al}<em>2\text{Mn}, \text{Al}</em>{16}\text{Mn}_3 )</td>
</tr>
<tr>
<td>AZ80</td>
<td>( \text{Al}_{10}\text{Mn}_9, \text{Al}_2\text{Mn}, \text{Al}_2\text{Mn}_4 )</td>
</tr>
<tr>
<td>AZ91D</td>
<td>( \text{Al}_{19}\text{Mn}_4, \text{Al}_2\text{Mn}, \text{Al}_2\text{Mn}_4 )</td>
</tr>
</tbody>
</table>

2.4 Characterization of Corrosion Products
Tested specimens were examined by SEM and XRD in order to study the morphology and evolution of corrosion products formed on the surfaces of the alloys.

3. Results and Discussion
3.1 Microstructural Characterization
Plan view optical micrographs of studied materials are presented in Figure 1. Commercially pure Mg and the AZ31 alloy consist of equiaxial grains with dimensions in the range of 40–50 μm and 5–100 μm respectively (Figs. 1a–b). The AZ80 and AZ91D casting alloys show two different solidification microstructures. The AZ80 alloy reveals a biphasic microstructure with Mg grains and grains with precipitation of a fine lamellar aggregate, \( \alpha-\text{Mg} + \beta-\text{Mg}_1\text{Al}_{17} \) (Fig. 1c). The AZ91D alloy consists of \( \alpha-\text{Mg} \) primary dendrites and a partially divorced eutectic \( \alpha-\text{Mg}/\beta-\text{Mg}_1\text{Al}_{17} \) with the \( \beta \)-phase in the form of coarse particles at the interdendritic regions (Fig. 1d). The presence of manganese in the AZ alloys favoured the formation of Al–Mn intermetallic inclusions with various stoichiometries (\( \text{Al}_2\text{Mn}, \text{Al}_3\text{Mn}, \text{Al}_6\text{Mn}_5, \text{Al}_{11}\text{Mn}_4, \text{Al}_{19}\text{Mn}_4 \)) according to TEM characterization (Fig. 2, Table 2).

Figure 3 shows topographic images and surface potential profiles of the AZ31 and AZ80 alloys. These results provided information about the local nobility of different microstructural phases on a submicron scale. For all three Mg–Al alloys, Al–Mn particles presented a cathodic behaviour, with potential values up to 300 mV higher than the surrounding magnesium matrix. For the AZ80 and AZ91D alloys, the potential difference between the \( \beta \)-phase and the surrounding material was found to be ~ 50–100 mV. This difference is smaller than the one found for the die-cast AZ91D alloy in, which was about 200 mV. This discrepancy is possibly associated with the different microstructure of the alloys and the different intermetallic inclusions present.

Table 2: TEM identified Al–Mn second phase particles.

<table>
<thead>
<tr>
<th>Material</th>
<th>Particle types</th>
</tr>
</thead>
<tbody>
<tr>
<td>AZ31</td>
<td>( \text{Al}_{19}\text{Mn}<em>4, \text{Al}</em>{11}\text{Mn}_4, \text{Al}<em>2\text{Mn}, \text{Al}</em>{16}\text{Mn}_3 )</td>
</tr>
<tr>
<td>AZ80</td>
<td>( \text{Al}_{10}\text{Mn}_9, \text{Al}_2\text{Mn}, \text{Al}_2\text{Mn}_4 )</td>
</tr>
<tr>
<td>AZ91D</td>
<td>( \text{Al}_{19}\text{Mn}_4, \text{Al}_2\text{Mn}, \text{Al}_2\text{Mn}_4 )</td>
</tr>
</tbody>
</table>

Figure 1: Optical micrographs of test materials a) Mg; b) AZ31; c) AZ80 and d) AZ91D.

Figure 2: Bright field TEM micrographs and electron diffraction patterns of some of the Al–Mn inclusions in the a) AZ80 and b) AZ91D alloys.
local variations in the composition of the intermetallic phases. Thus, in [9] a die-cast alloy was examined, whereas as-cast AZ80 and AZ91D alloys were used in the present study. Despite the previous, from the surface potential maps, it is clear that the $\beta$–Mg$_{17}$Al$_{12}$ phase and the Al–Mn particles act as local cathodes when coupled to the $\alpha$–Mg phase. The surface coverage of the $\beta$–phase is much higher than that of the Al–Mn particles and this first phase should play a more important role in the corrosion of the AZ80 and AZ91D alloys.

3.2 Gravimetric results

Figure 4 shows mass gain versus time of AZ80 alloy exposed to salt fog environment at 20 and 35°C with three different NaCl concentrations (2, 3.5 and 5 wt.%). For the three tested saline concentrations, the AZ80 alloy exhibited slightly continuous mass gain during the entire test, which increased with both saline concentration and temperature, due to accumulation of corrosion products on the surface. A similar behaviour was observed for the AZ31 and AZ91D alloys. Figure 5 shows the mass gain of tested alloys after their exposure to salt fog environments. Unalloyed Mg revealed the fastest degradation with complete disintegration of the specimens after 2 days of exposure at 35°C. AZ31 alloy revealed two different responses depending on the temperature. At 20°C, the surface was gradually covered with corrosion products and mass gain was observed during the entire test, whereas at 35°C, gradual mass loss of the AZ31 alloy was observed due to formation of loose and non-protective corrosion products on the surface. At 20°C, all the materials revealed mass gain with increasing chloride ion concentration.

Material degradation was considerable reduced for the AZ80 and AZ91D alloys compared with the Mg and AZ31 materials. The AZ80 alloy revealed lower corrosion rate than the AZ91D alloy, which was possibly related to microstructural effects.
mass gain at 98% RH and 25°C with the AZ80 and AZ91D alloys revealing the lowest values. This indicated a positive effect of Al on the corrosion resistance. At 98% RH and 50°C, mass loss was observed during the first 4 days of exposure due to magnesium dissolution, followed by a plateau until the end of the test that indicated similar rates for magnesium dissolution and formation of corrosion products. The mass gain increased with increasing the temperature. The influence of this parameter was more noticeable than that of the alloy composition/microstructure, which was only noticeable for humidity values above 90% RH.

Figure 7 shows the mass gain of tested alloys after 28 days of exposure to humid environments. The mass gain of all specimens exposed to 80–98% RH/25°C was similar, suggesting little influence of the alloy composition. The most noticeable change was observed at 98% RH, especially at 50°C, where the materials revealed considerable higher degradation than that observed at 80% and 90% RH. At 98% RH/50°C, the corrosion rate decreased in the order Mg>AZ31>AZ80>AZ91D. Therefore, the microstructural differences between the AZ80 and the AZ91D alloys were not as relevant as in the salt fog test.

3.3 Morphology and characterization of corrosion products

Figure 8 illustrates the scanning electron micrographs of the plan views of the initial stages of corrosion attack of the AZ31 and AZ91D materials after exposure to salt fog for 4 h (5 wt.% NaCl/35°C, Figures 8a–b) and humid environment (98% RH/50°C, Figures 8c–d). For the AZ31 alloy exposed to salt fog, the corrosion attack commenced at the $\alpha$–Mg/Al–Mn interfaces as it was predicted by the surface potential maps. The AZ91D alloy revealed preferential corrosion in the centre of the $\alpha$–Mg dendrites (5.6 wt.% Al). Occasionally, corrosion attack was located around the Al–Mn particles situated within the $\alpha$–Mg dendrites but not around the particles embedded in areas with high aluminium content, i.e. $\beta$–Mg$_7$Al$_3$ and (Al–rich)–$\alpha$–Mg. A similar behaviour was observed for the AZ80 alloy. In humid environments, the
early stages of corrosion of the AZ91D alloy revealed preferential corrosion in the centre of the α-Mg dendrites without the Al–Mn inclusions having a noticeable effect, although preferential corrosion around these inclusions was observed for the AZ31 alloy. Figure 9 shows the backscattered scanning electron micrographs of the cross-sections of the AZ31, AZ80 and AZ91D magnesium alloys after 21 days of exposure to salt fog (5 wt.% NaCl/35°C). Mg is not shown due to its complete dissolution after 2 days. A thick layer that incorporated coarse particles of Al3Mn, Al10Mn3, Al11Mn4, Al2Mn, Al8Mn5) was also detected. Peaks of hydrated magnesium carbonate hydroxide (hydromagnesite Mg5(CO3)4(OH)2·4H2O) were also detected due to the degradation of the α–Mg phases and their thicknesses were below 2 μm (Figure 10). Figure 11 shows the low angle XRD study (incident angle 1°) of test materials after exposure to salt fog environment (5 wt.% NaCl) for 21 days at 35°C and humidity environment (98% RH at 50°C). The main corrosion product was brucite, Mg(OH)2. Peaks of hydrated magnesium carbonate hydroxide (hydromagnesite Mg5(CO3)4(OH)2·4H2O) were also detected for the AZ alloys, which possibly forms through the reaction of Mg(OH)2 with atmospheric CO2.

4. Conclusions
1. Corrosion attack of Mg, AZ31, AZ80 and AZ91D materials in salt fog increased with increasing temperature and Cl concentration. In general, the effect of temperature was more noticeable than that of chloride concentration. The corrosion attack decreased in the order Mg>AZ31>AZ91D>AZ80.
2. Mg–Al alloys revealed good corrosion resistance in environments with relative humidity up to 90% at room temperature. Higher temperature and relative humidity lead to increased formation of corrosion products consisting of brucite (Mg(OH)2) and hydromagnesite (Mg5(CO3)4(OH)2·4H2O).
3. Al–Mn second phase particles revealed several stoichiometries (Al5,Mn4, Al5Mn, Al2Mn, Al4Mn, Al8Mn5, Al11Mn4, Al11Mn5, Al11Mn6) and potential differences up to 300 mV higher than the magnesium matrix. These particles only played a noticeable role in the early stages of corrosion of the AZ31 alloy, facilitating initial corrosion attack at their interface with the magnesium matrix. For the AZ80 and AZ91D alloys, the corrosion behaviour is more influenced by the intense aluminium segregation phenomena generated during the solidification process than by the possible galvanic couples between Al–Mn and β–Mg,Al1 phase with the Mg matrix. Thus, corrosion attack commenced at the α–Mg dendrites for the AZ80 and AZ91D alloys. The AZ80 and AZ91D alloys revealed the highest corrosion resistance of all tested materials due to higher aluminium content in the composition of the alloy and to the β–Mg,Al1 phase acting as physical barrier against corrosion.

5. References

Acknowledgements
The authors are grateful to the MCYT (Spain, Project MAT 2009–09845–C02–01) and MICINN for financial support (Ramón y Cajal, RYC–2008–02038).
PYEROY STARTS PENUMULTIMATE PHASE OF TOWER BRIDGE PAINT JOB

Industrial services specialist Pyeroy has started work on the penultimate stage of repainting London’s iconic Tower Bridge. Repainting the high-level walkways will take approximately five months to complete and will be carried out seven days a week.

Pyeroy has constructed a temporary access staircase on the south east tower, which will be used by the contractors during the restoration of the walkways.

Two 12.0 x 7.5 metre cradles have been attached to the underside of the eastern walkway which will be transferred to the western walkway in early September and dismantled in late October.

The Port of London Authority by-laws require that a bundle of straw by day and a white light by night to be suspended from the bridge to alert marine craft passing under the bridge to the reduced headroom.

Originally it was expected that two extended closures of Tower Bridge - one for two months and one for three months - would be required in order to complete these works.

However, the City of London Corporation has worked with Transport for London, the Port of London Authority, the Local Councils and painting contractor Pyeroy to ensure this has been reduced to 36 night time closures.

The new paintwork, which has a life expectancy of 25 years, is essential to protect the steelwork and preserve the bridge for future generations.

Pyeroy won the multi-million pound contract in 2008 after the City of London Corporation decided to refurbish landmark structures and other key gateways ahead of the 2012 Olympic Games.

Brendan Fitzsimons, director of Pyeroy’s Infrastructure Division said: “Tower Bridge is a prestigious project, which has gone very well, and the City of London Corporation is very happy with the results to date.

“It shows our extensive experience in undertaking projects of this importance as well as a reputation for quality of work, safety standards and professionalism.”

City surveyor Peter Bennett said: “We are at the end of our three-year programme to re-paint Tower Bridge.

“it is vital to ensure this important London landmark, built in 1894, stays in good working order for decades to come – for all of us to use and enjoy.

“We have been working very closely with Transport for London in particular to ensure the refurbishment is undertaken with as little disruption to local residents and traffic.”

The overnight closures will take place between 11pm and 5am and will be completed by November.

The closures have been scheduled to avoid any planned closures to Rotherhithe Tunnel, London Bridge and Southwark Bridge, as well as the forthcoming weekend closures of the Blackwall Tunnel.

Some key facts about the contract:

- 22,000 litres of paint will be used
- Tower Bridge is being repainted in its red, white and blue colour scheme
- Pyeroy will use a revolutionary new paint system, which is designed to last for 25 years, with a top-up every 12 years
- 1,500 tonnes of expendable abrasive will be used to blast the bridges back to its metal framework before repainting
- 40,000 motorists and pedestrians cross Tower Bridge every day

The Pyeroy Group is based in Gateshead and employs 1000 people working on industrial, construction and marine projects throughout the UK and Ireland.

The company provides a range of industrial services, which comprise contract scaffolding and equipment hire, surface preparation and application of marine/industrial protective coatings, insulation, civil engineering / building works and environmental management services such as asbestos removal.

For more information visit: www.pyeroy.co.uk

POTENTIAL IN THE WINDFARM INDUSTRY

There was a day when we all thought that energy was a given but unfortunately things do go wrong and in this instance this is where Belzona was the perfect solution to help repair and maintain a windfarm providing electricity to a community in North Wales.

After an initial enquiry from a customer, an order was taken for a small quantity of the product Belzona 1831 (UW Metal), a product launched in January 2008 specifically to target the power distribution industry for leaking transformers.

The operator of the farm requested if Belzona could visit site to advise on application of the product to the transformer radiator fins situated at the base of the turbines, of which there were 24 transformers (one per turbine).

At this point, only a couple of the fins were leaking, however, if oil was lost from one transformer, then the entire farm would shut down due to the turbines being interlinked.

After our first initial visit, it became clear that the serious issue of the deterioration of the majority of transformer fins would not benefit from a simple emergency repair kit although useful; we wanted to provide a more long term solution.

As a result, we offered the customer a ‘One Belzona Solution’ through Belzona Technosol Limited. This would entail a full survey of all 24 transformers detailing the repairs required depending on the severity of damage.

Following the survey which took only one day, it was established that a large percentage of fins would require plate bonding prior to application of a protective coating to attain full encapsulation. This meant that we were able to give a very cost effective solution but also giving longevity of the repair.

Following agreement from the customer, work commenced and lasted for a couple of weeks due to the ‘wonderful welsh weather’. The response from the customer following the application was 100% positive, commenting on the way we approached the job from day one, endeavouring to give the best solution and just as importantly, delivering it.

To date there are 2875 onshore operational wind turbines in the UK with another 623 presently under construction. It seems we have only just scratched the surface of a rapidly growing industry.
HALF SHELL PROTECTION FOR CHAPEL CROSS EFFLUENT PIPE

When the Chapelcross Magnox nuclear power station was constructed nearly fifty years ago a 6 km effluent pipe discharged up to a million gallons of cooling water daily into the Solway Firth. Although the 15 in dia pipe was originally only designed to last 25 years, several years ago it was given additional protection with Winn & Coales Denso Ultraseal Tape. Its life has now been further extended, with Denso protective materials again being specified, in order to meet the decommissioning and de-fuelling needs of the Magnox North site and to minimise the risk of discharging contaminated limescale which has built up inside the effluent pipe.

This latest £2.2m life extension project, carried out by main contractor Radius Systems Ltd, has involved sliplining with a polyethylene inner pipe. This involved breaching the pipe at eight points along its length and inserting the 180mm dia inner polyethylene pipe. The areas where the inner sleeve was inserted were then re-installed with a bolted half-shell arrangement. To protect the new steelwork for the extended life span of the pipe, civils sub-contractor R H Irving Construction Ltd applied Winn & Coales Denso Hi-Tack primer, Densyl Mastic (creating a profile over the bolts), Denso Hi-Tack Tape, Denso Ultraseal Tape and Denso Acrylic Topcoat.

For further information from: Winn & Coales (Denso) Ltd, Chapel Road, London SE27 OTR
Tel: 020 8670 7511 Fax: 020 8761 2456 e-mail: mail@denso.net Website: www.denso.net

ARCHCO-RIGIDON PROTECTION FOR OFFSHORE OIL PROCESS VESSELS

Contractors Blastpride Holdings Ltd of Cardiff are using Winn & Coales Archco-Rigidon 423d lining to protect special design large process vessels for the offshore oil industry.

The Archco-Rigidon coating is based on glass flake vinyl ester.

There are a total of eight process vessels measuring 4.9m in diameter and ranging from 15 to 18m in length. Before lining the vessels with the Archco-Rigidon coating Blastpride are shotblasting the surfaces to the Swedish standard SA 21/2 – 3.

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NEW IMPROVED DENSOClad TAPE

Leading manufacturers of anti-corrosion and sealing products Winn & Coales (Denso) Ltd are pleased to announce two new unique features to their range of Densoclad Tapes.

Densoclad Tape, which is used for the corrosion prevention of buried or immersed pipes and fittings is already one of the company’s most durable products. The optimum application of Densoclad includes a 55% overlap of the tape. For ease and correct application, Densoclad now features the product name and details, which are printed on the tape as a guide for a 55% overlap (see image). Not only will this speed up application, accuracy and reduce wastage, it will also allow customers to identify in the future which Denso product they have originally applied.

Densoclad Tape can be applied cold; it is compatible with common pipe coatings and has excellent adhesion to the pipe and to itself. Densoclad Tape has outstanding resistance to cathodic disbonding and is available in standard and HT (High Temperature) grades for tropical climates. Densoclad Tape comes in 40, 50 and 70 grades (thickness) for a choice of protection options.

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WINN & COALES INTERNATIONAL LTD MEET THE QUEEN

On Monday the 19th of July, Executive Directors of Winn and Coales International Ltd; Brian Dunsterville and Chris Winn attended a special reception at Buckingham Palace to meet Her Majesty, The Queen. This special occasion was in honour of the company’s latest achievement; winning a prestigious Queen’s Awards for Enterprise.

Leading manufacturers of anti-corrosion and sealing products, Winn and Coales International won the award for International Trade. This award recognises the substantial growth in sales across the globe, despite the worst recession for forty years. This result is a direct reflection of the quality, hardwork and dedication that all the staff at Winn and Coales International group put into the products and services they offer to their clients.

“I am extremely proud of the consistent innovation that Winn and Coales International Ltd demonstrates. Receiving the Queens Award and meeting Her Majesty The Queen was a privilege and a career highlight”. Brian Dunsterville - Executive Director.

For further information from:
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ERRATUM

In the last issue of Corrosion Management there appeared a review article on the “IOM3-ICorr Underground Corrosion” seminar held on the 27th May 2010. It has been brought to our attention that there were some minor errors/ misunderstandings in the article. The following addresses these issues.

a) The affiliation of Dr. Gareth John is in fact Intertek-CAPCIS, and not UMIST.

b) Dr. John would like to point out that whilst he commented that the AWWA 10-point system was widely used, he also pointed out that it was also widely misused and is not, in his opinion, the best option. He recommends use of the DIN 50 929 part 3 method.

It should also be noted that there is a web link to the different presentations, which can be found at:
http://www.iom3.org/events/underground-corrosion-one-day-seminar
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<tr>
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<th>Address</th>
<th>Contact Information</th>
</tr>
</thead>
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<td>T: 01505 324777</td>
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<td>Merseyside Coatings Ltd</td>
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<td>Paintel Ltd</td>
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<td>T: 07730 691227</td>
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<td>Palmers Ltd</td>
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<td>T: 02476 710294</td>
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<tbody>
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<td>01302 772222</td>
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<td>Steel Protection Consultancy Ltd</td>
<td>7a High Street Mews, High Street, Leighton Buzzard, Beds, LU7 1EA, UK</td>
<td>01525 852500</td>
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<tr>
<td>Sussex Blast Cleaning</td>
<td>Unit 35-37 Station Road, Hailsham, East Sussex, BN27 2ER</td>
<td>01323 849229</td>
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<tr>
<td>TEMA Engineering Ltd</td>
<td>5-6 Curran Road, Cardiff, CF10 5DF, UK</td>
<td>020920 344556</td>
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<tr>
<td>Tees Valley Coatings</td>
<td>Riverside Park Road, Middlesbrough, Cleveland TS2 1UT</td>
<td>01642 228141</td>
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<tr>
<td>The Renovate Services Co.</td>
<td>Amlwch Industrial Estate, Anglesey, LL68 9BQ</td>
<td>01407 831331</td>
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<tr>
<td>Watson Steel Structures</td>
<td>Lostock Lane, Lostock, Bolton, BL6 4BL</td>
<td>01204 699999</td>
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</tbody>
</table>
DIARY DATES 2010/11

14th October 2010
London Branch Joint Meeting with LMS
Speaker: Richard Holt of Subspection Ltd on corrosion monitoring in the marine environment.
Venue: Naval Club, 38 Hill Street London W1 17.30 for 18.15 start

11th November 2010
AGM and London Branch joint meeting with J&WS
Speaker: Mike Taylor of PPC Protective and Marine Coatings on linings for internal protection of storage tanks including the use of weldable primers
Venue: Naval Club, 38 Hill Street, London W1 17.30 for 18.15 start

2nd December 2010
Annual London Branch Luncheon
Royal Overseas League Club
Co-ordinator - Mike Allen
For further details contact mike.allen9@btinternet.com

7th-8th December 2010
Corrosion Management Essentials
Venue: Aberdeen
This 2-day workshop will describe the model process of corrosion management for the upstream oil and gas industry using practical examples of corrosion threats and mitigation methods. Delegates will understand the benefits of corrosion management in relation to safety and asset preservation and how corrosion management fits into the wider safety framework.
Member price - £845 + VAT
Non-member - £945 + VAT
For further details contact Will Sadlerson
Email: wsadler@energyinst.org
or visit www.energyinst.org/training

9th December 2010
London Branch visit to the Varsity Match at Twickenham
Details from Mick Ball at mball@denso.net

1st - 3rd November 2011
The Surface World Show 2011 with Correx
Venue: Pavilion NEC, Birmingham
CORREX 2011 will be a major event in the UK corrosion industry aimed at everyone interested in coatings and cathodic protection: engineers, specifiers and practitioners.
Conferences, workshops, courses and seminars will run in tandem with the exhibitions.
For more information contact Nigel Bean on:
Tel: +44 (0) 1442 826826 Email: nigelbean1aol.com
Web: www.surfaceworldshow.com

27th November - 1st December 2011
Fray International Symposium
Venue: Hilton Cancun, Cancun, Mexico
Honoring the distinguished work and lifetime achievements of Prof. Derek Fray. The symposium will be based in the equally important three topical areas: principles, technologies and industrial practice with special emphasis to a globally sought clean environment of 21 century.
For further details contact Dr. Florian Kongoli
Email: fkongoli@flogen.com
www.flogen.com/FraySymposium

SHORT COURSES

29-30 November 2010
New Energy Institute workshop on Corrosion Management
The workshop will describe the model process of Corrosion Management for the upstream oil and gas sector and is based on the EI publication ‘Guidance for corrosion management in oil and gas production and processing’.
Contact: Will Sadler
Email: wsadler@energyinst.org
Tel: 020 7467 7135

9th-12th November
Corrosion Control in the Oil and Gas Industry
Amsterdam: - Further details contact Colin Britton,
Tel: +44 (0)1480-860943 Email: cbrit79727@aol.com
or website at www.cfpa.com

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