

Figure 1

CORROSION OF METALS IN ROPE ACCESS

Dr Chris Robbins

SUMMARY

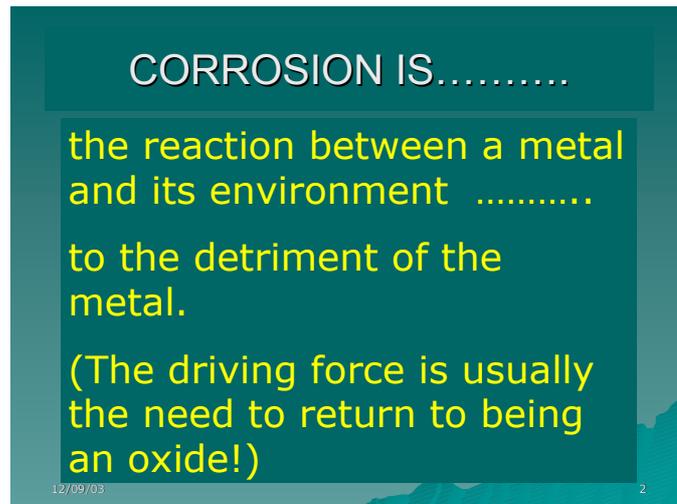
Basic aspects of metallic corrosion in ambient conditions are presented. This is followed by a brief review of the more common corrosion problems that could affect metal components used in rope access work, together with some examples. Some suggestions are made for users and operators on the prevention and mitigation of corrosion in equipment.

INTRODUCTION

Rope access systems employ numerous devices to enable technicians to reach and maintain work positions while they carry out their tasks. Most of these devices are attached to ropes and harnesses and frequently include moving parts, springs and rope gripping or friction surfaces in their design. Thus, the inspection and maintenance of all equipment items is an essential component in an overall safe system of work involving rope access.

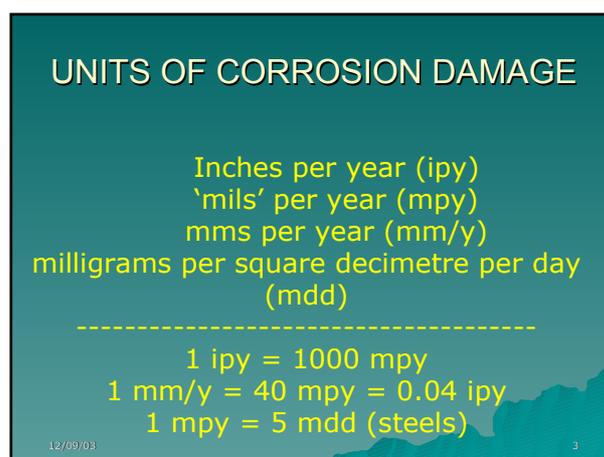
As the business of rope access expands, the amount, variation, complexity and hours of usage of components is inevitably increasing. Life of equipment is a significant factor in the proper management of rope access. It would not be unusual to find hardware items that have survived 10 or 15 years of service that are still serviceable. Equally, some items may not survive even one season if used in onerous conditions. One of several potential degradation mechanisms that can jeopardise the safe and effective operation of rope access hardware is corrosion.

In most cases, items of equipment will be withdrawn from service because of wear, replacement by alternative devices or for 'cosmetic' reasons. In some cases, however, useful life may be limited by corrosion damage. Thus, life of components is based on inspection, not least to meet legal requirements (e.g. LOLER Regs. 8 & 9). This presentation is intended to provide some background to the subject of corrosion particularly as it applies to typical rope access components. It is not the intention to give specific advice or guidance on particular items since, as always, such information should be obtained from the manufacturer/supplier of the equipment.

CORROSION – Definition**Figure 2**

... may be defined as “the reaction between a metal and its environment” to which we may add.... “to the detriment of the metal”. The reason for adding the second phrase is because there are some reactions that are positively useful and protective. Examples are the surface oxidation on aluminium and stainless steels. The oxide films formed in both cases provide protective layers that generally prevent further attack. These films form rapidly under the right conditions. The aluminium surfaces subjected to rope wear during descent on figures of eight will rapidly regain the oxide protection removed by abrasion from the rope. However, not all oxide films are protective – rusts on iron and steel do not protect and can even accelerate attack of the underlying metal from which they form. Nor are protective films protective under all conditions, as will be seen later.

Corrosion is measured in a number of units, perhaps the most readily visualised being ‘millimetres per year’. This is only valid for uniform loss from a surface and has little value when considering the more common localised forms of corrosion attack unless the measurements are made at local sites (e.g. pits). Similarly, weight loss of coupons under test conditions gives little indication of localised rates. A further limitation on conventional units is when corrosion leads to or is involved in cracking processes.

**Figure 3**

This presentation will be limited to dealing with rope access equipment. Therefore, many other aspects of corrosion that are not of direct relevance will be excluded (e.g. erosion, high temperature, microbial attack, impressed current protection). Additionally, the emphasis will be on carbon steels,

stainless steel and aluminium alloys as the majority of rope access equipment are manufactured from them at present.

CORROSION - Some basics



Figure 4

Every science has its 'language' and corrosion is no different. Below are some words or phrases that may be used later; a brief explanation for each is given:

Anodic reaction - this is where a metal goes from its metallic state to an ion, losing an electron in the process:



.... in other words the metal is corroding at this point as the metal atom is removed from the bulk material.

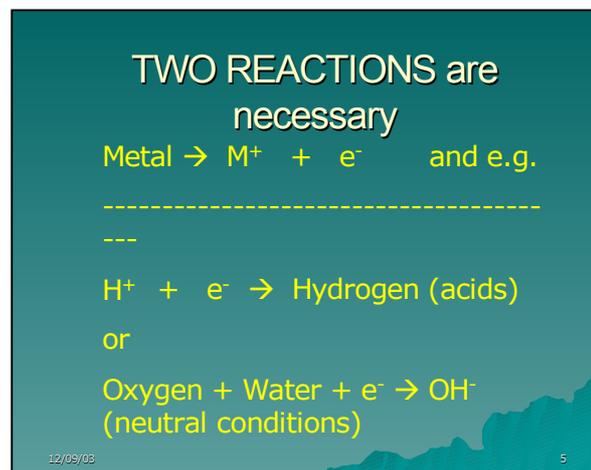
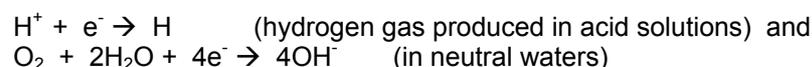


Figure 5

But it cannot corrode unless there is an opposite reaction which accepts the electron released.... the **cathodic** reaction. There are many possible such reactions; two are:



The second reaction demonstrates the dual need of oxygen and water – the absence of either stopping the process. Also note the need for a conductance path, usually based on water. The more

dissolved ions in the water, the greater its conductance and hence, the greater the corrosion rate. Chlorides are the most common and also very active but other ions may also contribute to conductance and corrosion – sulphates, nitrates and so on.

In dry conditions corrosion virtually ceases, but be aware that corrosion may continue even in apparently 'dry' conditions if humidity allows. Although in sub-zero conditions conductance in ice is negligible, it should be born in mind that that localised high concentrations of salts can prevent freezing locally and corrosion may continue in these locations. [So wash the salt off the car even during winter!]

Therefore, in any corrosion process you have an anode (corroding metal) and a cathode, in a similar way as a battery has a positive and a negative, and both are necessary to complete the circuit and allow current flow. This analogy will become evident when considering the galvanic series later.

AN EXAMPLE - CORROSION OF STEEL

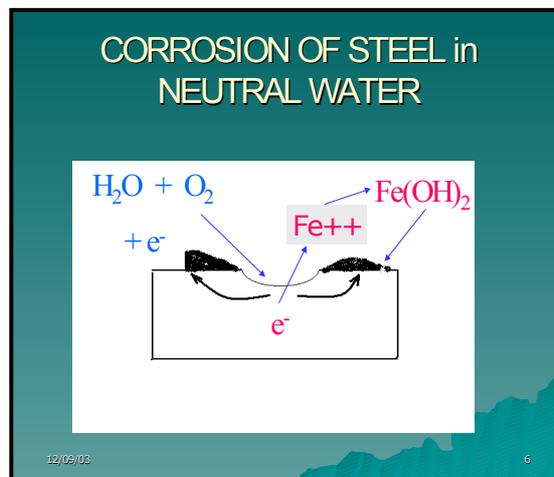


Figure 6

An example of the above is corrosion of steel. As iron corrodes in neutral waters the electrons produced feed the cathodic reaction between water and oxygen, generating OH^- ions. This leads to the formation of iron hydroxides that later will give the familiar rusts of Fe_2O_3 and Fe_3O_4 . It may be noted that an excess of OH^- ions would oppose this particular cathodic reaction and this explains why steels corrode less in high pH alkaline conditions than in neutral or acid conditions.

Concrete rebars are surrounded by high pH in cements. Providing there is no access to other corrosive species (e.g. chlorides) then low corrosion rates may be expected. However, should salt water penetrate (via surface cracks or along exposed rebars), corrosion will be stimulated and this will cause spalling. This progressively cracks the structure, admitting further solution deeper into the structure and so the process escalates. Existing bolting points, fixed into concretes and limestones, might seem to be protected against rusting due to the relatively high pH conditions. However, penetration by chlorides and de-icing salt, corrosion of the fixing inside the structure could still occur. Any doubt as to their integrity (e.g. rust streaks and spalling) should lead to rejection of the fitting for rope access use or, at least, proof testing prior to re-use.

High pH conditions may suit steels. They do not suit aluminium alloys.

GALVANIC SERIES



Figure 7

Another concept, also based on the anode/cathode reaction pair above, is that of the **galvanic series**. Any metal immersed in a solution of its own salts will attain a set potential, and always the same potential (for set conditions) - the Standard Electrode Potential. (e.g. Hydrogen = 0 volts, Au = +1.5 V, Fe = -0.44 V etc). When any two different metals are connected together in electrolytes, current will flow as a result of the difference in the potentials of the two metals. This will result in corrosion of the metal at the lower potential, and, conversely, protection of the metal at the higher potential.

A practical variation is to use a common electrolyte, seawater usually, and to include alloys in the list of potentials so obtained. This is the **Galvanic Series**. It is often presented simply as a list of metals and alloys arranged in the order of their potentials with more noble at one end and least noble (and more easily corroded) at the other. If any two different metals are connected together then the list will suggest which of the two will corrode preferentially. Additionally, the further apart two metals are in the list, the greater the driving force for corrosion of the more anodic metal.

Some points to note:

- Stainless steels appear high up the table towards the 'noble' end. This is due to the protection given by a very thin film of chromium oxide when in its passive condition. Should this film not form or be damaged and not repair, then stainless steels will behave similarly to carbon steels in those localities – hence the dual positions in the table.
- Thin oxide films forming on aluminium alloys also are protective, partly by acting as an electrical insulator and preventing or impeding direct contact with other metals. However, as with stainless steel, the film is not always protective and localised breakdown would lead to rapid corrosion particularly in a galvanic or crevice situation.
- The table does not take account of many variables that may be encountered in situations other than seawater at normal temperatures. Therefore, it should not be relied upon for other circumstances.
- Carbon is very 'noble'. Contact of most alloys with carbon-rich materials may be deleterious (e.g. soots, brake dusts, exhaust deposits, graphitic deposits). A good reason for keeping alloy wheels washed of brake dust deposits!

METAL STRUCTURES

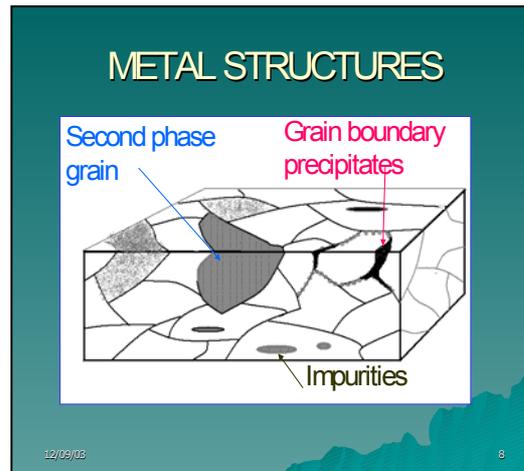


Figure 8

A brief examination of metal surfaces is needed before considering the various types of corrosion that can afflict rope access equipment. Metals consist of grains; each grain is attached to its neighbours. Not all grains have the same structure and this is particularly the case in many alloys. A grain that differs from its neighbours (second phase) may have a different position in the galvanic table and this can lead to highly localised anode/cathode cells developing on the surface.

At boundaries between grains, precipitates can form during, for example, heat treatment and welding. These precipitates inevitably have a different structure to the surrounding bulk metal and may be the cause of similar localised corrosion processes. The presence of impurities, trapped during the melting, casting and forging operations, may also trigger corrosion locally, again resulting from the proximity of anodic and cathodic sites.

TYPES OF CORROSION



Figure 9

It will be apparent from the above that there are many different forms of corrosion that could take place and below are some examples:

- **Uniform attack**

Typically found in bare steels exposed to moist air; items such as unprotected steel karabiners. Not usually a severe problem in PPE items when in use because time of exposure is usually short and is easily recognised. However, extended storage of steel components in wet or damp conditions (with wet ropes in kit bags?) could give rise to extensive corrosion. It can also be a problem for thin section items such as unprotected steel wire ropes and springs (although crevice corrosion is the more usual concern in such cases – see below).

As a 'rule of thumb', typical corrosion rates for carbon steel in a marine environment would be about 0.1-0.15 mm/yr. This would double for every 10°C increase above ambient. Uniform corrosion is predictable and covers the whole surface. Although microscopically the corrosion may actually be numerous anode/cathode sites operating between various grains, the overall effect is of a generally even advance of the corrosion front.

Of greater concern, however, may be 'left in place' items such as pitons, bolts and other 'permanent' anchor points, particularly where such items are exposed to marine or industrial atmospheres (chemical plant). Although uniform corrosion may be the primary mode of attack, it may not be visible and measurable within the fixing. The only advice that can be given is to be aware, and, if in any doubt, test or use something else!

Aluminium alloys are generally protected by their oxide films but only within a neutral range of about 5-8 pH. Outside this range general attack may occur, although the more localised forms of attack to be described will be more noticeable. Stainless steels will not show uniform attack.

- **Galvanic attack**

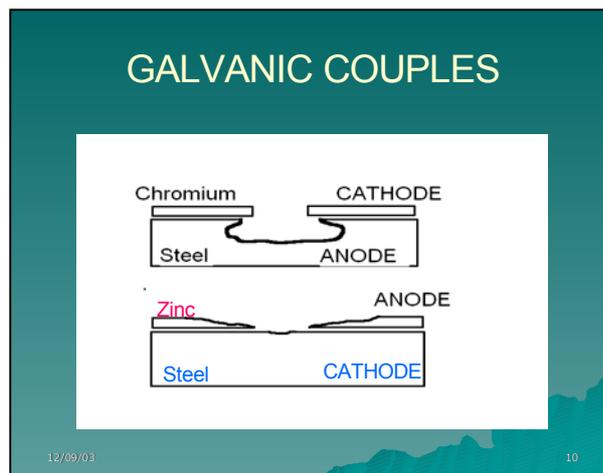


Figure 10

This occurs when two different metals are connected together and have a conducting solution present. Inevitably, one of the metals will be more noble than the other. The more 'different' the metals are electrochemically, the greater will be the tendency for the least noble to corrode. Steel pins in aluminium bodies, chromium plate on steel buckles and zinc protection of steel wire are examples.

Localised rates can be high but note that the oxide films that form on both aluminium alloys and stainless steels are electrically insulating. Therefore, galvanic attack **may** be limited when these metals are involved. However, in combined wear and crevice situations, where any oxide film on the surfaces may be subject to repeated disruption, galvanic attack between metals could be severe and may be hidden from view inside hinge points, for example.

Zinc coatings, applied to steels, corrode sacrificially to protect the underlying steel. Although zinc may be completely removed locally by corrosion or abrasion, it may still provide some protection over a distance. Nevertheless, if sufficient zinc is removed, corrosion of the steel will eventually occur. Galvanised wire may dull with age but the real concern would be the appearance of small rust spots. These would indicate that the galvanising had been consumed and that the steel

underneath was now unprotected. Discard would probably be the only course of action. Special lubricants are usually applied to wire ropes in most industrial applications to prevent corrosion. However, in rope access this may be inappropriate because of spread of lubricant onto textiles, other equipment and hands. Above about 50°C zinc is no longer protective towards steel.

Localised failure of cathodic coatings, such as chromium plating, can lead to very high rates of corrosion of the underlying metal. This may be exaggerated by the high surface area of cathode relative to the small area of corroding anode beneath the plating. For most equipment items, such plating is applied for decorative effect and to give a smooth, hard and wear resisting surface. It may be a consideration not to pack and store, say, chrome plated items in contact with aluminium or galvanised steel components if there is any moisture being present – despite protective oxides!

Metals lying close to one another in the table will have a lower tendency to generate galvanic corrosion of the slightly less noble metal. Aluminium and zinc (galvanising) would be such a pairing, typified by aluminium swages on wire. This situation is further eased by the tendency of the aluminium to form a protective film.

One final point – in severe cases, the edges of chromium plate left at corroded areas of the underlying steel can be sharp and could abrade textiles. Such surface roughness would be apparent during inspection. Whilst not necessarily grounds for discard because of physical damage, it may justify discard of severely pitted chrome plated items to protect textile equipment if the item is likely to come into running contact with ropes and slings.

- **Crevice attack**

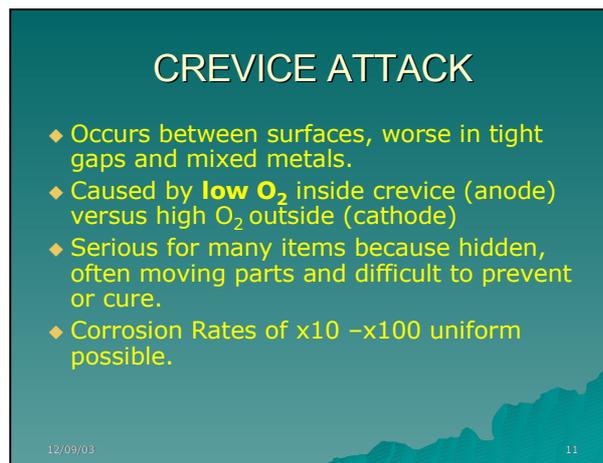


Figure 11

When oxygen depletion occurs in tight gaps, such as hinges, pivot points, wire rope and coiled springs, corrosion can occur. The primary driving force is a cell set up between high and low oxygen areas (differential aeration). In this case the cathode is the high oxygen area (outside) and the anode is the low oxygen area inside the crevice or even beneath deposits and surface debris. [Another good reason for cleaning gear immediately after use]. Increase in acidity within the crevice occurs and this will also attack protective films on aluminium and stainless steel. The tighter the joint the worse the problem because the greater the differential oxygen and the lower volume for acidification. Alloy crabs should have 'open' gate hinges for this reason.

The rates of attack can be high; perhaps 10-100 x faster than uniform rates of attack but the primary concern is that the extent of damage may not be evident, as described above for galvanic attack. Outward signs may appear superficial. Some indications of potential problems may include 'sticky' gates on karabiners, uneven rotation or seizure of pulley wheels and corrosion products appearing on the surface of wire ropes especially when flexed to reveal inner strands.

Items prone to crevice attack should be thoroughly washed whilst operating moving parts. This is to remove contaminants (mainly chlorides) from within crevices before drying, inspecting, and

storage. Wire rope items are more difficult to deal with in this respect, both stainless steel and galvanised steel. This applies not only to the wire itself but also any fixtures, eyes and rungs for ladders. Outward evidence, such as staining or 'growth' (i.e. swelling) or extrusion of sealant resins at rung fixings would be grounds for closer examination at least or, more likely, discard. Aluminium and carbon steel corrosion products are voluminous and most likely to be the cause of swelling.

Simply greasing or spraying penetrant on wet components is not sufficient. Once well established, crevice corrosion products are difficult to remove and, together with salts, are not soluble in organic solvents – a point repeated later. This would be particularly the case with wire ropes and items with close fitting moving components. The corrosion products may act as abrasives and accelerate wear and/or seizure. If present, water-soluble contaminants should first be removed before applying any organic protection approved by the manufacturer.

A frequently offered piece of advice to minimise galvanic corrosion is to incorporate an insulating washer or separator to prevent metal-to-metal contact. Such devices may be helpful in this respect but do little to prevent crevice attack, which may be severe in such locations.

A crevice may also be formed between a metal component and textiles. In this case the position may be worsened by the long drying time of textiles and the difficulty of removing water-soluble salts from the textile. Buckles on harnesses may be prone to extended damp contact with belt materials and it would not be unusual to find evidence of crevice or pitting attack in these items.

- **PITTING ATTACK**

Crevice and pitting are fundamentally very similar processes.

Those metals most prone to pitting are those that form passive films such as stainless steel and aluminium alloys. The pits usually form at sites on the surface where the film is broken or not able to form because the underlying surface contains an inclusion, impurity or ground in foreign body. This is why stainless steels and aluminium alloys should never be abraded or ground with incompatible materials if you want to avoid pitting attack – never use wire wool on stainless steels. Stainless steel wire brushes may be used on both stainless steels and aluminium.

Rates of penetration can be high because the area under attack (the anodic site) is very small and the cathodic site (the surrounding surface) very large. Once the surface is breached, usually with the help of chloride ions, the solution quickly becomes acidic within the embryo pit and attack accelerates. The acidity in pits can be typically pH 2-3.

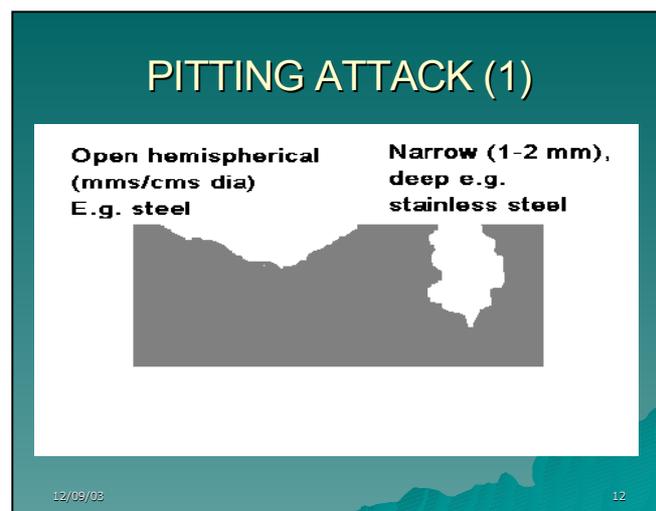


Figure 12

Pit shapes vary; shallow dish shaped pits or more severely damaged areas often occur on steels (sometimes initiated beneath rust or oxide/slag). Stainless steels frequently have small 1-2 mm

diameter deep pits perhaps 2 mm deep. Aluminium may exhibit several forms but, because attack tends to be intergranular, pits are often small and steep sided. Pit sites frequently have nodules or mounds of deposit sitting on top.

Removal of pitting is rarely successful in the long term. Re-passivation (re-oxidation) cannot reach the bottom of deep pits. Additionally, even superficial drying may leave a hygroscopic salt behind inside pits, allowing the process to continue in humid conditions. As for crevice attack, pitting of buckles on harnesses may also occur due to extended drying times.

Shallow pits can be removed by abrading the surface but this in itself may be counterproductive for items already coated or anodised (aluminium). Additionally, removal of significant metal if needed to remove pitting may weaken a component and should not be attempted without advice from the manufacturer. Severely pitted components are best discarded rather than attempting to refurbish them.

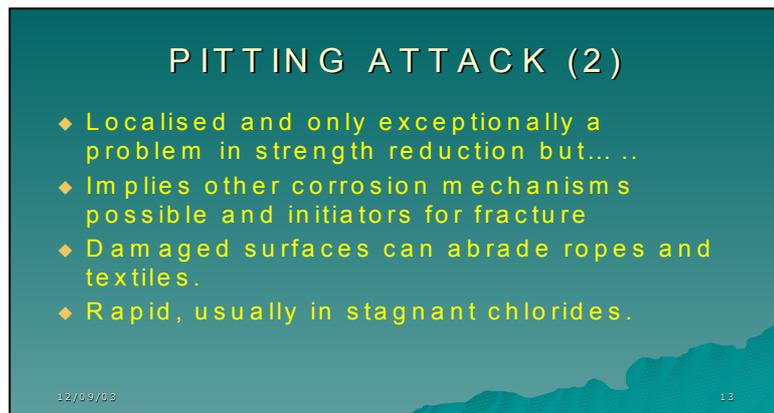


Figure 13

Although superficial pitting itself does not usually have a major effect on mechanical strength of equipment, its presence is an indicator that the component has been exposed to corrosive conditions. Additionally, corrosion pits may act as initiation sites for more severe degradation mechanisms – such as the next item.

- **STRESS CORROSION CRACKING (and CORROSION FATIGUE)**

(These items have been put together as they share several common factors. Both involve the breakdown of a protective film followed by the simultaneous action of a crack opening stress and a corrosive medium continuing to propagate cracks. In the case of stress corrosion cracking, the stress is essentially static whilst in corrosion fatigue the stress is varying and usually cyclic).



Figure 14

The problem of stress corrosion cracking in stainless steels is unlikely to afflict rope access workers under normal conditions, which is just as well as it can occur suddenly and catastrophically! The requirements for stress corrosion cracking in stainless steel are:

- Stress – usually at or near to the yield stress.
- Temperature – above about 50-60°C, usually higher.
- Chlorides – others also but chlorides most likely.
- Time – hours, days or even years, whilst maintaining all the above.

It is difficult to envisage how, under normal working conditions, all the above can operate together. Nevertheless, it is as well to be aware of the potential problem and hence the need to avoid unnecessary exposure of equipment to high temperatures in chloride containing environments, and not just whilst in use. Rapid abseils can generate moderately high temperatures in fixed components, but gear left in the proximity of flares, petrochemical production plant, welding or heat treatment plant typically may also be subject to heating.

Stresses can be retained from manufacture, particularly welding, pressing, stamping and heat treatment. It is not just the imposed stresses in service that may be the most significant in this context. Also, stress raisers could increase nominal stresses applied by 2 or 3x locally (notches, threads).

Again, it is emphasised that it is the combination of **all** these factors simultaneously that is necessary to induce stress corrosion cracking. It only requires the avoidance of any one to eliminate the potential for cracking.

The process often starts with local breakdown of the oxide film at high stress points, followed by crack initiation and propagation either intergranularly or transgranularly. This process may be relatively slow until cracks reach a critical size. Crack propagation thereafter may be very rapid. Pitting is often a precursor to stress corrosion cracking, so evidence of pitting should trigger a search for the extremely fine, often branching cracks usually to be found at stress raisers (notches, grooves, threads). This is really the province of the specialist and his equipment. Rough abrasion to help reveal possible cracks is unhelpful as it is likely to seal over the surface, preventing dye penetrant gaining access (a common method for crack detection).

Very few cases of stress corrosion cracking in rope access or related activities have been reported in equipment and these have generally been from hot climates and often associated with shortcomings in the fabrication of the failed components. It is possible that cracks had developed well before being revealed in use but this is surmise.

The case for aluminium alloys is similar in some respects. Acid chlorides also are the prime cause, again allied to high stresses (usually from fabrication) and temperatures. Stress corrosion cracking has also occurred in humid air. Aluminium alloys for rope access equipment are *generally* based on the 5000, 6000 or the 7000 series of wrought alloys. The former are mainly alloys with magnesium intended for marine applications and essentially resistant to stress corrosion cracking. The 6000 alloys, containing magnesium, silicon and others, has intermediate corrosion resistance but higher strength than the 5000 series and is frequently used in aircraft frames, for example. The higher strength Al-Zn-Mg age-hardenable 7000s alloys have reduced corrosion resistance and are susceptible to stress corrosion cracking under the right conditions. These are amongst the alloys of choice for many high strength components, such as karabiners, despite this potential weakness.

As with stainless steels, signs of pitting may be the precursor to stress corrosion cracking. Again, prevention of unnecessary exposure to chlorides and temperature are the primary defence tactics. It is tempting to suggest that where exposure to high salinity and high ambient temperatures are inevitable, such alloys should be avoided. However, it is unlikely that the specification of each and every item within a stop, cam or crab would be known and, hence, is unrealistic.

It is worth repeating that the stresses imposed in normal use are likely to be moderate compared to locked-in residual stresses from manufacture. Therefore, because an item has not sustained

any service loading does not justify assuming that it must be free of chloride induced cracking if all other factors have been present (temperature, chlorides).

A form of corrosion mainly found in the heat treatable aluminium alloys is **exfoliation**. This occurs where the grain structure is elongated and 'flattened' along a particular direction. Corrosion occurs preferentially along the grain boundaries, often beneath the surface, leading to layers of metal virtually peeling away. This is often associated with alloys prone to stress corrosion cracking (and stress corrosion cracking conditions may have been involved) and, hence, should be viewed seriously.

Finally, any temptation to use a dishwasher to wash and clean equipment should be resisted, unless it is as an experiment to induce stress corrosion cracking deliberately!

- **HYDROGEN EMBRITTLEMENT**

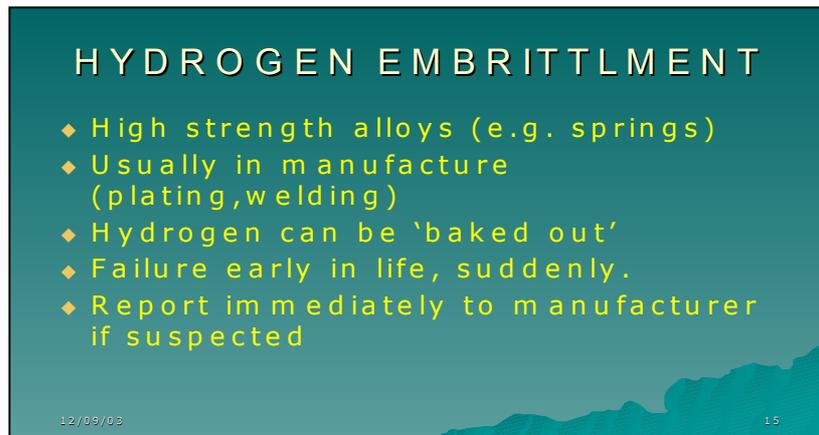


Figure 15

This mainly concerns high strength steels such as are used in springs, pins or bolts manufactured to yield strengths of over about 600MPa. Hydrogen is able to diffuse through the relatively open iron crystals and accumulate in highly stressed areas and assists crack nucleation and eventual propagation at up to about 1 mm/s. Failure is brittle, that is, accompanied by little strain to failure – i.e. breaking before bending.

The usual sources of hydrogen are from manufacturing processes such as acid pickling (used in preparation for galvanising), electrochemical plating (such as chromium on springs) and welding (damp electrodes). Thus, most of the prime causes are outside the control of the rope access worker. Fortunately, the problem is well known to platers and fabricators and is now rarely encountered.

Hydrogen, being very mobile in the iron structure, will tend to diffuse out in time, a fact used by manufacturers to 'bake out' hydrogen if there is any fear it may be present. Thus, the potential danger will normally decrease with life in the case of rope access components. The most likely manifestation of the problem would be an 'early' failure of, say, chrome plated springs or galvanised high strength wire.

Aluminium and stainless steel alloys are less prone to picking up hydrogen (tighter atomic structure), but any hydrogen that may have been absorbed during manufacture is more difficult to remove. As with steels, the higher strength alloys are more at risk.

There is little that the rope access worker can do to prevent such failures but by purchasing well-tried equipment from reputable manufacturers the risks can be minimised. Should such failures be encountered (and identified!), they should be reported immediately to the manufacturer as this is likely to be a 'batch' problem and urgent recall may be required (LOLER Reg.10). One more reason for maintaining a good 'paperwork' system for equipment control.

PREVENTION AND MITIGATION OF CORROSION

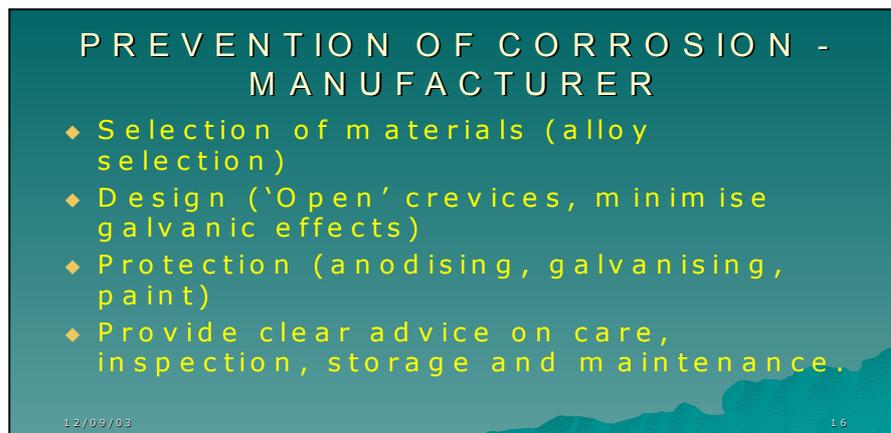


Figure 16

The dominating measures for securing long safe life of equipment are with the designer and manufacturer. Selection of optimum materials, design details (e.g. to minimise tight crevices), provision for ease of cleaning and inspection are typical factors that would be taken into account by reputable manufacturers. For example, if a high strength aluminium alloy is selected for a karabiner, the manufacturer may decide to provide additional anodising protection (and a bit of colour). Therefore, the first line of defence is to purchase equipment from those suppliers you trust.

The second line of defence is to read the instructions for use. Advice will be given on storage, cleaning etc. and limitations on use, usually including aspects of corrosion. Although there is a temptation to rely on in-house experience, it can never be as great as that of the manufacturer. Additionally, he may have made subtle changes to equipment items in the light of experience and this may not be immediately apparent in newly purchased items.

The supplier of equipment cannot be responsible for unreasonable neglect, abuse or misapplication of equipment. Therefore, on bringing equipment into service there must be a rigorous regime of traceability, inspection and storage. Inspection, carried out in the cool and calm of a workshop, is the primary filter in stopping defective equipment returning to the worksite.



Figure 17

The final backstop, however, is the user or operator and it is to this person that the notes below are aimed (LOLER Reg. 8). All operatives should receive some form of training in the pre-use checking of equipment and this should include at least identification of potential corrosion damage. Not in any

particular order, here are some hopefully helpful tips on corrosion related issues, mostly common sense but with some 'science' behind them:

- **Try to select equipment most suitable for the anticipated environment.** Not always possible for various reasons, multiple metals within one component (e.g. ascenders), weight limitations etc. but if preferences exist, use them.
- **Check condition and operation of all items immediately before use.** Although routinely carried out, it is primarily only physical operation of the item that is checked (gate operation on karabiners, locking return on ascender cams etc) – probably without even looking at the item. Even though equipment items may have been checked before despatch to site, there may still have been ample time and exposure to corrosive conditions during transit for gates to corrode and jam, springs to fail or spindles to seize.
- **Never be fooled by appearance.** Although a steel karabiner may look unsightly, it may still be quite serviceable whereas a bright and shiny alloy crab may have suffered severe crevice corrosion within the gate pivot pin area, rendering it useless. Bright stainless steel wire may be suffering severe crevice attack between strands.
- **Know where to look and what to look for.** Examples: white powder deposits (aluminium oxides) on aluminium components at joints, threads and pivot points; uneven operation of rollers, pulley wheels and gates. Particular care should be exercised with items that include wire rope in their construction (etriers, ladders, cams).
- **Try to wash and dry equipment that may have been contaminated with salt or other contaminants as soon as possible after use.** This should be the case even if using the equipment the next day. Operate all movable items whilst washing to help remove any entrained material from crevices and this includes opening up any metal buckles on harnesses. If other chemicals or materials were involved, such as cement dusts, chimney deposits, guano, grit etc – first wash yourself then the equipment. If equipment cannot be dried immediately, keep it in fresh air rather than confined in warm moist conditions (let passive films repair and keep temperatures low).
- **Even if cleaning with organic solvents is necessary, still use a water wash if ionic contaminants may be present.** Although it may be necessary to use organic solvents to remove oils, greases, paints etc. these may not remove salts and other inorganic materials. A water wash may still be needed, as salts are not soluble in organic solvents.
- **Do not abrade items to clean them.** E.g. no wire wool on stainless steels. Abraded products themselves could be worked deep into crevices during the cleaning operation itself, making a bad situation worse. This is a job best left to the workshop.
- **Try to avoid storing or packing wet or damp ropes and fabrics (slings, tapes, harnesses) with hardware.** Textiles will retain moisture for longer and could contain significant contaminants/debris picked up during work. Metal components permanently attached to harnesses may be a problem.
- **Ensure procedures for dealing with defective or questionable equipment are followed.** Equipment suspected of being exposed to gross contamination, such as by strong acids (e.g. battery acid) or alkalis (e.g. caustic soda) should be grounds for impounding prior to inspection/re-use or disposal.
- **Always inspect fixed anchors points critically.**
- **Remember the cathodic reactions!**

FINALLY

The incidence of actual failure of rope access equipment, due to corrosion in all its forms, is thankfully rare. This is largely due to a number of factors that include:

- A knowledgeable trained workforce, alert to potential problems and with a high degree of 'self-interest'.
- High frequency of close inspection and examination of all items in use.
- Corrosion damage generally becoming obvious well before a significant threat is realised.
- Relatively short exposure times of equipment to degrading environments.
- Design and manufacture utilising generally corrosion resistant materials.
- A high degree of inherent robustness in rope access equipment.

The high level of safety to-date has been achieved in the industry by close attention to all the many components that go into a safe system of work – training, techniques, planning and so forth. Corrosion failure of a component, whilst in service, would inevitably be of immediate concern at the worksite itself, but it would also indicate significant 'system' failures. Raising awareness may help to ensure this situation does not arise, and help maintain or improve the standards of the industry.

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