Forward

Although concrete is an inherently durable material concrete repair or protection may become necessary for many reasons. This guide addresses the most common Australian repair situation, i.e. concrete damage due to corrosion of reinforcement.

Concrete repair is not difficult but there are many technical facets and a multitude of materials suppliers. Structure and building restorations are frequently managed by companies that are more familiar with structural design and project management aspects and hence there are only few engineers that are fully conversant with the full range of repair options.

Cathodic Protection (CP) and cathodic prevention are less understood than conventional patch repairs and the mystic and myths that surrounds them tends to deter non experts from using them. Although Australia was an early adopter of CP systems (as GM of Taywood Engineering I was responsible for the first commercial above ground CP system applied in Australia over 30 years ago) Australian's have become quite stayed in adoption of the wide variety of concrete CP systems that have been developed overseas. As a repair specifier I became increasingly aware that only a few standard systems were being used in Australia. The systems used in Australia were quite reliable when correctly designed and applied but could be relatively expensive to design, install and maintain. More economical, easy to install systems available overseas were not being introduced to Australia.

As Chairman of PCTE, a company distributing concrete testing equipment from around the world, I was exposed to these CP systems at international inspection and repair conventions. In order to make these systems available in Australia SRCP was formed and distribution agreements entered with some of the worlds leading cathodic protection anode and control system suppliers. SRCP now offer a complete range of CP systems for concrete structures and can provide the most appropriate solutions to most concrete repair situations.

However, many restoration managers unfamiliar repair technology are unclear how to evaluate what repair method, and more often what electrochemical system, to adopt to best meet client needs. A major objective of this guide is to provide them background to the selection procedures although it is also intended to describe anode systems available. SRCP are able and willing to provide more detailed information on repair method selection.

Frank Papworth, SRCP Chairman
Updated Feb 2020

F. Papworth has over 35 years experience in concrete durability consultancy. He was chairman of the CIA Durability Committee from 2008 to 2015 and was chairman of fib Commission 8 on service life design. He is also chair of fib Action Group 4 on durability requirements for Model Code 2020, the first time design for existing structures (i.e. concrete repair) will be incorporated into a code.

SRCP are distributors in Australia for:

Cover – High Level Bridge, Perth. Protector’s Cassette system was used to cathodically protect prestressed bridge beams. Designed by GHD and installed by Savcor.
Index

Background: Concrete Repair Systems 4
What type of repair 4
Condition Assessment and Type of Repair 5
Patch Repair and Cathodic Prevention 6
Cathodic Protection Introduction 7

Sacrificial Anodes 8
Surface Mounted – Zinc Layer Anode (ZLA) 8
Discrete - Roll Anodes 9
Internal – ZDA Anodes 9
ZAP Magnesite 10

Impressed Current Systems 12
MMO Coated Titanium Anodes 12
Embedded Anodes 12
  HISEO Ribbon Mesh Anodes 12
  HISEO Net Anodes 12
  HISEO Saw tooth Ribbon (New Structures) 13
Discrete Anodes 14
  dureAnode 4 Standard and Vertical 14
  durAnode R1 and R2; durAfat 16
  CorrAnode Discrete 17
  HISEO discrete 17
Surface Mounted Anodes 18
  Cassette by Protector 18
  corroDisc by corrPRE 18
Conductive Coating 19
  Zebra by Protector 19
Control Systems 20
  durApower 1+3 (simple manual systems) 20
  durAcentre 4+8 (major systems, remote monitored) 20
  durAjust 485 corrosion monitoring system 20
  durApower 485 control and monitoring system 20
  Camur control and monitoring system 20
Cables and Connectors 21

CM3 Continuity Tester 22
Projects 24
Repair Selection Guide 27

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Concrete Repair Background

What Type of Repair

When chlorides penetrate to the reinforcement in sufficient quantity, or carbonation to rebar depth occurs, the reinforcement begins to corrode.

As expansive corrosion products form the pressure fractures the concrete. Whether the resulting distress is cracking, spalling or delamination the repair designer has to determine the approach to inspection and repair.

Typically the first step is to determine if the issue will only ever be localised or if it is a much wider future problem. Commonly chloride ingress, carbonation and cover are relatively uniform and hence initial distress at corners is quickly followed by more widespread failures.

At Garden Island Low Level Bridge delamination increased from 20% to 80% in the two years between first survey and repair commencement. Earlier electrical potential testing would have identified widespread corrosion activation. Urgent cathodic protection installation would then have eliminated the need for the deck replacement that was undertaken.

Conversely at Kleenheat Gas Tanks combined analysis of cover and carbonation distributions showed spalling related to only a few areas of where bars were very close to the surface. Only patching of localised damage was required. Not even coating was necessary.

These examples show the importance generally, but not always, of detailed investigation in order to identify the appropriate method of repair.

Repairs to only evidently distressed concrete is only likely to be an acceptable approach if:

- Corrosion initiation is localised (e.g. low cover areas),
- There is a wider problem but the owner accepts additional repairs will become necessary in a relatively short time frame (Singapore Port Authority accepted a 2 year shotcrete repair cycle as being the appropriate repair solution to soffits as it met budgetary limits),
- The structure has a short design life requirement, e.g. holding repairs for a couple of years are adequate (this occurred on a Dampier Salt bridge that had a residual life of only 5 years and the area of falling concrete could be fenced off).

Where a long term repair is required and chloride ingress or carbonation is widespread then the decision becomes whether to:

a) use cathodic protection to eliminate the break out of sound but chloride contaminated concrete.

b) break out around actively corroding reinforcement to remove sound but chloride contaminated concrete.

Breakout of sound concrete can be a noisy process disturbing tenants and can lead to expensive structural support requirements. For impressed current cathodic protection (ICCP) or sacrificial anode cathodic protection (SACP) only loose concrete needs to be removed. ICCP gives a 50+ year design life but involves high cost design and maintenance while SACP typically has a 15-20 year life and low design and maintenance requirements.
Condition Assessment and Types of Repair

The level of condition assessment links directly to the repair types that can be practically developed. The two principle options are detailed below.

Option 1 : Visual Inspection and Drummy Testing

Visual Inspection and drummy testing are undertaken to record the quantity of concrete that already has signs of corrosion distress. If this is the only testing then there will be no information to gauge the extent of current, and imminent corrosion activation. Repair of just the distressed areas is likely to leave areas of active corrosion that will continue to corrode, even if coated to prevent further chloride ingress.

If only visual and drummy testing meets clients objectives then the repairs options are:

a. **Patch Repair Only** – Typically patch repairs require breakout behind the reinforcement to remove chloride contaminated concrete. With no testing for the extent of chloride activated reinforcement beyond the distressed area conventional practice is to breakout 150mm beyond the evident area of corrosion. The repair would include an isolation coating on the reinforcement.

   Typical area of concrete breakout where no cathodic protection is employed. Breakout of sound concrete behind reinforcement is expensive, noisy and structurally significant.

   ![Diagram](remove-hard-sound-concrete-easily-removed-cracked-spalled-concrete.png)

b. **Patch Repair Plus Incipient Anode Protection** – This is much the same as a) but low powered sacrificial anodes are incorporated in the edges of the patch to protect the bars just outside the patch. This is referred to as cathodic prevention, a much lower level of protection relative to cathodic protection. Further repairs would likely be required around the patched area at an early age if the low powered anodes were not used. Because these anodes do not stop corrosion of active steel, and because the zinc volume is small, concrete is removed from around the bars in the patch and the bars are electrically isolated from the anode in order to reduce the current drawn from the anodes.

c. **Patch Repair Plus Local Cathodic Protection** – In this technique higher powered sacrificial anodes are used in, around, or on the repair patches to provide local cathodic protection. This means that expensive and noisy breaking out behind the bars is not required. The anodes also provide the incipient anode protection. To reduce anode consumption the exposed reinforcement can be coated with a cement coating followed by an epoxy coating. More anodes are required for c) than for b).

Option 2 : Full Condition Assessment

A full condition assessment generally comprises the following stages:

1) **Visual and Drummy Survey.** This identifies the quantum of distressed concrete.

2) **Electrical Potential Survey.** This identifies areas that are already corroding but not yet distressed. Corrosion rate testing may be required in some areas to confirm activation is real.

3) **Corrosion Activation Front Depth.** Whether from chloride ingress or carbonation. The data is also used to model the distribution of the corrosion activation front in the future.

4) **Cover distribution.** Together with the current and predicted corrosion activation fronts this gives current and predicted extents of future corrosion.

5) **Resistivity Tests.** Where cathodic protection is to be employed resistivity tests will give an indication of the throw of protection.

6) **Electrical Continuity.** This will give an indication of whether reinforcement will require electrical connection between bars

Following the survey the following repair options would be reviewed:

a. **Patch Repair Only**

b. **Patch Repair Plus Incipient Anode Protection**

c. **Patch Repair Plus Local Cathodic Protection.**

d. **Impressed Current Cathodic Protection** – This is the ultimate in concrete repair. The repair approach is to patch the delaminated areas (no breakout of sound contaminated concrete) and apply CP to all areas that will become active in the design life.

e. **Sacrificial Anode Cathodic Protection** – Similar to d) except the system may be more localised, have a shorter design life (20 years) but requires little design and maintenance.
Electrochemical Repair Background

Patch Repair and Cathodic Prevention

Over 30 years ago it was identified that when just the distressed areas were patched the areas around the patch failed in a short time. This is called the ‘incipient anode’ or ‘halo effect’ and is described in the sketches to the right.

Initially this effect was reduced by use of reinforcement coatings in the repair. Although this slows the corrosion of the incipient anode area it does not stop it. To provide protection to incipient anodes low powered sacrificial anodes were introduced. These replaced the original anodic steel as the polarizing sacrificial anode and gave a degree of protection to the incipient anode.

Cathodic prevention and cathodic protection are two very different processes used in different circumstances. The processes are described in the graph below (Sergi’s simplification of Bertolini’s domains of electrochemical behaviour of steel in concrete). For cathodic prevention a small shift in the potential of uncorroded reinforcement leads to an increase in the chloride activation level (A→B→C). The same small shift in potential for corroded rebar would not protect the active steel (D→E) as pits will be present. A much higher shift (D→F) is required to give cathodic protection to corroding reinforcement.

Significance of reinforcement polarisation on corrosion control - cathodic prevention and cathodic protection.

As incipient anode areas have not corroded cathodic prevention using anodes that give a small potential shift (i.e. small anodes at wide centres) may be effective. However, the potential shift is insufficient to provide cathodic protection and sound but chloride contaminated concrete must be removed from around active reinforcement if cathodic protection is not applied.

Cathodic Protection Introduction

Cathodic protection systems supply negatively charged electrons to the reinforcement that cause a large shift in electrical potential (D→F) to a more negative potential. This potential shift can be measured using reference cells embedded in the concrete.

Standards

ISO 12696 “Cathodic Protection of Steel in Concrete” provides a performance standard for cathodic protection design of new and old structures. The potential shift is measured as the difference between the potential immediately after turning of the power supply (‘instant off’) and the potential at a given time after turning off the power supply (e.g. at 24hrs from turning of the power it is called the 24hr decay and the criteria for cathodic protection is a 100mv minimum decay).

Low powered anodes that do not give this level of protection but do give a potential shift may be suitable for use in cathodic prevention but are not acceptable for cathodic protection. corrPRE’s sacrificial anodes shown in pages 8 and 9 are generally designed to give cathodic protection although they also provide cathodic prevention in areas further from the anode where the polarisation will be lower. As shown corrPRE have now developed a low output anode for cathodic prevention which is useful in small scale repairs where breakout around corrosion prevention which is limited to areas in small scale repairs where breakout around the bar with epoxy coating of the reinforcement is practical.

ISO 12696 also provides general information on what inspection measures should be employed and lists general CP repair considerations, e.g.:
• designed, tested and installed to meet its intended life.
• monitoring using reference electrodes to show the system complies.
• with standard potential shift criteria.
• anode current densities not to exceed design values.

CP installation procedures given in ISO 12696 include:
• criteria for electrical continuity of reinforcement and requirements for extent of continuity checking.
• monitoring all zones of ICCP and representative areas of SACP systems.
• each zone of an ICCP system to have:
  • 2 reinforcement connection points for the cathode current and one for the steel concrete potential.
  • multiple positive anode connections.

ISO 12696 also includes information on:
• avoidance of short circuits.
• safety requirements to electrical standards.
• testing of the CP systems during installation.

Differences between ICCP and SACP Systems

Major differences between ICCP and SACP systems are:

a) When an anode is connected to reinforcement in concrete the circuit immediately starts to draw current. In impressed current systems that current is virtually limitless but with sacrificial anode systems the current immediately starts to waste the anode and this limits the anodes life much more significantly than in ICCP.

b) The reinforcement polarisation by SACP systems is limited by the potential of the anode and this typically means that hydrogen discharge will not occur. This means that there is no hydrogen embrittlement risk to prestressing steel. With impressed current systems much higher polarisations are possible and hence the power must be limited on prestressed structures to ensure this does not occur.

c) The protection provided by ICCP can vary due to the environment or the power may be inadvertently switched off. Hence, ICCP must be monitored at regular intervals. The cost of monitoring can be high. As SACP systems cannot be controlled they are generally not monitored. Where monitoring is required it is generally at a low frequency and only on selected areas in order to show the system is functioning correctly.

d) Cathodic Protection systems have a hybrid action in repassivating the reinforcement and moving chlorides to the anode. After 20 years the CP system may not be required.

Selection of a Cathodic Protection System

As will be shown in pages 8-15 there is a wide array of cathodic protection systems. BCRC have developed a procedure to ensure that the designer can demonstrate that the most appropriate system has been selected for a particular project. The process is in four parts:

Part 1 : Establish Owner Preferences - The designer determines the owner’s values in regards reliability, speed of installation, intrusiveness during installation, flexibility, aesthetics etc.

Part 2 : Review CP Systems - A five point scale is used for each relevant criteria and a weighting applied to the specific project.

Part 3 : Indicative Pricing - The systems that best meet the client values are then priced to give a dual assessment (see table below).

Part 4 : Specification - The systems that are both economic and meet the client needs are incorporated into the CP specification so that they can be priced by the market.

<table>
<thead>
<tr>
<th>Anode Type</th>
<th>Cheapness Score</th>
<th>Acceptance Score</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Initial Cheapest</td>
<td>Maintenance Cheapest</td>
</tr>
<tr>
<td>Mesh</td>
<td>50</td>
<td>20</td>
</tr>
<tr>
<td>Sawtooth Ribbon</td>
<td>30</td>
<td>20</td>
</tr>
<tr>
<td>Ribbon mesh</td>
<td>10</td>
<td>15</td>
</tr>
<tr>
<td>Cassette</td>
<td>20</td>
<td>15</td>
</tr>
<tr>
<td>CoroDisc</td>
<td>50</td>
<td>15</td>
</tr>
<tr>
<td>DurAnode4</td>
<td>30</td>
<td>20</td>
</tr>
</tbody>
</table>

Table showing an assessment of anodes suitability for a specific project.
Sacrificial Anodes

Zinc Layer Anode (ZLA)

Sacrificial anode CP systems are much simpler than impressed current systems and the Zinc Layer Anode (ZLA) system is particularly simple. It comprises zinc sheet with an adhesive that also keeps the zinc active. Simply clean the concrete surface, pull off the ZLA topliner, press the anode to the concrete surface and electrically connect the ZLA to the reinforcement.

This unique anodes is listed in Concrete Society TR73 Appendix B3.

Details of the Zinc Layer Anode

- Ion conductive adhesive gel
  - Approx. 900 micron
- 99% Zinc 250 micron thick (500 micron AOR)
- 75 micron thick PET topliner
- Zinc weight
  - 250 microns: 1.785 kg/m²
  - 500 microns: 3.570 kg/m²
- Width roll: 25cm
- Length roll: 20m
- Area per roll: 5 m²

ZLA is supplied in cases of 12 rolls.

Installation of a ZLA system where monitoring is required. Typically in large systems one or two areas may be monitored for a few months. In small systems monitoring is not normally undertaken.

Junction box if protection checking required

Connection is brazed and then epoxy coated

Two coats of cementitious coating

Zinc sheet

Adhesive/activator

ERE 20

Half cell

Rebar connection

Connection between rebar layers if protecting both faces

Rebar

Applications

The most common use of ZLA is on buildings where it is applied because:

- breakout, and therefore disturbance, are minimal as ZLA provides full CP,
- only loose concrete is removed so temporary structural support is generally not required,
- there is no complex wiring or control systems so ZLA can be applied by any repair contractor,
- it is the lowest cost CP system available.

ZLA protection corridors, support columns and cantilever beams of external superstructure.
Roll Anodes are strips of ZLA rolled up to provide several layers of zinc to give a cylinder that can then be inserted into a drilled hole filled with ZAP paste, and sealed in with 25mm of grout. Typically many anodes are installed over an area and connected as a string with a connection to the reinforcement intermittently along the string. Roll Anodes provide simple cathodic protection with no power supplies. They are typically installed without monitoring as that significantly increases cost. Bespoke anodes can be supplied but the following sizes are common:

<table>
<thead>
<tr>
<th>Anode Length (mm)</th>
<th>125</th>
<th>250</th>
<th>500</th>
<th>750</th>
<th>1000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anode Dia. (mm)</td>
<td>22</td>
<td>22</td>
<td>22</td>
<td>22</td>
<td>22</td>
</tr>
<tr>
<td>Hole Dia. (mm)</td>
<td>24</td>
<td>25</td>
<td>30</td>
<td>31</td>
<td>26</td>
</tr>
<tr>
<td>Zinc Weight (gms)</td>
<td>110</td>
<td>180</td>
<td>220</td>
<td>440</td>
<td>720</td>
</tr>
<tr>
<td>No of Anodes/Kit</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>ZAP cartridges</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>7</td>
<td>10</td>
</tr>
</tbody>
</table>

Roll Anodes are used instead of ZLA:

i) in tidal and splash zones where the waterproofing of ZLA might be compromised,

ii) where rough concrete surfaces means ZLA might have poor contact or bond (e.g. coated surface and exposed aggregate),

iii) where operations means coated ZLA would not be durable (e.g. high abrasion or impact),

iv) where geometry of the element precludes ZLA use.

Roll Anodes may be installed in wet areas, such as splash and tidal zones, while ZLA is installed in the atmospheric zone above.

ZDA

ZDA anodes have a high zinc mass and a high current output which in general will give true CP. They are electrically connected to reinforcement using the inbuilt strap and embedded within the concrete patch. They are used to give cathodic protection to:

a) steel within the patch so that breakout of sound contaminated concrete is not necessary,

b) to the active steel around the patch area.

Use in conjunction with ZLA or Roll Anodes if reinforcement activation extends beyond around 200mm from the patch.

Sizes of anodes are shown below:

Type | Size (mm) | Zinc | Packing
-----|-----------|------|---------
ML10 | 100×50×15 | 180g | 24pcs
ML30 | 300×50×15 | 540g | 12pcs

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**Performance**

Sacrificial anodes in concrete were originally introduced as low powered anodes for cathodic prevention. These anodes were based on zinc activated by lithium hydroxide. The reactions is very different to the corrPRE anodes which are based on zinc in a pH 5 chloride based gel which gives a high output. The difference in performance can be seen from a standard cyclic voltametric test.

CUT results (right) show that the slightly acid pH of ZAP gives a very much greater polarisation than ZAP that is alkaline and both give far greater polarisation than zinc in lithium hydroxide mortar.

This high output translates to field tests. For the apartment parapets shown below tests of ZLA over 2 years showed continued high output and achievement of the 100mv CP criteria.

Repeat testing for ZLA and Roll Anodes have shown that over many years the polarisation continues to meet code requirements.
ZAP Magnesite

Chlorides in magnesite toppings penetrate to the floor reinforcement which then corrodes causing concrete spalling and delamination. Conventional repairs can be expensive and unreliable as it is difficult to remove all the chlorides. corrPRE have developed two low cost effective electro chemical systems. One is to bond zinc sheet with Zinc Activator Paste (ZAP Magnesite) to the floor surface and cover with a self levelling topping. The other is to apply Zinc Layer Anode (ZLA) to the soffit. With a connection to the reinforcement either system provides galvanic cathodic protection to the reinforcement to ensure corrosion is halted with minimal concrete and topping removal.

The system adopted where only the top of the magnesite floors is accessible is corrPRE’s zinc sheet with site applied ZAP. ZAP dries to a relatively stiff paste. The system is designed with a topping that will bridge the zinc strips.

For full compliance with Cathodic Protection codes monitoring of CP systems is required and this entails wiring of the electrical connections back to a junction box to permit intermittent monitoring. This is important with ICCP systems as the current has to be adjusted over time. With SACP system there is no such adjustment and hence monitoring is not generally required. On large projects a couple of areas can be designed to be monitored.

The ZAP Magnesite system is typically based on checking for continuity of the reinforcement and connections and accepting that once connected the current will inevitably flow, although monitoring can be installed.
Magnesite can be supplied in three versions.

**Full ZAP Magnesite Kit**

In this kit everything the contractor needs for a full installation, including topping and tools are supplied:

1. 2 rolls 125mm x 40m long zinc strips
2. 15 ZAP cartridges
3. 1 ZAP application nozzle
4. 4 potted rebar connections
5. 6kg Ardex P82 primer kit
6. 80 bags Ardex K22F
7. Application nozzle & gun
8. Prepared wiring
9. Soldering system
10. Epoxy connection coat

The system is shipped with 6 kits/FCL

**Basic ZAP Magnesite Kit**

In this system only the anode and topping materials are supplied:

1. 2 rolls 125mmx40m long zinc strips
2. 15 ZAP cartridges
3. 6kg Ardex P82 primer kit
4. 80 bags Ardex K22F

The system is shipped with 6 kits/FCL

**Minimal ZAP Magnesite Kit**

Only the anode materials are supplied

1. 2 rolls 125mm x 40m long zinc strips
2. 15 ZAP cartridges

The system is shipped with 20 kits/FCL or in single or multiple kits by sea or air.
What is MMO Coated Titanium

Mixed Metal Oxide (MMO) coated titanium (Ti) anodes give a very low loss of material and high current output for long life impressed current cathodic protection systems. MMO Ti is the standard material used in impressed current anode systems. This anodes is listed in Concrete Society TR73 Appendix B4 and as noted there different manufacturers have different process and hence quality of production is critical to the success of the anode.

SRCP supply HISEO anodes which are ASTM B265 Grade 1 Ti coated with MMO and manufactured by Chemical Newtech of Italy. The titanium has the following properties:

- Electrical resistivity: 0.006 ohm/m
- Tensile strength: 0.24 MPa
- Yield strength: 0.17 MPa
- Elongation: 25%

The titanium is annealed and etched in acid to obtain the necessary roughness for the optimal coating thickness. The MMO catalysts are oxides of iridium and ruthenium stabilised with oxides of titanium, tantalum, niobium and tin. MMO is applied in 16 layers to give the thickness that determines the anode life at a given current.

Each anode batch is verified by accelerated performance tests to NACE TM0108-2008 and TM0294-2007. The anode is placed in sulfuric acid or sodium sulfate and a current of 3 to 10kA/m² is passed.

HISEO Ribbon Mesh Anodes

Ribbon anodes are standard widths of MMO Ti mesh that is inserted in slots cut into the concrete surfaces. The slots are filled with a cementitious grout and the anodes connected to the transformer rectifier (see page 16). Ribbon spacing depends on the element current demand as determined by the reinforcement density and exposure.

Ribbon mesh is available in 10, 12, 13, 15, 20 and 25mm widths. The titanium is 0.6mm thick and expanded thickness is 1.15mm.

HISEO Net Anodes

Net anodes are pinned to the concrete surface and made ionically continuous with the concrete by spraying with shotcrete or covering with a topping. They provide a robust design with good current distribution provided the shotcrete application is of high quality.

Concrete Society report TR 73 notes “The physical properties of the material are as would be expected from a strong, ductile metal, i.e. it can be bent or formed to conform to the contour of the concrete. It can be cut with metal shears to tailor around awkward shapes or to avoid metallic objects protruding from the concrete surface. With suitable precautions it can be welded to itself or to titanium (coated or uncoated) strips or wires as current connectors. Ductility is adequate for making reliable compression joints, using titanium, niobium or tantalum materials for the joint.”

Net anodes are typically not used:

a) in the tidal and lower splash zones due to the difficulty of applying a quality shotcrete layer
b) on some structures where the weight of the shotcrete layer is unacceptable (e.g. buildings and bridge decks)

50m long x 1.2m wide rolls are supplied as follows.

<table>
<thead>
<tr>
<th>Type</th>
<th>CNT</th>
<th>15</th>
<th>25</th>
<th>35</th>
</tr>
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<tbody>
<tr>
<td>Diamond Long. (mm)</td>
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<td>22</td>
<td>19</td>
<td></td>
</tr>
<tr>
<td>Diamond Transv. (mm)</td>
<td>85</td>
<td>62</td>
<td>38</td>
<td></td>
</tr>
<tr>
<td>Weight (kg)</td>
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<td>0.29</td>
<td>0.33</td>
<td></td>
</tr>
<tr>
<td>Max current density (mA/m²)</td>
<td>20</td>
<td>30</td>
<td>45</td>
<td></td>
</tr>
</tbody>
</table>
Cathodic Protection of New Structures

Cathodic protection is a suitable means of corrosion control on new structures that are severely exposed and/or have a high consequence of failure. Cathodic protection may be the most suitable means of protection but that can only be determined after a full appraisal including a life cycle cost and risk assessment for all alternatives, e.g. stainless steel and coatings.
Where provision for future cathodic protection is a design requirement it may be necessary to install anodes at construction if they can not be practically installed at a later date.

Sawtooth Ribbon anodes are simple to install in concrete pours using special clamps and connectors making it ideal for use in new structures. However MMO mesh anodes are also used with appropriate fixings. Saw tooth ribbon can also be installed in narrow slots in existing structures.

MMO coated Ti sawtooth ribbon anode is available as a 6.35mm solid or 10mm expanded mesh ribbon. It has a crest height of 5mm. 10mm saw-tooth ribbon mesh is supplied as a 50m roll while 6.35mm wide solid ribbon is provided as a 25m coil.

Sawtooth Rebar Clamp - The clamps fits around the reinforcement and the sawtooth ribbon anode clips into the clamp. The clamp comes in five different sizes with different colours.
- Blue - 12mm rebar
- Red - 16mm rebar
- Yellow - 20mm rebar
- Green - 25mm rebar
- Yellow - 32mm rebar

Sawtooth Rebar Connector
Titanium connector with titanium nut to connect 1.2mm feeder wire to 6.35mm Sawtooth anode ribbon. The connector is fastened to the concrete with a Rawl plug.

Sawtooth Holding Disc
A 20mm diameter x 33mm high orange plastic fixings that are tapped into a hole drilled in the concrete. The threaded length that fits into the hole is 8mm diameter.

Sawtooth End Clamp - The end clamp is used to tighten the sawtooth ribbon from one end to the other. At least one of the end clamps is also used to connect a 1.2mm titanium feeder wire. A titanium nut is used to fasten the feeder wire and sawtooth ribbon to the built in titanium connector.

HISEO Saw Tooth Ribbon

Saw tooth ribbon anodes are simple to install in concrete pours using special clamps and connectors making it ideal for use in new structures. However MMO mesh anodes are also used with appropriate fixings. Saw tooth ribbon can also be installed in narrow slots in existing structures.

MMO coated Ti sawtooth ribbon anode is available as a 6.35mm solid or 10mm expanded mesh ribbon. It has a crest height of 5mm. 10mm saw-tooth ribbon mesh is supplied as a 50m roll while 6.35mm wide solid ribbon is provided as a 25m coil.
Impressed Current Systems – Discrete Anodes

durAnode 4

Discrete anode is the term for any anode that is placed in a drilled hole inside the concrete. The anodes can be sacrificial such as corrPRE’s Roll Anode or an impressed current anode such as CPI’s durAnode. As the anodes can be placed in any position and connected together in a string they give tremendous flexibility and precision for what they protect. They can be used to provide localized or widespread protection either on their own or in conjunction with surface mounted or embedded anodes.

Anodes on or in the surface distribute the current predominantly to the outer layers of reinforcement but discrete anodes can also target deeper reinforcement or reinforcement on far faces which would otherwise be inaccessible.

More recently discrete anodes have been used to protect embedded metals deep in historic buildings where steel sections are covered in mortar or brickwork. Discrete anodes can be installed to be largely invisible and are ideal where a change to the surface appearance is unacceptable.

durAnode Standard and Vertical

durAnode 4 is the fourth generation of the durAnode. The durAnode 4 Standard and Vertical comprise a long, small diameter tube anode made from a MMO titanium mesh. The anode is designed with proprietary grouting and distributor cable systems. The combination of small diameter hole, simple grouting and defect free connections leads to a highly cost effective and durable installation.

The durAnode system is the most popular discrete anode system in the world and has a successful installation record dating back to 1986.

durAnode advantages over other anodes include:

a) a built in pre-resistor which eliminates IR drop problems and uneven current distribution and allows long anode strings to be developed,
b) a unique anode connection system that requires no soldering but allows highly reliable connections (see page 13),
c) a complete range of control systems developed specifically for durAnodes (see page 16),
d) a grouting system that gives simple hole sealing and ensures complete backfill when installed in walls and soffits (see page 13).

The length of durAnode 4 Standard and durAnode4 Vertical varies from 100mm to 600mm in 50mm intervals.

Installation

After locating the reinforcement with a covermeter or radar the location of the anode is selected to be mid way between reinforcement (12mm minimum hole to rebar). The 12mm anode hole is then drilled 30mm longer than the anode length. The hole is tested for rebar proximity using the durAbar down hole tester. The anode is then inserted and grouted. Finally the 1.2mm diameter sleeved wire is laid between anodes and the pins torqued down to make the anode connection.
**Standard**

The durAnode is the result of constant development of 30 years. All shaft parts are made of titanium to ensure high durability even though they are typically totally hidden from view.

**durAdunk**

This is a special tool for fixing durAnode 4

**Vertical**

The durAnode vertical is designed to be installed in soffits. After drilling the 12mm hole for the anode, the end of the hole is reamed out for the 26mm diameter end seal. Simply push in to seal the hole. A hole in the plastic discs enables grout to be injected without spillage while a breather to the end of the anode lets air be expelled.

**durAnode 4**

The durAnode is the result of constant development of 30 years. All shaft parts are made of titanium to ensure high durability even though they are typically totally hidden from view by being buried in the structure. The small diameter also enables them to be installed in brickwork mortar joints. The following order details apply to standard and vertical anodes.

<table>
<thead>
<tr>
<th>Length</th>
<th>Resistance</th>
<th>Product No</th>
</tr>
</thead>
<tbody>
<tr>
<td>100 mm</td>
<td>510 ohm</td>
<td>1400100</td>
</tr>
<tr>
<td>150 mm</td>
<td>510 ohm</td>
<td>1400150</td>
</tr>
<tr>
<td>200 mm</td>
<td>510 ohm</td>
<td>1400200</td>
</tr>
<tr>
<td>250 mm</td>
<td>510 ohm</td>
<td>1400250</td>
</tr>
<tr>
<td>300 mm</td>
<td>510 ohm</td>
<td>1400300</td>
</tr>
<tr>
<td>350 mm</td>
<td>510 ohm</td>
<td>1400350</td>
</tr>
<tr>
<td>400 mm</td>
<td>220 ohm</td>
<td>1400400</td>
</tr>
<tr>
<td>450 mm</td>
<td>510 ohm</td>
<td>1400450</td>
</tr>
<tr>
<td>500 mm</td>
<td>220 ohm</td>
<td>1400500</td>
</tr>
<tr>
<td>600 mm</td>
<td>220 ohm</td>
<td>1400600</td>
</tr>
</tbody>
</table>

**Torque screwdriver Product no 1800200**

89mm long hex bit Product No 18003000

**Torquing Screwdriver**

The torqueing screwdriver has a replaceable bit and device to hold the anode while tightening the pin.

**durGrout inject 150**

A significant number of failures have occurred with discrete anodes due to poor grouting leaving air voids. The durAnode system is designed to overcome this issue.

duraGrout inject 150 is specifically formulated for injection of the durAnodes and reference electrodes. It is a shrinkage compensated hydraulic cementitious (Type Cr(VI)) grout that is 1600kg/m³ and ionically conductive and gives a 28 day compressive strength of 40MPa, expansion of 1-3% and Wenner resistivity of 4 kohm cm. Resistivity at 2 years is 11 kohm cm.

Although specifically developed for durAnode durAgroot can be used for grouting any discrete anode.

The syringe used to inject the dureAnodes has a 7mm nozzle that fits exactly the hole in the end seal of the anode.
The durAnode R1 and R2 were developed for thin elements (slabs and precast) unable to take the length of the Standard or Vertical anodes. The R1 has one roll of 25mm wide MMO Ti ribbon and the R2 has two. Nominal diameter is 25mm.

Titanium wire passes through the slot with no baring of the protective covering. The titanium threaded pin is then torqued down with a special screwdriver. At the set torque the pin has penetrated the covering and made perfect electrical contact with the titanium wire without exposing it.

Air bleed hole

5mm grout hole filled using a special syringe. Special connection wire designed to work with pin and torqueing screwdriver.

The durAfat is a special design of the standard durAnode. A spiral of titanium mesh is welded on to the head of the anode. This anode can be used on elements of limited thickness.

<table>
<thead>
<tr>
<th>Length</th>
<th>Resistance</th>
<th>Product No</th>
</tr>
</thead>
<tbody>
<tr>
<td>150 mm</td>
<td>510 ohm</td>
<td>1407150</td>
</tr>
<tr>
<td>200 mm</td>
<td>510 ohm</td>
<td>1407200</td>
</tr>
<tr>
<td>400 mm</td>
<td>510 ohm</td>
<td>1407400</td>
</tr>
<tr>
<td>800 mm</td>
<td>510 ohm</td>
<td>1407800</td>
</tr>
</tbody>
</table>

Heathcote Clock Tower, Perth, WA.

80 No 250mm long durAnode 4 standards were used by Freyssinet to protect upper and lower concrete ring beams. Monitored using ERE20’s and powered by durApower 1+3 the complete CP materials and equipment was under $20,000.

durAnode Calculator

The durAnode calculator is a simple spreadsheet prepared by SRCP based on design information and methods provided by Paul Chess, an international CP expert. Provide. The input and output is shown below.

Anodes Protecting Whole Column

| Anodes in X section (defined by anode layout in column) | 3 |

| Maximum anode spacing to base design on (m) | 0.4 |
| Maximum output of anode/m length at 110mA/m² (mA) | 5.3 |
| Max long term current output at anode surface (mA/m²) | 220 |
| Pref. long term current output at anode surface (mA/m²) | 110 |
| Anode diameter (cm) | 0.8 |
| Pre-resistor (ohms) | 220 |
| Voltage of CP system (V) | 2 |
| Specific concrete resistivity (Kohm cm) | 15 |
| Calculated resistance of anode (ohm) | 90 |
| durAnode output at 220 mA/m² (mA) | 3.2 |
| durAnode output at 110 mA/m² (mA) | 1.6 |
| Calculated anode current at voltage & resistance (mA) | 1.0 |
| Current OK at less than preferred long term anode output | 300 |

<table>
<thead>
<tr>
<th>Vertical Spacing of Anode Layers (m)</th>
<th>Steel Surface Area (m²/lin m col)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very Light</td>
<td>Light</td>
</tr>
<tr>
<td>0.2</td>
<td>0.40</td>
</tr>
<tr>
<td>0.6</td>
<td>0.40</td>
</tr>
<tr>
<td>1.0</td>
<td>0.40</td>
</tr>
<tr>
<td>1.5</td>
<td>0.40</td>
</tr>
<tr>
<td>2.0</td>
<td>0.40</td>
</tr>
<tr>
<td>4.0</td>
<td>0.18</td>
</tr>
</tbody>
</table>

Below: Marine structure that used durAnodes in three rows. In Germany, one of the most discerning CP markets, over 20,000 durAnode per year are sold.
Discrete Anodes Background
Discrete anodes based on MMO ribbon mesh have found extensive use in Europe. Originally they were simple strips of mesh grouted into drilled holes but as current requirements for heavily reinforced civil structures have increased fabrications of multiple strips of anode welded together are being commonly used. The high surface area of anode enables the anode current density limits needed to prevent acidification of the grouts to be maintained in the safe range while giving a high current output for each anode.

CorrAnode Discrete Tube Anodes
CorrAnode is a tube made form MMO-Ti mesh That is then installed in predrilled holes and grouted with a SiliGrout. Although the grout is acid resistant the NACE limits of 110mA/m² for the long term should be maintained.

The standard anode is 12mm diameter and 100mm long giving 45cm² of expanded anode surface area. Any length of anode can be supplied and can be fitted with a suitable connection. Ti crimped ‘t’ piece is standard. Holes should be 15mm diameter and filled with grout from the bottom of the hole.

HISEO Discrete Anodes
Chemical Newtech fabricate discrete anodes to specific order but sell as standard HISEO Discrete Anodes. These six bladed anodes have diameters from 19 to 35mm and lengths from 10 to 40 cm in 5 cm intervals. They are made from ribbon anodes spot welded to 3 mm rod or 6.35 mm x 0.6 mm plate.

Current output for 100 yr life (i.e. 110mA/m²):
- 19mm – 0.63 mA/10cm
- 25mm – 0.83 mA/10cm
- 30mm – 1mA/10cm

CorrPre SiliGrout
Siliglout is a 100% inorganic composition. An acid proof mortar consisting of a liquid binder and finely divided silica filler. The mortar hardens by internal chemical action, which produces an insoluble silica gel. The mortar is resistant to most acids and salts. The mortar is completely inert to all organic solvents.

Compressive Strength: 25 MPa at 28days
Flexural Strength: 5MPa at 28days
Specific Gravity: 2100kg/m³
Applicable pH’s: greater than 2
Resistant to: Salts, oils, greases and acids.
Impressed Current Systems – Surface Mounted Anodes

Background

Impressed current anodes can be mounted on the surface of concrete in various ways to provide cathodic protection. All that is required is an ionic conductor between the anode and concrete surface and a secure way of mounting the anode. Such anode systems can have the advantage of:

**Speed of installation** – with limited preparation anode can be installed at great speed and limited disruption.

**Light weight** – The anode can be mounted in a light weight carrier such that very little weight is added to the structure.

Cassette

Cassette is a ribbon anode impressed current cathodic protection (ICCP) system where instead of burying the ribbon anode in the concrete it is mounted in an inert panel with a glass fibre pad to spread the current from the ribbon to the concrete surface. Cassette is ideal where ever there is limited access or wet conditions. It is rapidly installed with limited noise, no mess and with inert components the risk of failure is low. More importantly its simple installation generally leads to significant cost savings on the project.

**Cassette vs 2**

The all new Cassette 2 has been developed in response to demand for a fireproof system, with insulated fixings, and decorative appearance.

Cassette system has a number of features that make it suitable for:

- rapid installation. Useful in shutdowns for example.
- low reinforcement cover. Short circuit risk of ribbons in slots eliminated
- aesthetically sensitive areas
- areas where minimal concrete preparation is advantageous
- restricted access or confined space areas such as basements
- areas where fitting behind pipes and other objects is useful
- water and seawater exposure as they do not cause corrosion of the system. Suitable under wharves, in leaking basements, in tunnels and on mine or industrial sites where inundation is possible. It can be designed for tidal and splash zones.

No special skills or equipment are required and the system can be installed by any competent repair contractor with an electrician.

**CorroDisc 125**

CorroDisc is an impressed current cathodic protection anode that provides great flexibility in where to place the anodes.

With these surface anodes there is no drilling of the concrete. The anodes are bonded to the surface and connected in a string to the TR unit. They are Ideal for small areas of isolated corrosion in an industrial environment. CorroDisc products are based around MMO coated titanium expanded mesh in an acid resistant mortar.

Surface mounted anodes are electrochemically bound to the concrete using corrPRE’s patented ionically conductive paste or low resistance repair mortar. A 6mm plastic fixing at the centre enables the anode to be securely fastened while the mortar bedding hardens.

- Size: 125mm x 12mm
- Weight: 250 g
- 2 Insulated connections: Ti wire 1mm dia. x 50mm long
- Minimum reinforcement cover: 15mm
- Minimum bond strength: 1.5MPa
- Typical anode density: 4 to 8 /m²
- Expanded metal surface area: 113cm²
- Expected design Life: 100 years at 5 mA/anode
  - 50 years at 10 mA/Anode
  - 30 years at 16 mA/anode
Zebra Conductive Coating

In conductive coating ICCP systems the primary anode is typically a titanium wire. The current delivered by the wire is then spread over the concrete surface using the conductive coating. The conductive coating is then covered to provide an aesthetic, wear resistant finish.

Conductive paint anodes have a long and successful history for the ICCP of reinforced concrete. The first systems introduced in 1984 were solvent based film forming coatings and have lasted for 15-20 years, consistent with their design life (Concrete Society TR 73 Appendix A1). Newer water based coatings were subsequently introduced to overcome health issues with earlier systems but these had the same drawback of a conductive filler in high resistance binder meaning a high driving voltage was required.

Conductive coating CP systems are the most common CP systems worldwide because of their light weight (0.5kg/m²), low cost, flexibility, even current distribution, low disruption during installation and aesthetically pleasing finish. They are ideal for buildings.

ZEBRA System

In 2005 a patent was granted for Protector’s Zebra conductive coating for impressed current cathodic protection. This has a low resistance silicate binder that absorbs into the concrete. It is breathable and runs at very low voltage which reduces the acidification that led to limited design life of other systems.

History

This system has been in use since 1990 in Europe by the developers, Protector. Over 400 systems have been installed mainly on structures in Norway, Germany and the Netherlands. Control and monitoring of many of the systems since 1992 has used the Camur system and there is a wealth of data on the performance of the Zebra CP system.

Design

Design is relatively simple. The maximum output for each CP zone is 20mA/m² and the maximum output from the Camur Fix Volt is 3 or 8 Amps.

Hence each CP zone can be a maximum of 100m² and 250m² for 3 Amp and 8 Amp Fix Volt respectively. However, CP zones are often much smaller than this as the area within a zone must have similar protection requirements.

The Zebra system has many features that give it its high performance and life. It can also be coated with a range of decorative or hardwearing surfaces making it suitable in many applications.

Build up of the Zebra Cathodic Protection System Where an Abrasion Resistant finish is required (e.g. floor slab)

Application of Zebra to a basement car park slab and bottom 300mm of walls

Building Facades

Car Park Capillary Rise Zone

Balcony Soffits

Suspended and Slabs of Grade
Impressed Current Control Systems & Components

CPI durApower

All ICCP system require a power supply. This can be an expensive item but recently low cost power supplies have become available.

The durApower 1+3 Unit

At the simplest and lowest cost level are the durApower1+3 units, which can be incorporated in existing cupboards, to control very simple CP systems. An internal logger stores performance data.

The durApower 1+3 System

Typically a number of durApower1+3 units are assembled in a small cabinet with a transformer to give a manually operated multiple channel supply to energise small to medium simple CP systems.

The durAcentre 4+8 System

The durAcentre4+8 system is a bespoke control system for major CP installations. The basic component of the system is the durAcentre4+8 card that can control 4 anode zones (4 outputs) and has 8 voltage inputs.

Each durAcentre4+8 card within the system has an individual address and 200 addresses are available. Hence, the system can control 800 anode zones with a total of 1600 half cell inputs. Where there is a large number of durAcentre4+8 cards involved they will typically be distributed around the structure. They will all communicate with a Central Control Unit (CCU) which can be operated remotely or directly.

The durAdjust485 Monitoring System

The durAdjust485 central control unit typically comprises:

- Cabinet
- The PC computer running durAdjust software and fitted with a HUB allowing 4 branches

- Large touchscreen
- GSM modem
- durAlpr – Up to 64 LPR monitors on 8 cards
- durahold – Up to 64 half cell probes on 8 cards
- duraStore – logger for storage of data

For monitoring structures only or operating with a CP system. This system can be operated both manually and automatically and can be customised to an individual structures needs.

The durApower485 System

The durApower485 System is based around a central control unit which is the same as durAdjust485 CCU and substations which are the same as the durAdjust monitoring substation except they can also include one or several durApower485 power supply system with a maximum output of 6A at 18 volts.

The substations will contain a durAstore module and an appropriate number of durAhold cards. Communications, software and remote control are the same as the durAdjust485.

Camur

The Camur system is a component based system that uses a bus to monitor and control the CP system. Software and components for local and remote monitoring are available.

Half Cells

ERE 20

The ERE 20 manganese dioxide half cells are the only embedded real half cell that maintains a stable potential over a long reliable life. Proven performance over 30yrs. The only solution for corrosion monitoring their stability makes them the reference cell of choice for discerning customers. Most popular for CP monitoring in Germany and Scandinavia.

Low cost MMO durAmmo reference cells for CP depolarisations have a 1.2mm Ti wire with PP insulation. Can withstand substantial current drainage. These have a potential of +110mv relative to copper sulphate.

<table>
<thead>
<tr>
<th>Type</th>
<th>Length</th>
<th>Diameter</th>
<th>Cable</th>
<th>Product No</th>
</tr>
</thead>
<tbody>
<tr>
<td>ERE20</td>
<td>100 mm</td>
<td>64.5 mm</td>
<td>5m</td>
<td>5250500</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>10m</td>
<td>5251000</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>30005</td>
<td></td>
</tr>
<tr>
<td>Extra Cable</td>
<td>30 mm</td>
<td>6 mm</td>
<td>2m</td>
<td>5300200</td>
</tr>
<tr>
<td>durAmmo</td>
<td></td>
<td></td>
<td>5m</td>
<td>5300500</td>
</tr>
</tbody>
</table>
Titanium CP Connectors

Anode Feed Wire – Concrete Surface
Where the current feeder wire is in conduit on the surface of the concrete it is insulated copper wire with connection to buried feeder wire in a junction box. The cables are designed using standard electrical practices for current capacity and voltage drop. Voltage drop is to be less than 5%. Driving voltage depends on the ease of passage of current to the rebar but for 10mA/m² is typically:

- Mesh & overlay: 4 Volts
- Ribbon in slot: 6 Volts
- Mesh discrete: 4 Volts
- durAnode: 6 Volts (including 2 V pre-resistor)
- corroDisc: 8 Volts
- Cassette: 8 Volts
- Zebra: 2 Volts

Anode Feed Wire – Buried In Concrete
Feeder wire in the concrete is titanium because the titanium to MMO coated titanium connection in concrete is likely to generate acid due to the passage of current. This would cause corrosion of the copper wire unless completely and perfectly encapsulated. Use of titanium eliminates the need for this.

Anode Feed Wire – Buried In Concrete
There is considerable redundancy in the multiple earth return cabling and hence copper cable with XLPE or fluorocarbon polymer sheath for alkali resistance.
CM-3 Continuity Tester

Guaranteed Continuity Testing

Electrical continuity of reinforcement and cable connections are critical if potential and LPR results are to be meaningful and if cathodic protection systems are to work. Yet in Australia many of those doing the testing and installation do not test properly. Use of the CM-3 means that all continuity tests will be correct and testing will be rapid.

When using Cathodic Protection to stop corrosion on steel reinforcement in concrete, it is extremely important that

- all the steel rebars are electrically connected – unconnected rebars will not be protected and are likely to corrode.
- all electrical connections to, and between anodes can sustain the CP current loads.

To verify these aspects you need a suitable measurement instrument. Often a simple Digital Multimeter (DMM) is used, but:

- as there are only small potentials between the rebars measured, the resistance measurements of such an instrument is not reliable
- the potential (voltage) between the test points unreliable. Although a reading of 0 indicates relatively high probability of continuity, it is still an indirect measurement that can make the operator draw the wrong conclusions.
- Continuity may exist at the low DMM current but it may break down at higher operational currents.

The CM-2 verifies electrical continuity directly, measuring resistance by sending a relatively large current (0.5 Ampere) through the connection being tested for 0.5 seconds. Then the CM-2 verifies again by checking that the residual voltage between the test points falls to 0 within 100 ms after the resistance measurement is interrupted.

Steel connection is with an included probe. The probe has a sharp spring loaded tip whose impact on depression cuts through rust.

The CM-3 has a lithium ion battery that is charged using the supplied charger.

The instrument accepts common 4 mm banana connectors, cables for rebar connection are not included but the resistance of any cable can be tared off at the press of a button.

Resistance in measurement cables may easily be eliminated through CM-2’s calibration feature.

Continuity Specification

An appropriate specification for continuity testing to guarantee that there is electrical continuity, and that will not breakdown under CP applied currents is given below:

“The electrical continuity between reinforcing bars or elements of steel in concrete shall be tested by measuring the resistance using a current of 250 mA min. for a minimum 0.5 seconds. The acceptance criteria for such testing shall be stable values and a resistance less than 1 Ω measured at the end of the applied current pulse, confirmed by 0 V residual voltage measured 0.1 seconds after the applied current is interrupted.”

The measurement can be performed with automatically with CM-3.
# CM-3 Continuity Tester

## Technical Data

<table>
<thead>
<tr>
<th>Specification</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Resistance range</strong></td>
<td>0 – 10 ohm</td>
</tr>
<tr>
<td><strong>Resistance resolution</strong></td>
<td>0.1 ohm</td>
</tr>
<tr>
<td><strong>Resistance measurement</strong></td>
<td>0.5 A / 1 s (mean value of 5 readings in the last 0.5 s)</td>
</tr>
<tr>
<td><strong>Residual voltage range</strong></td>
<td>± 2 Volt</td>
</tr>
<tr>
<td><strong>Residual voltage resolution</strong></td>
<td>0.1 Volt</td>
</tr>
<tr>
<td><strong>Residual voltage delay</strong></td>
<td>100 ms (delay between measurement of resistance and residual voltage)</td>
</tr>
<tr>
<td><strong>Minimum battery voltage</strong></td>
<td>9.5 Volt</td>
</tr>
<tr>
<td><strong>Min time each automatic measurement</strong></td>
<td>3 seconds</td>
</tr>
<tr>
<td><strong>Maximum total resistance (in cable and between rebars)</strong></td>
<td>12-ohm</td>
</tr>
<tr>
<td><strong>Screen</strong></td>
<td>LCD with bright backlight. 5mm high text.</td>
</tr>
<tr>
<td><strong>LCD backlight off</strong></td>
<td>90 seconds</td>
</tr>
<tr>
<td><strong>Auto off</strong></td>
<td>60 minutes</td>
</tr>
<tr>
<td><strong>Current consumption</strong></td>
<td>100 mA (backlight on), 600 mA (10-ohm, 1 s during rebar measurement)</td>
</tr>
<tr>
<td><strong>Battery</strong></td>
<td>10.95 Volt / 2.7 Ah Li-Ion (60 x 45 x 20 mm, 0.25 kg)</td>
</tr>
<tr>
<td><strong>Weight (main unit w/battery)</strong></td>
<td>Approx. 0.6 kg</td>
</tr>
<tr>
<td><strong>Dimensions (main unit)</strong></td>
<td>190 x 128 x 54 mm</td>
</tr>
</tbody>
</table>

## Operating Instructions

<table>
<thead>
<tr>
<th>Function</th>
<th>Method</th>
<th>Initial Screen</th>
<th>Screen after seconds</th>
</tr>
</thead>
<tbody>
<tr>
<td>On/Off</td>
<td>Press and hold the On/Off button</td>
<td><img src="image1" alt="Initial Screen" /></td>
<td><img src="image2" alt="Screen after seconds" /></td>
</tr>
<tr>
<td>Calibrate to tare off cable resistance</td>
<td>Plug 4mm banana plugs on each end of rebar cable into Probe and Rebar sockets. Press and hold Test and On/Off buttons at the same time.</td>
<td><img src="image3" alt="Initial Screen" /></td>
<td><img src="image4" alt="Screen after seconds" /></td>
</tr>
<tr>
<td>Check continuity between 2 points</td>
<td>Plug one end of tared rebar cable into rebar socket and attach another end to point 1. Plug probe into Probe socket. Press tip of probe into rebar until it clicks. Press Test button</td>
<td><img src="image5" alt="Initial Screen" /></td>
<td><img src="image6" alt="Screen after seconds" /></td>
</tr>
<tr>
<td>Automatic mode</td>
<td>After taring and one or more tests press On/Off</td>
<td><img src="image7" alt="Initial Screen" /></td>
<td><img src="image8" alt="Screen after seconds" /></td>
</tr>
<tr>
<td></td>
<td>Press tip of probe into rebar until it clicks. Rebar connection will be recognized.</td>
<td><img src="image9" alt="Initial Screen" /></td>
<td><img src="image10" alt="Screen after seconds" /></td>
</tr>
</tbody>
</table>
ZLA applied to leaking joints on Milan ring road after long term assessment. Leakage through the joints of de-icing salt water led to early corrosion. 450 micron zinc applied.

ZLA applied to balcony edge. Note panels on right have had first undercoat layer applied. Panels were tested over 2 years to show CP criteria met for a period of 2 years.

ZLA applied to 232 Marine Parade, Cottesloe. Being adjacent to the ocean sea spray led to early corrosion activation of balconies, walkways and stairs. After 3 years performance is excellent.

Viaduc de Fourneaux, France. Constructed 1978. Applied to 7 viaduct foundation and column bases Total 4500 Roll Anodes 22mm diameter.

Embedded sacrificial anodes (GSC Super Anodes) provide protection to reinforcement within repairs to corroding reinforcement of a highway bridge.

Sacrificial anode (ZLA) applied locally to prestressed concrete beams where joint leakage has led to corrosion. SACP is safe for prestress and easily applied to small areas.
Projects

Denis Bridge, NSW. Roll Anode SACP system installed to one bridge pier. Monitored by RTA. Corrosion protection meeting CP criteria achieved.

Guildford Hotel, WA. ZDA SACP installed to give corrosion protection to steel beam.

Cape Perpetua Viaduct. CorrPre SACP Installed 1998 and monitored for 5 years. CP criteria met at end of monitoring period.

Billingham Forum. Swimming pool service ducts. Cassette ICCP applied in 2010 to Mott McDonald design. Construction period 6 weeks. Cassettes selected as a confined space and rapid to install without creating dust.

Emmertsgrund, Heidelberg. Zebra conductive coating ICCP system applied to basement slab. The primary anode and conductive coating are laid first and for trafficked floor slabs they are topped with a self leveller.

Apartments where Zebra conductive ICCP system applied to the soffits of balconies. Advantages are minimal preparation (no drilling or sawing for anodes), light weight and very rapid installation.
durAnode discrete anodes enabled flexible anode location, fast installation with minimal drilling and ability to provide current distribution required.

Cassette installed on a prestressed 'T' beam. Close centred single ribbon Cassettes used to ensure a uniform current distribution. Glass fibre bolts, nuts and washers as requested.

Mixed metal oxide coated titanium ribbon built into a critical wharf structure reduces the risk of failure and lower reinforcement cover reduces weight and cost.

Mixed metal oxide coated titanium ribbon pinned to the concrete and then covered with a self levelling screed which provides physical protection and spreads the currents.

Loy Yang Power Station. Cassettes installed around a foundation. Obstruction made fitting of other anodes difficult. Cassettes custom made in 2m lengths in order to fit vertically.

Silver Jubilee Bridge, Runcorn, UK. Opened in 1961 to cross the Mersey the bridge deck suffered corrosion due to de-icing salts. Cassettes used in trial section for 2 years and then installed to whole bridge.
Anode Selection Guide

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<tr>
<th>Electrochemical</th>
<th>Corrosion Resistance</th>
<th>Cathodic Efficiency</th>
<th>Anode Material</th>
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Back Cover – Garage, Melbourne. corrPRE’s Zinc Layer Anode system was used to cathodically protect low cover reinforcement in soffit carbonated concrete. Designed by Buildcheck Engineering Consultants and installed by Duratech for R&N Builders.
Cathodic Protection – Invariably the lowest whole of life cost repair system