FREEMASONS' HALL, LONDON

HERITAGE APPROVAL INFORMATION RELATING TO CATHODIC PROTECTION

For:

UNITED GRAND LODGE OF ENGLAND

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CORROSION ENGINEERING SOLUTIONS

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CORROSION ENGINEERING SOLUTIONS

1 INTRODUCTION

Corrosion Engineering Solutions [CES] has been commissioned to design an impressed current Cathodic Protection [CP] system to arrest on-going corrosion of the embedded steel frame of Freemasons' Hall, London.

Expansive corrosion of steel and iron members embedded in masonry, causing the cladding to crack and displace is a condition known to affect many early 20th Century structures of this type and is often referred to as Regent Street Disease.

The grand entrance of the building is to be repaired as part of Phase 6 of the overall refurbishment. This phase will be the first to incorporate CP.

As part of the project's management, the various heritage bodies involved in the building require a briefing on the nature of the proposed scheme, so that the impact on the listed façades [and any other aspects] can be properly assessed.

It is understood that the Grand United Lodge has its own internal board of heritage advisors. This board is made up of members of the organisation and has expertise including architects, structural engineers and heritage professionals. Due to the building being listed as a historic monument, the local authority and Historic England are also likely to have an interest in the proposals.

This document will layout the salient background information on the technology which is relevant, and then give an overview of the proposed scheme. At the time of writing, the CP design is at a very early stage, with detailed calculations and installation drawings yet to be produced. The intention is that this document will provide a single point of information to allow discussion and approval, prior to the CP design being finalised.

2 BACKGROUND TO CATHODIC PROTECTION

CP is a relatively obscure and specialist technology which, due to the wide variation its application, is often misunderstood. CP as a technology to treat corrosion of metals in historic buildings is particularly specialist and, unfortunately, has a history of some unsatisfactory projects and unscrupulous dealings.

This technology is, however, easily understood at a client level and there are many options, techniques and suppliers of materials which allow an open and transparent design, installation and commissioning process. Moreover, there are several BS, EN and ISO standards that allow impartial assessment and selection of materials, personnel, qualifications, and review of performance data. These include:

i. BS EN ISO 12696 – *Cathodic Protection of Steel in Concrete*. Although the affected areas of this structure are not made from reinforced concrete, this standard is generally accepted as applying to Regent Street Disease cases. This is specifically mentioned in the document under Note 2 of Cause 1 'Scope'.
ii. BS EN ISO 15257 – *Competence Levels of Cathodic Protection Persons*. This standard provides a basis for training and certification schemes across the various different uses of CP technology. In the UK, the Institute of Corrosion administers the scheme allowing clients to transparently assess who is [or is not] qualified to design, install, supervise, test or operate a CP system.
iii. BS ISO 19097 – *Accelerated Life Test Method for Mixed Metal Oxide Anodes for Cathodic Protection*. This is an internationally accepted test method to allow manufacturers to prove that a given anode product is of sufficient quality/robustness to operate in the intended environment, for the intended service life. Some projects have been affected by premature failure of anode materials and this test is a safeguard against this.
iv. Corrosion Prevention Association Technical Note 17 – *Monitoring & Maintenance of CP Systems Protecting Reinforced Concrete Structures & Steel-framed Buildings*. This guidance note takes the requirements for monitoring and reporting set out in BS EN ISO 12696 and explains them, with more detail on the technology involved.

2.1 HISTORY OF CP

This technology has a long history and is used in engineering across a very wide variety of sectors and structures. Although the basic principles are the same, the details of the application vary drastically and expertise in one area generally does not translate into another.

For example, the materials, design calculations and distances involved in protecting buried pipeline, or oil rigs have little or no relation to the same for reinforced concrete. Although there are much more similarity between reinforced concrete and steel-framed masonry-clad buildings, the expertise required is different again and applying a scheme based on a concrete structure, to a masonry structure, is likely to result in failure or unacceptable levels of damage to the heritage materials.

Below is an approximate timeline of CP technology and its different applications.

- 1824 Sir Humphry Davy reports galvanic CP of ships' hulls.
- circa 1910 Impressed current CP of buried steel structures.
- late 1940s Impressed current system to pipeline in Africa.
- mid 1950s CP of buried reinforced concrete structures.
- late 1970s CP of reinforced concrete bridge decks in US.
- mid 1980s First building - conductive coatings used as anodes.
- early 1990s Meshless conductive overlay anodes introduced as well as desalination [chloride extraction] and re-alkalisation in the UK.
- early 1990s CP used to protect steel framed buildings.
- mid 1990s CP using discrete anodes.
- late 1990s Galvanic CP systems.

CP for treating Regent Street Disease is, therefore, a relatively recent technology and this sometimes comes with commercial information rights to protect and lessons learnt from early failures. There is now, however, enough history for all the different applications and anode types that, provided the system is designed competently, a full and low maintenance design life can be achieved.

3 DESCRIPTION OF PROPOSED SYSTEM

This section of the report describes the proposed system and rationale for the selection, and the likely heritage impact.

3.1 GENERAL

The system is to be an impressed current system, with distributed control equipment and automated/remotely accessible control and monitoring facilities.

Remote controlled and automatic testing is important as the system will be large on completion. Compliant monitoring and records are important to demonstrate the building is protected and are often of interest to heritage authorities. Testing and reporting without automated/remotely controlled equipment would be prohibitively expensive and time consuming. The nature of the stone and UK weather means that regular adjustment will be required between seasons and as the system affects the building over time.

There are essentially three main forms of CP for concrete/masonry: galvanic [sacrificial], impressed current or a hybrid of the two. In this situation, only an impressed current system is likely to be effective. Galvanic systems function by sacrificially consuming the anode material meaning that replacement of the anode would be required at some stage within 15-20 years. Impressed current systems use an inert anode that can be designed/selected for a service life in excess of 100 years.

Galvanic systems also rely on the galvanic difference between the anode material [usually zinc] and the steel of the structure. This is typically less than 1 volt. Experience of designing and operating CP systems for similar structures shows that between 3 volts and 15 volts is required [typically 5 volts] to generate and distribute protection. This is due to the highly resistive nature of the masonry which are in the order of 10 times greater than those observed in reinforced concrete for which these systems were developed.

Galvanic or hybrid anodes for this application would also need to be larger than impressed current. An impressed current ribbon anode is approximately 0.9mm thick and can be inserted into a masonry joint. A galvanic or hybrid anode is typically between 28mm and 60mm diameter and would require more significant damage/alteration to the bed joints and stone blocks, than a ribbon.

A drawback of impressed current system is that they require more frequent and sophisticated monitoring and adjustment than the other options, which means the monitoring is more expensive. By contrast, however, neither galvanic CP or hybrid options can be adjusted and as such if adequate protection cannot be achieved there is little more which can be done without costly intervention.

The materials and equipment to be specified will be items that are available from several manufacturers and suppliers. Although there are high quality proprietary anode products or electronic control equipment, when procurement is limited to a single source it increases the costs and restricts the options of the installation contractor and owner/operator in future maintenance.

3.2 ANODE SYSTEM

The scheme will utilise titanium anodes coated in a mixed metal oxide. These are impressed current anodes and have a long history for use in masonry-clad buildings. These anodes come in many forms [tape, rods, tube, expanded mesh-ribbon] and sizes in each case and are available from several different manufacturers.

The scheme is likely to use expanded mesh ribbon anodes, embedded into the masonry joints. The reason for the selection is that there are many suppliers of high quality ribbon anodes who can provide conformance documentation for their products, and this anode type is likely to have the least impact on the historic fabric.

In the accompanying sketch [CN19-016-J335-SK001] a 20mm wide ribbon anode is used. It is likely that once the location and section size of the steel members are understood that a smaller anode [10mm to 13mm] can be used in some, if not all, locations. This will reduce material and installation costs and reduce the need for removal of otherwise sound original heritage materials.

Photograph 1 shows a network of ribbon anode prior to grouting in place. The example is a carrarware façade, rather than the Portland stone at Freemason's Hall but the layout is likely to be similar.

Photograph 1 – Anode ribbon prior to grouting into the masonry joints.

Internal installation is not an option as the building is occupied and the internal finishes are as historically important as the external façade [the building contains some of the best preserved late-deco finishes and fixtures in the world].

An external installation of any type would, therefore, require all of the cabling, anodes and sensors to be installed into the masonry joints which would require extensive chasing of the joints even if rod anodes were used [for example]. The ribbon anode approach therefore reduces the amount of work, noise, HAVs and dust required.

It is possible that a few rod anodes will need to be installed in certain locations to achieve current distribution. Certain details, e.g. where there is a large amount of steel at significant depth, may require rod anodes to be installed. These will be small diameter rods [probably 10mm or 12mm Ø] positioned at the intersection between perp and bed joint or at internal corners, and the edges of the drill holes will be carefully and sympathetically repaired by the stone mason.

3.3 MONITORING SENSORS

The surface potential of the steel will be monitored using a series of Silver/Silver Chloride reference electrodes and solid state decay probes. Each sensor is installed into the masonry and connected back to the control equipment via copper cable [embedded into the masonry joint].

The reference electrodes are between 10mm and 25mm diameter and, as such are larger than the masonry joints. Photograph 2 shows a box of reference electrodes soaking in water prior to installation.

Photograph 2 – A set of reference electrodes on site ready for installation

Photograph 3 – A close up view of a single reference electrode [with cap removed] prior to installation.

As the units are larger than the masonry joints at Freemasons' Hall, drill holes will be required, which will impact on the edges of the stone blocks. The units will be positioned at bed and perpend joints where possible, but always in the most discreate location available and avoiding cutting through individual stone blocks.

It is also good practice to drill the holes at a slight downward angle, to improve grouting. The result is that an oval shaped hole will be needed at each sensor position, which will require careful repair by the stone mason. It is likely that there will be 32 sensors in Phase 6 [8 per zone].

Photograph 4 – A decay probe on site ready for installation.

3.4 CONTROL EQUIPMENT

The size of the structure requires that the electronic power supply and control cabinets [sometimes referred to as TR units – Transformer Rectifier] be distributed around the building. The locations are yet to be determined but it is likely that there will be one hidden inside the tower at high level, and a second within the roof level service void.

In each the cabinet is to be positioned in a service area, and somewhere that can be easily/safely accessed for maintenance and the annual testing.

An example of a CP control cabinet is shown in Photographs 5 and 6.

Photograph 5 – An example of a CP control cabinet [TR]

Photograph 6 –Inside of a CP control cabinet [TR]

3.5 RE-POINTING & REPAIR

As described above, the majority of the CP components [anode ribbon, cabling etc] will be installed into the masonry joints of the façade. In some cases, it is possible that anode rods [if needed] and reference electrodes will require drill holes to be made, which are larger than the masonry joint.

Photographs 7 and 8 are from a previous project on a listed Portland stone façade. This scheme utilised rod anodes but the photographs serve as a worst-case illustration of what drilling may be required.

Photograph 7 – joint chases and drill holes in a Portland Stone façade

Photograph 8 – a close-up view of a drill hole and chased out joint.

In each, the anode ribbon will be grouted into position using a cementitious mortar specially formulated for CP use. The cables will then be laid outboard of the grouted anode, and the outer 10mm to 25mm will be re-pointed using a lime:sand mortar which will be formulated to match the appearance of the original.

Photographs 9 and 10 show the same area discussed above after re-pointing. To the left hand side of Photograph 9 the cables were left exposed to allow the inspectors to understand the installation. In the actual installation, none of the CP components will be visible on completion.

	
Photograph 9 – Re-pointed stonework after CP installation	*Photograph 10 – a close-up view of repaired/re-pointed stonework.*

4 PERFORMANCE MONITORING

As described above, the system is to be a fully automated impressed current system with remote control and monitoring facilities. This allows the operation, monitoring and reporting of the system to be fully compliant with BS EN ISO 12696.

The performance of the system is of interest to the various heritage bodies, therefore, a summary of the regime/requirements is given below.

i. Function checks via remote access. At intervals not exceeding 1 month, the system will be remotely accessed and the output settings, current, voltage and any alarms will be inspected.
ii. Quarterly assessment of performance and adjustment of settings via remote access. At intervals not exceeding 3 months the automated depolarisation test data will be downloaded and assessed on a zone by zone basis. The system settings will be adjusted, based on that assessment, to account for seasonal variations and changes over time.
iii. Annual visual inspection of protected façades. At intervals not exceeding 12 months the protected facades should be inspected to ensure the system is protecting the structure as intended. This inspection should be undertaken from available access [pavement, roof top etc].
iv. Annual testing and inspection of CP system to confirm automated data logging. At intervals not exceeding 12 months, a certified CP engineer is to inspect and test the CP system to validate the automatically logged data.
v. Annual performance report detailing the system performance, any faults and recommendations for remedial work.
vi. Management and archiving of existing historic information, monitoring data and reports on behalf of United Grand Lodge.

The lifetime records for the system will comprise, in addition to the installation records, design documents and O&M manual; the annual monitoring reports and appendices of logging data. These reports shall conform with the requirements of BS EN ISO 12696.

5 QUALITY STATEMENT

We confirm that we have exercised reasonable skill and care in the preparation of this report, which has been produced for and on behalf of Corrosion Engineering Solutions Ltd.

The information contained within this report is based upon information available at the time of writing. If further information becomes available, we reserve the right to review the content provided.

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