Restoration of Arkwright House—10 Years Later

Manchester, UK

Submitted by C-Probe Systems, Ltd.

View from Parsonage Gardens of Arkwright House following restoration in 1998

Arkwright House is an important part of Manchester, UK's heritage. It was designed in a neoclassical style by local architect Harry S. Fairhurst (1868–1945). Named after Richard Arkwright, the eighteenth century Lancashire cotton magnate, the building was constructed in 1927.

During WWII, the building was used as the North West Command Post of government with an office and sleeping quarters dedicated for Winston Churchill's use during his strategic visits to the North West. After the war, Arkwright House was used as the offices of the Department of Transport. The restoration was commissioned by a well-known international bank and today the 100,000 ft^2 (9290 m^2) building is owned by a pension fund management firm and used as prestigious city center office space.

Problems that Prompted Repair

The worst problems seemed to be focused on the top three (of seven) floors, making traditional repair unavoidable.

The embedded steel frame is clad in outer skins of masonry and, sometimes, inner skins of brickwork. At the time of construction, it was common practice to fill the resultant voids with mason's mortar. Unfortunately, the mortar can act as a direct path for moisture penetrating through the structure and cause corrosion of the stanchions behind the cladding.

The build-up of exfoliated rust layers, sometimes expanding as much as 0.4 to 0.8 in. (10 to 20 mm) for only 0.08 to 0.12 in. (2 or 3 mm) of base steel, caused tensile forces to build up behind the masonry, resulting in cracking and movement of the block and brickwork. This physical effect in turn exacerbated the problem by acting as a path for further moisture ingress and an acceleration of corrosion.

Two independent surveys were conducted by the structural engineer and corrosion consultancy firms making up the engineering team to identify

Aesthetic deterioration caused by the cracking of the stonework the nature and extent of the problems and expand their survey to identify the appropriate repair and protection strategy.

Restoration Scheme (1996 to 1998)

The full scope of the restoration can be summarized as follows:

- Replacement of cracked and displaced portland stone (to three elevations) and brick to the rear light wells;
- Rebuilding of Levels 6 and 7 with empathy to historic technique and aesthetics;
- Application of impressed current cathodic protection (ICCP) to Levels 1 through 5 (to complement traditional repairs);
- Application of ICCP to Levels 6 and 7 (to complement the reconstruction);
- Early detection monitoring added to ground level with provision for future ICCP;
- Replacement of lead flashing to coping, window heads, and balconies and string courses;
- Overhaul and refurbishment of existing windows, frames, and sills prior to repainting with traditional oil-based eggshell paint;
- Cement pointing at perimeter of sash window frames and stonework were repointed with traditional lime mortar;
- Refurbishment of hardwood external double doors prior to coating with matching traditional wood stain and polish; and

View of steel frame with diminished cross section to the flange and web and demonstrating exfoliated rust layers

Using anode drill holes to perform final inspection for voiding with bore scope

- Cleaning of entire building to comply with conservation specialist's requirement.

Table 1 summarizes the decision-making principles relating to the corrosion management issues.

This was used as the basis for the next phase that considered the best approach to provide a durable and long-term solution that would allow more control over the problem without radically changing the appearance of the building.

Table 1: Optional strategies for providing durability

Remediation option	Description	Considerations
Do nothing/monitor	Carry out minimum repairs and monitor the continuing degradation until further action is required.	Such an approach is appropriate for those areas that have the potential for corrosion but are presently not actively corroding. Further repairs likely within 10 to 15 years.
Conventional repair	Repair areas where steelwork has suffered significant loss of section and areas where expansive corrosion has resulted in significant disruption to the adjacent building fabric (that is, structural adequacy has been compromised).	Reconstruction is the most effective long-term solution but is disruptive and expensive and hence should be restricted to areas that are considered essential.
Corrosion inhibitor	Inhibitors can be applied to exposed surfaces, injected, buried as emitters, or fogged into voids to control corrosion of the steelwork.	Corrosion rate monitoring is recommended to ascertain effectiveness of the inhibitor and reapplication may be anticipated at 5- to 10-year intervals.
Cathodic protection	Steelwork is protected from corrosion by the application of a small current at low voltage. Discrete anodes may be inserted into the mortar infill between the cladding and the steel frame.	Ongoing monitoring and adjustment is required. Time to first maintenance is determined by the life of the anodes, which should provide at least 25 years of service.

Following a mock-up study of the effectiveness and logistics of installing capsule corrosion inhibitors and ICCP in the form of discrete anodes, the latter was chosen for the main construction phase and designed accordingly.

Traditional repair was unavoidable in many places and indeed the corrosion management scheme was devised to minimize this aspect of the work. This was achieved by removing the external cladding, removing the corrosion products by the needle-gun method, and treating the steelwork with a formulated coating finish for future protection prior to reestablishing the façade.

Labor-intensive preparation by needle gunning corrosion product from deconstructed sections of the façade

Following prime coat, a final high build coat is applied prior to rebuilding the façade

Installation of discrete anodes complied with conservation policy and the principle of "minimum intervention"

The mock-up installation was highly successful. Data showed that the electrochemical condition could be altered and controlled and that the end aesthetic passed the inspection by third-party conservation specialists.

The final installation saw 3700 anodes drilled in externally and is controlled in 24 zones (four per building level) that are networked together internally via the risers and the cables managed within the suspended ceiling space to avoid internal disruption.

The performance was managed using remote access to data and Internet access to reporting and was issued to the owner on an annual basis.

Performance Over the 10 Years Since Restoration was Completed

In terms of cathodic protection performance, its use in transitional steel frame buildings does not coincide entirely with the principles of either the NACE RP02:90 recommended practice or European Standard BS EN 12696:2000 relating to its use in reinforced concrete.

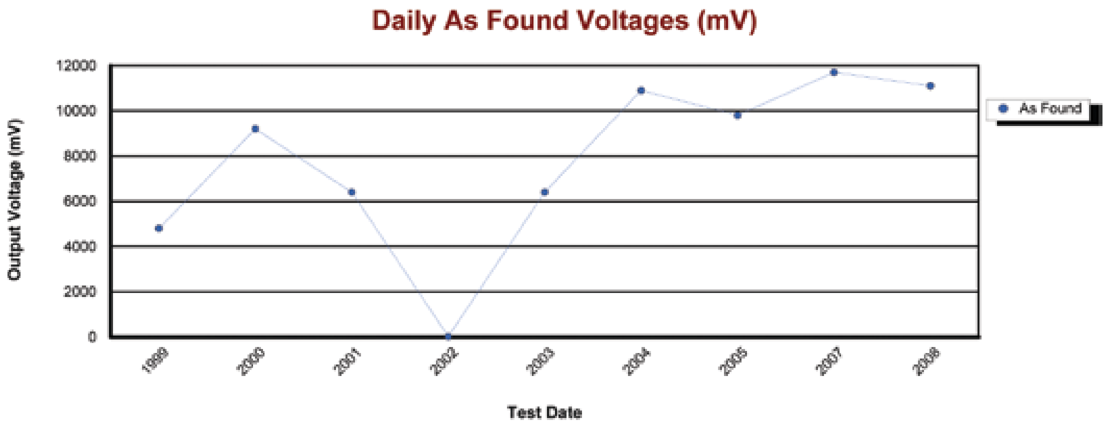
The absence of alkalinity in the substrate and the presence of a more neutral environment meant that performance criteria especially associated with potential decay were assessed with caution.

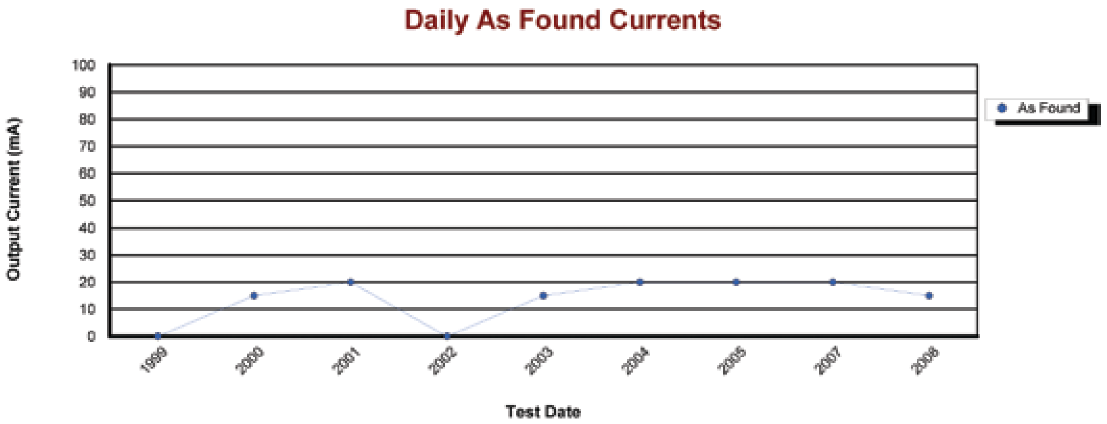
The performance is summarized in the following over the full period for one position at R8.1 on Level 2. There are 96 ICCP monitoring locations for the building as well as specific corrosion rate assessment of specific features such as window frames and stone cramps for stray current pick-up of unbonded extraneous metals.

This example performance is typical of data achieved on the project and is displayed in terms of potential decay (continuous achievement of greater than 100 mV after 4 hours and 150 mV after 24 hours). Moreover, an assessment is made of change from the original preenergized condition (base) to the condition existing at each stage annually following the potential decay test. This is a measure that relates directly back to existing ASTM C876 standards and allows us to assess electrochemical change.

In addition to these electrochemical tests, the power supplies are assessed daily to ensure no power outage is undetected but also as a measure of stability to the ICCP protection current and driving voltage. The annual measurement is summarized here for the duration of the management to date.

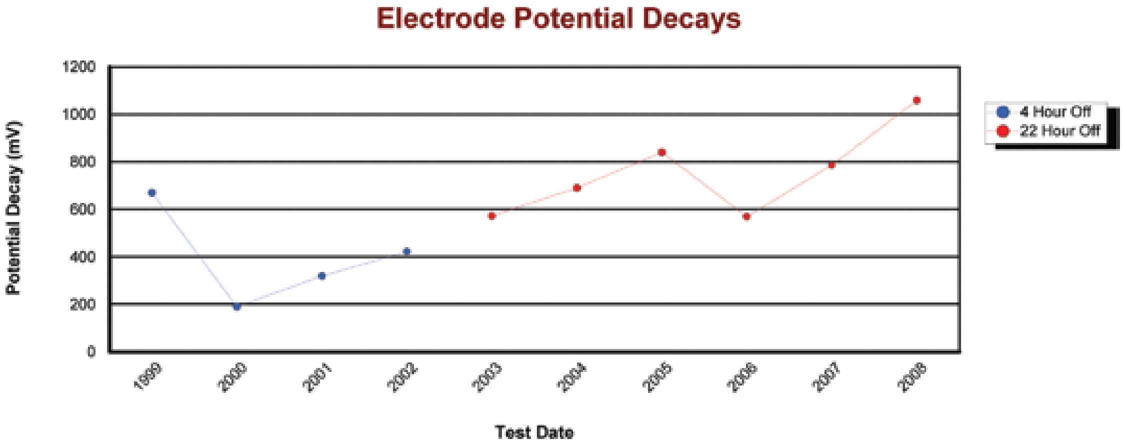
All ICCP zones were started up and achieved the required polarization well within the specified requirements in mid-April 1999. The ICCP system is currently under a rolling yearly monitoring and maintenance contract through the specialist cathodic protection subcontractor directly to the owner as part of the warranty.

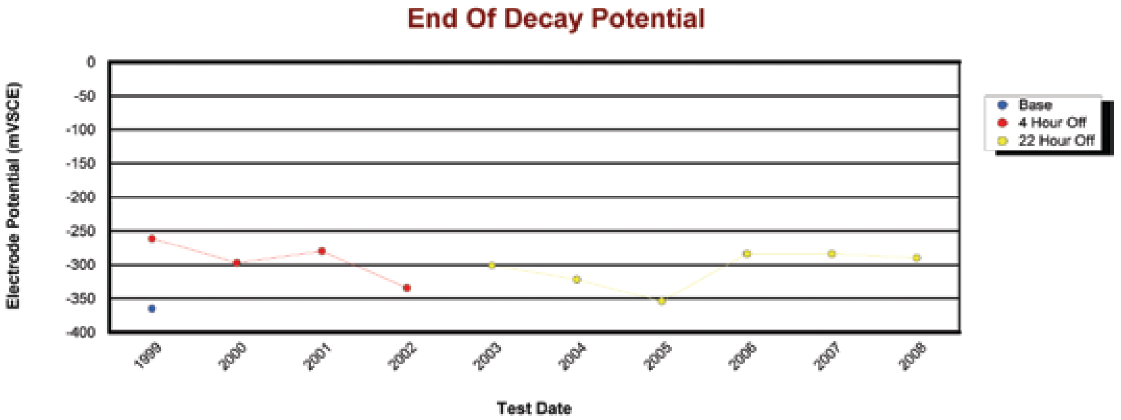




Note that the power is supplied in constant current mode and the driving voltage varies with environmental demand (zero represents an outage).

The current supplied (apart from the outage in 2002) has been consistently 20 mA or less, representing around 3% of capacity but providing consistent protection.





The data demonstrate a consistent achievement of 100 mV potential decay and a shift of end of decay potential towards a less active potential (–360 mVCSE toward –275 mVCSE) that would represent a move from high to medium risk if left unenergized.

The data also show us that without the ICCP system operating, the building would revert to a corrosion condition even after 10 years of operation.

Prior to this project, the restoration method would have almost certainly focused on the affordability of a complete tear down and repair with coatings. However, ICCP assisted significantly with achieving a complete protection to the building at an affordable cost.

Special Features of the Project

Uniqueness

- First building in the UK with brick and stone to receive ICCP as part of a restoration scheme for a transitional steel frame construction;
- First building in the UK to demonstrate performance data to prove protection is both needed and is sustainable; and
- First building in the UK to use the corrosion management system as a due diligence tool for valuing an asset.

State-of-the-Art Methods

- Anode system choice to comply with 25-year warranty requirements and aesthetic appearance;
- Management system that can be remotely monitored and controlled over the Internet for immediate and proactive operation and reporting;
- Acceptance of variation from standard reinforced concrete performance criteria to provide environmental exposure relevance as it relates specifically to historic masonry buildings; and
- The specialist design and evaluation team completed the comprehensive and necessary steps to determine the root cause, quantify the components, and specifically locate them to meet the owner's requirements and from an unknown starting position.

Aesthetics

- Compliance with all the requirements of the City of Manchester conservation guidelines and the UK national conservation authority (English Heritage);
- Despite the requirement to be intrusive during the repair of the stone and the installation of the ICCP stone inserts, the building looks largely untouched following completion; and
- Maintenance of the appearance after 10 years of operation of the building protection system.

The success of this installation and restoration has seen a similar strategy adopted to over 20 buildings in the UK. Moreover, the U.S. has now seen the systems adopted in 2007 and 2008 in Florida and New York City.

Without the combined expertise of the owner's design team and the specialties of the contractors and their corrosion-protection subcontractors, the establishment of these types of cost-effective solutions may never have gotten off the ground.

A view of Arkwright House after the works have been completed (left) and after 10 years since restoration was completed (right), showing no signs of deterioration

Arkwright House

Owner
CB Richard Ellis Limited
Manchester, United Kingdom

Project Engineer/Designer
ROC Consulting
Manchester, United Kingdom

Repair Contractor
Mott MacDonald
Altrincham, United Kingdom

Material Suppliers/Manufacturers
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Dunham Massey, United Kingdom

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Tamworth, United Kingdom