MADEIRA TERRACE, BRIGHTON

MADEIRA TERRACE REFURBISHMENT
REFURBISHMENT OF EXISTING IRONWORK
MATERIALS & WORKMANSHIP SPECIFICATION

31 OCTOBER 2023

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Ref: 12719-HOP-06-XX-SP-D2-5001 P2

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APPENDICES

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1.0 GENERAL

1.1 Scope of Works

The works comprise of the assessment and refurbishment of existing substructure elements at Madeira Terraces, Brighton. This Specification only applies to permanent substructure elements. Any unforeseen structural elements not covered in this document will be specified individually as required.

The scope of the works to be carried out, comprises of the replacement / refurbishment of the following elements:

- Careful dismantling and removal of existing iron work.
- Careful logging and transport to an offsite facility for assessment and repair
- Sampling and testing to confirm representative material strengths
- Sampling and testing to establish existing defects
- A hold point for the above, for the Engineer to consider test results and to make a decision on if existing components are suitable for incorporation back into the works.
- Assuming Assessment confirms suitability for reuse of existing components, it is anticipated repairs will be completed by fusion welding with associated Quality Assurance.

This specification covers existing structurally significant components listed below.

- Existing columns
- Existing corbel brackets
- Existing Trusses
- Existing Spandrels
- Existing Balustrade Infill panels.

Existing Balustrade standards are not considered appropriate to reincorporated into the works.

Note: this specification should be read in conjunction with the contract drawings

1.2 General

This Specification is part of the Contract documentation and should be read in conjunction with construction Drawings. If details are missing or ambiguous, refer back to the Engineer for further information. Parties are hereafter referred to as follows:

Employer:	Brighton and Hove City Council
Engineer:	HOP Consulting Limited
Architect:	Purcell Architects
Principal Designer:	Purcell Architects
Principal Contractor:	TBC

This Specification will describe the quality of materials and standard of workmanship to be adopted in the works and shall be read in conjunction with contract documents, the specified standards and other specified guidance documents.

Variations to this specification are subject to the Engineer’s discretion and Client’s approval.

Contractor shall note the project involves the refurbishment of and existing Iron structure which is protected under the listed building act. The principal approach involves the following tasks:

i) Careful dismantling of the existing structure;
ii) Removal to offsite facility for inspection and verification testing, particularly tensile strength of cast iron and the identification of concealed defects;
iii) Assessment of element capacity informed by (i) & (ii) above;
iv) Where deemed suitable for reincorporation into the works, elements are to be repaired by the cast iron fusion welding specialist with associated quality assurance.
v) Assuming all of the above achieve a successful outcome to justify existing ironwork for reuse, elements are to be painted and returned to site for re-erection;
vi) Should individual elements fail the assessment process these are to be replaced in recast components cast from SG Cast Iron.

The contractor shall allow for all 'fitting' operations associated with the nature of such a refurbishment project e.g. dimensional control, competency of site staff and dealing with the inevitable uncertainties.

1.3 Standards and Materials

All work shall be carried out in accordance with the requirements of current British Standards, European standards and International ISO standards as appropriate to the materials and methods involved. In addition, work shall be carried out in accordance with the recommendations and guidance of manufacturers and recognised trade associations and organisations such as CIRIA, HSE, BRE, BCA and ICE.

All materials for the permanent works shall be new and of best quality unless otherwise specified e.g. refurbished elements supported by appropriate testing. All materials shall be delivered to the site in the manufacturer's wrappings or suitable stillage. Qualified and skilled operatives shall carry out the work. Products to be handled, stored used or fixed with care in accordance with manufacturers recommendations, to ensure that they are not damaged prior to or after incorporation into work. Inform the Engineer if this conflicts with any other specified requirement. Submit copies of manufacturer's recommendations to Engineer when requested.

Where a choice of manufacturer or source of supply is allowed for any particular product or material, the whole quantity required to complete the work must be of the same type, manufacture and/or source. Do not change without approval. Produce written evidence of sources of supply when requested by the Engineer.

Special techniques and additional supervision shall be used as necessary to achieve best quality work and accuracy well within that listed in BS 5606:1990.

All elements of the works are to be designed for a 60 year design working life.

1.4 Good Practice

Where and to the extent that materials, products and workmanship are not fully specified they are to be:

1) Suitable for the purposes of the works stated in or inferred from the contract documents.

2) In accordance with good building practice, including the relevant provisions of current codes and standards.
3) Workmanship to be carried out by or under the close supervision of experienced tradesmen, skilled in the particular type of work.

1.5 Health & Safety (CDM Regulations 2015)

The Contractor's particular attention is drawn to the requirement for a developed Health and Safety Plan (with special reference to temporary works and access/egress), which shall be detailed in the Contractor's Construction Phase Plan (CPP).

It is the Principal Designer's role to prepare the Health and Safety File, however Employers, Designers, Contractors and other sub-contractors have a legal duty to supply the information necessary for compiling the file.

Only information likely to be significant in relation to Health and Safety in future work need be included.

Examples of the type of information required for the Health and Safety File are as follows; please note that this list is not exhaustive;

- Record drawings and plans used and produced throughout the construction process along with design criteria;
- General details of the construction methods and materials used;
- Details of any tests carried out and pile installation records;
- Details of the structure's equipment and maintenance facilities;
- Maintenance procedures and requirements for the structure;
- Manuals produced by specialist contractors and suppliers, which outline operating and maintenance procedures and schedules for plant and equipment installed as part of the structure;
- Proposals for maintenance access.

To aid coordination and co-operation, all documents should be submitted electronically to the Principal Designer in Portable Document Format (PDF).

1.6 Temporary Works

The Contractor is responsible for all temporary works and the stability of the works in progress/under construction and for all temporary works coordination in accordance with BS 5975:2019. The Contractor shall erect all necessary working and protective scaffold and ladders to enable full access to the works at all levels for inspection as the works proceed.

Temporary support should be provided such that normal operations, including public and neighbouring sites, emergency vehicle access are able to continue un-hindered and safety of the public and personnel is not compromised.

Note: the Contractor must ensure temporary support provides resistance to, lateral and longitudinal (axial) forces equivalent to that of the permanent condition such that local or global stability is not compromised.

1.6.1 Temporary Works Design Loads

The Contractor is responsible for all temporary works and for the stability of the work in progress. The safety of the existing structure must be maintained with due regard to potentially unusually high wind loads in conjunction with dead and dynamic loading.

Allowance may also need to be made for moving machinery on the deck in addition to the live loading from the public.

Loads must, in addition, include any extra load from plant, equipment, services, cabling, pipes or the like. Method related sequencing may be required to achieve this e.g. formwork for the deck poor may be designed to accommodate any back propping loads required to enable construction.

Minimum loading to be allowed for in temporary works design:

DEAD LOADS	**kN/m²**
New concrete deck	
(excluding SW ironwork including superimposed surfacing)	10.0
Shelter loads (included in the Live Load allowance below)	N/A
LIVE LOADS	
Deck level/public areas	5.0
WIND LOADS	To be assessed by the Contractor dependent on location and programme / season
SERVICE/PLANT LOADS	To be assessed by the Contractor dependent on Method related sequencing
STORAGE OF MATERIAL / EQUIPMENT	The Principal Contractor shall ensure that the weight of any materials or equipment stored on the deck is distributed such that it is <5kN/m² (Allowance assumes 28 day cube strength has been achieved, should this not be the case to be assessed by the contractor)

1.7 Licensing

All works to be completed in accordance with the associated statuary licencing including the planning and Listed Building Conditional Consents. The contractor shall note that this specification along with the Iron reuse Strategy for the project has been submitted to Historic England (The Regulator) with a view to achieve discharge of conditional Consent and hence the works require alignment with the processes set out. Should the contractor consider a departure from this approach is required the contractor should raise this with the Engineer / Architect well in advance of mobilisation such that maximum time is available to agree any changes to the approach with Historic England.

1.8 Existing services

Services and utilities exist in the works area, refer to Preconstruction Information. The Contractor should allow for proprietary protection/isolation of such services as appropriate and close liaison with the Project team. Where new structural elements are to be installed around existing services due care and attention should be given to such services and alteration where necessary.

1.9 Dimensions

Site dimensions given are nominal only. Spans and depths of elements will be individual to each location. The schedule drawings only give a general indication of the scope of the works and size of members.

The Contractor is responsible for taking site dimensions to enable fabrication details to be produced. All drawings are indicative only and physical measurements must be taken with any significant discrepancies reported to the Engineer.

1.10 Site Levels

All levels shown relate to Ordnance Datum and are approximate and should not be used without verification on site.

2.0 IRONWORK TO BE REFURBISHED

2.1 General

All material used in the permanent works whether refurbished or new shall be obtained from a manufacturer / supplier, approved by the Engineer and shall in all respects comply with the relevant standards.

Detailing and fabrication of all steelwork / Ironwork and connections (including onsite cutting, fitting, welding and connecting new elements to existing adjacent elements) is the responsibility of the Contractor, all in accordance with BS EN 1993-1 and the latest edition of the National Structural Steelwork Specification (6th Edition, CE marked version, 2010).

All permanent structural materials shall be supplied with certification so as to confirm authenticity of the material properties and chemical composition. Chemical analysis of the proposed material, together with the results of mechanical tests where appropriate, must be submitted to the Engineer for approval before fabrication / refurbishment commences.

Neoprene separators or similar to be agreed by the client are required where different metals are connected to avoid bimetallic corrosion. This being particularly relevant where some existing elements are known to have been recast in Aluminium i.e. columns and spandrels. Following careful dismantling this connection will be carefully inspected for bimetallic corrosion and a decision made if existing recast Aluminium can be reincorporated into the works.

2.2 Preamble

The Design team have explored various repair techniques available for cast iron repair / refurbishment with this work summarised in Appendix A, ‘Cast Iron Repairs Technical Memorandum’.

The design team working with a specialist repair house have concluded the preferred approach appropriate for the Terraces as being ‘Gas Fusion Welding’. Contractors are welcome to submit alternative methods for consideration however these will only be accepted following a technical submission and trialling of sample repairs to the Engineer / Architect.

Due to the specialist nature of the cast Gas Fusion Welding process the contractor shall submit full details of the preferred subcontractor organisation including certifications, staff skills, knowledge and experience with supporting qualification of proposed operatives and, quality assurance processes and provision for a minimum 1 year materials and workmanship warrantee. Following client review of the submitted proposals acceptance or otherwise of the preferred subcontractor shall be at the express instruction of the contract administrator.

There follows a general outline performance specification of the salient activities expected.

2.3 Fabrication

2.3.1 General

Fabrication shall be generally in accordance with BS EN 1090 and Eurocode 3 to Execution class, EXC2.

Reasonable departures to deal with the variations in existing iron will need to be reviewed and considered and approved by the Architect / Engineer throughout the refurbishment process. The program has been sequenced in such a way that the first section of the works comprising of 6 No. bays will inform the overall refurbishment approach e.g. form a pilot for the overall project.

Care shall be taken to avoid fabrication methods which could cause distortions or embrittlement of the ironwork.

Unsuitable marking paints, grease, oil or other deleterious materials shall be removed prior to fabrication.

2.3.2 Cutting

The edges and ends of all elements and the ends of sections shall be accurately finished by planing, sawing, grinding or milling. Any burring of edges shall be removed. Hand flame cut edges are not acceptable.

2.3.3 Joints

Joints are anticipated to be similar to existing. Where this differs the location of all joints shall be suited to both the existing arrangement and the Contractor's facilities for fabrication, handling, transport and erection. The location and details of all joints shall be subject to the approval of the Engineer.

All bolted splices shall be provided with hole tolerance detailed on the contract drawings. Packing plates or ‘build up’ of existing cast iron elements by fusion welding may be required to overcome poor original control of tolerance from the original castings which are noted as being variable.

2.3.4 Bolt Holes

Punching is not permitted and all holes are to be drilled / reamed.

All burrs shall be removed.

When holes are drilled in one operation through two or more separable parts, those parts shall be connected securely with clamps during drilling, then separated and have all burrs removed.

Holes in components for ordinary bolts shall be to the following sizes:

1. Not exceeding 14mm diameter bolts – 1mm greater than the nominal bolt diameter
2. 16-24mm diameter bolts – 2mm greater than the nominal bolt diameter
3. Greater than 24mm diameter bolts – 3mm greater than the nominal bolt diameter
4. Slotted holes for accommodating thermal movement to be as detailed on contract drawings.

Holes for bolts shall not be formed by a gas cutting process.

If holes are drilled incorrectly in any plate or section, they shall not be plug welded and re-drilled without the agreement of the Engineer.

2.4 Bolts, Nuts & Washers

For all black bolts (non-preloaded), nuts and washers shall comply with the requirements of BS EN 1090-2:2018, BS EN 15048-1:2016 & BS EN 1993-1-8:2005 (Eurocode 3). Grades of bolts are as specified on the Drawings. Nuts and washers shall be compatible with the grade of the bolt.

All bolted connections shall be visually checked after they are bolted up with the structure aligned locally.

All black bolts shall be tightened securely in the finished work and the length of each bolt shall be such that after tightening at least three threads project beyond the outer face of the nut.

Locking devices (specifically Nyloc nuts/ Nylon-insert lock nuts) required to prevent loosening of the assembly, shall be provided as specified on the drawings. Locking devices shall comply with the requirements of BS EN 1090-2:2018.

Torqueing of locking devices should be to the manufacturer's specification. Over torqueing of nyloc nuts/ Nylon-insert lock nuts will damage nylon insert and reduce locking power and must be avoided.

Nyloc nuts/ Nylon-insert lock nuts must not be re-used. Re-use results in reduced locking power due to re-stressing of the nylon insert.

2.5 Welding

2.5.1 Qualification and Testing of Welders

The tests listed in BS EN ISO 15614-8:2016 shall be carried out.

The approval and testing of welders shall be in accordance with BS EN ISO 9606-1:2017and BS EN 1090-2:2018 as appropriate. The Contractor shall submit to the Engineer test records for all welders prior to commencing work.

Welding should be carried out only under the direction of an experienced and competent supervisor. A certificate of welding supervision issued under the Certification Scheme for Welding and Inspection Personnel (CSWIP) or similar will be accepted as evidence of competence.

A record shall be kept to enable major butt welds to be identified with the welders responsible for the work.

Finished work shall not be marked by hard stamping for this purpose.

2.5.2 Dimensional Control

Welding procedures shall be such that distortion during the welding process is reduced to a minimum and any localised distortion is rendered negligible in the tolerances for the final structure.

Distortion by welding beyond the specified tolerances may be corrected only using an approved method as not to be deleterious to the structure

Suitable allowances for contraction of joints during welding shall be made in the calculation of the length of components before welding so that the finished lengths are correct within normal acceptance tolerances.

2.5.3 Temporary Welded Attachments

Temporary welded attachments shall be used only where identified as a requirement of the fabrication and erection procedure and of a form that can be removed without damaging the structure.

Due consideration shall be given to the position of temporary welded attachments so as to avoid unintended effects.

Removal of temporary welded attachments shall be by cutting or chipping and not by breaking the back of the fillet weld. The surface of the material shall be ground smooth without loss of thickness.

2.5.4 Weld Surface Finish

The weld surface finish shall comply with the acceptance criteria in BS EN 1090-2:2018 and BS EN ISO 5817:2014 or equivalent.

2.5.5 Inspection of Welds

The Contractor shall appoint an independent inspector. The inspector shall carry out all necessary tests, to ensure that the welding acceptance criteria are being met for all permanent works. The Contractor shall ensure that the inspector carried out all the necessary testing and in sufficient time to permit any remedial work to be carried out.

Copies of all the inspector's reports shall be sent direct to the Engineer / Architect as soon as practicable after each inspection.

Prior to weld inspection all loose rust and scale, slag residue and weld spatter shall be removed.

All welds shall be 100% visually inspected in accordance with BS EN ISO 17637:2016 or equivalent fusion welding standard. A weld subject only to visual inspection and not requiring non-destructive testing as given below shall be acceptable if:

- The weld is free from cracks;
- The weld exhibits full fusion between parent plate and weld metal;
- All craters are filled;
- Welds exhibit the required size and profile;
- Welds are free from excessive undercut and/or overlap. (Undercut shall not exceed 1mm or 5% of the material thickness whichever is the lesser).

Welding shall be subject to Non-Destructive Testing (NDT) in accordance with BS EN 1011-1:2009 or equivalent. The following shall apply.

- Magnetic Particle Inspection (MPI) shall be carried out in accordance with BS EN ISO 17638:2016. Test frequencies are indicated in the inspection and test plan section of this report. The welds to be inspected shall be agreed with the independent inspector with the acceptance standard as detailed in BS EN ISO 23278:2015 or equivalent. Care shall be taken to avoid arcing between work piece and probe when an electrode source is used to produce the required magnetic field;
- The preferred method of NDT for fillet welds is MPI. However, where for any reason MPI cannot be used Dye Penetrant Testing in accordance with BS EN ISO 3452-1:2013 may be used instead with the agreement of the Engineer.

All butt welds shall be subject to 100% Ultrasonic testing to BS EN ISO 17640:2018 in the initial pilot phase with testing frequencies likely to be relaxed for later phases, refer to Inspection and test plan section of this specification.

2.6 Protection of Replacement Ironwork Against Corrosion

All permanent ironwork is considered to be sited in the CM5 environment and resides in an ongoing coastal damp/wet environment and should be prepared and protected to the criteria outlined in this specification.

2.6.1 Protective Coatings

All new / refurbished ironwork to be protected with shop applied paint protection in line with the Architectural Specification section M 60.

The surface of new bolts, nuts, washers etc., used in the works shall be prepared and coated

3.0 INSPECTION AND TEST PLAN DOCUMENTATION

3.1 General

All testing shall be carried out by organisations accredited by UKAS.

Any areas broken out, cored or drilled for the purposes of testing or sampling shall be made good using the approved repair materials or techniques and agreed method statement.

Testing shall be undertaken in accordance with the approved Inspection and Test Plan (ITP) as outlined in the following schedule. The contractor should allow for development of this initial plan.

Test	Specification clause / method.	Frequency and timing	Limit
1.0 Prior to careful dismantling			
Dimensional survey of existing base plate locations.	Existing baseplates to be located and exposed such that the holding done arrangement is recorded and appropriate control installed (offsets & accurate dimensional control) to enable re-erection of columns to the same position and final setting out of ground beam.	To be completed prior to careful dismantling 100% of column bases.	N/A like for like
Record of precondition prior to percussive deck removal operations.	Contractor to prepare a precondition record of condition supported with record photographs and annotated field sheets and or database / spreadsheet to record readily determinable visual defects within each bay. Provide a short, annotated record on each major component produced by competent person.	To be completed prior to percussive breakout of bay under consideration or its adjacent bay to record gross readily inspectable defects.	Detect visually readily inspectable defects from ground / deck with no special access requirement. Capture fractures, distress holing and gross defects.
2.0 Following removal of existing Deck / during careful dismantling.			
Tagging of Artifacts	All historic fabric artifacts to be carefully tagged with an Aluminium 'dog tag' or similar punched with item grid location and reference number to be advised by Architect. A record drawing is to be developed and maintained by the contractor recording elements removed and ultimately elements re-erected as works progress. Drawing to be issued and updated monthly to the Architect.	During careful dismantling. 100% for the initial section. For later sections it is anticipated that eaves beams, filler joist, and balustrade standards would be exempted. 100% for remaining artifacts.	Reason to provide and effective audit trail of tracking and recording historic building fabric.
Identification of existing Aluminium components by rudimentary handling weight test.	During dismantling it is anticipated that normal handling operations can be used to identify potential Aluminium artifacts from Iron (ferrous) ones. This is to be supplemented by testing during handling with a hand magnet.	100% of artifacts anticipated to be undertaken during normal handling operations.	Results to be recorded on the artifact data base record.

Test	Specification clause / method.	Frequency and timing	Limit
Visual inspection of disassembled artifacts prior to shipping.	Visual onsite inspection and update of Database and field sheets to record significant structural defects e.g. holes, fractures, casting defects, loss of section, necking.	100% for the initial section. For later sections it is anticipated that eaves beams, filler joist, and balustrade standards would be exempted. 100% for remaining artifacts.	Visual inspection by competent person.
3.0 Off site Inspection			
Magnetic Particle Inspection & visual inspection following grit blasting.	MPI & visual inspection by competent person following the removal of surface finishes (Paint). All defects identified to be logged on updated database / field sheets. MPI inspection to BS EN ISO 17638:2016.	100% for the initial section. Subject to the review of the pilot bay test frequency may be relaxed to at the express discretion of the Engineer.	All visually identifiable defects enhanced with MPI to identify near surface defects and fractures concealed from naked eye inspection.
Metallic Composition	TBC with Fusion Welding specialist for electrode selection.	100% for the initial section. Subject to the review of the pilot bay test frequency may be relaxed to at the express discretion of the Engineer.	UKAS accredited test results to be issued to the Engineer within 5 days of issue.
Tensile Test sampling	Tensile test samples to be taken from representative sample of Balustrade Infill, Truss and Column. With recovered sample Tensile testing to BS EN ISO 6892-1:2019.	100% for the initial section. Subject to the review of the pilot bay test frequency may be relaxed to at the express discretion of the Engineer.	UKAS accredited test results to be issued to the Engineer within 5 days of issue.
Compressive testing	TBC with testing house		UKAS accredited test results to be issued to the Engineer within 5 days of issue.

4.0 Gas Fusion Welding Quality Assurance inspections			
	Inspection & Repair Record sheets to be provided. Provide sample sheets for agreement at outset.	100%	
5.0 Physical Load testing			
Physical load testing of Trusses	Depending on the results of testing and subsequent assessment provided there is a realistic possibility of improving the assessed capacity it is anticipated that Physical load testing of at a minimum the first 6NO. Trusses and 6No. of balustrade infills be completed to verify truss capacity. Physical load testing will need to be developed with a suitable specialist expertise to derive the load test particulars. Load Testing shall be broadly in accordance with DMRB CS 463. Load test to be considered as Supplementary intended as adjunct to theoretical calculations. It is anticipated a suitable test can be developed with a suitable specialist testing house adopting kentledge with associated instrumentation e.g. strain gauges and dial indicators.	Initial allowance for 6No. Trusses and 6No. balustrade infill panels. Testing to be completed on the pilot trusses in advance of the main works following theoretical justification after receipt of element specific tensile testing results are able to justify there is a realistic possibility of improving assessed capacity.	UKAS accredited test results to be issued to the Engineer within 5 days of issue.

3.2 Non-compliance

Where a repair fails to demonstrate compliance then all similar repairs executed on the same day shall be considered at risk.

The contractor shall propose corrective action to the Engineer for acceptance. This may include removal of material repairs to establish acceptability or otherwise of the repair. The contractor shall bear the cost of such additional testing and removal / reinstatement.

APPENDIX A – CAST IRON REPAIRS TECHNICAL MEMORANDUM

Madeira Terrace Phase 1 Project – Cast Iron Repairs Technical Memorandum

FOR INFORMATION ONLY

Ref: LRS/12719-06 Rev.A

02 August 2022

1.0 INTRODUCTION

This brief technical memorandum presents the typical properties, defects and repair methods for Cast Iron, focusing on structural performance.

Structural Cast Iron elements at Madeira Terrace include Lattice Beams, Columns, Spandrel panels, bolted connections, Edge Beams and Balustrades, most of which are relatively thick and ornately profiled. Non-structural elements include Gutters, Hoppers and Keystone Masks.

2.0 MATERIAL PROPERTIES

Cast Iron typically contains between 2 and 6% carbon and is a brittle metal which cannot be easily welded or forged. Other typical impurities that affect material properties include silicon, manganese, sulphur, phosphorous, chromium and copper. Some of these impurities have been found to reduce rates of corrosion in Cast Iron.

Historically, Cast Iron has been divided in to three sub-sets based on type and quantities of impurities: Grey Cast Iron (best quality); White Cast iron (Harder, more brittle and less reliable) and Mottled Cast Iron (contained more sulphur and more prone to cracking during cooling).

It should be assumed that, unless noted otherwise, Grey Cast Iron has been used in historic structures. However, there was still considerable variation in carbon and impurity content, resulting in a wide range of Compressive and Tensile strengths depending on exact metallurgic composition, with tensile strength typically only about 20% of the compressive strength. It is due to this wide variation that best practice guidance recommends a somewhat conservative approach to the structural assessment of Cast Iron.

Care should be taken to carefully preheat the parent cast iron member prior to any sudden and/or localised heating or cooling as this can induce thermal shock, embedding stresses in the material and inducing a potential failure surface, resulting in either immediate cracking, or increasing risk of sudden failure in the future.

3.0 TYPICAL DEFECTS AND INSPECTION

As with any casting process, there can be variations in cross-sectional thickness and an increased risk of hidden defects which cannot be easily investigated. These defects may include sub-surface or hairline fractures due to shrinkage or blowholes formed during cooling.

Various structural reports have highlighted that the terraces are visually in a poor state of repair with numerous defects, most notably cracking to lattice beams and spandrel panels, resulting in closure to the public over safety concerns in 2012. It is thought highly likely that further defects are hidden from view, particularly around connections.

Additionally, existing members at Madeira Terrace have been overpainted with multiple layers of lead-containing paint, likely masking the true condition of the Cast Iron under. In order to fully assess and repair elements full dismantlement is required and shot-blasting of elements ex-situ in a controlled environment.

Non-destructive testing methods such as visual inspection, liquid dye penetration, magnetic particle inspection, radiographic inspection, ultrasonic testing etc should be used by an experienced specialist post shot-blasting to identify defects for repair.

4.0 REPAIR METHODS

Repairs should intend to reinstate or provide betterment of original condition as far as possible and it is important to bear in mind that repair types will be specified based on the requirements of the project, not on techniques available from any one supplier.

We recognise that a wide range of techniques, with individual variations between specialist suppliers are available, and that the summary below does not cover every possibility. As such the final repair type will typically be determined with the appointed specialist once the elements can be inspected (either on site, in a local logistics/processing facility set up near to site, or at the supplier's facility). The supplier would typically be the Contractor's choice noting that they may be able to offer supply chain efficiencies.

4.1 Cold Stitching

Cold stitching is predominantly used for repairs of cracks in non-profiled sections (such as plates) and involves drilling out a series of bands across a crack defect using a jig and inserting premade 'keys'. Threaded holes are then drilled along the line of the crack, bolts screwed in, and the heads sheared off. The repair material is then chiselled and ground down to achieve a smooth finished as required.

CIRIA C664 Iron and steel bridges: condition appraisal and remedial treatment states that *"it is not possible to quantify the strength of a stitched repair so it is often necessary to couple it with other works."* as such this method in isolation would potentially be unsuitable for use in structurally significant and ornately profiled items, such as those typically found at Madeira Terrace, subject to discussion with specialist supplier.

Figure 1 – example of cold stich repair sequence using Metalock Repair System, image courtesy of https://www.metalockengineering.com/en/metalock-engineering-uk-limited/repairs/metal-stitching/

4.2 Strengthening

This typically involves application of plates or a collar/sleeve for circular elements to provide additional section strength and/or to 'span' over defect which could be affixed in a number of ways such as welding, epoxy resin or bolting. Fibre Reinforced Polymer might be considered as a suitable alternative, subject to detailed design.

Strengthening is generally only considered as a temporary measure when used with cracking, as it does not repair the original defect leading to a high probability of continued propagation. This technique may be suitable however where section thickness has been reduced due to corrosion, such as inside columns, provided that the cause of corrosion is mitigated and the residual section is suitably protected to prevent further deterioration (see Section 8.0).

4.3 (Two-part) Epoxy Putty/ Resin

Epoxy Putties typically come as a two-part adhesive (a resin and a hardener) with a wide variety available suitable for usage with different materials and environmental conditions.

Recommend consultation with specialist supplier and contractor to ensure that material is suitable for the intended use in an exposed maritime environment, including provision of adequate strength and design life requirements and would not incur an additional maintenance burden.

Subject to specialist advice, it is not thought that this method would be suitable to support significant loading but may be suitable for cosmetic or minor repairs (such as keystone masks).

4.4 Traditional Welding

The three most common types of welding methods are:

- Stick - Shielded Metal Arc Welding (SMAW),
- MIG - Metal Inert Gas Welding (GMAW) and
- TIG - Gas Tungsten Arc Welding (GTAW).

Although techniques and materials used vary, all three methods very locally heat the parent material and a filler material (e.g., nickel) using a wire rod/electrode which is fed in to a weld pool to melt the two materials fusing them together. Care should be taken not to induce thermal shock as described in Section 2.0. Subject to discussion with a specialist supplier this technique may not be suitable for more heavily loaded elements.

4.5 Brazing

Brazing utilises capillary action to distribute a molten filler material between the surfaces of the parent material. Brazing does not melt the parent material and is usually undertaken at much lower temperatures than traditional welding although care should still be taken not to induce thermal shock as described in Section 2.0. Subject to discussion with a specialist supplier, it is unlikely that technique would be able to provide the required structural resistance to support imposed loadings.

4.6 Gas Fusion Welding

The process described here is as per CIWS's methodology, although alternative suppliers may be able to provide a similar technique:

- Metallurgic analysis is carried out to identify the composition of the parent material so that the filler material used is an exact match.
- Damaged areas are removed by mechanical processes where required to reveal sound parent material.
- The entire element is then preheated in a tightly controlled environment to between 500 and 700℃ over a period of 12 to 18 hours, depending on a number of factors.
- The defective area is then locally heated to approximately 1300℃ to melt the parent metal and the filler material is introduced along with a specially developed flux to ensure successful fusion.
- The entire element is then cooled slowly over up to 36 hours to ensure full stress relief.

Given the requirements for the project, we consider this to likely be most suitable for both major and minor structural repairs, meaning that all works could be executed by a single supplier. This reduces likelihood for need to recast elements, compared to other (single source) methods of repair, reducing carbon impact and improving heritage retention. This repair restores the element to its full strength, and therefore would be unlikely to require any further maintenance during the design life.

5.0 REPAIR OR REPLACEMENT?

Although retention of original material is intended as far as possible, it is accepted that some elements may be beyond practical or economic repair. Where these elements are of low heritage value replacement by recasting or use of alternative materials may be appropriate (see Section 7.0). Furthermore, some elements (such as lattice beams) vary in length and shape across the terraces, whereas other elements (such as Edge Beams) are likely to be much more repetitive, simplifying replication if required. Cost benefit analysis and carbon impact or replacement vs repair to be carried out by others.

6.0 WORKMANSHIP

As demonstrated in Section 4.0 there are a wide range of repair types available, from a plethora of specialist suppliers. Given the heritage value and stakeholder interest in the project, it is of increased importance that the chosen supplier is able to evidence that their methodology is suitable for the intended use. Furthermore, they should be able to provide a record of identified defects to justify works undertaken and a warranty/guarantee for all repaired structural elements.

7.0 MIXING METALS

Galvanic, or bi-metallic corrosion is an electrochemical process which occurs when two metals are connected; one of the metals corrodes preferentially to the other due to the presence of an electrolyte (such as water). Care should be taken to avoid this wherever possible, by matching the material used, or by use of insulting material to form a barrier, such as isolation washers, however these have a limited design life and can create a maintenance issue in the future. Careful consideration should be given to material

properties of any replacement elements and detailing, for example use of slotted holes, to accommodate movement.

8.0 CORROSION PROTECTION

In order to prolong the life of the cast iron and reduce maintenance requirements, it is recommended that a corrosion protection system suitable for use with ferrous materials in a marine environment is applied to all Cast Iron elements prior to reassembly.

In the permanent condition, many areas of the structure are obscured from view, and although every effort is made, corrosion/moisture traps are inevitable. As such it is deemed best practice to apply a comprehensive corrosion protection system to all surfaces in a controlled 'shop' environment prior to reconstruction, touching up any damage to the paint system on site as required.

9.0 CONCLUSION

In this brief technical memorandum, we have highlighted the difficulties faced with repairing Cast Iron and a number of commercially available repair types to help the client team make an informed decision.

Some of the unique challenges and performance requirements at Madeira Terrace include, but are not limited to:

- Significant structural loading on many elements including full crowd loading,
- Environmental considerations (exposed coastal)
- Requirement to minimise maintenance requirements over a 60-year design life,
- Likelihood of hidden and varied defects (corrosion, major/minor cracking etc)
- Heritage and conservation considerations,
- Ornate profiling of many elements.

Considering the options explored in this technical memorandum, we consider that Gas Fusion Welding is likely to be the most suitable method of repair. Using this method, it is likely that the vast majority of defects could be repaired, resulting in all works being executed by a single supplier. Subject to full assessment by others, this is likely to reduce fiscal and carbon costs as well as maximise heritage retention by reducing requirements for recasting. Furthermore, this method could be used on ornately profiled elements and should result in restoration of full structural capacity, likely eliminating the need for any further maintenance during the design life.

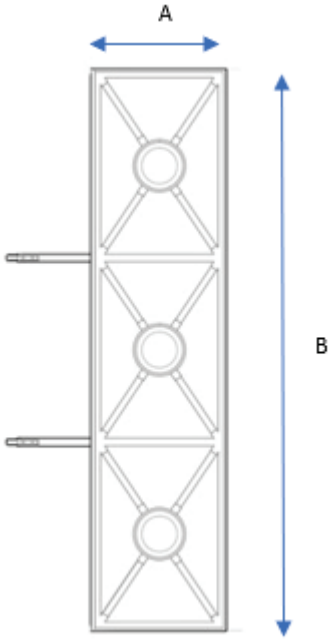
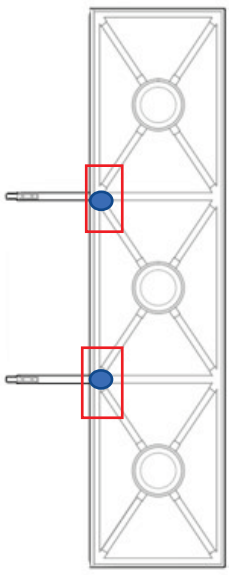
APPENDIX B – SAMPLE ARTIFACT LOG SHEETS

Incoming Inspection

Batch: Trial

Date Received: April 2023

Customer	Madeira Drive	**CIWS WO Number**	35292
		MD ID Number	BP1 - TRIAL
		Component Type	Balustrade Panel

Inspection Criteria		**Results**	**Notes**
	Check tag attached to component		
1	MPI	Yes – identify findings below	**Insert Date of Inspection: 31/05/2023**
2	Measurements taken	Yes– insert measurements as shown. 	A – 29cm B – 238.5cm
3	Identify any cracks mark on casting with yellow pen and mark on drawing. Drill hole where marked in blue to 6mm dia x 10mm depth – note findings		Weak point Third party repair No drilling carried out as third party weld found , this will need to be removed before repair

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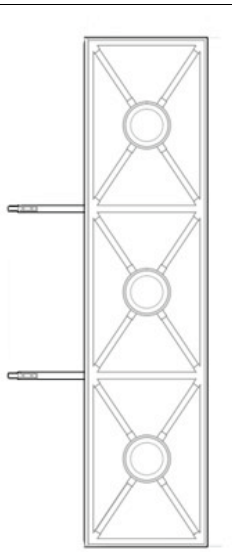
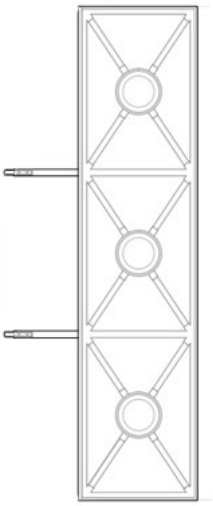
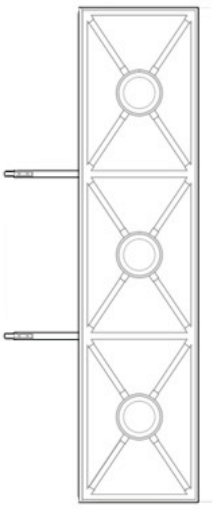
Incoming Inspection

Batch: Trial

Date Received: April 2023

4	Check for pitting corrosion >5mm in depth and >5mm in diameter mark on casting with yellow pen and mark on drawing		Ok
5	Check for decorative repair mark with yellow pen on casting and mark on drawing		Ok
6	Identify any damaged threads if any mark on casting and on drawing. Also need measure thread diameters Detail any other defective area to include cracks propagating to surface lamination		Thread Diameters : None
7	Photo taken once inspection complete, and all areas marked take multiple photos of defect areas	Yes Min 2 Max 4	

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Incoming Inspection

Batch: Trial

Date Received: April 2023

Pre-Repair Photographs:	
	
Photo 1:	Photo 2:
	
Photo 3:	Photo 4:
Post Repair Photographs:	
MPI Date: Weld Date: Welder: DPI Date:	

Incoming Inspection

Batch: Trial

Date Received: April 2023

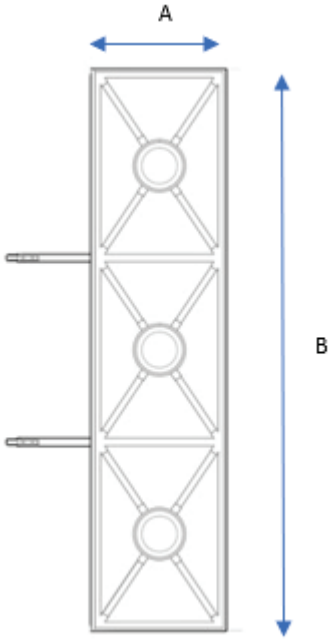
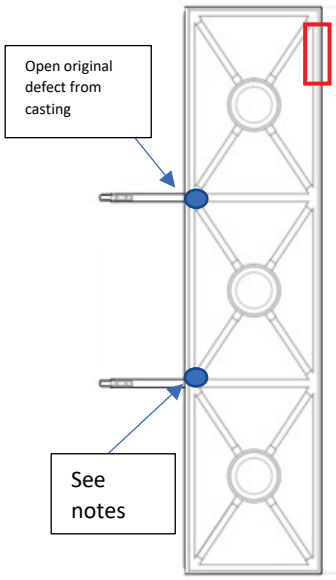
Photo 1:	Photo 2:
Photo 3:	Photo 4:

Incoming Inspection

Batch: Trial

Date Received: April 2023

Customer	Madeira Drive	**CIWS WO Number**	35293
		MD ID Number	BP2 – TRIAL
		Component Type	Balustrade Panel

Inspection Criteria		**Results**	**Notes**
	Check tag attached to component		
1	MPI	Yes – identify findings below	**Insert Date of Inspection: 18/05/23**
2	Measurements taken	Yes– insert measurements as shown. 	A = 485mm B = 239mm
3	Identify any cracks mark on casting with yellow pen and mark on drawing. Drill hole where marked in blue to 6mm dia x 10mm depth – note findings		Small crack on top Drilled hole to determine any defects internally 10mm depth 10mm dia all clear (assumption is the defects rise to the surface during casting production and leaves open defect on surface) *Photo 3*

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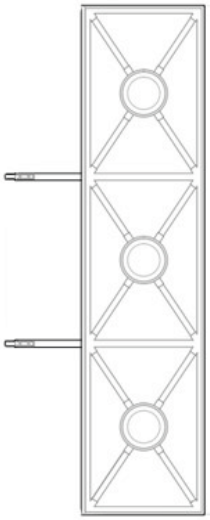
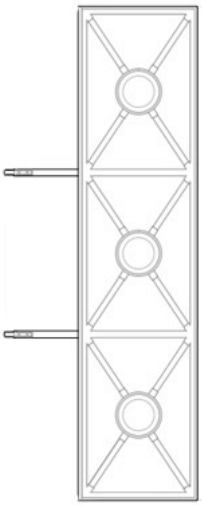
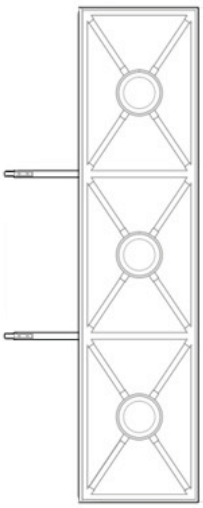
Incoming Inspection

Batch: Trial

Date Received: April 2023

4	Check for pitting corrosion >5mm in depth and >5mm in diameter mark on casting with yellow pen and mark on drawing		None
5	Check for decorative repair mark with yellow pen on casting and mark on drawing		OK
6	Identify any damaged threads if any mark on casting and on drawing. Also need measure thread diameters Detail any other defective area to include cracks propagating to surface lamination		Thread Diameters : None
7	Photo taken once inspection complete, and all areas marked take multiple photos of defect areas	Yes Min 2 Max 4	

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Incoming Inspection

Batch: Trial

Date Received: April 2023

Pre-Repair Photographs:	
	
Photo 1:	Photo 2:
	
Photo 3:	Photo 4:
Post Repair Photographs:	
MPI Date: Weld Date: Welder: DPI Date:	

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Incoming Inspection

Batch: Trial

Date Received: April 2023

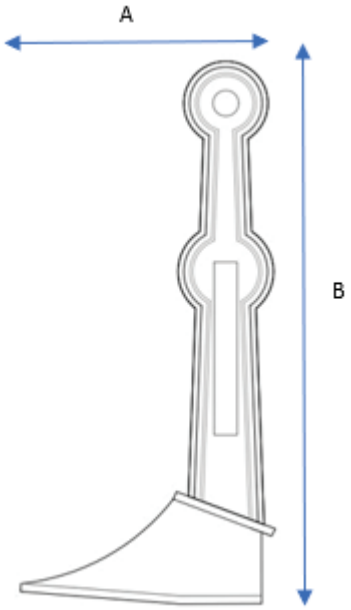
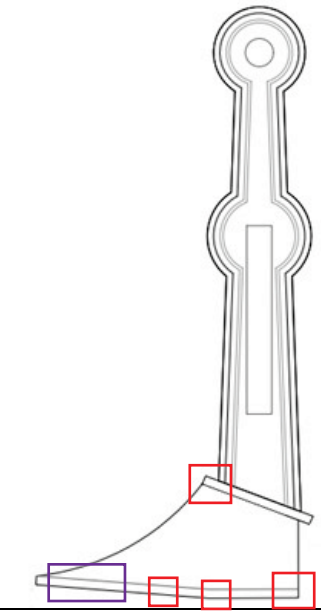
Photo 1:	Photo 2:
Photo 3:	Photo 4:

Incoming Inspection

Batch: Trial

Date Received: April 2023

Customer	Madeira Drive	**CIWS WO Number**	35296
		MD ID Number	BS1 - Trial
		Component Type	Balustrade Stanchion

Inspection Criteria		**Results**	**Notes**
	Check tag attached to component		
1	MPI	Yes – identify findings below	**Insert Date of Inspection: 01/06/2023**
2	Measurements taken	Yes– insert measurements as shown. 	A = 59cm B = 131.5cm
3	Identify any cracks mark on casting with yellow pen and mark on drawing		Cracks on support frame Cracks on base frame Cuts also found on lefthand bottom of base frame

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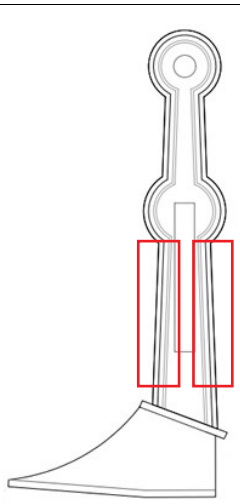
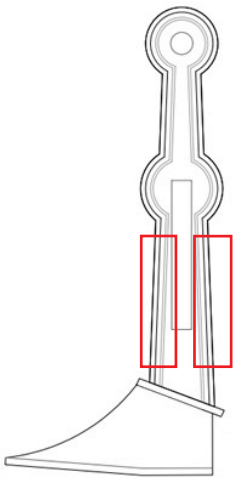
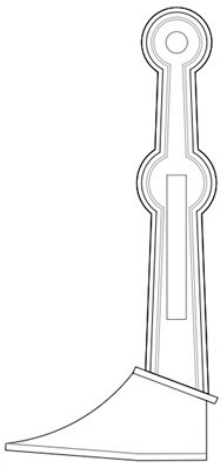
Incoming Inspection

Batch: Trial

Date Received: April 2023

4	Check for pitting corrosion >5mm in depth and >5mm in diameter mark on casting with yellow pen and mark on drawing		Eroded base frame. Eroded decoration sides
5	Check for decorative repair mark with yellow pen on casting and mark on drawing		Erosion on decorative sides.
6	Identify any damaged threads if any mark on casting and on drawing. Also need measure thread diameters Identify any damaged bolt holes. Detail any other defective area to include cracks propagating to surface lamination.		Thread Diameters : None None found
7	Photo taken once inspection complete, and all areas marked take multiple photos of defect areas	Yes Min 2 Max 4	

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Incoming Inspection

Batch: Trial

Date Received: April 2023

Pre-Repair Photographs:	
	
Photo 1:	Photo 2:
	
Photo 3:	Photo 4:
Post Repair Photographs:	
MPI Date: Weld Date: Welder: DPI Date:	

Incoming Inspection

Batch: Trial

Date Received: April 2023

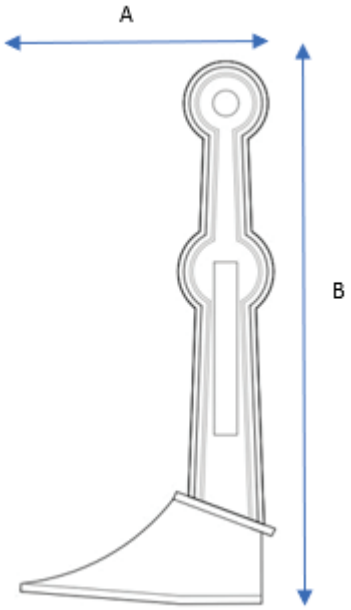
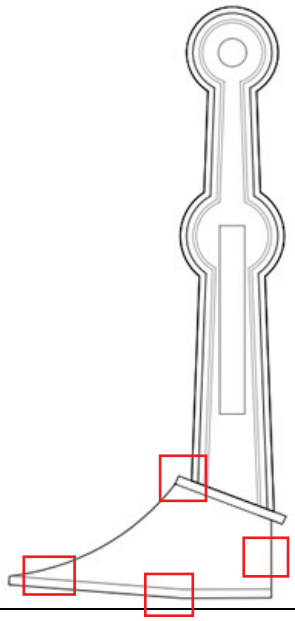
Photo 1:	Photo 2:
Photo 3:	Photo 4:

Incoming Inspection

Batch: Trial

Date Received: April 2023

Customer	Madeira Drive	**CIWS WO Number**	35297
		MD ID Number	BS2 - Trial
		Component Type	Balustrade Stanchion

Inspection Criteria		**Results**	**Notes**
	Check tag attached to component		
1	MPI	Yes – identify findings below	**Insert Date of Inspection: 1/06/2023**
2	Measurements taken	Yes– insert measurements as shown. 	A = 29cm B = 131.5cm
3	Identify any cracks mark on casting with yellow pen and mark on drawing		Cuts and cracks support frame and on the base frame.

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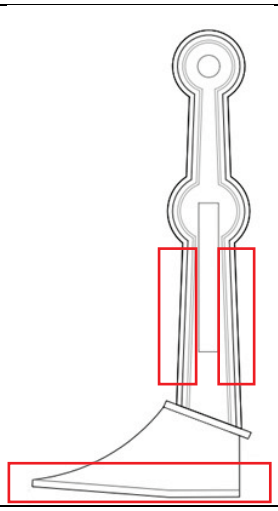
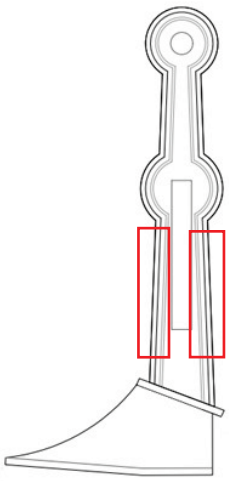
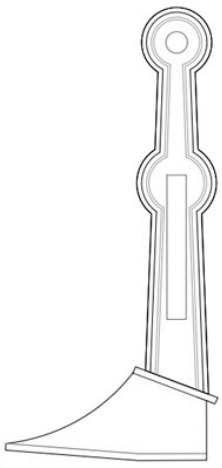
Incoming Inspection

Batch: Trial

Date Received: April 2023

4	Check for pitting corrosion >5mm in depth and >5mm in diameter mark on casting with yellow pen and mark on drawing		Eroded base frame & eroded decorative sides.
5	Check for decorative repair mark with yellow pen on casting and mark on drawing		Eroded decorative sides.
6	Identify any damaged threads if any mark on casting and on drawing. Also need measure thread diameters Identify any damaged bolt holes. Detail any other defective area to include cracks propagating to surface lamination.		Thread Diameters : N/A
7	Photo taken once inspection complete, and all areas marked take multiple photos of defect areas	Yes Min 2 Max 4	

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Incoming Inspection

Batch: Trial

Date Received: April 2023

Pre-Repair Photographs:	
	
Photo 1:	Photo 2:
Photo 3:	Photo 4:
Post Repair Photographs:	
MPI Date: Weld Date: Welder: DPI Date:	

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Incoming Inspection

Batch: Trial

Date Received: April 2023

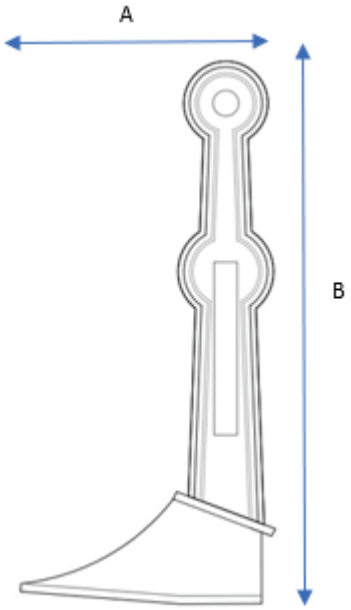
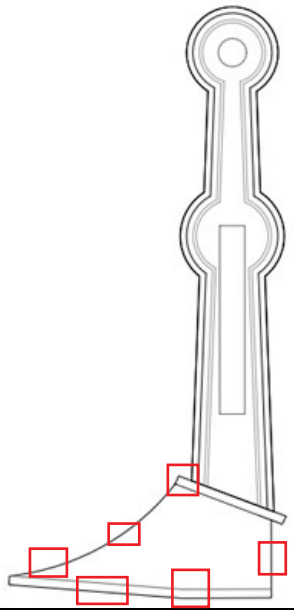
Photo 1:	Photo 2:
Photo 3:	Photo 4:

Incoming Inspection

Batch: Trial

Date Received: April 2023

Customer	Madeira Drive	**CIWS WO Number**	35298
		MD ID Number	BS3 - Trial
		Component Type	Balustrade Stanchion

Inspection Criteria		**Results**	**Notes**
	Check tag attached to component		
1	MPI	Yes – identify findings below	**Insert Date of Inspection: 1/6/23**
2	Measurements taken	Yes– insert measurements as shown. 	A = 59cm B = 131.5cm
3	Identify any cracks mark on casting with yellow pen and mark on drawing		Multiple cracks and chips on base frame

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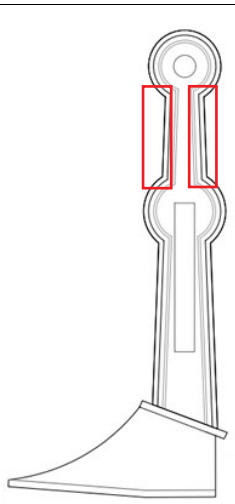
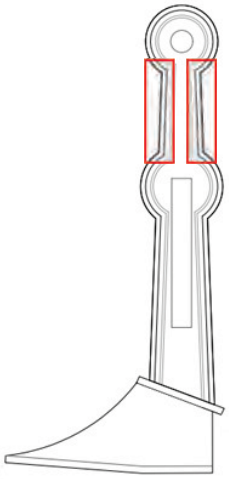
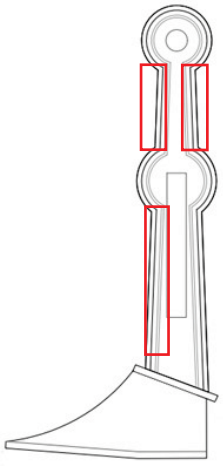
Incoming Inspection

Batch: Trial

Date Received: April 2023

4	Check for pitting corrosion >5mm in depth and >5mm in diameter mark on casting with yellow pen and mark on drawing		Erosion on both decorative sides
5	Check for decorative repair mark with yellow pen on casting and mark on drawing		Erosion on both decorative sides Long cut on left side
6	Identify any damaged threads if any mark on casting and on drawing. Also need measure thread diameters Identify any damaged bolt holes. Detail any other defective area to include cracks propagating to surface lamination.		Thread Diameters : N/A
7	Photo taken once inspection complete, and all areas marked take multiple photos of defect areas	Yes Min 2 Max 4	

ciws

Incoming Inspection

Batch: Trial

Date Received: April 2023

Pre-Repair Photographs:	
	
Photo 1:	Photo 2:
Photo 3:	Photo 4:
Post Repair Photographs:	
MPI Date: Weld Date: Welder: DPI Date:	

ciws

Incoming Inspection

Batch: Trial

Date Received: April 2023

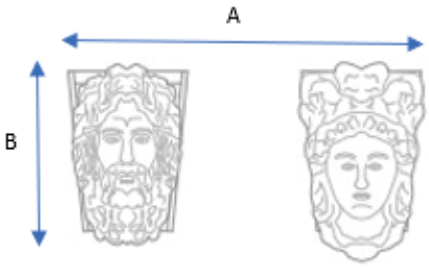
Photo 1:	Photo 2:
Photo 3:	Photo 4:

Incoming Inspection

Batch: Trial

Date Received: April 2023

Customer	Madeira Drive	**CIWS WO Number**	35299
		MD ID Number	SM1 – Trial H26
		Component Type	Spandrel Mask – Poseidon

Inspection Criteria		**Results**	**Notes**
	Check tag attached to component		
1	MPI	Yes – identify findings below	**Insert Date of Inspection: 02/06/2023**
2	Measurements taken	Yes– insert measurements as shown. 	A = 67cm B = 51cm
3	Identify any cracks mark on casting with yellow pen and mark on drawing		Missing parts on both faces & bolt holes in reverse side
4	Check for pitting corrosion >5mm in depth and >5mm in diameter mark on casting with yellow pen and mark on drawing		Ok
5	Check for decorative repair mark with yellow pen on casting and mark on drawing		Ok
6	Identify any damaged threads if any mark on casting and on drawing. Also need measure thread diameters		Thread Diameters : N/A

Incoming Inspection

Batch: Trial

Date Received: April 2023

	Detail any damaged bolt holes Detail any other defective area to include cracks propagating to surface lamination and missing architectural decoration Also identify missing sections **Remove bolt and retain (looks like a lemon squeezer – need to try and retain as much as possible so careful removal required)**		Bolt removed *see photo 3*
7	Photo taken once inspection complete, and all areas marked take multiple photos of defect areas	Yes Min 2 Max 4	

ciws

Incoming Inspection

Batch: Trial

Date Received: April 2023

Pre-Repair Photographs:	
	
Photo 1:	Photo 2:
	
Photo 3:	Photo 4:
Post Repair Photographs:	
MPI Date: Weld Date: Welder: DPI Date:	

ciws

Incoming Inspection

Batch: Trial

Date Received: April 2023

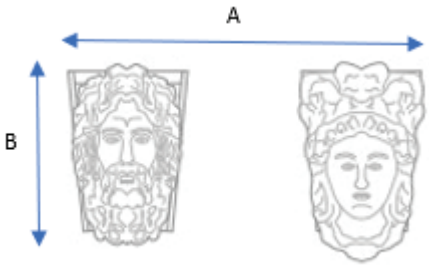
Photo 1:	Photo 2:
Photo 3:	Photo 4:

Incoming Inspection

Batch: Trial

Date Received: April 2023

Customer	Madeira Drive	**CIWS WO Number**	35300
		MD ID Number	SM2 – Trial H26
		Component Type	Spandrel Mask – Amphitrite

Inspection Criteria		**Results**	**Notes**
	Check tag attached to component		
1	MPI	Yes – identify findings below	**Insert Date of Inspection : 02/06/2023**
2	Measurements taken	Yes– insert measurements as shown. 	A = 61cm B = 56cm
3	Identify any cracks mark on casting with yellow pen and mark on drawing		Missing pieces from bolt holes Female Mask has 1 bolt hole cracked.
4	Check for pitting corrosion >5mm in depth and >5mm in diameter mark on casting with yellow pen and mark on drawing		Ok
5	Check for decorative repair mark with yellow pen on casting and mark on drawing		Ok
6	Identify any damaged threads if any mark on casting and on drawing. Also need measure thread diameters		Thread Diameters : N/A

ciws

Incoming Inspection

Batch: Trial

Date Received: April 2023

	Detail any damaged bolt holes Detail any other defective area to include cracks propagating to surface lamination and missing architectural decoration Also identify missing sections **Remove bolt and retain (looks like a lemon squeezer – need to try and retain as much as possible so careful removal required)**		Bolt removed *see photo 2*
7	Photo taken once inspection complete, and all areas marked take multiple photos of defect areas	Yes Min 2 Max 4	

ciws

Incoming Inspection

Batch: Trial

Date Received: April 2023

Pre-Repair Photographs:	
	
Photo 1:	Photo 2:
	
Photo 3:	Photo 4:
Post Repair Photographs:	
MPI Date: Weld Date: Welder: DPI Date:	

ciws

Incoming Inspection

Batch: Trial

Date Received: April 2023

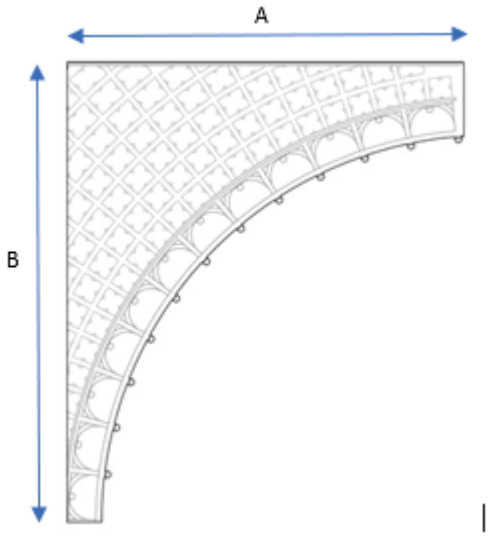
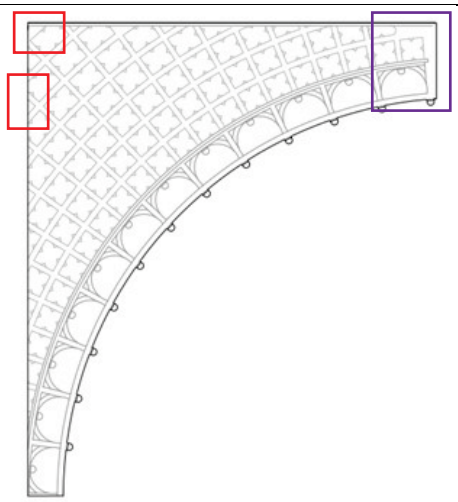
Photo 1:	Photo 2:
Photo 3:	Photo 4:

Incoming Inspection

Batch: Trial

Date Received: April 2023

ustomer	Madeira Drive	**CIWS WO Number**	35295
		MD ID Number	SP1 - TRIAL
		Component Type	Spandrel Panel

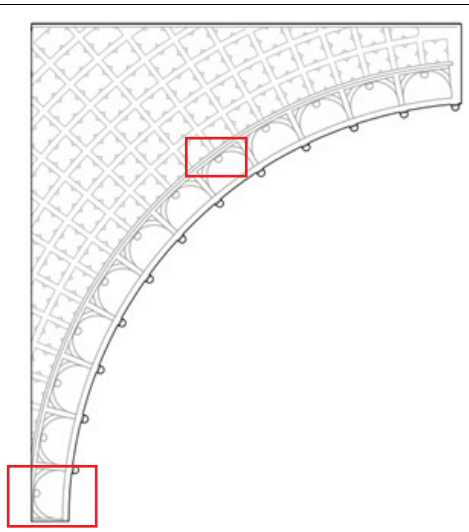
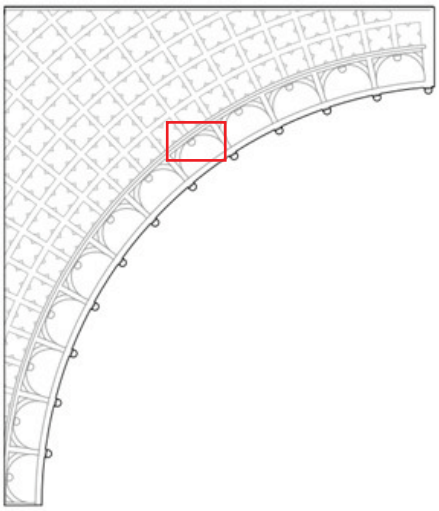
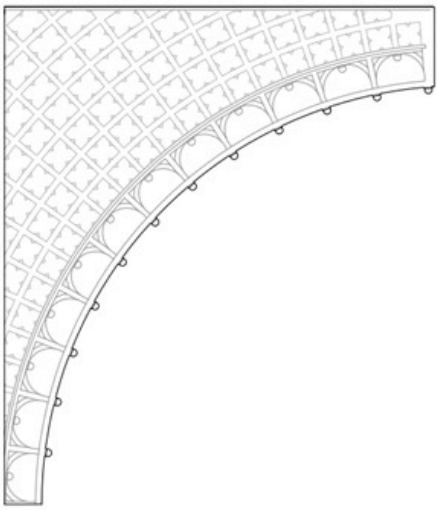
Inspection Criteria		**Results**	**Notes**
	Check tag attached to component		
1	MPI	Yes – identify findings below	**Insert Date of Inspection 31/05/23**
2	Measurements taken	Yes– insert measurements as shown. 	A = 2515 mm B = 2230mm
3	Identify any cracks mark on casting with yellow pen and mark on drawing		Cracks found two locations on lefthand side and missing section on righthand side of section

ciws

Incoming Inspection

Batch: Trial

Date Received: April 2023

4	Check for pitting corrosion >5mm in depth and >5mm in diameter mark on casting with yellow pen and mark on drawing		Corrosion on decorative side Eroded bolt hole
5	Check for decorative repair mark with yellow pen on casting and mark on drawing		Small corrosion
6	Identify any damaged bolt holes mark on casting and on drawing. Detail any other defective area to include cracks propagating to surface lamination. **Ensure screw bolts are removed and retained.**		Thread Diameters : Screw bolt stuck – once pre-heated for repairs bolt expected to become loose
7	Photo taken once inspection complete, and all areas marked take multiple photos of defect areas	Yes Min 2 Max 4	

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Pre-Repair Photographs:	**Photo 1 :**
	
Photo 2:	Photo 3:
	
Photo 4: 	Photo 5:
Post Repair Photographs:	
MPI Date: Weld Date: Welder: DPI Date:	

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Photo 1:	Photo 2:
Photo 3:	Photo 4:

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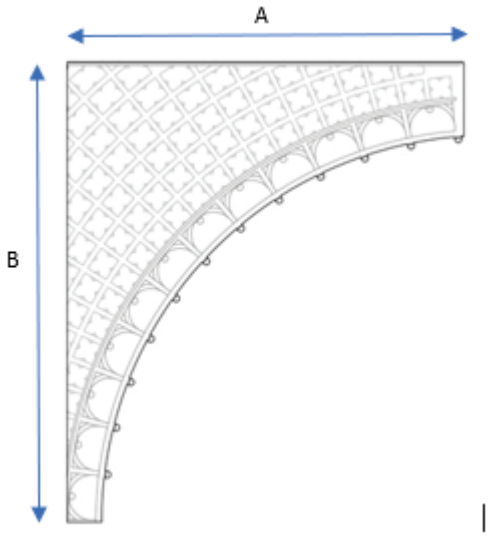
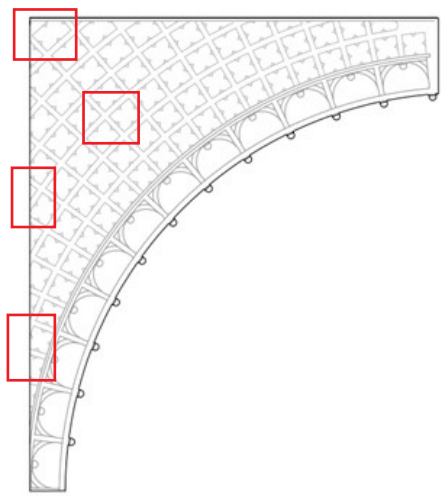
ustomer	Madeira Drive	**CIWS WO Number**	35294
		MD ID Number	SP2 - TRIAL
		Component Type	Spandrel Panel

Inspection Criteria		**Results**	**Notes**
	Check tag attached to component		
1	MPI	Yes – identify findings below	**Insert Date of Inspection: 18/05/23**
2	Measurements taken	Yes– insert measurements as shown. 	A = 2520mm B = 2305mm
3	Identify any cracks mark on casting with yellow pen and mark on drawing		Cracks found Major cracks at right angle top lefthand corner

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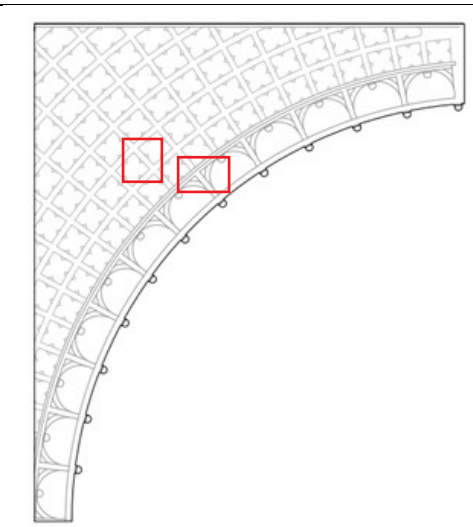
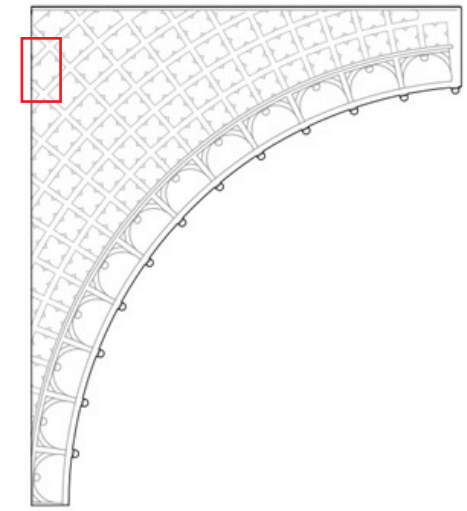
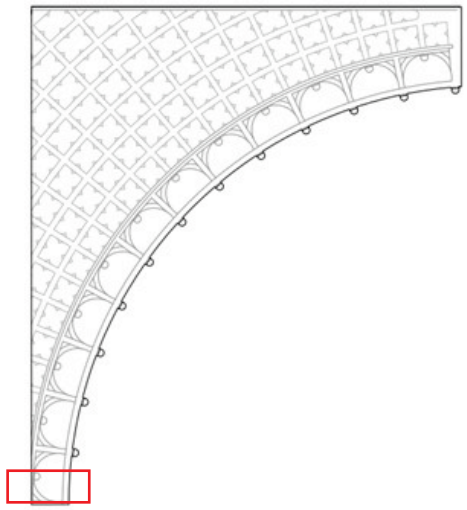
4	Check for pitting corrosion >5mm in depth and >5mm in diameter mark on casting with yellow pen and mark on drawing		Small amount of pitting
5	Check for decorative repair mark with yellow pen on casting and mark on drawing		Piece broken off
6	Identify any damaged bolt holes mark on casting and on drawing. Detail any other defective area to include cracks propagating to surface lamination. **Ensure screw bolts are removed and retained.**		Thread Diameters : Screw bolt stuck once pre-heated for repairs bolt expected to become loose
7	Photo taken once inspection complete, and all areas marked take multiple photos of defect areas	Yes Min 2 Max 4	

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Incoming Inspection

Batch: Trial

Date Received: April 2023

Pre-Repair Photographs:	
	
Photo 1:	Photo 2:

ciws

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Batch: Trial

Date Received: April 2023

	
Photo 3:	Photo 4:
Post Repair Photographs:	
MPI Date: Weld Date: Welder: DPI Date:	

Incoming Inspection

Batch: Trial

Date Received: April 2023

Photo 1:	Photo 2:
Photo 3:	Photo 4: