Guidelines for Manufacturing, Assembly and Testing of Marine Energy Conversion Systems

Foreword

This document has been prepared in consultation with The European Marine Energy Centre Ltd (EMEC) and with other interested parties in the UK marine energy community. It is one of twelve publications in the *Marine Renewable Energy Guides* series, included in the following figure.

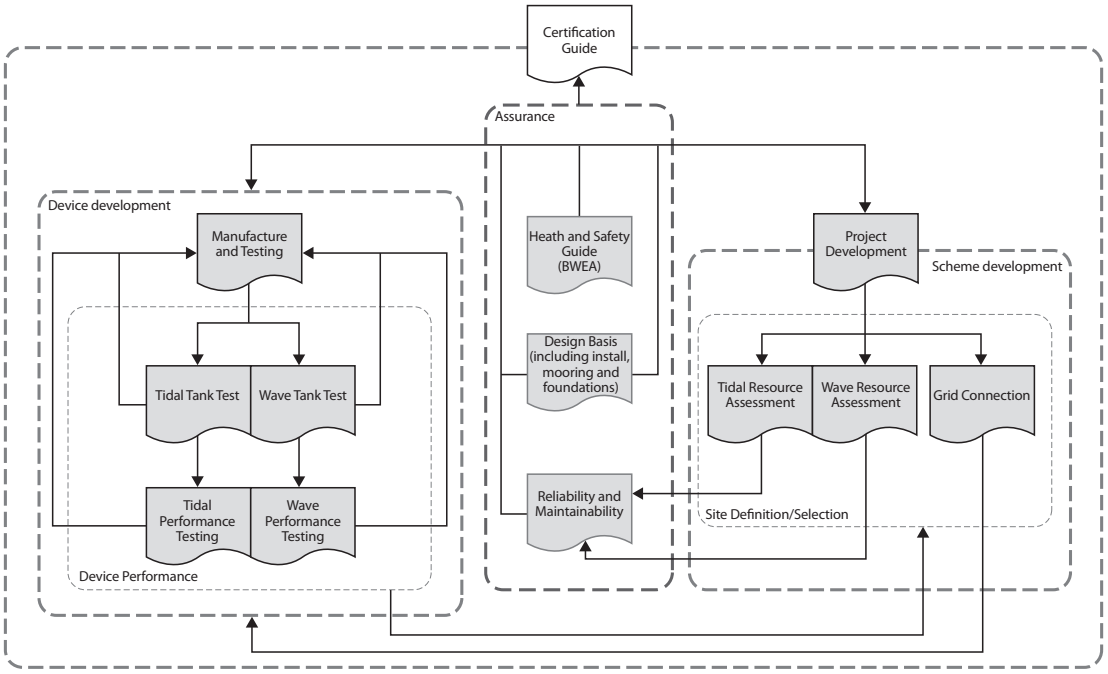

Figure 1 — Marine Renewable Energy Guides

Acknowledgements

This document was written by Andrew McNicoll of Neptune Deeptech, under contract from the European Marine Energy Centre Ltd (EMEC).

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Marine Renewable Energy Guides

EMEC™ ORKNEY
The European Marine Energy Centre Ltd

First published in the UK in 2009 by BSI, 389 Chiswick High Road, London W4 4AL

Typeset in Great Britain by Monolith – www.monolith.uk.com
Printed by The Charlesworth Group, Wakefield

British Library Cataloguing-in-Publication Data
A catalogue record for this book is available from the British Library

ISBN 978-0-580-66793-0

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Introduction

When harnessing the environment to generate renewable energy, it is usually necessary to locate devices in areas that can see extreme operating and environmental demands on design and manufacturing quality.

It is therefore vital to ensure that clear guidance and control measures are specified to ensure the survivability and reliability of equipment being manufactured. Inadequate design and manufacturing control may create serious and costly failures in service.

Manufacturing processes and quality requirements vary significantly through the engineering industry. The procedures and processes used during manufacture have a significant influence on the cost, quality, and ultimately the performance of the product.

The quality of the device cannot be guaranteed by inspection alone. Even the most extensive Non-destructive Testing (NDT) cannot guarantee the strength of weld, and inspection reports cannot guarantee that dimensional tolerances have been achieved. Quality has to be built into the product by the application of robust procedures and processes that can be verified by an independent verification body or certification body used in a certification scheme standard.

Companies wishing to have devices manufactured should consider the type of engineering expertise required and ensure that their selection is based on the long-term success of the project. Particular attention should be made to manufacturers' normal scope of services, certified accreditations (ISO 9001), competencies and verification processes and industry sectors.

Where possible, the manufacturer should be consulted during the design stages. The engineering expertise that manufacturers can provide will add efficiencies and reduce cost.

This guideline document has been prepared to provide manufacturers and purchasers information on manufacturing practices appropriate to the marine renewable energy industry.

1. Scope

This guideline document specifies techniques for planning and building quality into the manufacturing processes and so provides an initial framework for providing consistency within the industry.

It covers the manufacture of tidal stream generators (floating and subsea), wave energy converters, offshore wind energy converters and devices generating power from a renewable energy source in the marine environment.

It does not cover offshore installations and operations already covered by the safety case regulations, shipping (already covered by the Marine Equipment Directive), land-based energy converters that are not in the marine environment, sub-components built and certified to existing national standards, or application and consideration of EU directives within the equipment and installation and cabling.

This guideline document may also be used for assessing manufacturers' capability for producing equipment for the demanding renewable energy market and providing a basis for acceptance by interested parties.

NOTE It is advisable that designers and manufacturers of devices review the statutory requirements of the assembly on a case-by-case basis. The following directives may be considered:

- Pressure equipment directive (PED).
- Transportable pressure equipment directive (TPED).
- Low voltage directive (LVD).
- Electromagnetic compatibility (EMC).
- Machinery directive (MD).
- Explosive atmospheres directive (ATEX).
- Lifting operations and lifting equipment regulations (LOLER).

Relevant information on manufacturing legislation can be found at:
http://ec.europa.eu/enterprise/newapproach/standardization/harmstds/reflist.html

2. Normative references

The following referenced document is indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

BS EN ISO 15614-1 *Specification and qualification of welding procedures for metallic materials — Welding procedure test — Arc and gas welding of steels and arc welding of nickel and nickel alloys*

3. Terms, definitions and abbreviations

3.1 Terms and definitions

3.1.1
can
tube or pipe rolled from plate and longitudinally seam welded

3.1.2
drawings
design drawings, or shop drawings approved for construction

3.1.3
inspection and test plan
document issued by the manufacturer defining the scope of inspection activities based on the scope of supply with the option for the client to indicate the level of attendance during the manufacture/testing process

NOTE Third-party attendance points are also recorded on the Inspection and Test Plan.

3.1.4
inspection release certificate
certificate issued by inspector to indicate that the material or equipment has been satisfactorily inspected to the order requirements and accepted

3.1.5
primary structure
all those components of offshore installations, the failure of which would seriously endanger the safety of the installation including all attachments welded to it

3.1.6
standard
document, established by consensus and approved by a recognized body, that provides, for common and repeated use, rules, guidelines and characteristics for activities or their results, aimed at the achievement of the optimum degree of order in a given context

NOTE Standards should be based on the consolidated results of science, technology and experience, and aimed at the promotion of optimum community benefits.

[ISO/IEC Guide 2:2004, definition 3.2]

3.1.7
surveillance
process of inspecting tests, calibrations or other activities to ensure that the necessary quality is maintained, operation is within safety limits, and operation is to be maintained within limiting conditions

3.1.8
validation
performed during commissioning and a confirmation that the final product matches the original concept, specification and/or design requirements

3.2 Abbreviations

ASME	American Society of Mechanical Engineers
ASNT	American Society of Nondestructive Testing
AWS	American Welding Society
DFT	Dry Film Thickness
DPI	Dye Penetrant Inspection
EMEC	European Marine Energy Centre
FAT	Factory Acceptance Testing
GMAW	Gas Metal Arc Welding
GSFCAW	Gas Shielded Flux Cored Arc Welding
GTAW	Gas Tungsten Arc Welding
ICB	Independent Certification Body
IEC	International Electrical Commission
IP	Ingress Protection
IRC	Inspection Release Certificate
ISO	International Organization for Standardization
ITP	Inspection and Test Plan
IVB	Independent Verification Body
IV&VB	Independent Verification and Validation Body
MPI	Magnetic Particle Inspection (or examination)
NCR	Non-conformance Report
NDT	Non-destructive Testing
PCN	Personnel Certification in Non-destructive Testing
PQR	Procedure Qualification Record
PWHT	Post-weld Heat Treatment (or Treated)
RT	Radiographic Testing
SAW	Submerged Arc Welding
SMAW	Shielded Metal Arc Welding
SSFCAW	Self-shielded Flux Cored Arc Welding
UT	Ultrasonic Testing
UTS	Ultimate Tensile Strength
WPQR	Weld Procedure Qualification Record
WPQT	Weld Procedure Qualification Test
WPS	Welding Procedure Specification

NOTE The list above are abbreviations frequently encountered in the manufacturing industry.

4. Contract review (including agreed inspection stages and certification)

4.1 Contract review

Many energy converters will be designed and specified by institutions or businesses without adequate or appropriate manufacturing or project management experience in wet renewable energy converters. It is therefore important that purchasers and manufacturers meet and mutually agree a defined scope of work and technical specifications applicable to the manufacture to ensure the success of the project objectives (see Table 1).

The specification and contractual requirements issued by the client should be reviewed by the manufacturer to ensure that they have the process capability and the resources necessary to carry out the manufacture. Ambiguous or unclear work scopes should be clarified at the contract review stage and circulated to all interested for agreement prior to the commitment to undertake the work.

4.2 Contractual requirements

The listed contractual and technical requirements should be reviewed by the manufacturer. Exclusions or additions to these requirements should be agreed by all interested parties.

Table 1 — Items for manufacturer, purchaser and/or Inspecting Authority agreement

Clause	Description
4.2.1	Detailed Inspection and Test Plan shall be submitted for review. See example Appendix 3
4.2.2	Weld procedure qualifications, which have been witnessed by an independent verification body (IVB) that meet the requirements of a recognized weld standard (see Bibliography)
4.2.3	The weld procedures proposed shall have mechanical and impact properties to meet requirements of base material. The weld procedure specifications should be appropriate for the service requirements, supported by weld procedure qualification records (WPQR) demonstrating mechanical properties have been achieved
4.2.4	Weld operator qualifications will be carried out to a recognized international standard and witnessed/certified by an independent certification body
4.2.5	Weld data records containing operators and NDT history during manufacture will be produced and available for review during manufacture

Clause	Description
4.2.6	Identification and traceability
4.2.7	Companies without a quality management system accredited to ISO 9001 shall supply all material to BS EN 10204:2004 type 3.2
4.2.8	Unless specified otherwise, all primary steel shall be supplied in accordance with BS EN 10204:2004 type 3.1
4.2.9	NDT technicians to be qualified in accordance with recognized industry standard (see Bibliography)
4.2.10	In the absence of a certified ISO 9001 quality management system, dimensional reports shall be supplied with any calibration records for equipment used
4.2.11	The manufacturer shall inform client at the tender stage on the extent of subcontracted services
4.2.12	Specify type and percentage of NDT and acceptance standard
4.2.13	Specify heat treatment requirements if applicable
4.2.14	Lifting attachments (for large loads) and lifting tackle etc. shall be tested and recorded on a certificate of thorough examination
4.2.15	Results of pressure and hydro testing shall be recorded by the use of a chart recorder and calibrated pressure gauges
4.2.16	Surface coating and preparation of surfaces prior to coating shall be monitored and dry film thickness checks taken to verify acceptance
4.2.17	Electrical inspection and testing shall be required
4.2.18	Hydraulic fluid analysis shall be required
4.2.19	Agree extent and capability to carry out factory acceptance testing (FAT)

5. Manufacture and workmanship

5.1 Materials

Material control and traceability are essential to ensure the specified grades of materials are used on primary structures, for example:

- Low yield materials, if used, could result in mechanical or structural failure of the device;
- High yield materials could result in failure due to inappropriate welding processes.

Materials shall meet the drawing/specification and be appropriate to the weld procedure properties and to the design requirements of the device and its service environment. Deviations from drawings/specification shall be documented and approved by the client prior to implementation. In the event of incorrect material use, non-conformances shall be raised and dispositions approved by the client.

Unless otherwise stated, steel and other metals such as bronzes shall meet the following requirements as a minimum:

- Yield/Tensile requirements;
- Charpy impact values and design temperature of the equipment;
- Steel grouping as specified in PD CEN ISO/TR15608.

This includes drive shafts, couplings, keys, dowels and bolting used to attach primary structure items.

Concrete products and other composite materials such as glass and reinforced plastic, used for load bearing elements of the structural items, shall be supplied in accordance with the grade detailed on the specification. Test certificates/certificate of conformities shall be supplied with each batch of material that specifies where appropriate:

- Source of material;
- Strength of material in UTS;
- Particle size;
- Density and specific gravity;
- Content.

Material requisitions/purchase orders shall be traceable to the material certification through all stages of manufacture/fabrication, with marking transferred at each stage to ensure traceability back to mill certification.

Companies without an accredited quality management system to ISO 9001 should supply all primary structural elements in accordance with BS EN 10204:2004 type 3.2.

Supplied products shall be fully identified by legible and durable marking.

All primary materials shall be uniquely identified and this identification shall be traceable to material certification. Material maps will be provided in accordance with the project requirements to indicate the identification number on the relevant drawings.

5.2 Material handling and forming

5.2.1 Material handling

Materials shall be handled and stored in such a manner to prevent deterioration, damage and contamination. Low stress stamps or indelible inks should be used for transfer of mill cast marking.

Stainless steel and alloys welds shall be segregated from carbon steels as far as reasonably practicable. Grinders, files and other metal working tools used for stainless steel shall be free from carbon contamination.

Stainless steel welds should be passivated with a pickling solution after work has been completed.

Materials shall be handled in such a manner that will prevent stress marks. Temporary attachments and strong backs will be removed by grinding. The remaining tack weld shall be ground smooth after removal of the attachment. Temporary stiffeners shall not be broken by hammering.

Plate edges and corners shall be ground to remove slag tramlines left by the burning process.

Pad eye holes shall be drilled and deburred to prevent stress areas.

5.2.2 Forming materials

Hot and cold forming should be done by machine processes as far as practicable. Local heating or hammering should not be used. The forming and heating operations should be monitored to ensure material properties are not significantly altered.

5.2.3 Rolled cans

Rolled steel cans should have no significant peaks, dips or flat areas. Unless specified by the design, circularity of structural rolled cans shall be within the following tolerances measured at any one cross section.

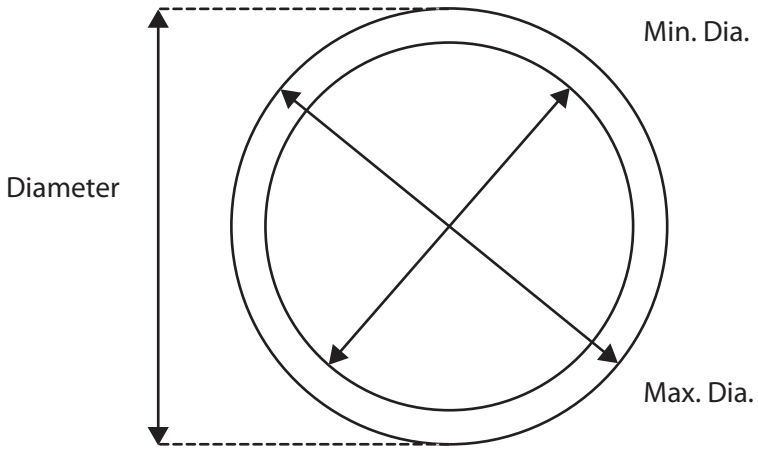

Table 2 — Tolerances for structural rolled cylinders

Diameter	Tolerance out of roundness
≤ 600 mm	1 % Diameter
≥ 600 mm ≤2000	1 % Diameter or 6 mm whichever is greater
≥ 2000	1 % Diameter or 16 mm whichever is greater.

Rolled shells subject to internal and external pressure should meet the dimensional requirements of PD 5500 or other acceptance specification.

6. Welding

6.1 Weld procedures

No production welding shall commence until the weld procedure has been established/ qualified by the manufacturer. The same requirement shall be applicable to subcontractors involved in the welding process of the primary structure. Weld procedure qualification tests (WPQT) shall be run in accordance with a recognized national standard and endorsed by an IVB.

The selection of weld procedures for specific materials shall be based on steel groups and subgroups detailed within the tables of BS EN ISO 15614-1.

NOTE Certain sub component design standards may require approval to specific standards.

6.2 Operator qualifications

No production welding shall commence until welders/operators have been qualified in accordance with a recognized international standard. Operator/welder qualification tests shall be witnessed and endorsed by an IVB.

6.3 Weld equipment

Welding equipment shall be adequately maintained and fully calibrated to ensure the welding parameters can be confidently set in line with the Welding Procedure Specification (WPS). Calibration of equipment shall conform to a national standard.

6.4 Weld consumables

Weld consumables, for example wire, electrodes, flux and shielding gas shall be the same classification to those specified on the WPS. The storage and handling of consumables shall be in accordance with the manufacturers' instructions to prevent damage and deterioration.

6.5 Weld preparation and distortion

Weld preparation and application shall be in accordance with the WPS. The information on the WPS should be communicated to welders/operators. Weld shrinkage and distortion should be taken into consideration prior to welding. Checks for laminations of material should be carried out in certain circumstances, for example, DPI of joint preparation or (UT) of plate along joint. The application of strong backs, excess metal and post-weld machining should be considered. Preheat may be required by WPS and should be controlled accordingly.

6.6 Weld monitoring

The manufacturer shall implement systems to enable process checks on welding activities during manufacture. Checks shall identify and record WPS, consumables, preheat volts, amps, travel speed, heat input, cooling rate and welder/operator.

6.7 Post-weld heat treatment

Post-weld heat treatment (PWHT) shall be carried out to an agreed procedure by qualified operators working with calibrated equipment. Heating and cooling rates shall be defined (often derived from WPS).

Drawings and specifications may specify areas that require post-weld heat treatment. Alternatively the PWHT may be at the manufacturers' discretion, i.e. certain high yield materials require PWHT to guarantee mechanical strength.

Weld procedures that include PWHT shall be used when PWHT is required. Procedures without PWHT shall be prohibited from welding parts requiring heat treatment. Non-destructive testing, including any hardness testing, of welds that have been subject to PWHT shall be carried out after completion of the heat treatment process.

6.8 Visual weld quality

Welds shall be of a specific size and profile. Excess penetration should be avoided in butt welds. Welds shall blend smoothly into the parent material without undercut or cold-lap. Grinding of cap weld shall be prohibited except where the drawing/specification require

this or minor dressing between stop/starts and removal of ark strikes or if required for UT examination.

The completed welds and materials shall be free of spatter, slag, porosity, lack of fusion and ark strikes.

Fillet weld sizes shall meet the drawing/specification. Leg length size shall be measured to verify weld size.

Welder identification shall be recorded against primary structure welds.

7. Inspection and testing of welds

7.1 Non-destructive testing – general

Non-destructive testing shall be carried out on welds and materials as specified on drawings or agreed specifications. The manufacturer should be responsible for ensuring that all NDT operations are controlled and meet the requirements of the client's specification or applicable national or international standards (see 7.2) and this guideline document.

The manufacturer should confirm the procedures that they wish to be utilized with the NDT technician or company prior to testing. This may be in the client specification or design requirements. The NDT personnel should have a complete understanding of the procedures being used and be informed of acceptance criteria and percentages of NDT required.

The manufacturer should provide suitable access to all primary structure to enable inspection activities to be performed. NDT of welded areas should not be carried out until suitably cool.

7.2 NDT procedures

Written procedures shall be available that describe the methods that will be utilized in carrying out NDT. NDT procedures shall be written by a person who is qualified to personnel certification in non-destructive testing (PCN) level III and shall be based on the requirements of a recognized national standard. Procedures should be qualified by demonstration of their ability to detect known defects.

7.3 NDT operators

As a minimum, non-destructive testing should be carried out by personnel who have been trained and qualified for the type of testing being carried out. The operator's competence should be verified and certified by a level two (II) technician to either PCN or American Society of Nondestructive Testing (ASNT) level 2.

NOTE Certain sub-component design standards may require NDT operator qualifications to a specific recognized standard.

7.4 NDT reports

The NDT operator shall issue reports describing the weld or item tested. The reports shall clearly distinguish between acceptable and rejected items. The reports shall also specify NDT procedures, acceptance criteria and percentages tested.

7.5 Repair of reject welds

Imperfections that are not acceptable shall be either repaired or deemed not to conform to the applicable specification. An understanding of the root cause of weld failures should be determined prior to carrying out any weld repairs. Repair weld shall be carried out to a procedure approved by the IVB.

Areas that have been repaired shall be subject to 100 % NDT to the same standard as the original inspection. Welds repairs should not be carried more than twice in the same area without client approval.

7.6 Proof load testing

A load test by a competent person shall be applied to any handling points in accordance with LOLER, to prove the safety integrity prior to use. The load applied shall be determined in the design.

DPI (magnetic particle inspection (MPI) for the carbon steel only) shall be carried out on handling point welds after applying the test load. Defects found during post load test MPI shall be removed and subjected to a further proof test and MPI.

Load testing may also be specified to verify the integrity of load bearing attachments.

Records of tests shall be recorded on a certificate of thorough examination.

8. Assembly

8.1 Fitters

Personnel involved in the assembly and testing of equipment should have acquired the necessary competences to ensure the assembled part does not suffer damage during assembly and operates in the specified safe and reliable manner.

Personnel should be experienced in mechanical fitting and should be able to demonstrate the following competences where required:

- Ability to use calibrated measuring equipment, accurately read them, convert reading to report format and understand the importance of caring for the instruments.
- Experience and knowledge regarding the equipment being worked upon.

- Appreciation of the importance of defect finding and reporting.
- Ability to recognize and appreciate critical sealing areas.
- The ability to identify good and defective parts that cannot be measured.
- Be aware of the type of records retained, including quality plans, and the reasons for creating them.
- Ability to read engineering drawings in conjunction with bills of materials and assembly and test procedures.
- Understand the nature of pressure and function testing and be familiar with pressure recording and pressure measuring instruments.
- Understand the application of torque valves and the use of torque measuring equipment and wrenches.
- Understand the application of hydraulic systems/tube bending, swage fittings and cleanliness standards.
- Understand alignment requirements of couplings.

Fitters' work should be monitored and directed by experienced supervisory personnel.

8.2 Work environment and tools

Parts shall be stored and assembled in a clean environment. Fitting areas should be segregated from any shot blast, spray painting, fabrication or other activities that can create dust or particulate contamination (i.e. welding and grinding).

Torque wrenches, gauges and other tools that are used to verify the assembly meets specification shall be calibrated.

8.3 Assembly records

Motors, pumps, generators and coupling assemblies should be fitted together in accordance with the sub-component manufacturer's installation instructions. Parts requiring special alignment (couplings) should be verified by the manufacturer as part of their inspection, test records and inspection plans. Vibration measurements should be taken from gearboxes, motors and pumps at the factory testing stage to verify good alignment.

Special care should be taken on machined and coated surfaces to protect from damage. Damaged items should be reported and corrective actions agreed. Items that do not fit together should also be recorded on a non-conformance report (NCR) detailing actions taken to rectify damaged items. Records of non-conformances and deviations shall be compiled and inserted into the 'As Built' dossier.

8.4 Hydraulic fitting

Hydraulic systems shall be assembled in accordance with industry good practice, such as the following:

- Pipe ends shall be de-ragged using a deburring tool.
- Pipe bends shall be formed using the correct diameter and radius of forming tool.
- Hydraulic and air pipes shall be flushed clean prior to assembly.
- Swaged fittings shall be made up in accordance with manufacturer's instructions.
- The use of plumbers thread tape shall be prohibited. Threaded pressure containing fittings shall be sealed with an appropriate sealing compound.
- Piping should be fitted into place without any force being applied.
- A sample of hydraulic fluid shall be analysed for contamination after testing (see Appendix 1).

8.5 Piping systems

Piping systems shall be subject to NDT and pressure testing prior to assembly. The pipe work shall be flushed clean prior to assembly.

The following aspects of pipe fitting shall be considered:

- Piping should be fitted into place without any force being applied.
- Flange faces shall be undamaged and free from paint or dirt.
- Tightened stud bolts should have two threads showing through the nut.
- Flange bolt holes shall straddle centrelines.

8.6 Testing of pressure containing assemblies

During fluid filling operations, components need to be positioned to remove potential of air pockets. Parts and/or assemblies should then be vented to minimize air pockets.

Prior to pressure testing, the operator involved with activity shall ensure the following:

- No unauthorized personnel are within the confines of the test area.
- Hazard warnings are displayed to identify 'Pressure testing in progress'.
- Equipment is not subjected to shock loading such as hammer testing while on full over-pressure test.

- Until a reasonable time has elapsed, to not approach equipment subjected to maximum high pressure testing. Pressure in excess of 75 bar may be considered as high pressure.
- To avoid risk of freezing, test fluid temperature during test should not be less than 7 °C (45 °F).
- Care shall be taken not to overstress equipment during test. Test pressures shall be specified by the design engineer and agreed by all parties prior to commencement. No testing shall begin prior to the test specification being issued. The test procedure should specify test pressure, working pressure and test duration as a minimum.
- Hydro or gas tests shall be verified using a calibrated pressure gauge. The test engineer should record the items tested on the chart recording and sign off if test was acceptable to specification.
- Further hydro or gas testing shall be required in the event of additional welding to the pressure containing surface.
- Due to the danger of stored energy, gas testing shall not be carried out unless specified by the design engineer.
- Where gas testing is specified, additional pressure limiting and pressure relief devices shall be installed within any gas test equipment.
- Gas leaks should be detected by submersing in fluid or application of soap solution.

Hydro testing of hydraulic systems can be done with hydraulic fluid (provided appropriate precautions are taken).

9. Electrical installation

9.1 Work instructions

Electrical installation shall be carried out by a qualified technician or engineer in accordance with a set of drawings, charts or similar information related to the assembly, which has been designed by a competent and qualified professional.

9.2 Materials

Glands and enclosures shall meet the IP rating detailed on the design specification and will be suitable for the environment in which it will finally operate.

9.3 Inspection

The electrical installation should be assembled and inspected by qualified electrical engineers in accordance with the design specification and requirements of the latest edition of the IEE Regulations – BS 7671, which include the following:

- Deviations from the design shall be recorded and agreed by the competent and qualified professional.
- Records of deviations shall be inserted into the 'As Built' dossier.
- Completed equipment shall be inspected and recorded on an Electrical Installation certificate (see Appendix 2).
- Ingress protection checks may be requested by the client prior to connecting live power supply to the device.
- Testing of electronics and software in accordance with the design specification.

10. Surface coatings

10.1 Pre-blasting preparations

Before blasting, grind all rough welds, sharp steel edges, fillets and corners to a smooth, round contour finish, removing all weld splatter. All surfaces (100 %) shall be free from any foreign matter such as weld flux, residue, slivers, oil, grease, salt etc. prior to blast cleaning. Mask all areas not requiring blasting and/or coating. The blasting abrasive shall be dry, clean and free from contaminates that would be detrimental to the performance of the coating.

10.2 Paint requirements

Paint systems should be detailed on purchase order, specifications, drawing or other documentation. Contrasting colours shall be used for successive coats within a coating system, with the exception of stripe coats.

10.3 Paint application

The base coat shall be applied within four hours after blasting. A 'stripe coat' shall be applied, with the product specified for the second coat, by brush to all weld seams, bolts, corners, areas not fully reachable by spray and similar areas prior to the spray application of the second coat.

A coating shall not be applied when any of the following environmental conditions exist:

- The surfaces to be painted are damp or wet;
- The steel surface temperature is less than 5 °F (3 °C) above the dew point temperature;
- The relative humidity exceeds the paint specification.

The coatings shall be applied according to the coating manufacturer's application instructions and client specifications.

10.4 Repair and touch-up requirements

Edges of existing coating shall be feathered towards the substrate prior to coating. The coating manufacturer's application procedure may require unique procedures for repair and touch-up. Therefore, the coating manufacturer's procedure shall be followed.

10.5 Certification requirements

Written certification shall be provided for each lot of parts coated. It shall list the coating manufacturer, preparation method, coating used, batch number, expiration date of coating and DFT.

11. Factory and acceptance testing

As much factory/shore based testing as possible, reasonable, practicable and in agreement with client, should take place prior to shipping to site.

The full extent of the factory testing should be detailed on a test procedure and the methodology agreed by the client, manufacturer and IVB prior to commencement.

The client shall specify the performance levels required to demonstrate that the design and manufacture is acceptable.

Testing may include, but not be limited to:

- visual examination;
- pressure testing;
- leak testing;
- NDT;
- load testing;
- electrical continuity and performance testing;

- ingress protection/leak testing;
- fluid analysis;
- earthing checks;
- energizing of cylinders, motors, pumps, gearboxes and generators, where possible;
- conducting safety checks on brakes, couplings and isolation devices;
- vibration testing;
- friction and temperature testing of moving parts;
- system control and operational testing;
- strain gauging of highly stressed components under simulated load;
- extended cyclonic testing;
- mooring point load tests;
- mooring disconnect simulations;
- emergency simulations.

12. Certification

An 'As Built' dossier shall be compiled during the manufacturing stages. The contents of this document should be consistent to the requirements of the contract review (Table 1) and shall contain the minimum information where applicable:

- Certificate of Conformity.
- Inspection and test plan (see Appendix 3).
- IVB Certificate of Conformity/Release Note.
- Welding procedures, specifications and qualification records.
- Welder qualification records.
- Material traceability records.
- Material certification.
- Dimensional records and calibration.
- Load test certificates of thorough examination.
- Pressure test chart recordings.
- Heat treatment reports.
- Electrical continuity inspection report (see Appendix 2).

- Concessions and agreed deviation requests.
- NDT reports.
- Coating inspection reports.
- Hydraulic fluid analysis (see Appendix 1).
- Alignment checks and vibration readings on drive couplings.
- Factory acceptance testing results.

The 'As Built' dossier shall be copied to the owner who should retain it for the life of the device.

Appendix 1. Fluid Analysis Report – sample

FLUID ANALYSIS REPORT

Customer: _____ Part No: _____

Equipment: _____ Serial No: _____

Location: _____ Fluid: _____

Reference No: _____ Date: _____

Report Summary

Analysis Method Used

Results

Function	Ref No	Cycles	Class	Accepted

Comments

Acceptance

…… Date ……..
Manufacturer

…… Date ……..
Customer

…… Date ……..
Certifying Authority

Appendix 2. Electrical Installation Certificate – sample

ELECTRICAL INSTALLATION CERTIFICATE

ITEM DESCRIPTION: _____

PART NO: _____

SERIAL NO: _____

QUANTITY: _____

CUSTOMER NAME AND ADDRESS: _____

_____

MANUFACTURER: _____

CONSTRUCTOR/TESTER: _____

NEXT TEST DATE: _____

SUPPLY CHARACTERISTICS AND EARTHING ARRANGEMENTS	Earthing System	
	Live conductors	
	Normal Voltage	
	Frequency	
	PFC	
	Ze	
	Main Fuse	
PARTICULARS OF INSTALLATION		
COMMENTS ON EXISTING INSTALLATION		
SCHEDULES		
EARTH LOOP TEST		
INSULATION TEST		
RCD TEST		
IP TEST	PASS	
	FAIL	

Appendix 3. EMEC Manufacturing Standard

			ITP NO.		P.O. NO.	LEGEND: W = WITNESS R = REVIEW H = HOLD M = MONITOR			
SAMPLE INSPECTION AND TEST PLAN			REV NO.		Pages				
MANUFACTURER:		DESCRIPTION OF ITEM:				EQUIPMENT NO:			
TASK No and	Task Description	QUALITY CONTROL	CONTROLLING PROCEDURE	ACCEPTANCE CRITERIA	VERIFYING DOCUMENTS	INSPECTION REQUIREMENTS (W/H/R/SU)			Inspector Supervisor
PROBABLE						Manufacturer	Client	IVB	SIGNATURE
DATE		ACTIVITY	INSTRUCTION						
1	Review potential client requirements	Contract review		EMEC manufacturing standard	Minutes				
2	Material Register and verification of certification	Compile traceability		EMEC manufacturing standard					
3	Review of welding procedures	Welding to procedure		EMEC manufacturing standard	WPS				
4	Tack up fabrications	Monitor fabrication		Drawing and specification					
5	Welding and heat treatment	Welding to procedure	WPS	Drawing and specification	Weld log				
6	Visual inspection of fabrications	Visual		Drawing and specification	Inspection report				

7	NDT of welds as per specification	Non-destructive testing		Drawing and specification	Report				
8	Machining operations	Dimensional and visual inspections		Drawing and specification	Dimensional report				
9	Load testing of lifting attachments	Non-destructive testing		Drawing and specification	Report				
10	Hydro or gas testing pressure containing parts	Non-destructive testing		Drawing and specification	Chart record				
11	Surface coatings	Coating thickness Inspection		Drawing and specification	Coating report				
TASK No	Task Description	QUALITY CONTROL	CONTROLLING PROCEDURE	ACCEPTANCE CRITERIA	VERIFYING DOCUMENTS	INSPECTION REQUIREMENTS (W/H/R/SU)			Inspector Supervisor
PROBABLE DATE						Manufacturer	Client	PROBABLE	SIGNATURE
12	Assembly of components	Supervision		Drawing and specification	Assembly records				
13	Fluid analysis of hydraulic systems	Inspection		Drawing and specification	Appendix 1				
14	Electrical installation tests	Inspection		Drawing and specification	Appendix 2				
16	Leak testing of device	Inspection		Drawing and specification	Inspection report				
17	Function testing	Inspection		Drawing and specification	Inspection report				
18	Manufacturing dossier	Review certification		Drawing and specification	As build data				
19	Final inspection and release	Inspection		Drawing and specification	Release note				

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ASME V *Nondestructive examination*

ASME VIII *Boiler and pressure vessel code*

ASME IX *Welding and brasing qualifications*

ASME B31.3 *Process piping*

ASNT-TC-IA *Recommended practice for personnel carrying out non destructive testing*

AWS D1.1 *Welding code for structural steel*

BS EN ISO 9001 *Quality management systems*

BS EN 287 *All parts / Approval testing of welders for fusion*

BS EN 288 *All parts / Specification and approval of welding procedures for metallic materials*

BS EN 571 *Liquid penetrant inspection*

BS EN 10204 *Metallic products types of inspection documents*

BS EN 1290 *Magnetic particle examination of welds*

BS EN 1435 *Radiographic examination of welded joints*

BS EN 15614-1 *Specification and approval of welding procedures for metallic materials*

BS EN 1714 *Ultrasonic examination of welded joints*

BS 7671 *IEE Wiring Regulations*

Lifting Operations and Lifting Equipment Regulations 1998

NAS 1638 *Cleanliness requirements of parts used in hydraulic systems*

PCN – *Recommended practice for personnel carrying out non destructive testing*

PD CEN ISO/TR15608 *Guidance on steel grouping*

PD 5500 *Pressure vessels*