WAVE AND CURRENT ENERGY GENERATING DEVICES CRITERIA AND STANDARDS

June 2009

FINAL REPORT

Prepared by

PCCI, INC.
300 North Lee Street Suite 201
Alexandria, VA 22314

Prepared for

MINERALS MANAGEMENT SERVICE
Engineering & Research Branch
381 Elden Street
Herndon, VA 20170-4817

This study was funded by the Minerals Management Service, U. S. Department of the Interior, Washington, DC, under Contract No. M08PC20032.

Table of Contents

List of Abbreviations

ABS	American Bureau of Shipping
AEAU	Alternative Energy and Alternate Use
ANSI	American National Standards Institute
API	American Petroleum Institute
BMP	Best Management Practices
CFR	Code of Federal Regulations
CIRIA	(British) Construction Industry Research and Information Association
COP	Construction and Operations Plan
CVA	Certified Verification Agent
CWA	Clean Water Act
CZMA	Coastal Zone Management Act
DOI	Department of Interior
DNV	Det Norske Veritas
EIS	Environmental Impact Statement
EMEC	The European Marine Energy Centre Ltd.
EPRI	Electric Power Research Institute
FAA	Federal Aviation Administration
FERC	Federal Energy Regulatory Commission
GAP	General Activities Plan
HMRC	Hydraulic & Maritime Research Centre of the Ireland Marine Institute
IEA	International Energy Agency
IEC	International Electrotechnical Commission
MMS	Minerals Management Service
MOU	Memorandum of Understanding
NEPA	National Environmental Policy Act
NTL	Notice to Lessees and Operators
ROW	Right-Of-Way
RP	Recommended Practice
RUE	Rights-Of-Use and Easement
OCS	Outer Continental Shelf
OES	Ocean Energy Systems
QA	Quality Assurance
SAP	Site Assessment Plan
TC	Technical Committee
TEC	Tidal Energy Converter
UK	United Kingdom
USCG	US Coast Guard
WEC	Wave Energy Converter

WAVE AND CURRENT ENERGY GENERATING DEVICES
CRITERIA AND STANDARDS

1. BACKGROUND

The combination of an increasing energy market and depletion of natural gas and oil reserves in the U.S. has resulted in renewed interest in developing renewable sources of energy, including the conversion of ocean waves and currents into usable forms of energy. The ocean is an appealing source of renewable energy because of its high power density, meaning it can potentially produce large amounts of electricity. A 2007 report by the Electric Power Research Institute (EPRI) states that U.S. wave and current resources have the potential to meet 10% of the nation's electrical power demand.

Numerous applications have already been submitted to the Federal Energy Regulatory Commission (FERC) and Minerals Management Service (MMS) for the siting of devices to convert hydrokinetic energy from ocean currents and waves. Additional applications have been announced or are still under development. The marine hydrokinetic industry is in a nascent state and includes new technologies that must be evaluated to determine if current regulations are adequate to ensure safety of personnel and the environment.

Regulation of offshore hydrokinetic energy is shared by several federal, state and local authorities. Section 388 of the Energy Policy Act of 2005 amended the Outer Continental Shelf Lands Act to grant the Secretary of the U.S. Department of the Interior (DOI) discretionary authority to issue leases, easements, or rights-of-way (ROW) for activities on the Outer Continental Shelf that produce or support production, transportation, or transmission of energy from sources other than oil and gas. The Secretary delegated this authority to the Minerals Management Service, which has extensive experience in oil, gas and marine minerals (sand and gravel) offshore leasing. Examples of potential renewable energy projects include, but are not limited to: wind energy, wave energy, ocean current energy, solar energy, and hydrogen production. Under this new authority, MMS published final regulations in April 2009 intended to encourage orderly, safe, and environmentally responsible development of renewable energy resources and alternate use of facilities on the OCS. Also in April of 2009 a Memorandum of Understanding between DOI and FERC was signed which recognized that MMS has exclusive jurisdiction to issue leases, easements, and rights-of-way regarding OCS lands for hydrokinetic projects; and FERC has exclusive jurisdiction to issue licenses and exemptions for hydrokinetic projects located on the OCS.

Section 633 of the Energy Independence and Security Act of 2007 authorized a program of research, development, demonstration, and commercial application to expand marine and hydrokinetic renewable energy production, including a program to address standards development. The Act requires consultation with the Secretary of the Interior, and with other Federal agencies.

In February 2008 MMS issued a Broad Agency Announcement for Alternate Energy Research under its Technology Assessment and Research Program. Since MMS has specific responsibility under the Energy Policy Act it was necessary to undertake this study to assess the existing regulations and identify any gaps in the regulations.

2. TECHNOLOGY CONTEXT

In order to identify design, installation, and operational issues associated with wave and current energy generating devices, as well as applicable codes or standards, it was first necessary to describe the important characteristics of these devices and their major subsystems, and to catalogue the common and unique attributes of existing and proposed wave and current energy generating devices. Appendix A contains a functional taxonomy of generic types of wave and current energy generating devices organized into logical technology classifications based on physical function, resource, platform type and major subsystems. A glossary of terms accompanies the taxonomy. This taxonomy and glossary is used throughout this report to ensure consistent terminology and technology descriptions when identifying device hazards and applicable criteria.

Figures A-1 through A-3 are provided to illustrate some of the terms in the glossary. For detailed descriptions, drawings and photographs of individual wave and current energy generating devices, we recommend the reader peruse the U.S. Department of Energy's Marine and Hydrokinetic Technology Database located on the web at http://aspdev.optimle.com/eere/.

3. REGULATORY CONTEXT

A. Regulatory entities that have jurisdiction over wave and current energy generating devices on the outer continental shelf areas of the United States are as follows:
   - MMS (43 USC 1337 (p))
   - FERC
   - U.S. Army Corp of Engineers
   - U.S. Coast Guard
   - Coastal State Agencies responsible for Coastal Zone Management Act (CZMA), Clean Water Act (CWA), and National Historic Preservation Act provisions

B. MMS role in alternate energy regulation.

   The Minerals Management Service, as part of the U.S. Department of the Interior, was given authority to grant leases, easements, and rights of way for the development of promising new energy sources, such as offshore wave and current energy, and for ensuring that renewable energy development on the OCS proceeds in a safe and environmentally responsible manner, under Section 388 of the Energy Policy Act of 2005 (43 U.S.C. §1337(p) Leases, easements, or rights-of-way for energy and related purposes).

   MMS has developed a Renewable Energy and Alternate Use Program and has published final regulations to carry out its responsibility in 30 CFR Part 285, Renewable Energy and Alternate Uses of Existing Facilities on the Outer Continental

Shelf. MMS plans to publish a guidance document to support the regulations which will describe the type of information it is looking for in various plan submittals.

Part 285 makes it unlawful for any person to construct, operate, or maintain any facility to produce, transport, or support generation of electricity or other energy product derived from renewable energy resource on any part of the OCS except under and in accordance with the terms of a lease, easement or right-of-way issued pursuant to the OCS Lands Act (U.S.C. Title 43, Chapter 29, Subchapter III). Section 285.600 requires the submission of a Site Assessment Plan (SAP), Construction and Operations Plan (COP), or General Activities Plan (GAP) and receiving MMS approval of the plan(s) as set forth in that section.

- The SAP describes the activities (e.g., installation of metrological buoys or towers) the lessee plans to perform for the characterization of the commercial lease, including project easements, or to test technology devices. The SAP must describe how the lessee will conduct the resource assessment or technology testing activities. It must include data from physical characterization surveys (e.g., geological or geophysical surveys or hazard surveys); baseline environmental surveys (e.g., biological or archeological surveys); and for facilities deemed by MMS to be complex or significant, the SAP must include a Facility Design Report, a Fabrication and Installation Report, and a Safety Management System.
- The COP must describe the construction, operations, and conceptual decommissioning plans under the commercial lease, including the project easement, for all planned facilities, including onshore and support facilities. Paragraph 285.621 states that the COP must demonstrate that proposed activities "Use best available and safest technology" and "best management practices". The COP must contain information for each type of structure associated with the project and how the Certified Verification Agent (CVA) will be used to review and verify each stage of the project. The CVA is defined in Paragraph 285.112 as an individual or organization experienced in the design, fabrication, and installation of offshore marine facilities or structures, who will conduct specified third-party reviews, inspections and verifications. For all cables, including those on project easements, the COP must describe the location, design and installation methods, testing, maintenance, repair, safety devices, exterior corrosion protection, inspections, and decommissioning. Additional information requirements for the COP are detailed in paragraph 285.626.
- The GAP is a requirement for limited leases, ROW Grants and RUE Grants and must describe the proposed construction, activities, and conceptual decommissioning plans for all planned facilities, including testing of technology devices and onshore and support facilities to be constructed for the project, including any project easement for the assessment and development of the limited lease or grant. Its required content is similar to that for the SAP.

Paragraph 285.700 requires the submission of a Facility Design Report and a Fabrication and Installation Report before installing facilities described in an approved

COP, SAP or GAP. The Facility Design Report must include a location plat, detailed facility drawings, a complete set of structural drawings, a summary of the environmental data used for design, a summary of the engineering design data, a complete set of design calculations, copies of project-specific studies (e.g. oceanographic and soil survey reports), a description of loads imposed on the facility, a geotechnical report and certification statement. API RP-2A-WSD is incorporated by reference in Paragraph 285.115 which addresses inspections and assessments.

MMS also has published a Programmatic Environmental Impact Statement (EIS) for Alternative Energy Development and Production and Alternate Use of Facilities on the OCS (MMS 2007-046). This EIS examines the potential environmental consequences of implementing the MMS Renewable Energy and Alternate Use Program and will be used to establish initial measures to mitigate environmental consequences.

The MMS Record of Decision: Establishment of an OCS Alternative Energy and Alternate Use Program (December 2007) records the decision that the MMS reached to select the Preferred Alternative set forth in detail in the Final Programmatic EIS and establish the AEAU Program. The Record of Decision adopts initial Best Management Practices (BMPs) that were developed as mitigation measures in the Final Programmatic EIS. Among other requirements, the adopted BMPs include requirements for lessees and grantees to:

- develop a monitoring program to ensure that environmental conditions are monitored during construction, operation, and decommissioning phases.
- conduct seafloor surveys in the early phases of a project to ensure that the renewable energy project is sited appropriately and to avoid or minimize potential impacts associated with seafloor instability, other hazards, and to avoid locating facilities near known sensitive seafloor habitats
- take reasonable actions to minimize seabed disturbance during construction and installation of the facility and associated infrastructure, and during cable installation
- employ appropriate shielding for underwater cables to control the intensity of electromagnetic fields
- reduce the scouring action of ocean currents around foundations by taking all reasonable measures
- evaluate marine mammal use of the proposed project area and design the project to minimize and mitigate mortality or disturbance
- evaluate avian use of the project area and design the project to minimize or mitigate the potential for bird strikes, and reduce perching opportunities
- comply with Federal Aviation Administration (FAA) and US Coast Guard (USCG) requirements for lighting while using lighting technology that minimizes impacts to avian species
- avoid or minimize impacts to the commercial fishing industry by marking applicable structures with USCG approved measures to ensure safe vessel operation

- avoid or minimize impacts to the commercial fishing industry by burying cables, where practical, to avoid conflict with fishing vessels and gear operation; and inspect the cable burial depth periodically during project operation
- implement turbidity reduction measures to minimize effects to hard-bottom habitats, including seagrass communities and kelp beds, from construction activities
- place proper lighting and signage on applicable energy structures to aid navigation per USCG circular NVIC 07-02 (USCG 2007)
- conduct magnetometer tows using 30-m (100-ft) line spacing in areas where there is a high potential for shipwrecks

MMS also issues Notices to Lessees and Operators (NTL's) that supplement the regulations that govern operations on the OCS and provide clarification or interpretation of regulations and further guidance to lessees and operators in the conduct of safe and environmentally sound operations. There are two types of NTL's: those issued at the regional level pertinent just for the region and those issued nationally that are effective nationwide for all MMS regions. The NTL's can be found on the MMS web site at http://www.mms.gov. NTL's have been issued addressing:

- OCS inspection program
- OCS sediment resources
- synthetic mooring systems
- ocean current modeling
- incident and oil spill reporting
- vessel strike avoidance and injured / dead protected species reporting
- shallow hazards survey and report requirements
- biological survey and report requirements
- archaeological survey and report requirements
- decommissioning of facilities
- oil spill response plans
- warning signs for power cables
- military warning and water test areas
- procedures for the submission, inspection and selection of geophysical data and information collected under a permit as well as other topics

A Memorandum of Understanding (MOU) between MMS and FERC that clarifies the jurisdictional understanding regarding renewable energy projects in offshore waters on the OCS was signed on April 9, 2009. The MOU states that MMS has exclusive jurisdiction to issue leases, easements, and rights-of-way regarding OCS lands for hydrokinetic projects; and FERC has exclusive jurisdiction to issue licenses and exemptions for hydrokinetic projects located on the OCS. One of the unclear areas of jurisdiction is which agency has NEPA responsibilities. MMS will conduct any necessary environmental reviews, including those under the National Environmental Policy Act (NEPA), related to their leasing actions, and FERC may choose to become a cooperating agency for any OCS hydrokinetic project. However, the MOU also states that FERC will conduct any necessary analyses, including those under NEPA, related to the issuing of licenses. The MOU also states that FERC will not issue preliminary permits for hydrokinetic projects located on the OCS. FERC will not issue a license or exemption to an applicant for an OCS hydrokinetic project until the applicant has first obtained a lease, easement, or right-of-way from MMS for the site, and MMS will provide a provision in all leases, easements, or right-of-way for OCS hydrokinetic projects that states construction and operation of the project cannot commence without a license or exemption from FERC, except in circumstances where FERC has notified MMS that a license or exemption is not required.

The USCG and MMS have signed a number of MOUs and Memorandum of Agreement (MOAs) covering the joint or overlapping jurisdictions related to OCS facilities and activities. On 30 September 2004 an MOU was signed to act as a guide in promoting a joint response to future issues of overlapping jurisdiction, and could include renewable energy projects. It provided for the development and implementation of future MOAs developed under the guidelines of this MOU to provide specific guidance on each agency's role and shared responsibilities on the OCS. Subsequently the following MOAs were implemented:

- OCS-01, Agency Responsibilities, effective 9/30/04
- OCS-02, Civil Penalties, effective 9/12/06
- OCS-03, Oil Discharge Planning, Preparedness, and Response, effective 5/23/07
- OCS-04, Floating Offshore Facilities, effective 2/28/08

This last MOA provides an Offshore Facilities Systems/Sub-System Responsibility Matrix which lists the lead agency for responsible for system and sub-systems associates with floating OCS facilities.

The USCG is also in the process of negotiating a MOU with FERC addressing wave and current energy generating devices.

C. Device permitting requirements

MMS plan and information requirements for issuance of OCS leases and rights-of-way grants and start of construction or installation are contained in 30 CFR Part 285, Subpart F.

FERC permitting procedures for hydrokinetic projects are contained on their website at http://www.ferc.gov/industries/hydropower/indus-act/hydrokinetics.asp. In order to allow testing of new hydrokinetic technology devices FERC has developed expedited procedures for licensing hydrokinetic pilot projects which have a short (five year) licensing term. FERC anticipates that developers will then be able to transition from a pilot project license to a build-out license which will be handled as a relicensing of the pilot project and will entail a standard (30 to 50-year) licensing process including a NEPA review and full opportunity for participation by all stakeholders.

FERC has signed agreements with the State of Oregon, dated 3/26/08, and the State of Washington, dated week of 6/1/09, to coordinate their reviews of water power projects in state waters. The Oregon agreement specifically applies to wave energy projects while the Washington State agreement specifically applies to "hydrokinetic" projects, which draw on the movement of water from waves, tides, or currents. Under the MOUs, the two parties (FERC and the State) will notify each other when one becomes aware of a potential applicant for a preliminary permit, pilot project license, or commercial license. They will also agree on a schedule for processing any license applications, and they will coordinate the environmental reviews for the projects. The agreements also leave room for the State of Oregon to prepare a comprehensive plan on the siting of wave energy devices and for the State of Washington to prepare a comprehensive plan on the siting of hydrokinetic projects. In the agreements FERC commits to take the state plan into consideration when issuing a license for any hydrokinetic project.

It is common for the U.S. Army Corps of Engineers and the applicable state to have a Joint Permit Application for use in applying for permits for work in the waters of the United States within the applicable state. The applications are available from the Army Corp of Engineers Districts.

4. CRITERIA IDENTIFICATION

A. Device design criteria

Following is a list of criteria that should be included in any regulations for the design of ocean wave and current generating devices:

1. Platform
   i. Common to Floating and Fixed Systems
      - Site selection and hazards survey
      - Environmental data (met-ocean event definitions)
      - Geotechnical data
      - Loads to consider (O&M, environmental, transport, installation)
      - Hull integrity and stability
      - Structural analysis, allowable stresses and loads
      - Fatigue assessment
      - Corrosion control criteria
      - Access for operation and maintenance
   ii. Specific to Floating Systems
      - Structural analysis, allowable stresses and loads
      - Hull integrity and stability
      - Mooring System
   iii. Specific to Fixed Systems
      - Structural analysis, allowable stresses and loads
      - Foundation design

- Scour protection

2. Power Conversion Systems
    i. Rotor – nacelle assemblies
        - Basis of design
        - Loads to consider (actuation, hydrodynamic, shut down, transport, installation)
        - Machinery components
    ii. Displacer assemblies
        - Basis of design
        - Loads to consider (actuation, hydrodynamic, shut down, transport, installation)
        - Machinery components
    iii. Yaw Control Systems
        - Basis of design
        - Loads to consider (actuation, hydrodynamic, shut down, transport, installation)
        - Machinery components
    iv. Electrical Generators
    v. Power Conditioning / Substations
    vi. Riser / Power Collection / Transmission Cables
        - Cable route selection and survey requirements
        - Criteria for crossings (other cables, pipelines, anchorage areas, navigational channels)
        - Component / material standards
        - Riser design criteria
    vii. Auxiliary Systems
        - Supervisory control and data acquisition
        - Emergency safety systems
        - Piping systems (working fluids, lubricants, and water ballast system)

Appendix B compares the design requirements contained in the applicable codes and standards summarized in Table 1 against this list of design criteria which should be addressed in the regulations.

B. Device modeling and testing criteria

The scope of device modeling and testing standards should address the following subjects:

1. Types of testing and test programs
2. Physical small-scale model tests (in wave or towing tanks)
3. Open ocean prototype or large-scale model tests (in natural waters)

Appendix C compares the design requirements contained in the applicable codes and standards summarized in Table 1 against this list of design criteria which should be addressed in the regulations.

C. Device construction, transportation and installation criteria

The scope of device construction, transportation and installation criteria standards should address the following subjects:

1. Materials and components qualification or acceptance testing
2. Structural fabrication of platforms
3. Machinery and equipment installations in or on platforms
4. Transport and offshore installation

Appendix D compares the construction, transportation and installation requirements contained in the applicable codes and standards summarized in Table 1 against this list of design criteria which should be addressed in the regulations.

D. Device operations criteria

The scope of device operations criteria standards should address the following subjects:

1. Inspection, Planning and Scheduling
2. Platform
    i. Floating
    ii. Fixed
3. Mooring System
4. Power Conversion Systems
5. Riser / Power Collection / Transmission Cables
6. Auxiliary Systems

Appendix E compares the operations requirements contained in the applicable codes and standards summarized in Table 1 against this list of design criteria which should be addressed in the regulations.

E. Decommissioning Criteria

The decommissioning activities of wave and current energy generating devices will closely resemble the commissioning activities summarized in Section C. The criteria provided in Section C also apply to decommissioning.

Appendix F provides a guide for the use of this report by developers seeking to match their device to the identified criteria and existing information in published codes and standards.

5. CODES AND STANDARDS

A. Unlike other energy sectors, wave and current energy generation is in an early stage of development and there are no established industry consensus codes and standards. Existing practices being utilized by the offshore oil and gas industry, new guidelines developed by Classification Societies, and guidelines and standards being developed by the United Kingdom (UK) marine renewable energy conversion community all have some potential application to the development of regulations governing wave and current energy conversion devices. Efforts are currently underway by IEC Task Committee TC-114 to develop industry consensus standards for international acceptance.

Based on our review of existing codes and standards developed for the offshore oil industry, and new codes and standards being developed in Europe to specifically address these new technologies, we selected the following list of documents as those most applicable to the wave and current energy conversion industry:

- ABS – Guidance Notes on Review and Approval of Novel Concepts
- ABS – Guide for Risk Evaluations for the Classification of Marine-Related Facilities
- API RP 2A – Fixed Offshore Structures
- API RP 2I – Mooring Hardware Inspections
- API RP 2L – Heliports for Fixed Offshore Platforms
- API RP SK – Stationkeeping Systems for Floating Structures
- API RP 2SM – Synthetic Ropes for Offshore Mooring
- CIRIA C666 – Guidelines for the use of metocean data through the life cycle of marine renewable energy development
- DNV-OS-C301 – Stability and Watertight Integrity
- DNV-OS-C401 – Fabrication and Testing of Offshore Structures
- DNV-OS-D101 – Marine Machinery Systems and Equipment
- DNV-OSS-D201 – Electrical Installations
- DNV-OSS-312 – Certification of Tidal and Wave Energy Converters
- DNV-RP-A203 Qualification Procedures for New Technology
- DNV – Guideline for Wave Energy Converters
- EMEC – Assessment of Performance of Tidal Energy Conversion Systems
- EMEC – Assessment of Performance of Wave Energy Conversion Systems
- EMEC - Guidelines for Design Basis of Marine Energy Conversion Systems

- EMEC – Guidelines for Manufacturing, Assembly, and Testing of Marine Energy Conversion Systems
- EMEC – Guidelines for Marine Energy Converter Certification Schemes
- EMEC - Guidelines for Grid Connection of Marine Energy Conversion Systems
- EMEC – Guidelines for Health and Safety in the Marine Energy Industry
- EMEC – Guidelines on Reliability, Maintainability and Survivability of Marine Energy Conversion Systems
- EMEC – Guidelines for Project Development in the Marine Energy Industry (draft)
- EMEC –Tank Testing of Wave Energy Converters (scoping document)
- Germanisher Lloyd IV, 14, Part 1 – Ocean Current Turbines
- HMRC – Ocean Energy: Development and Evaluation Protocal
- IALA Recommendation O-131 – Marking of Offshore Wave and Tidal Energy Devices
- IEA OES Annex II – Development of Recommended Practices for Testing and Evaluating Ocean Energy Systems
- IEC 61400-3 Ed. 1.0 B:2009 – Design requirements for Offshore Wind Turbines
- IMCA AODC 35 – Code of Practice for the Safe Use of Electricity Under Water
- ISO 2394:1998 General Principals on Reliability of Structures

ABS Rules are widely used in the offshore shipping community, but are not as widely used by the offshore oil and gas industry in the U.S., which relies on the API Recommended Practices. Most of their Rules for offshore installations are duplicative to those contained in the API and DNV publications listed. For this reason, only the ABS guidance notes for novel concepts and risk evaluations have been included.

American Petroleum Institute Recommended Practices are already accepted by MMS and the offshore industry. The API RPs for electrical installations were not general enough for application in an environment where petroleum fumes were unlikely, so the more general DNV standards have been cited instead.

DNV offshore standards are widely used in the offshore design and installation community, and address basic subjects such as stability, watertight integrity, fabrication, and machinery, making them applicable to these new devices. DNV has also been proactive in developing guidelines that specifically address wave energy convertors.

EMEC has been at the forefront of the European effort to develop guidelines specifically addressing wave and current energy conversion development. We expect that many of their documents will become the basis for new IEC standard drafts.

GL, like DNV, has been proactive in developing Rules for the offshore renewable energy industry, with rules already published for offshore wind turbines and ocean current turbines.

International organizations, like IALA, IEA, IEC, IMCA and ISO have developed standards for international use. We have included those which are not duplicative of those by the organizations summarized above.

Table 1 provides a summary of these applicable practices, guidelines and standards in the following areas:

- Scope
- Coverage (design, materials, construction , maintenance, operation and decommissioning)
- Applicability
- Development and Organization of the document

6. EXISTING REGULATORY CRITERIA

There are no existing U.S. regulatory criteria governing wave and current energy devices. Table 2 compares our list of recommended design criteria in Section 4 with the requirements for submittals contained in MMS 285 and for FERC Pilot Plant licenses, currently the only existing regulations in the U.S. governing wave and current energy devices.

TABLE 1

SUMMARY OF APPLICABLE CODES AND STANDARDS

STANDARD	SCOPE	COVERAGE	APPLICABILITY	DEVELOPMENT AND ORGANIZATION
ABS 116 – Guidance Notes on Review and Approval of Novel Concepts	Guidelines suited to an application with a high degree of novelty; alternatives to ABS rule requirements suggested to use Guide for Risk Evaluations instead (see next entry). Includes several ways of defining new/novel concepts; provides a checklist to help identify them. Also includes description of novel concept approval process.	Design, Materials, and Maintenance	ABS is one of the three largest class societies; guidelines used domestically and internationally.	Published in June 2003; used to help develop natural gas carriers and offshore facilities among others. ABS commissioned by the US government and the USCG to act in many maritime matters that relate directly to the safety of life and property at sea.
ABS 117 – Guide for Risk Evaluations for the Classification of Marine-Related Facilities	Applicable to marine-related facilities with design characteristics that include alternative means of compliance to ABS classification rules. Includes a description of the risk evaluation process, and a detailed explanation of each step of the process. Also covers comparative versus absolute risk assessment.	Design	ABS is one of the three largest class societies; guidelines used domestically and internationally.	Published in June, 2003; used to help develop natural gas carriers and offshore facilities among others.
API RP 2A-WSD – Planning, Designing, and Constructing Fixed Offshore Structures – Working Stress Design	Contains engineering design principles and practices that have evolved during the development of offshore oil resources. Includes site selection, loading conditions, fatigue analysis, foundation design, and other factors. Also includes procedures for inspection and maintenance surveys.	Design, Materials, Construction, and Maintenance	Widely used in offshore oil and gas industry. Existing facilities can be converted to alternate uses such as renewable energy. Referenced in 30 CFR Part 250 Proposed Rule.	First published in October 1969. Many other editions followed; most recent errata and supplement published March 2008. Under jurisdiction of the API subcommittee on offshore structures.
API RP 2I – In-service Inspection of Mooring Hardware for Floating Structures	Includes procedures for planning, conducting, or supervising a mooring inspection. Also guidelines on whether to reject, repair, or replace mooring hardware. Specifically does not address tension factor of safety and fatigue, although some discussion is given to corrosion allowance	Maintenance	Widely used in offshore oil and gas industry. Mooring systems are required for many offshore structures; same practices can be applied to renewable energy facilities.	First published in May 1987. Third edition released April 2008. Under jurisdiction of the API subcommittee on offshore structures.

TABLE 1

SUMMARY OF APPLICABLE CODES AND STANDARDS (continued)

STANDARD	SCOPE	COVERAGE	APPLICABILITY	DEVELOPMENT AND ORGANIZATION
API RP 2L – Planning, Designing, and Constructing Heliports for Fixed Offshore Platforms	Includes operational consideration guidelines, design load criteria, heliport size and marking recommendations, and other heliport design recommendations.	Design, Materials, Construction, and Operations	Widely used in offshore oil and gas industry. Existing oil and gas facilities can be converted to alternate uses such as renewable energy.	Originally published in December 1978. Most recent edition was May 1996. Under jurisdiction of the API subcommittee on offshore structures.
API RP 2SK – Design and Analysis of Stationkeeping Systems for Floating Structures	Presents a rational method for analyzing, designing or evaluating mooring systems used with floating units. Provides a uniform analysis tool which, when combined with several factors, can be used to determine the adequacy and safety of the mooring system. Some design guidelines for dynamic positioning systems are also included.	Design and Analysis	Widely used in offshore oil and gas industry. Mooring systems are required for many offshore structures; same practices can be applied to renewable energy facilities.	First published June 1995. Updated May 2008. Under jurisdiction of the API subcommittee on offshore structures.
API RP 2SM – Recommended Practice for Design, Manufacture, Installation, and Maintenance of Synthetic Ropes for Offshore Mooring	Provides guidelines on the use of synthetic fiber ropes. Also highlights differences between synthetic rope and traditional steel mooring systems, and provides practical guidance on how to handle these differences during system design and installation.	Design, Materials, Construction, Installation, and Maintenance	Widely used in offshore oil and gas industry. Mooring systems are required for many offshore structures; same practices can be applied to renewable energy facilities.	Published March 2001, updated May 2007. Under jurisdiction of the API subcommittee on offshore structures.
CIRIA C666 - Guidelines for the use of metocean data through the life cycle of a marine renewable energy development	Developed to identify and recommend uses of metocean data. Includes a review of metocean data types, data sources and identifies the importance of good data management.	Design, Construction, Installation, Operations, Maintenance and Decommissionin g	CIRIA is a British construction industry research and information association. Applicable to both current and wave energy devices. Discussion of data sources not applicable to U.S.	Published 2008.
DNV-OS-C301 – Stability and Watertight	Gives requirements related to the following design parameters of offshore installations: buoyancy	Design	DNV is one of the three largest class societies; guidelines	Published in October 2008. Updated in April 2009.

TABLE 1

SUMMARY OF APPLICABLE CODES AND STANDARDS (continued)

STANDARD	SCOPE	COVERAGE	APPLICABILITY	DEVELOPMENT AND ORGANIZATION
Integrity	and floatability, wind exposed portions, draft range at various modes of service, watertight and weathertight closings of external openings, internal watertight integrity and watertight divisions, lightweight and loading conditions.		used internationally.	
DNV-OS-C401- Fabrication and Testing of Offshore Structures	Provides a standard to ensure quality of all welding operations used in offshore fabrication	Construction	DNV is one of the three largest class societies; guidelines used internationally.	The October 2008 version updates the April 2004 edition as amended in October 2007.
DNV-OS-D101 – Marine and Machinery Systems and Equipment	Provides principles, technical requirements, and guidance for the design, manufacturing and installation of marine and machinery systems and equipment for floating offshore installations.	Design, Construction, Installation,	DNV is one of the three largest class societies; guidelines used internationally.	Published in October 2008. Amends the previous October 2006 edition.
DNV-OS-D201 – Electrical Installations	Includes recommendations on electrical system design, equipment such as power transformers, semi-conductor converters, and cables, as well as installation guidelines. Also touches on certification procedures.	Design, Construction, Installation, Operations, and Maintenance	DNV is one of the three largest class societies; guidelines used internationally.	Published January 2008. Version updated in October 2008 but no actual changes.
DNV-OSS-312 – Certification of Tidal and Wave Energy Converters	Describes necessary certification procedures. Draws on the Guidelines on Design and Operation (see next entry) for much of its certification standards. Also includes requirements for manufacturers or other suppliers to be assigned certification, as well as the format for submitted documentation.	Design, Materials, Construction, Installation, Operations, and Maintenance	DNV is one of the three largest class societies; guidelines used internationally.	Published October 2008. Minor corrections and revisions to be published twice a year; none yet.
DNV – RP-A203 Qualification Procedures for New Technology	Provides a systematic approach to the qualification of new technology, ensuring that the technology functions reliably within the specified limits.	Design, Installation, Operations, and Maintenance	DNV is one of the three largest class societies; guidelines used internationally	Developed in 200 and 2001 in co-operation with industry partners as part of the Norwegian Research Council

TABLE 1

SUMMARY OF APPLICABLE CODES AND STANDARDS (continued)

STANDARD	SCOPE	COVERAGE	APPLICABILITY	DEVELOPMENT AND ORGANIZATION
	Applicable for components, equipment and assemblies offshore.			Program, DEMO 2000. Published in 2001.
DNV – Guidelines on Design and Operation of Wave Energy Converters	Provides guidance on applying existing codes and standards to wave energy conversion devices. Includes design advice on material selection, structural design, and mooring systems. Also contains considerations on safety, electrical and mechanical equipment, and instrumentation, as well as manufacturing requirements and operations suggestions.	Design, Materials, Construction, Installation, Operations, and Maintenance	DNV is one of the three largest class societies; guidelines used internationally.	Commissioned by the Carbon Trust during the 2004-2005 Marine Energy Challenge and published May 2005.
EMEC – Guidelines for Design Basis of Marine Energy Conversion Systems	Considers not only manufacturing, testing, operation and maintenance, but also transportation, installation, emergency situations, and decommissioning. Covers all subsystems of marine energy devices such as control and protection mechanisms, internal electrical systems, mechanical and hydraulic systems, and support structures.	Design, Materials, Construction, Installation, Operations, and Maintenance	Guidelines developed specifically for marine renewable energy in Britain, Europe, and internationally.	Published in January 2009 after being in development by EMEC since 2007. Scottish Government-backed research facility based in Stromness, Orkney; facilitates and coordinates the development of standards on behalf of the marine renewable energy industry.
EMEC – Guidelines for Marine Energy Converter Certification Schemes	Provides a set of standards certification boards should follow and developers should look for when attempting certification of a device. Includes deliverables from a developer such as a design assessment and survey reports, as well as the certificates rewarded, such as type and project certificates.	Design, Materials, Construction, Operations, and Maintenance	Guidelines developed specifically for marine renewable energy in Britain, Europe, and internationally. Draft submitted to the Certification Advisory Board for consideration.	Published in January 2009 after being in development by EMEC since 2007.
EMEC – Guidelines for Manufacturing, Assembly, and Testing of Marine Energy	Specifies requirements for factory-based testing of marine energy devices; possibly used as design verification of the device. Includes discussion of welding, safety, and evaluation of	Design, Materials, Installation, and Operations	Guidelines developed specifically for marine renewable energy in Britain, Europe, and	Published in January 2009 after being in development by EMEC since 2007.

TABLE 1

SUMMARY OF APPLICABLE CODES AND STANDARDS (continued)

STANDARD	SCOPE	COVERAGE	APPLICABILITY	DEVELOPMENT AND ORGANIZATION
Conversion Systems	materials. Describes several forms of testing, such as mechanical performance. Also includes a discussion of various surface coatings.		internationally. Draft has been submitted to IEC TC 114 for consideration.	
EMEC – Guidelines for Grid Connection of Marine Energy Conversion Systems	Defines the engineering and safety aspects of the electrical interface with the grid at marine energy sub-stations. Establishes responsibilities at the interface and procedures for compliance with power quality requirements. Also addresses specific issues with isolated and local grids.	Design, Operations, Maintenance	Guidelines developed specifically for marine renewable energy in Britain, Europe, and internationally. Draft has been submitted to IEC TC 114 for consideration.	Published in January 2009 after being in development by EMEC since 2007.
EMEC – Guidelines for Health and Safety in the Marine Energy Industry	Provides multiple steps to health and safety procedures, including policy, implementation, organization, risk identification, training, operational control, emergency preparedness and response, and performance monitoring. Also considers weather conditions and navigational planning.	Design, Installation, Operations, and Maintenance	Guidelines developed specifically for marine renewable energy in Britain, Europe, and internationally.	Published in October 2008 after being in development by EMEC since 2007.
EMEC – Guidelines for Reliability, Maintainability and Survivability of Marine Energy Conversion Systems	Furthers several important issues from the Design Basis and Health and Safety Guidelines (see previous entries). Discusses various technical and operational factors affecting RMS, how to achieve assurance requirements, and various ways to mitigate risk. Also includes methods of improving RMS.	Design and Operations	Guidelines developed specifically for marine renewable energy in Britain, Europe, and internationally.	Published in January 2009 after being in development by EMEC since 2007.
EMEC – Guidelines for Project Development in the Marine Energy Industry	Defines development checkpoints and identifies key responsibilities for marine energy projects. Includes a list of project stages such as development, installation, operation and maintenance, and decommissioning. Also discusses crucial steps in each stage such as	Design, Installation, Operations, and Maintenance	Guidelines developed specifically for marine renewable energy in Britain, Europe, and internationally.	Not yet published. A draft developed by the Halcrow Group for EMEC was issued July 2008.

TABLE 1

SUMMARY OF APPLICABLE CODES AND STANDARDS (continued)

STANDARD	SCOPE	COVERAGE	APPLICABILITY	DEVELOPMENT AND ORGANIZATION
	matching technologies with different sites, infrastructure and logistics, marine vessel capabilities, and security issues.			
EMEC – Assessment of Performance of Wave Energy Conversion Systems	Discusses considerations for measuring performance, such as test site, wave measurements, system power output, and meteorological measurements – all for open sea test sites. Also includes guidelines for reporting data.	Test Procedures	Guidelines developed specifically for marine renewable energy in Britain, Europe, and internationally. Draft has been submitted to IEC TC 114 for consideration.	Published in January 2009 after being in development by EMEC since 2007.
EMEC – Assessment of Performance of Tidal Energy Conversion Systems	Discusses considerations for measuring performance, such as test site, current measurements, and system power output. Also includes guidelines for reporting data.	Test Procedures	Guidelines developed specifically for marine renewable energy in Britain, Europe, and internationally. Draft has been submitted to IEC TC 114 for consideration.	Published in January 2009 after being in development by EMEC since 2007.
EMEC –Tank Testing of Wave Energy Converters	Provides guidelines to scale up results from tank testing. Includes wave tests as well as the appropriate use of regular and irregular seas. Also discusses test equipment, such as the prototype, the laboratory, and data acquisition hardware.	Design, Test Procedures	Guidelines developed specifically for marine renewable energy in Britain, Europe, and internationally.	Not yet published. A Scoping Document, V3 was released July 2007.
Germanischer Lloyd – Rules and Guidelines IV: Industrial Services Part 14 – Guideline for the Certification of	Provides basic rules for design and safety of ocean energy devices; specifically not a full design procedure and safety manual guideline. Following rules results in approval and certification. Includes procedures required for both Type Certification and Project	Design, Materials, Construction, Installation, Operations, and Maintenance	Germanischer Lloyd one of the top ranked class societies; guidelines used internationally.	Compiled in 2005; wind guidelines used as baseline last updated in 2007.

TABLE 1

SUMMARY OF APPLICABLE CODES AND STANDARDS (continued)

STANDARD	SCOPE	COVERAGE	APPLICABILITY	DEVELOPMENT AND ORGANIZATION
Ocean Energy Converters Part 1: Ocean Current Turbines (draft)	Certification. Certification procedure taken from Guideline for the Certification of Offshore Wind Turbines.			
HMRC – Ocean Energy: Development and Evaluation Protocol	Development and evaluation protocol specifically adapted for the advancement of wave energy devices.	Design, Test Procedures	The Protocol is restricted to buoyant type devices or those termed 2^{nd} Generation WECs up to prototype or pilot plant.	Published in 2003.
IALA Recommendation O-131 – Marking of Offshore Wave and Tidal Energy Devices	Guidelines intended for stakeholders such as national administrations, as well as energy contractors. Lists situations requiring navigation buoys, as well as the proper paint, top-marks, lights, etc. Also includes considerations during construction, such as radio navigational warnings, as well as advising contingency plans.	Construction, Operations, and Maintenance	Guidelines developed specifically for marking marine renewable energy conversion facilities.	Prepared June 2005. IALA, on-profit organization; coordinates improvements to visual aids to navigation throughout the world. The General Assembly of IALA meets about every 4 years; the Council of 20 members meets twice a year to oversee the ongoing programs.
IEA OES Annex II – Development of Recommended Practices for Testing and Evaluating Ocean Energy Systems	Recommended practices for testing and evaluating ocean energy systems to improve comparability of experimental results.	Test Procedures	The U.S. Department of Energy is a participating member.	Published in 2003. In 2006 the Executive Committee of IEA-OES agreed to extend the Annex to address prototypes. The extension of the work program was launched in 2007.
IEC 61400-3 Ed. 1.0 B:2009 - Design requirements for offshore wind turbines	Specifies requirements for assessment of external conditions at an offshore wind turbine site, and together with IEC 61400-1, specifies essential design requirements to ensure the engineering integrity of offshore wind turbines.	Design	Contains useful information and terminology that should be applicable to offshore current turbines.	Published 2009. Earlier committee draft circulated on 1/13/06 for comment. Available from ANSI.

TABLE 1

SUMMARY OF APPLICABLE CODES AND STANDARDS (continued)

STANDARD	SCOPE	COVERAGE	APPLICABILITY	DEVELOPMENT AND ORGANIZATION
IMCA AODC 35 – Code of Practice for the Safe Use of Electricity Under Water	Discusses various applications of electricity under water and the hazards arising from each, e.g. electric shock, hot surfaces, or electric arcs. Also includes recommendations for the selection, installation and maintenance of safety apparatus. Specifically notes outlined measures may not be adequate for surface crew.	Design, Installation, and Operations	International standard; can apply to any operation requiring underwater use of electricity	Published January 1985 AODC was merged into IMCA, an international trade association representing offshore, marine and underwater engineering companies.
ISO 2394:1998 General Principals on Reliability of Structures	Specifies general principals for verification of the reliability of structures subjected to known or foreseeable types of forces.	Design, Installation, Operations, and Maintenance	International standard intended to serve as a basis for national standards.	Second edition published in 1998 replaced the first edition from 1996.

TABLE 2

OCEAN ENERGY DEVICE GUIDELINES
COMPARISON OF RECOMMENDED DESIGN CRITERIA WITH MMS 285 AND FERC LICENSE SUBMITTAL REQUIREMENTS

CRITERIA	MMS 285	FERC Pilot Project Criteria
Platform		
Floating Systems		
Site selection and hazards survey requirements	Required in the SAP, COP, and GAP	Not addressed.
Environmental data requirements (metocean event definitions)	Required in the Facility Design Report.	Required by application §5.18(b)(1)
Geotechnical data recommendations	Results from survey with supporting data required in the SAP, COP and GAP.	Required by application §5.6(d)(3)(ii)

TABLE 2

OCEAN ENERGY DEVICE GUIDELINES
COMPARISON OF RECOMMENDED DESIGN CRITERIA WITH MMS 285 AND FERC LICENSE SUBMITTAL REQUIREMENTS (continued)

CRITERIA	MMS 285	FERC Pilot Project Criteria
Loads to consider (O&M, environmental, transport, installation)	Required in the Facility Design Report.	Not addressed.
Hull stability requirements	Design must meet the requirements of the U.S. Coast Guard.	Not addressed.
Structural analysis, allowable stresses, and loads	Required in the Facility Design Report.	Not addressed.
Fatigue assessment	Required in the Facility Design Report.	Not addressed.
Corrosion control criteria	Not addressed.	Not addressed.
Access for operation and maintenance	Required in the Facility Design Report.	Not addressed.
Mooring system	Required in the Facility Design Report.	Required by application §5.18(b)(4)(ii)
Unique to Fixed Systems		
Foundation design	Required in the Facility Design Report..	Not addressed
Scour protection	Not addressed.	Not addressed
Power Conversion Systems		
Rotor / Nacelle Assemblies	Not addressed.	Not addressed
Displacer Systems	Not addressed.	Not addressed
Yaw Control Systems	Not addressed.	Not addressed
Electrical Generators	Not addressed.	Not addressed
Power Conditioning / substations	Not addressed.	Not addressed
Riser / Power Collection / Transmission Cables		Required by application §5.18(b)(4)(ii)

TABLE 2

OCEAN ENERGY DEVICE GUIDELINES
COMPARISON OF RECOMMENDED DESIGN CRITERIA WITH MMS 285 AND FERC LICENSE SUBMITTAL REQUIREMENTS (continued)

CRITERIA	MMS 285	FERC Pilot Project Criteria
Cable route selection and survey requirements	Required in the GAP.	Not addressed
Criteria for crossings (other cables, pipelines, anchorage areas, navigational channels)	Not addressed except in 285.816 which requires a plan of corrective action	Not addressed
Component / material standards	Required in the GAP.	Not addressed
Riser design criteria	Required in the GAP.	Not addressed
Auxiliary Systems		
Subsea equipment considerations	Not specifically addressed. Could be covered by the Facility Design Report	Not addressed
Supervisory control and data acquisition (SCADA)	Required as part of Safety Management System with SAP, COP or GAP.	Could possibly be included in the General Project Facility and Operations Monitoring articles, though they seem to be exclusively concerned with the monitoring of effects of the devices on the environment.
Emergency safety systems	Required as part of Safety Management System with SAP, COP or GAP.	Presumable part of the required Project Safety Plan.
Piping systems (working fluids, lubricants, and ballast water)	Not addressed.	Not addressed

7. REGULATORY GAP ANALYSIS

A. Gap Identification

Existing regulations do not specify requirement for the various criteria. As an example, the regulations do not state what return period the wave and current energy generating devices should be designed for, only that loading information must be submitted. The MMS regulations rely on the use of a CVA to certify that the design of the structure is "in accordance with accepted engineering practices."

B. Gap Analysis

This gap analysis was undertaken to suggest which existing standards may be best used to inform the development of any new regulations or to inform the ongoing development of IEC TC-114. Of the 31 different standards summarize in the tables of Appendices B through E, only a handful provide substantive guidance on any given criterion, and many either do not address a particular criterion or provide no substantive guidance beyond stating that the criterion should be addressed.

The following list of criteria indicates the most relevant existing standard(s) for each criterion. Relevant existing standards are labeled either P for "primary" or S for "secondary." Primary standards should be the first consulted and used for a given criterion. Secondary standards provide supplemental information not addressed in the primary standard. The designation S_W refers to secondary standards directed solely towards wave energy devices or projects, and the designation S_C refers to secondary standards directed solely towards submerged current turbines or projects.

The entries for each standard across a particular criterion are entered in the tables of Appendices B through E, and these should be consulted to locate the appropriate chapter or section in a recommended primary or secondary standard.

DEVICE DESIGN CRITERIA

1. Platform

   i. Common to Floating and Fixed Systems

      - Site selection and hazards survey
        P: DNV-OSS-312
        S: EMEC Project Development

      - Environmental data (met-ocean event definitions)
        P: API RP 2A-WSD
        EMEC Design Basis
        S_W: DNV Wave Energy Converter Design
        EMEC Performance of Wave Energy
        S_C: GL Ocean Current Turbines
        EMEC Performance of Tidal Energy

- Geotechnical data
  P: EMEC Design Basis
  IEC 61400
  S: EMEC Project Development

- Loads to consider (O&M, environmental, transport, installation)
  P: ABS 116
  API RP2A-WSD
  EMEC Design Basis
  S: DNV OS-D201
  EMEC Health and Safety

- Fatigue assessment (of hull or platform structure; moorings covered under ii)
  P: IEA OES Annex II
  ISO 2394:1998
  S: DNV Wave Energy Converter Design

- Corrosion control (for hull or platform structure; moorings covered under ii)
  P: DNV Wave Energy Converter Design
  IEC 61400
  S: DNV-OS-D201

- Access for operation and maintenance
  P: EMEC Health and Safety
  S: ABS 116
  CIRIA C666
  DNV Wave Energy Converter Design
  DNV-OS-C301
  GL Ocean Current Turbines

ii. Specific to Floating Systems

- Structural analysis, allowable stresses and loads
  P: GL Ocean Current Turbines
  ISO 2394:1998
  S: DNV-OS-D201
  EMEC Design Basis
  EMEC Certification Schemes

- Hull integrity and stability
  P: DNV-OS-C301
  S: DNV-OS-D201
  EMEC Design Basis
  EMEC Health and Safety
  GL Ocean Current Turbines

- Mooring System
  P: API RP 2SK
  API RP 2SM

S: DNV Wave Energy Converter Design
DNV-OS-312
EMEC Design Basis
EMEC Health and Safety
GL Ocean Current Turbines (cites GL Offshore Wind Turbines)

iii. Specific to Fixed Systems

- Structural analysis, allowable stresses and loads
  P: API RP 2A-WSD
  GL Ocean Current Turbines (cites GL Offshore Wind Turbines)
  ISO 2394:1998
  S: API RP 2L (for heliports on fixed platforms such as offshore substations)

- Foundation design
  P: API RP 2A-WSD
  DNV Wave Energy Converter Design
  EMEC Design Basis
  GL Ocean Current Turbines (cites GL Offshore Wind Turbines)

- Scour protection
  P: GL Ocean Current Turbines (cites GL Offshore Wind Turbines)
  S: EMEC Design Basis

2. Power Conversion Systems

i. Rotor–nacelle assemblies (including blade pitch control and nacelle yaw control)

- Basis of design
  P: GL Ocean Current Turbines (cites GL Offshore Wind Turbines)
  IEC 61400
  S: DNVOS-D201
  EMEC Design Basis

- Loads to consider
  P: GL Ocean Current Turbines
  IEC 61400
  S: DNVOS-D201
  EMEC Design Basis
  DNV Wave Energy Converter Design

- Machinery components
  P: GL Ocean Current Turbines
  IEC 61400
  S: EMEC Design Basis

ii. Displacer assemblies

- Basis of design
  P: DNV Wave Energy Converter
  IEA OES Annex II
  S: DNV-RP-A203

- Loads to consider
  P: DNV Wave Energy Converter
  IEA OES Annex II
  S: IEC 61400

- Machinery components
  P: DNV Wave Energy Converter Design
  S: EMEC Design Basis

iii. Electrical Generators
  P: DNV Wave Energy Converter Design (cites IEC 60034)
  GL Ocean Current Turbines (cites GL Offshore Wind Turbines)
  S: IMCA AODC 35

iv. Power Conditioning and Substation Equipment (transformers, switchgear)
  P: DNV-OS-D201
  IEC 61400 (cites IEC 61400-21 as comprehensive power quality standard)
  S: EMEC Grid Connection
  DNV Wave Energy Converter Design
  GL Ocean Current Turbines
  IMCA AODC 35

v. Electrical Riser, Power Collection, and Transmission Cables

- Cable route selection and survey
  P: EMEC Project Development
  S: EMEC Design Basis

- Components and materials
  P: IMCA AODC 35
  S: EMEC Design Basis
  GL Ocean Current Turbines (cites GL Offshore Wind Turbines)

- Riser cable design criteria
  P: EMEC Design Basis
  IMCA AODC 35
  S: DNV Wave Energy Converter Design

vi. Auxiliary Systems

- Supervisory control and data acquisition (SCADA) systems
  P: DNV Wave Energy Converter Design
  GL Ocean Current Turbines (cites GL Offshore Wind Turbines)
  S: DNV-OS-D201
  IMCA AODC 35
  EMEC Grid Connection
  EMEC Performance of Wave Energy
  EMEC Performance of Current Energy
  IEC 61400
  API RP 2SK

- Emergency and safety systems
  P: EMEC Health and Safety
  EMEC Certification Schemes
  IALA O-131 (navigational hazard marking)
  S: DNV-OS-D201
  DNV-OSS-312

- Piping systems
  P: DNV-OS-D101
  S: DNV-OS-D201
  EMEC Health and Safety

DEVICE MODELING AND TESTING

1. Types of testing and test programs
   P: EMEC Reliability, Maintainability, and Survivability
   S: DNV-OSS-312
   DNV- RP-A203

2. Physical small-scale model tests (in wave or towing tanks)
   P: IEA OES Annex II
   HMRC Part 1: Wave Power
   S: API RP 2SK (modeling mooring system behavior)
   S_W: DNV Wave Energy Converter Design
   EMEC Wave Energy Tank Testing

3. Open ocean prototype or large-scale model tests (in natural waters)
   P: HMRC Part 1: Wave Power
   EMEC Performance of Wave Energy
   EMEC Performance of Tidal Energy
   S: IEA OES Annex II

DEVICE CONSTRUCTION, TRANSPORT, AND INSTALLATION

1. Materials and components qualification or acceptance testing
   P: ISO 2394: 1998 (testing of structural materials)
   API RP 2SM (testing of synthetic mooring ropes)
   DNV-OS-D201 (testing of electrical equipment and cables)

2. Structural fabrication of platforms
   P: API RP 2A-WSD
   DNV-OS-C401
   EMEC Manufacturing
3. Machinery and equipment installations in or on platforms
   P: ABS 116
   S: DNV-OS-D101 (piping)
   DNV-OS-D201 (electrical equipment and cables)

4. Transport and offshore installation
    - P: EMEC Design Basis
      DNV Wave Energy Converter Design
      GL Ocean Current Turbines
    - S: CIRIA C666 (metocean conditions for offshore work)
      EMEC Health and Safety (personnel safety during offshore work)
      API RP 2SM (handling, installation, recovery of synthetic ropes)

DEVICE OPERATION, INSPECTION, MAINTENANCE, AND REPAIR

1. Inspection planning and scheduling
    - P: EMEC Certification Schemes
      DNV-OSS-312
    - S: CIRIA C666 (metocean considerations)
      EMEC Project Development
      ISO 2394: 1998 (structural reliability assessments)

2. Platform

    i. Floating
      - P: No substantial primary guidance found in existing standards

    ii. Fixed
      - P: API RP 2A-WSD

3. Mooring Systems
    - P: API RP 2I
    - S: API RP 2SM (synthetic mooring ropes)

4. Power Conversion Systems
    - P: IEC 61400
    - S: GL Ocean Current Turbines (cites GL Offshore Wind Turbines)

5. Electrical Riser, Power Collection, and Transmission Cables
    - P: No substantial primary guidance found in existing standards

6. Auxiliary Systems
    - P: No substantial primary guidance found in existing standards

As noted above, substantive guidance for operation, inspection, maintenance, and repair activities is largely lacking for floating platforms (e.g. wave energy absorbers, submerged current turbine nacelles), electrical cables, and auxiliary systems.

While there is indeed considerable guidance for periodic and special surveys after construction of classed (or type certified) offshore buoys, installations, and vessels, these requirements are specific to the classification organization such as ABS, DNV, or GL. It is anticipated that detailed survey requirements will be developed and modified based on long-term operational experience across tens to hundreds of floating platforms.

8. RECOMMENDED REGULATORY INITIATIVES

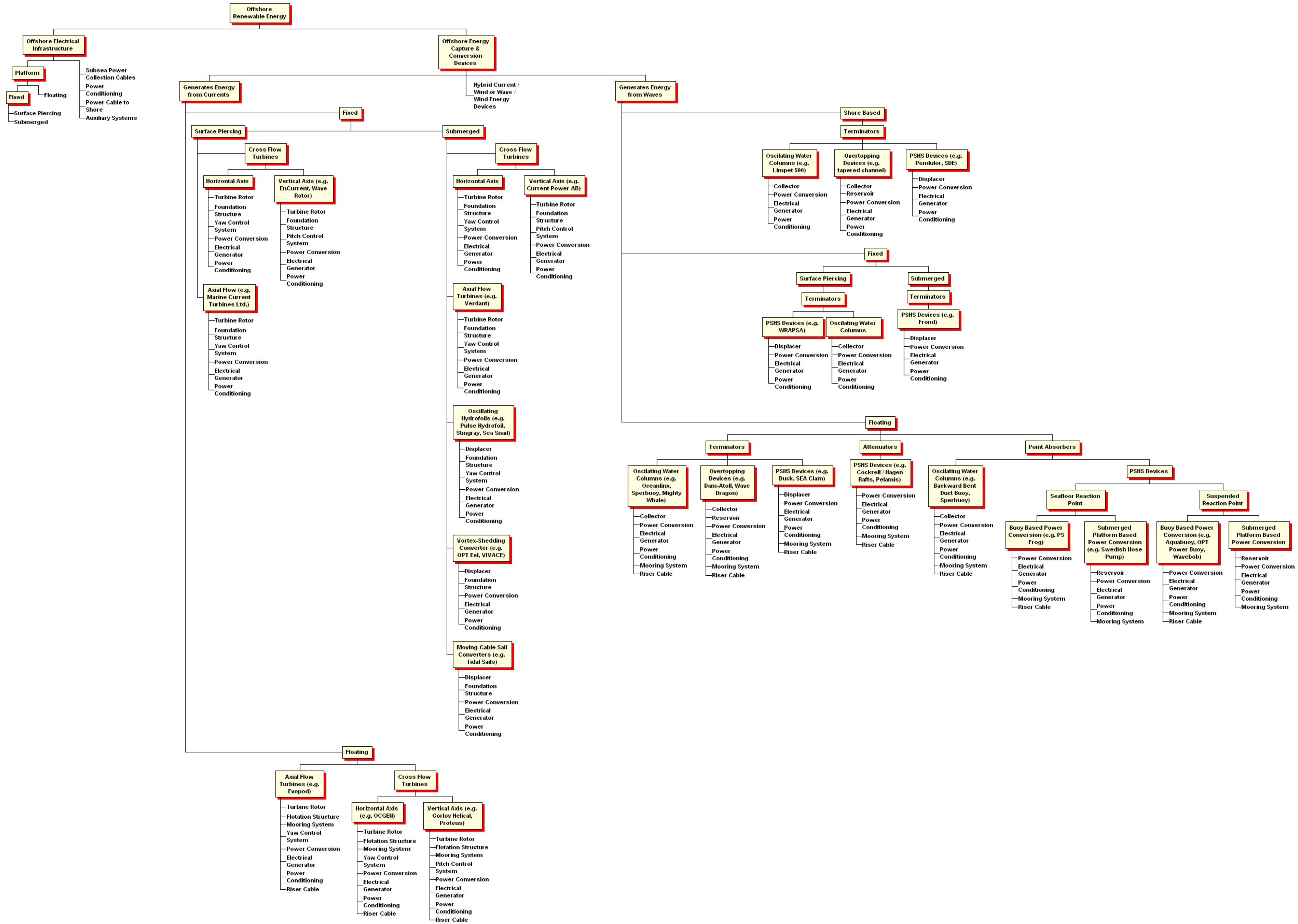
MMS is a participant in the IEC TC-114 effort to prepare a new technical specification governing design requirements for marine energy systems. Our review of the draft of the U.S. Proposal (ver 5.0) submitted to IEC in April 2009, indicates that document will address most of the items not currently addressed by MMS in 30 CFR Part 285. The one area not being covered by the proposed technical specification is access for operation and maintenance where it was recommended the technical specification be used in conjunction with the appropriate IEC and ISO standards (to be identified). We recommend that MMS not add missing criteria to existing regulations until the TC-114 effort is complete to ensure consistency with international regulations.

We anticipate that only single units for testing will be deployed before the IEC TC-114 effort is complete. In the interim, the tables provided in the Appendixes to this report can be used as a checklist to ensure the device meets current industry criteria and guidance.

This page intentionally left blank.

Appendix A – Ocean Energy Taxonomy, Glossary and Drawings

This page intentionally left blank.



Offshore Renewable Energy
Offshore Electrical Infrastructure
Platform
Fixed
Floating
Surface Piercing
Submerged
Subsea Power Collection Cables
Power Conditioning
Power Cable to Shore
Auxiliary Systems
Offshore Energy Capture & Conversion Devices
Generates Energy from Currents
Hybrid Current / Wind or Wave / Wind Energy Devices
Generates Energy from Waves
Fixed
Surface Piercing
Submerged
Cross Flow Turbines
Horizontal Axis
Turbine Rotor
Foundation Structure
Yaw Control System
Power Conversion
Electrical Generator
Power Conditioning
Vertical Axis (e.g. EnCurrent, Wave Rotor)
Turbine Rotor
Foundation Structure
Pitch Control System
Power Conversion
Electrical Generator
Power Conditioning
Axial Flow (e.g. Marine Current Turbines Ltd.)
Turbine Rotor
Foundation Structure
Yaw Control System
Power Conversion
Electrical Generator
Power Conditioning
Cross Flow Turbines
Horizontal Axis
Turbine Rotor
Foundation Structure
Yaw Control System
Power Conversion
Electrical Generator
Power Conditioning
Vertical Axis (e.g. Current Power AB)
Turbine Rotor
Foundation Structure
Pitch Control System
Power Conversion
Electrical Generator
Power Conditioning
Axial Flow Turbines (e.g. Verdant)
Turbine Rotor
Foundation Structure
Yaw Control System
Power Conversion
Electrical Generator
Power Conditioning
Oscillating Hydrofoils (e.g. Pulse Hydrofoil, Stingray, Sea Snail)
Displacer
Foundation Structure
Yaw Control System
Power Conversion
Electrical Generator
Power Conditioning
Vortex-Shedding Converter (e.g. OPT Eel, VIVACE)
Displacer
Foundation Structure
Power Conversion
Electrical Generator
Power Conditioning
Moving-Cable Sail Converters (e.g. Tidal Sails)
Displacer
Foundation Structure
Power Conversion
Electrical Generator
Power Conditioning
Floating
Axial Flow Turbines (e.g. Evopod)
Turbine Rotor
Flotation Structure
Mooring System
Yaw Control System
Power Conversion
Electrical Generator
Power Conditioning
Riser Cable
Cross Flow Turbines
Horizontal Axis (e.g. OCGEN)
Turbine Rotor
Flotation Structure
Mooring System
Yaw Control System
Power Conversion
Electrical Generator
Power Conditioning
Riser Cable
Vertical Axis (e.g. Gorlov Helical, Proteus)
Turbine Rotor
Flotation Structure
Mooring System
Pitch Control System
Power Conversion
Electrical Generator
Power Conditioning
Riser Cable
Shore Based
Terminators
Oscilating Water Columns (e.g. Limpet 500)
Collector
Power Conversion
Electrical Generator
Power Conditioning
Overtopping Devices (e.g. tapered channel)
Collector
Reservoir
Power Conversion
Electrical Generator
Power Conditioning
PSHS Devices (e.g. Pendulor, SDE)
Displacer
Power Conversion
Electrical Generator
Power Conditioning
Fixed
Surface Piercing
Terminators
PSHS Devices (e.g. WRAPSA)
Displacer
Power Conversion
Electrical Generator
Power Conditioning
Oscilating Water Columns
Collector
Power Conversion
Electrical Generator
Power Conditioning
Submerged
Terminators
PSHS Devices (e.g. Frond)
Displacer
Power Conversion
Electrical Generator
Power Conditioning
Floating
Terminators
Oscilating Water Columns (e.g. Oceanlinx, Sperbuoy, Mighty Whale)
Collector
Power Conversion
Electrical Generator
Power Conditioning
Mooring System
Riser Cable
Overtopping Devices (e.g. Dam-Atoll, Wave Dragon)
Collector
Reservoir
Power Conversion
Electrical Generator
Power Conditioning
Mooring System
Riser Cable
PSHS Devices (e.g. Duck, SEA Clam)
Displacer
Power Conversion
Electrical Generator
Power Conditioning
Mooring System
Riser Cable
Attenuators
PSHS Devices (e.g. Cockrell / Hagen Rafts, Pelamis)
Power Conversion
Electrical Generator
Power Conditioning
Mooring System
Riser Cable
Point Absorbers
Oscilating Water Columns (e.g. Backward Bent Duct Buoy, Sperbuoy)
Collector
Power Conversion
Electrical Generator
Power Conditioning
Mooring System
Riser Cable
PSHS Devices
Seafloor Reaction Point
Buoy Based Power Conversion (e.g. PS Frog)
Power Conversion
Electrical Generator
Power Conditioning
Mooring System
Riser Cable
Submerged Platform Based Power Conversion (e.g. Swedish Hose Pump)
Reservoir
Power Conversion
Electrical Generator
Power Conditioning
Mooring System
Suspended Reaction Point
Buoy Based Power Conversion (e.g. Aquabuoy, OPT Power Buoy, Wavebob)
Power Conversion
Electrical Generator
Power Conditioning
Mooring System
Riser Cable
Submerged Platform Based Power Conversion
Reservoir
Power Conversion
Electrical Generator
Power Conditioning
Mooring System

This page intentionally left blank.

Glossary

Attenuator - wave energy capture device with principal axis oriented parallel to the direction of the incoming wave and converts the energy due to the relative motion of the parts of the device as the wave passes along it

Axial Flow Turbine – subset of horizontal turbines used for low head and relatively high flow rate; suitable for tidal energy barrages or wave energy converters using overtopping

Buoy Based Power Conversion - power conversion system located in the actual PSHS device/buoy

Collector - structure that focuses or funnels waves into the power conversion system

Displacer – part of a wave energy device that moves in response to the waves; mechanical energy is extracted from the relative motion of the displacer relative to its fixed reference

Electrical Generator – device that takes the energy from the power conversion system and turns it into electricity

Floating - offshore energy capture and conversion device supported by buoyant members free to move on the surface of the ocean

Fixed - offshore energy capture and conversion device supported by a concrete caisson or steel platform with piles attached directly onto the seafloor

Mooring System - system of mooring cables, chain, fittings, lines and anchors that restrain a floating platform against the action of wind, wave and current forces

Oscillating Hydrofoil - similar to an aeroplane wing but in water; yaw control systems adjusts their angle relative to the water stream, creating lift and drag forces that cause device oscillation; mechanical energy from this oscillation feeds into a power conversion system

Oscillating Water Column - partially submerged structure that encloses a column of air above a column of water; a collector funnels waves into the structure below the waterline, causing the water column to rise and fall; this alternately pressurizes and depressurizes the air column, pushing or pulling it through a turbine

Overtopping Device - partially submerged structure; a collector funnels waves over the top of the structure into a reservoir; water runs back out to the sea from this reservoir through a turbine

Pitch Control System – when applied to horizontal axial flow turbines, adjusts the angle of a rotor blade relative to the rotor’s plane of rotation

Point Absorber - wave energy capture device with principal dimension relatively small compared to the wave length and able to capture energy from a wave front greater than the physical dimension of the device

Power Cable to Shore – electrical transmission cable connecting multiple subsea power collection cables to a shore-based power grid

Power Conditioning - one or more devices that adjust the voltage output of the electrical generator to whatever is appropriate to local loads; also helps to smooth out the differences in output between periods of high and low wave activity

Power Conversion – system to convert current or wave energy and transfer it through mechanical, hydraulic, pneumatic or electro-magnetic devices into a form suitable for input to the electrical generator

PSHS Device - Pitching/Surging/Heaving/Sway device; any of several devices that capture wave energy directly without a collector by using relative motion between a float/flap/membrane and a fixed reaction point

Reservoir – structure to store excess air or water not currently usable by the power conversion system; helps to smooth out the differences in output between periods of high and low wave activity; could be considered a form of mechanical power conditioning

Riser Cable – electrical transmission cable suspended between a floating platform and the seafloor where it terminates into a subsea power collection cable

Seafloor Reaction Point - using the seafloor, or rather an anchor imbedded in it, as a fixed reaction point for a PSHS device

Shore Based – an energy capture and conversion device located on, or attached to, the shore rather than on a platform located offshore

Submerged Platform Based Power Conversion - power conversion system located in a submerged platform or habitat

Subsea Power Collection Cable – electrical transmission cable connects one or more riser cables or a fixed platform to a single power cable to shore

Surface Piercing - fixed offshore platform that has all or part of its structure above the surface of the water

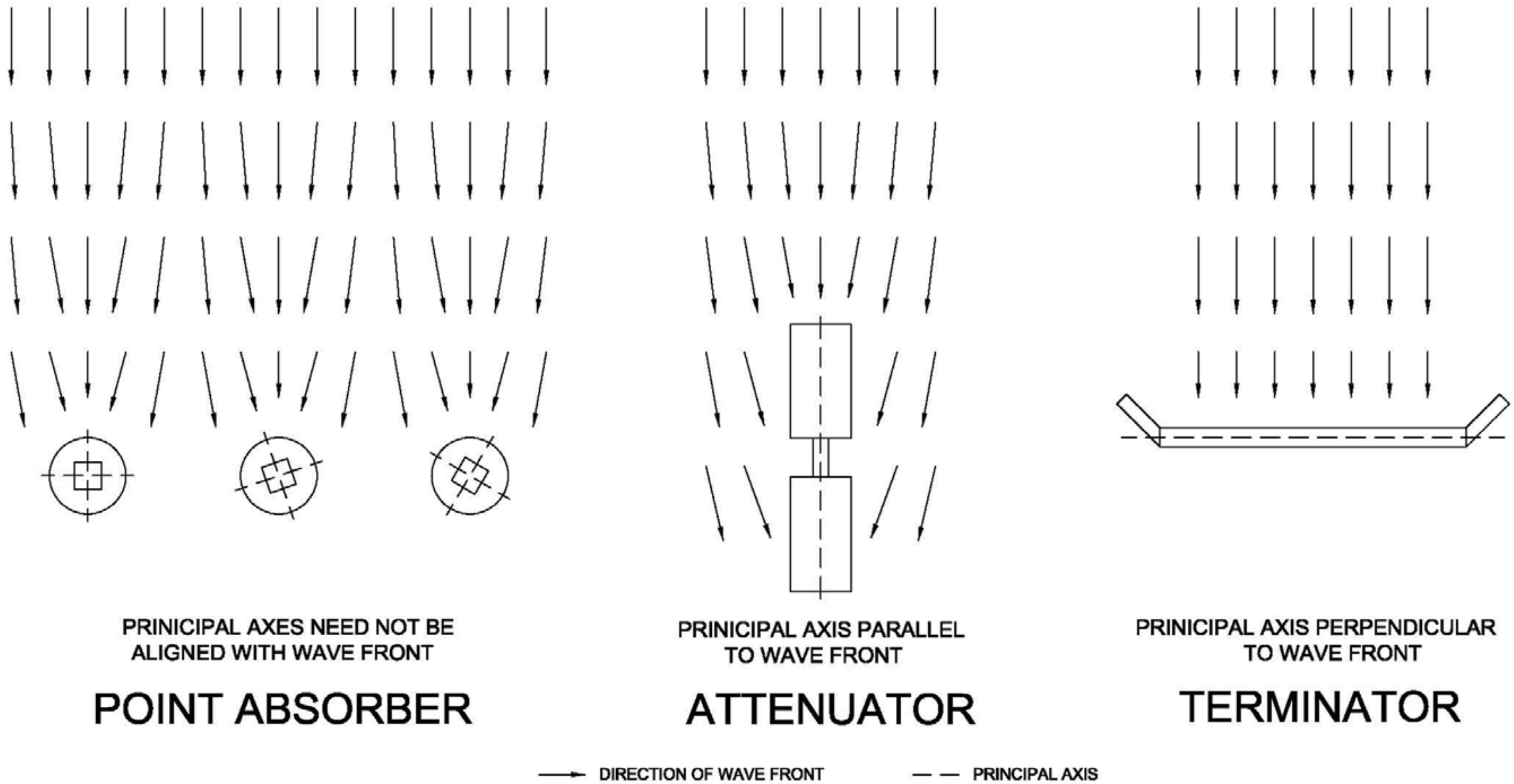
Suspended Reaction point - using a damper plate suspended above the seafloor as a relatively fixed reaction point for a PSHS device

Terminator - wave energy capture device with principal axis oriented perpendicular to the direction of the incoming wave and, if 100% efficient, terminates the wave; reflected and transmitted waves determine the efficiency of the device

Yaw Control System - adjusts the angle of a horizontal axis turbine or oscillating hydrofoil to keep it aligned with the principal direction of the current and achieve better efficiency

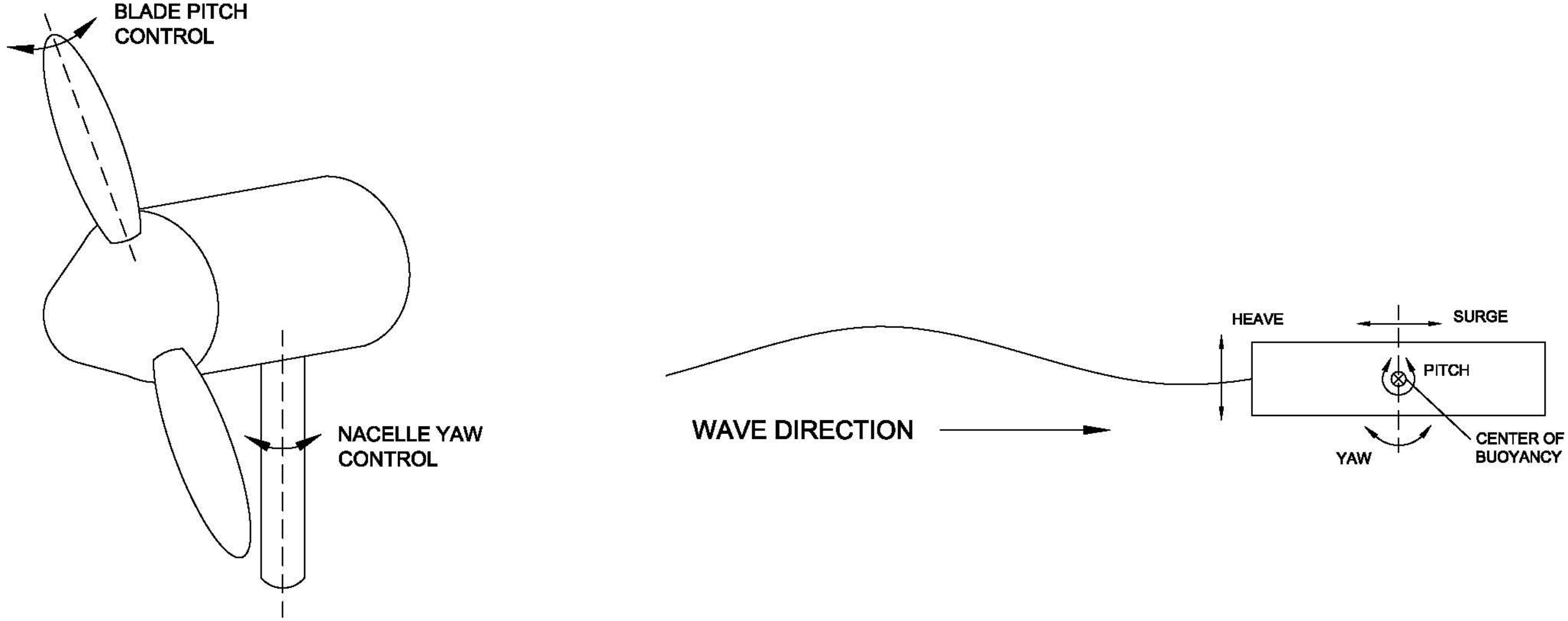
This page intentionally left blank.

FIGURE 1


PRINICIPAL AXES NEED NOT BE ALIGNED WITH WAVE FRONT
POINT ABSORBER
PRINICIPAL AXIS PARALLEL TO WAVE FRONT
ATTENUATOR
PRINICIPAL AXIS PERPENDICULAR TO WAVE FRONT
TERMINATOR
DIRECTION OF WAVE FRONT
PRINCIPAL AXIS

This page intentionally left blank.

FIGURE 2

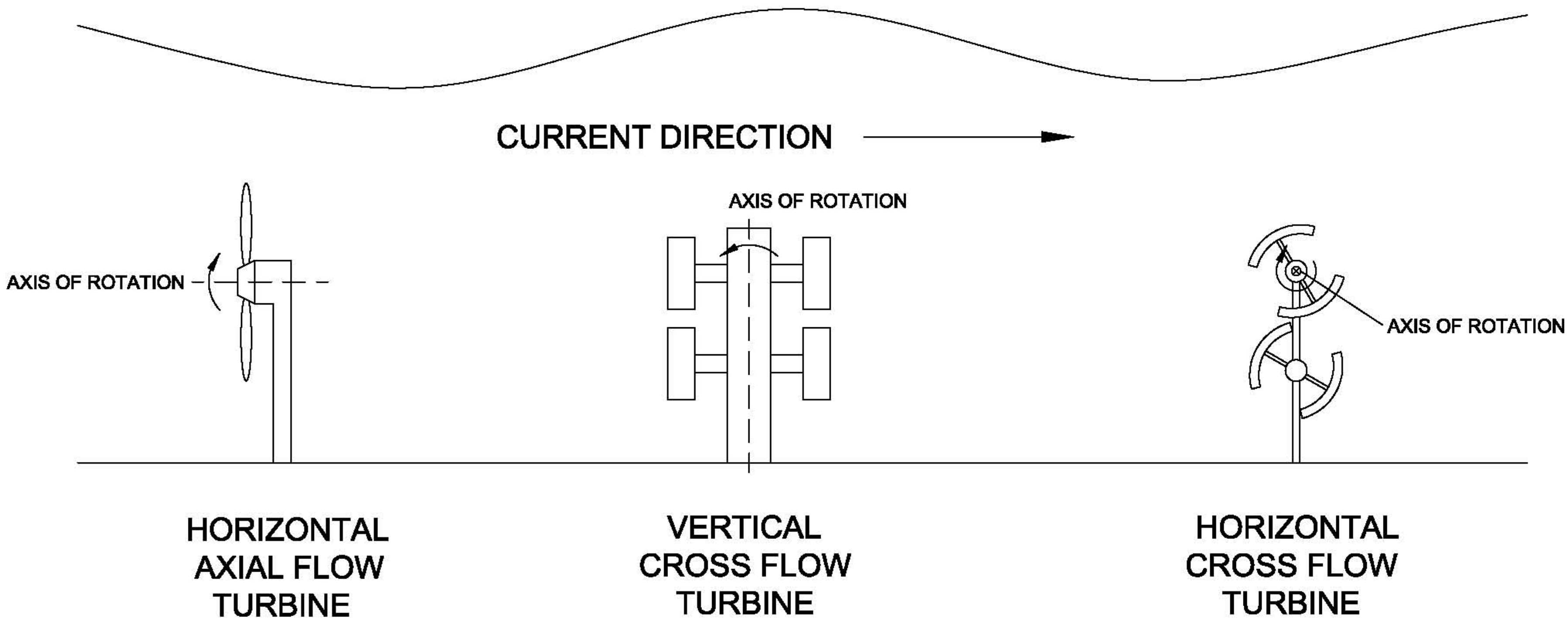


PITCH AND YAW OF
AXIAL FLOW TURBINE

PRINCIPLE ENERGY ABSORBING MOTIONS
FOR WAVE ENERGY DEVICES

This page intentionally left blank.

FIGURE 3



AXIAL FLOW VS CROSS FLOW

This page intentionally left blank.

Appendix B – Device Design Criteria

This page intentionally left blank.

CRITERIA	ABS 116	ABS 117	API RP 2A-WSD	API RP 2I	API RP 2L	API RP 2SK	API RP 2SM
Platform							
Common to Floating and Fixed Systems							
Site selection and hazards survey	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.
Environmental data (metocean event definitions)	(4.2.1.i) Requires design basis documents to be submitted that include the "operating envelope", working environment, design life, etc.	Not addressed.	(1.3.1) Experienced specialists should be consulted when defining the pertinent meteorological and oceanographic conditions affecting the platform site. Measured and/or model generated data should be statistically analyzed to develop the descriptions of normal and extreme environmental conditions for winds, waves, tides, currents, ice, active geologic processes (earthquakes, faults, seafloor instability, scour), marine growth, and other environmental information. (1.5) The recurrence interval for oceanographic design criteria should be several times the planned life of the platform. (1.7) Provides Exposure Categories for life safety and consequences of failure. (2) Provides guidelines for developing oceanographic design criteria that are appropriate for use with the Exposure Category Levels defined in 1.7.	Not addressed.	(2.2.c) Wind loads on offshore heliports should be determined in accordance with API RP 2A-WSD.	(4.1) Recognizes two classifications of environmental conditions when analyzing mooring systems: maximum design condition and maximum operation condition. (4.1.1.1) The recurrence interval design condition for permanent moorings should be determined by a risk analysis taking into account the consequence of failure. Mooring systems should be designed for the combination of wind, wave and current conditions causing the extreme load in the design environment. The most severe directional combination of wind, wave, and current forces should be specified for the permanent installation consistent with the site's environmental conditions. (4.2) Experienced specialists should be consulted when defining the pertinent meteorological and oceanographic conditions of a site. Statistical models are essential for adequately describing environmental parameters.	Not addressed.
Geotechnical data	Not addressed.	Not addressed.	(1.4) Addresses site investigation for foundations with sections addressing site investigation objectives, sea-bottom surveys, and soil investigation and testing. (2.3.6) presents guidelines for the design of a platform for earthquake ground motions including consideration and evaluation of seismic activity	Not addressed.	Not addressed.	(4.7) Bottom soil conditions should be determined for the intended site to provide data for the anchoring system design.	Not addressed.

CRITERIA	ABS 116	ABS 117	API RP 2A-WSD	API RP 2I	API RP 2L	API RP 2SK	API RP 2SM
Loads to consider (O&M, environmental, transport, installation)	(4.3) Loading and environment conditions to be considered include, but are not limited to, the following: Pressure and temperature induced loads and fluctuations; Static and dynamic loads; Dynamic loads imposed due to vessel motions; Loads imposed due to relative motion of the vessel; Loads imposed from cargo weight or process fluid flow dynamics; Fatigue and fracture effects; Wear and vibration effects; Chemical attack and associated material loss and cracking; Accidental loads	Not addressed.	(2.1.2.a) The following loads and any dynamic effects resulting from them should be considered in the development of the design loading conditions: dead loads, live loads, environmental loads, construction loads, removal and reinstallation loads, dynamic loads. (2.2.2) Consider for environmental loads combined with dead and live loads in various conditions (2.2.3) Consider dead loads combined with maximum temporary loads and appropriate environmental loads (2.3) Environmental loads to be accounted for include waves, wind, current, and earthquake (2.4) Dynamic loads should be considered and static loads increased by appropriate impact factors	Not addressed.	(2.3) The heliport should be designed for at least the following combination of design loads: dead load plus live load, dead load plus design landing load, dead load plus live load plus wind load. (2.4) Loads experienced during heliport construction including the static and dynamic forces that occur during lifting, loadout and transportation should be considered in accordance with API RP 2A.	(5.1) Environmental forces should be calculated in the following three distinct frequency bands to evaluate their effects on the system: steady forces such as wind, current, and wave drift are constant in magnitude and direction for the duration of interest; low-frequency cyclic loads can excite the platform at its natural periods in surge, sway, and yaw; wave frequency cyclic loads are large in magnitude and are the major contributor to platform member forces and mooring system forces. (6.1) Establishes basic design criteria for the following conditions: Intact condition Damaged condition Transient condition	Not addressed.
Fatigue assessment	Not addressed.	Not addressed.	(5.1) Detailed fatigue analysis should be performed for almost all structures; spectral analysis technique recommended (5.2) Consider stress responses for each sea state	Not addressed.	Not addressed.	(6.8) Fatigue design is required for permanent moorings only. A predicted mooring component fatigue life of three times the design service life is recommended. (7.1.2) Fatigue life estimates are made by comparing long-term cyclic loading to resistance to fatigue damage. (7.5) Gives detailed steps and several methods for performing fatigue analysis. (9.5) Discusses special fatigue conditions for single anchor leg mooring systems.	(4.6.7.1) Bend-over-sheave fatigue loading will be limited to any which occurs in deployment or retrieval operations. Tension, free-bending fatigue loading on taut mooring lines near terminations should be addressed by design that minimizes bending moments. (5.3.3) A safety factor of 10 times the design service life should be used. (10.4) The fatigue computation is performed in accordance with API RP 2SK.

CRITERIA	ABS 116	ABS 117	API RP 2A-WSD	API RP 2I	API RP 2L	API RP 2SK	API RP 2SM
Corrosion control	Not addressed.	Not addressed.	(8.5) Design in accordance with NACE RP-01-76	(3.1.5) Nongalvanized mooring-wire rope working in a marine environment with lubrication can rapidly develop severe corrosion.	(2.6) All materials, coverings, or coatings used to provide a nonskid surface should be structurally fastened to the deck or bonded with an adhesive that is not altered in the presence of fuel and oil contamination.	Not addressed.	(4.2.3.1.a) Fiber, yarn, and rope data used for design should denote whether the samples included a marine finish. (4.2.3.1.b) The fiber or rope supplier should demonstrate that the finish remains effective in seawater for at least one year.
Access for operation and maintenance	(4.3.5) The components of the application must be able to be inspected and maintained consistent with existing practice for surveyor access and placing personnel in hazardous situations. Also should not put abnormal loading on the application.	Not addressed.	Not addressed.	Not addressed.	(1.3.e) The location of access and egress stairways and ladders should be determined from platform configuration, equipment arrangement, and safety objectives. One primary access and egress route should be provided. (2.7) Where practical, the primary route should be provided with a depressed waiting area minimum of 7 ft. below the flight deck.	(2.2.6) A mobile mooring can often be visually inspected during retrieval or deployment. To inspect a permanent mooring, divers or ROVs are often used.	Not addressed.
Specific to Floating Systems							
Structural analysis, allowable stresses, and loads	(5.1(ii)) Completed design calculations potentially including: All relevant loading and its uncertainty; All relevant resistance factors including but not limited to yield, UTS, fracture toughness, and CTOD values	(1.2) If a proposed design is categorized as a Novel Concept according to ABS 116, that document should be followed instead. (5.1) Evaluate the proposed design using a simple risk assessment method, such as Change Analysis, Hazard Identification, Hazard and Operability, What-If and Failure Mode and Effects Analysis.	Not addressed.	Not addressed.	Not addressed.	Section 7 deals entirely with methods of analysis. Permanent moorings should be designed for extreme response and fatigue; mobile moorings only require analysis for extreme response. The section also discusses proper use of quasi-static and dynamic analysis, as well as transient analysis and when to use time-domain vs. frequency analysis is appropriate.	(4.6.2) MBS defined as average break strength minus two standard deviations from at least five samples. (5.1) Based on recommendations in API RP 2SK. (5.3.1) Maximum tension limits and factors of safety should be the same magnitude as for steel (see API RP 2SK) but with the breaking strength defined as MBS. (5.3.2) Tension should not drop below 10% MBS more than 500 times. (5.3.4) Minimum factor of safety for creep rupture is 10 for the intact condition and 5 for the damaged condition.

CRITERIA	ABS 116	ABS 117	API RP 2A-WSD	API RP 2I	API RP 2L	API RP 2SK	API RP 2SM
Hull integrity and stability	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.
Mooring system	Not addressed.	Not addressed.	Not addressed.	The entire document deals expressly with inspecting mooring hardware.	Not addressed.	The entire document deals expressly with the design of mooring systems.	(5.4.1) Mooring analysis should generally follow the methods provided in API RP 2SK. Issues that are unique to fiber rope moorings, including axial stiffness, rope length, creep rupture analysis, and axial compression fatigue analysis, are addressed in the following sections.
Specific to Fixed Systems							
Structural analysis, allowable stresses, and loads	Not addressed.	Not addressed.	(2.2.4) Design each member for the maximum stress in that member (3.1) Unless otherwise recommended follow AISC specifications; use rational analysis where element or loading is not covered by AISC (3.2) Addresses axial tension, axial compression including buckling, bending, shear, and hydrostatic pressure (4.1) Concerned with static design of joints formed by two or more tubular members; test data, numerical methods and analytical techniques may also be used	Not addressed.	(2.2.b) To allow for personnel and cargo transfer, rotor downwash, wet snow or ice, etc., a minimum live load of 40 psf should be included in the design. (2.2.d.1) The flight deck, stiffeners, and supporting structure should be able to withstand the exceptionally hard landing after power failure while hovering. (2.2.d.2) and (2.2.d.3) See Table 2.2 for landing gear information (2.2.d.4) Design landing load is the landing gear load times an impact factor of 1.5.	Not addressed.	Not addressed.
Foundation design	Not addressed.	Not addressed.	(6) Provides recommended criteria in Sections 6.1 through Sections 6.11 for pile foundations, and more specifically to steel cylindrical (pipe) pile foundations. The recommended criteria in Sections 6.12 through 6.17 address shallow foundations.	Not addressed.	(2.1) Unless otherwise noted, refer to API RP 2A.	Not addressed.	Not addressed.
Scour protection	Not addressed.	Not addressed.	(6.3.6) Handle by robust design or monitoring and remediation as needed	Not addressed.	Not addressed.	Not addressed.	Not addressed.
Power Conversion Systems							
Rotor / Nacelle Assemblies							
Basis of design	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.

CRITERIA	ABS 116	ABS 117	API RP 2A-WSD	API RP 2I	API RP 2L	API RP 2SK	API RP 2SM
Loads to consider (actuation, hydrodynamic, shut down, transport, installation)	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.
Machinery components	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.
Displacer Assemblies							
Basis of design	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.
Loads to consider (actuation, hydrodynamic, shut down, transport, installation)	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.
Machinery components	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.
Yaw Control Systems							
Basis of design	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.
Loads to consider (actuation, hydrodynamic, shut down, transport, installation)	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.
Machinery components	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.
Electrical Generators							
	Not addressed.	Not addressed.	Not addressed.	Not addressed.	(2.10) An emergency power supply should provide power to the perimeter and obstruction lighting.	(10.2.5) Any generator unit should be able to be automatically started by the power management system.	Not addressed.
Power Conditioning / Substations							
	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.
Riser / Power Collection / Transmission Cables							
Cable route selection and survey requirements	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.
Criteria for crossings (other cables, pipelines, anchorage areas, navigational channels)	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.
Component / material standards	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.
Riser design	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	(2.3.2) Refers to drilling risers - but states the mooring and riser systems must be designed to accommodate each other.	Not addressed.

CRITERIA	ABS 116	ABS 117	API RP 2A-WSD	API RP 2I	API RP 2L	API RP 2SK	API RP 2SM
Auxiliary Systems							
Supervisory control and data acquisition (SCADA)	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Section 10 discusses dynamic positioning systems and their requirements, such as sensors that provide feedback to a controller. Section 10.2.2 discusses their control systems in particular.	Not addressed.
Emergency safety systems	(5.1(v)) Typically, submissions required in the full approval phase of the project include: Drawings covering safety and features and ancillary systems in detail.	(7.3.(ix)) Minimum information to be provided includes: Identified risk controls (safeguards and mitigation measures) proposed for the design	(1.2.6) Safety of personnel requires attention to fire protection methods. Selection of the system depends on the function of the platform.	Not addressed.	(1.3.f) Heliport fire protection should be considered in the overall platform fire protection system.	Not addressed.	Not addressed.
Piping systems (working fluids, lubricants, and ballast water)	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.

Appendix B – Device Design Criteria

CRITERIA	CIRIA C666	DNV-RP-A203	DNV-OS-D201	DNV-OSS-312	DNV – Wave Energy Converter Design	EMEC – Design Basis	EMEC – Certification Schemes	EMEC – Manufacturing
Platform								
Common to Floating and Fixed Systems								
Site selection and hazards survey	(5.2) The primary criterion in site selection is a minimum level of potential resource most suited to the specific device characteristics. Inherently this will be based on metocean data archives of wind, wave or tidal stream that are of sufficient duration to characterize the synoptic variation in resource over the long term.	Not addressed.	Not addressed.	Requires use of the DNV Rules for Planning and Execution of Marine Operations. Pt. 2 Section 4 of the Rules (1.3.1.3) The type and extent of site survey should be determined in relation to the type, size and importance of the object to be installed and the uniformity of the seabed. Obstacles both on and in soil strata should be revealed.	(27.1) The site may have to vetted for environmental impact and if interfering with sites or migration routes of protected species. In any case, it is expected that an Environmental Impact Assessment (including all phases up to decommissioning) is to be carried out at an early stage of the project as part of the application process for the development of a wave farm.	Not addressed.	Not addressed.	Not addressed.

CRITERIA	CIRIA C666	DNV-RP-A203	DNV-OS-D201	DNV-OSS-312	DNV – Wave Energy Converter Design	EMEC – Design Basis	EMEC – Certification Schemes	EMEC – Manufacturing
Environmental data (metocean event definitions)	(6.3) Both EIA and engineering design require robust metocean data to underpin their respective activities. The specification of the metocean survey should be validated between the EIA contractor, design team and developer, and in certain cases it may be beneficial to offer the scope to the regulatory bodies to gain their endorsement, especially where this may respond to stakeholder concerns. The ICES Working Group on Marine Data Management has developed various guidelines to assist those involved in the collection, processing, quality control, and exchange of various types of (mainly) physical oceanographic data. (6.6.3) Validation of the tidal stream resource requires in situ monitoring for a minimum period of 30 days and for a sufficient number of sites to describe major variability which might be expected over the footprint of the development site. The capture radius of a TEC device and the relative position of the device in the water column require that flow measurement are sampled over the full depth and across channels	Not addressed.	Not addressed.	(3.B201) The environmental data used as a basis for the design should be submitted. This should include: waves; wind; current profile and turbulence; water depths; tide; soil conditions; marine growth, thickness and specific weight; seismic conditions; and design temperature.	(13.9) The parameters describing the environmental conditions shall be based on observations from or in the vicinity of the site of the wave energy device and on available knowledge about the environmental conditions in the area. The proper combinations and joint occurrences of waves and current conditions as given in DNV-OS-C101 (Design of Offshore Steel Structures, General) should be applied.	(6.4.2) The wind design basis shall apply the 1-hour wind speed, plus wind gust spectrum formulated as specified in API RP 2A. If some historical data is available the design process shall specify whether its accuracy is sufficient. (6.4.3) Wind measurements should be carried out using an anemometer at the proposed site. This data should be collected for a minimum of 1 year. Co-current data measured at a met station should also be obtained. Measurements should be carried out at a height that is close to that experienced by the device. These two sets of data should be correlated. (6.5.2) If data on tide levels exists the design process shall define whether its accuracy is sufficient. If no suitable information is available, then measurements should be taken over a suitable time period of at least 1 year. (6.5.3) Consider the combined effects of high tide levels, storm surges and also waves. (6.6) Design current velocities shall be established, taking into account all relevant components.	(7.4.2) Site-specific conditions shall form the basis for the project certification, with their impact on the foundations, structures, moorings and power output. The site assessment shall be prepared by the applicant to form part of the basis for the project certification.	Not addressed.

CRITERIA	CIRIA C666	DNV-RP-A203	DNV-OS-D201	DNV-OSS-312	DNV – Wave Energy Converter Design	EMEC – Design Basis	EMEC – Certification Schemes	EMEC – Manufacturing
Geotechnical data	Not addressed.	Not addressed.	Not addressed.	(3.B201) includes seismic conditions in the list of environmental data to be submitted as a basis of design. (3.B401) includes soil data in the documentation to be submitted for fixed tidal and wave energy converters.	(14) Design of foundations for wave energy converters shall be based on site specific information. The extent of site investigations and the choice of investigative methods shall take into account the type and size of the wave energy device, the uniformity of soil and seabed conditions. For application of anchors the soil stratigraphy and range of soil strength properties shall be assessed. Site investigations should provide information about the soil to a depth required to check effect of possible weak formations.	(6.3) The design process shall ensure that the seabed geotechnical features at the proposed location of deployment that are critical for the design and installation of the support structure or mooring are understood. (13.2) A thorough site investigation of the proposed deployment area shall be performed to confirm that the foundation design is suitable at a specific location – unless an over-engineered approach is adopted as per 6.3. The site specific investigation should confirm the following parameters: soil resistance to axial pile load, soil shear strength, uniformity of soil and seabed conditions, strata layer thickness, and representative ground parameters for each stratum.	(7.3.4.6) Documentation to be submitted for verification of the structural design of a fixed converter should include: soil data and foundation analysis.	Not addressed.

Appendix B – Device Design Criteria

CRITERIA	CIRIA C666	DNV-RP-A203	DNV-OS-D201	DNV-OSS-312	DNV – Wave Energy Converter Design	EMEC – Design Basis	EMEC – Certification Schemes	EMEC – Manufacturing
Loads to consider (O&M, environmental, transport, installation)	(7.4.2) Design for fatigue limits is required to assess the cyclical loading on structures by considering the loads caused by various combinations of metocean factors which occur during operational conditions, and taking into account issues such as wake effects. In contrast to extreme loads, the cyclical loads operate at much higher frequencies from seconds rather than years.	Not addressed.	(Ch.2,Sec.3.B201(a)) Electrical equipment and components shall be constructed to withstand, without malfunctioning, or electrical connections loosening, at least the following values: - vibration frequency range 5 to 50 Hz with vibration velocity amplitude 20 mm/s - peak accelerations ±0.6 g for vessels of length exceeding 90 m, and ±1 g for offshore units and installations and vessels of length less than 90 m (duration 5 to 10 s)	(3.B301) Typical documentation for floating converters will include: Design load plan, including design accidental loads; loading manual; design analyses, both global and local design, including temporary phases such as transit (3.B401) Typical documentation for fixed converters will include: Design load plan, including design accidental loads; design analyses, both global and local design, including temporary phases such as transit (3.G101) Design accidental loads should cover fire and explosion loads, impact loads from dropped objects and collisions, unintended flooding and loads caused by extreme weather.	(13.9) Design of a device shall be based on the most severe environmental loads the structure may experience. Environmental loads are mainly due to waves, currents, and wind. (13.10) Resistance of the structure against design accidental loads shall be checked. Typical accidental loads are: Impact from ship collisions; Impact from dropped objects; Fire; explosions; abnormal environmental conditions; Accidental flooding	(7.1) The following types of loadings shall be considered with respect to the design life of the device: permanent (dead) loads, variable functional (live) loads, accidental loads, loads induced by thermal expansion and contraction, loads due to entrained mass, loads induced by transient phases. (7.2.1) The design basis shall define a recognized design code so that the design load cases can be identified. (8.1.1) The design shall take into account all fatigue loadings and the resulting stresses. (14.3) Refer to environmental conditions (clause 6) which outlines loading upon the device and also forces directly on the mooring system (i.e. waves and current).	Not addressed.	Not addressed.
Fatigue assessment	(7.4.2) Design for fatigue limits is required to assess the cyclical loading on structures by considering the loads caused by various combinations of metocean factors which occur during operational conditions, and taking into account issues such as wake effects. In contrast to extreme loads, the cyclical loads operate at much higher frequencies from seconds rather than years.	Not addressed.	Not addressed.	(3.C101) Typical documentation for the position keeping system will include: Fatigue calculations of mooring line segments and accessories	(13.7) A detailed treatment of the methodology for Fatigue Limit State is presented in Appendix A.	(7.3.5) All units shall be capable of withstanding the fatigue loading to which they are subjected. The minimum design fatigue life of a device shall be the design life unless a longer life is specified by the design basis. (8.1.1) The design shall take into account all fatigue loadings and the resultant stresses. (8.1.2) In general floating structures and devices making use of resonant responses should be analyzed using spectral or time domain methods.	(7.3.4.6) Documentation for floating converter should include: fatigue calculations of mooring line segments and accessories	Not addressed.

Appendix B – Device Design Criteria

CRITERIA	CIRIA C666	DNV-RP-A203	DNV-OS-D201	DNV-OSS-312	DNV – Wave Energy Converter Design	EMEC – Design Basis	EMEC – Certification Schemes	EMEC – Manufacturing
Corrosion control	Not addressed.	Not addressed.	(Ch.2,Sec.3.D102(b)) Metallic enclosures installed where severe corrosion problems can be expected shall be made of especially corrosion resistant material or dimensioned with a certain corrosion allowance. (Ch.2,Sec.3.D102(c)) Light metal alloys shall be avoided as enclosure materials if not documented to be seawater resistant and installed so that local corrosion does not occur.	(3.B301) Typical documentation for floating converters will include: Corrosion protection. (3.B401) Typical documentation for fixed converters will include: Corrosion protection.	Section 12 addresses corrosion protection for steel, concrete, and composite structures, as well as for chains, steel wire, and fiber rope. Reference is also made to OS-C101, Section 10.	(11.1) The corrosion zones may be classified as follows: atmospheric, splash, inter-tidal, submerged, buried. The designer shall identify which zone each component of the device will exist within before being able to best consider forms of corrosion protection during design.	(7.3.4.6) Documentation for floating converter should include: corrosion allowance. (7.3.4.6) Documentation for fixed converter should include: corrosion protection.	(10.2) Paint systems should be detailed on purchase order, specifications, drawing, or other documentation. Contrasting colors shall be used for successive coats, with the exception of stripe coats.
Access for operation and maintenance	(7.5.2) During uninterrupted operation of moored devices there is minimum requirement for personnel access to the unit. Larger devices are likely to be disconnected and towed to a local maintenance facility for almost all planned or breakdown maintenance. Devices will need to be designed to that personnel access to the device, once moored at the maintenance facility, is straightforward and safe.	Not addressed.	Not addressed.	(3.B301) Typical documentation for floating converters will include: Description of access for inspection and maintenance of the structure. (3.B401) Typical documentation for fixed converters will include: Description of access for inspection and maintenance of the structure.	(25.1.3) In general all work should be planned in advance and agreed with the operations manager. (25.2) It is necessary to recognize that difficulties may be imposed by the device operating location. (25.2.1) Consideration should be given to access to areas to be inspected and the extent, frequency, and choice of inspection methods. (17.3.2) The arrangement of machinery and piping systems should be such that maintenance access may be readily facilitated.	(20.2) The design basis shall define how access for maintenance will be achieved; for instance via helicopter, rigid inflatable boat, or pilot boat	(7.3.4.6) Documentation for fixed converter should include: description of access for inspection and maintenance of structure.	Not addressed.

Appendix B – Device Design Criteria

CRITERIA	CIRIA C666	DNV-RP-A203	DNV-OS-D201	DNV-OSS-312	DNV – Wave Energy Converter Design	EMEC – Design Basis	EMEC – Certification Schemes	EMEC – Manufacturing
Specific to Floating Systems								
Structural analysis, allowable stresses, and loads	Not addressed.	Not addressed.	(Ch.2,Sec.2.I301(b)) Where a large machine is installed athwartships, the design of the bearings should be satisfactory to withstand the rolling specified in Pt.4 Ch.1 Sec.3 B of the DNV Rules for Classification of Ships. (Ch.2,Sec.3.D102) Enclosures shall have sufficient mechanical strength for their situation and their temperature shall not be so high that there is fire risk, damage to adjacent materials, or danger to personnel.	(3.B301) Typical documentation for floating converters will include: Structural design brief; structural categorization plan; structural drawings	Section 13 addresses structural design criteria, including ultimate limit state load factors for steel, concrete, and composite structures, and accident loads.	(7.3.2) In general, the structural design of the device shall be based on the elastic method of design. The permissible stresses in the structure shall be based on… the permissible (or allowable) stress. (7.3.3) The design basis shall specify the design philosophy, partial factors and recommended critical load cases within acceptable codes of practice. (7.3.4) When the plastic method of design based on the ultimate yield strength is proposed for the device, the load factors should be in accordance with an acceptable code of practice.	(7.3.4.3) Potentially critical loads and load cases to be analyzed in the detailed design of structures and components shall be identified. (7.3.4.6) Documentation for verification of structural design of floating converter should include: strength calculations of anchors, windlass components and fairleads	Not addressed.
Hull stability requirements	Not addressed.	Not addressed.	(Ch.2,Sec.3.B101(d)) Components for mobile offshore units shall be designed to operate satisfactorily under the following inclinations: 15 deg. from normal level in any direction under normal static conditions; 22.5 deg. under normal dynamic conditions; 25 deg for emergency installations	(3.B301) Typical documentation for floating converters will include: Stability, including inclining test procedure, stability manual watertight integrity plans, etc.; freeboard plan and list of watertight and weather tight items	(16.1) The OS-C301 Standard “Stability and Watertight Integrity” can be used as a guide. When the device is manned, these considerations are particularly important. (16.2) This should include consideration of compartment flooding in case of loss of watertight integrity or inadvertent shift of permanent ballast. Consider how to restore adequate stability through ballast pumps. Dynamic behavior may also require special considerations.	(12.1) Reference should be made to EMEC “Guidelines for Health & Safety in the Marine Energy Industry”. The following aspects should be considered in the design basis: required buoyancy or ballasting of the structure; pumping arrangements to achieve above; potential loss of watertight integrity and how it affects above (12.2) Stability calculations should be carried out for devices of the floating type or that might float during installation	(7.3.4.6) Documentation for floating converter should include: position and weight of buoyancy elements	Not addressed.

Appendix B – Device Design Criteria

CRITERIA	CIRIA C666	DNV-RP-A203	DNV-OS-D201	DNV-OSS-312	DNV – Wave Energy Converter Design	EMEC – Design Basis	EMEC – Certification Schemes	EMEC – Manufacturing
Mooring system	Not addressed.	Not addressed.	Not addressed.	(3.C101) Typical documentation for the position keeping system will include: Line and anchor pattern; Type, weight, and dimension of line segments; Anchor type, size, weight, and material spec.; Position and type of connection elements; Windlass, winch, and stopper design; Mooring line tensions in ULS and ALS limit states, etc.	Section 15 addresses mooring system analysis including: Acceptance criteria, ultimate limit state, accidental limit state, fatigue limit state, and anchor design. Reference is also made to OS-E301 Section 2, OS-C101 Section 11, as well as API RP 2SK and ISO/DIS 19901-7.	Section 14 deals entirely with mooring system design. Topics include configuration of the system, required components, loading, and anchor design.	(7.3.4.6) Documentation for floating converter should include: line and anchor pattern; type, weight, and dimension of all line segments; anchor type, size, weight, and material spec., etc.	Not addressed.
Specific to Fixed Systems								
Structural analysis, allowable stresses, and loads	Not addressed.	Not addressed.	Not addressed.	(3.B401) Typical documentation for fixed converters will include: Structural design brief; structural categorization plan; structural drawings	Not addressed.	(13.3) Design basis shall consider: all loads imposed on the support structure and the critical load cases	(7.3.4.6) Documentation for fixed converter should include: design load plan, including design accidental loads; design analyses, including temporary phases such as transit	Not addressed.
Foundation design	Not addressed.	Not addressed.	Not addressed.	(3.B401) Typical documentation for fixed converters will include: Soil data and foundation analysis	Section 14 addresses foundation design. The partial coefficient method is preferred in foundation design. The design shall consider both strength and deformations of the structure and of the soils. Reference is made to OS-C101 Section 11.	Section 13 deals entirely with foundation and support structure design. Topics include configuration of the system (gravity or pile), geotechnical parameters, stability of the seabed, and scour protection.	(7.3.4.6) Documentation for verification of structural design of fixed converter should include: field data in terms of location and orientation, soil data and foundation analysis; structural drawings, etc.	Not addressed.
Scour protection	Not addressed.	Not addressed.	Not addressed.	(3.B401) Typical documentation for fixed converters will include: Description of scour protection system	Not addressed.	(13.6) The following methods may be used to prevent scour: rock dumping; geotextiles and concrete block mattresses wall with concrete filling; seabed improvement by gluing the sand The environment impact of these solutions should also be considered.	(7.3.4.6) Documentation for fixed converter should include: description of scour protection system	Not addressed.

Appendix B – Device Design Criteria

CRITERIA	CIRIA C666	DNV-RP-A203	DNV-OS-D201	DNV-OSS-312	DNV – Wave Energy Converter Design	EMEC – Design Basis	EMEC – Certification Schemes	EMEC – Manufacturing
Power Conversion Systems								
Rotor / Nacelle Assemblies								
Basis of design	Not addressed.	(6.1) The new technology shall be unambiguously and completely described, through drawings, text, data, or other relevant documents. The specification shall identify all phases of the new technology's life and all relevant main parameters. The specification and functional requirements shall be quantitative and complete.	(Ch.2,Sec.5.A205) Machines shall be constructed so that when running at any working speed, all revolving parts are well balanced. (Ch.2,Sec.5.A207(a)) Shafts shall comply with the requirements in DNV Pt.4 Ch.4 Rules for Classification of Ships with regard to strength, bearings, and balancing.	(3.D101) Machinery and marine systems are covered by DNV-OS-D101.	(17.3.6.1) Lists several IEC technical reports that may be considered. The following design conditions should be considered: Project arrangement; hydraulic conditions; mode of operations, generator characteristics; system stability; etc.	(15.5.1) All mechanical equipment shall be capable of operating at all inclinations… that the device could experience. (15.5.2) Design basis should consider material degradation of mechanical equipment.	(7.3.4.4) Scope for certification shall include in-place conditions for: mechanical and turbine systems	Not addressed.
Loads to consider (actuation, hydrodynamic, shut down, transport, installation)	Not addressed.	Not addressed.	(Ch.2,Sec.5.A204(a)) Lists the excess torque general purpose rotating machines shall be designed to withstand. (Ch.2,Sec.5.A208) Rotating machines shall be capable of withstanding 1.2 times the rated maximum speed for a period of 2 minutes.	Not addressed.	(17.3.6.2) Operational loads include: environmental conditions, acceleration loads, reaction forces from generator torque, forces from deflection of floating structure, pressure loads plus centrifugal loads Extreme loads include: Forces from blade loss, or, in the case of a centrifugal impeller, parts from one blade root failure	Not addressed.	Not addressed.	Not addressed.
Machinery components	Not addressed.	Not addressed.	(Ch.2,Sec.2.I301(a)) Generating sets with horizontal shaft shall be installed with the shaft in the fore-to-aft direction.	Not addressed.	(17.3.1) Reference is made to OS-D101, as well as SOLAS Chapter II-1. Other DNV publications that may be relevant are: OS-A101, OS-B101, OS-C301, RP-A201, RP-A202	(15.5.3) Force transmitting components (shafts, linkages, etc.) shall comply with clauses 8, 9, and 15.5.1 of this document and ISO 76, 281, and 6336.	Not addressed.	Not addressed.

CRITERIA	CIRIA C666	DNV-RP-A203	DNV-OS-D201	DNV-OSS-312	DNV – Wave Energy Converter Design	EMEC – Design Basis	EMEC – Certification Schemes	EMEC – Manufacturing
Displacer Assemblies								
Basis of design	Not addressed.	See nacelle assemblies.	Not addressed.	See nacelle assemblies.	(17.3.4.1) Hydraulic cylinders and rams are fundamental to certain types of devices. They may be configured as a set in order to harness the relative motion of a device. The integrity of this configuration is very important to the power production of the device. (17.3.5) Pneumatic systems are likely to be of two types: Low pressure, high volume; High pressure, low volume. Issues with the latter type of system are listed.	See nacelle assemblies.	Not addressed.	Not addressed.
Loads to consider (actuation, hydrodynamic, shut down, transport, installation)	Not addressed.	Not addressed.	Not addressed.	Not addressed.	(17.3.4.1) Primary consideration is pressure containment. For a wave energy device, there are additional considerations: Fatigue of piston rod; Buckling of the piston rod; Degradation rate of hydraulic fluids; etc.	Not addressed.	Not addressed.	Not addressed.
Machinery components	Not addressed.	Not addressed.	Not addressed.	Not addressed.	(17.2) Onboard environmental conditions on WEC device should be specially considered, particularly when equipment is put into enclosed spaces where heat, humidity, salt content, etc. may be high.	See nacelle assemblies.	Not addressed.	Not addressed.
Yaw Control Systems								
Basis of design	Not addressed.	See nacelle assemblies.	Not addressed.	See nacelle assemblies.	Not addressed.	Not addressed.	Not addressed.	Not addressed.
Loads to consider (actuation, hydrodynamic, shut down, transport, installation)	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.
Machinery components	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.

Appendix B – Device Design Criteria

CRITERIA	CIRIA C666	DNV-RP-A203	DNV-OS-D201	DNV-OSS-312	DNV – Wave Energy Converter Design	EMEC – Design Basis	EMEC – Certification Schemes	EMEC – Manufacturing
Electrical Generators								
	Not addressed.	Not addressed.	(Ch.2.Sec.2.G301(a)) Generators shall be fitted with short circuit and overcurrent protection. (Ch.2.Sec.2.B101) Exciter and voltage regulation equipment is considered as part of the generator. (Ch.2.Sec.2.B105) For A.C. generators, the voltage shall be approximately sinusoidal, with a max deviation of 5% from peak value. Rest of Section B lists additional requirements for generators such as: Voltage and frequency regulation; Short circuit capabilities; Parallel operation.	(Sec.3.E101) Electrical systems are covered by DNV-OS-D201. Verification of the electrical system will be based on: Generator description	(17.2.1) The choice of generator type, speed, and rating must be made in consideration of the prime mover and its control system. Conventional synchronous and induction generators may be used in most devices using mechanical or hydraulic conversion, usually involving a storage accumulator of some form. Rotating electrical machines should be designed in accordance with IEC 60034.	(15.4.1) Electrical equipment shall be suitable for operation in the environmental conditions experienced by the device. The design basis shall identify standards to use for equipment in the device. (15.4.3) The electrical design of the device shall include a general arrangement plan showing the location of major items of equipment, for example the generator.	Not addressed.	Not addressed.

CRITERIA	CIRIA C666	DNV-RP-A203	DNV-OS-D201	DNV-OSS-312	DNV – Wave Energy Converter Design	EMEC – Design Basis	EMEC – Certification Schemes	EMEC – Manufacturing
Power Conditioning / Substations								
	Not addressed.	Not addressed.	(Ch.2.Sec.2.A201(a)) Electric distribution systems shall operate within the voltage and frequencies given in clauses 202 to 207. (Ch.2.Sec.2.A201(b)) Voltage variations deviating from the above are accepted in systems if they are intentionally designed for them (Ch.2.Sec.2.A201(c)) All voltages mentioned are root mean square values unless otherwise stated. (Ch.2.Sec.2.F101(a)) All switchboards and consumers shall be fed via switch-gear so that isolation for maintenance is possible. (Ch.2.Sec.2.F101(b)) Each important consumer shall be connected to a main switchboard by a separate circuit. (Ch.2.Sec.2.G401(a)) Transformers shall be fitted with circuit protection as required. Ch.2.Sec.2.G covers circuit and system protection for: (G300) Generators; (G400) Transformers; (G500) Motors; (G600) Batteries Ch.2.Sec.4.C covers control and protection circuits for switchgear assemblies.	(Sec.3.E101) Electrical systems are covered by DNV-OS-D201. Verification of the electrical system will be based on: Discrimination analysis	(17.2.2) Subsea AC transmission is feasible up to around 50 km. At distances beyond 50 km, transmission via a high voltage DC link will need to be considered. (17.2.4) The IEE forbids the use of oil filled transformers. IEC60076 power transformers should be used for this type of equipment. (17.2.6) Switchboards and control gear should be designed to IEC 62271-200 for high voltage and IEC 60439-1 and IEC 60092-302 for low voltage. DNV OS-D201 is also relevant.	(15.4.4) The design basis shall define the following parameters both at the device and at the grid connection point: Voltage; frequency; functionality of any voltage or frequency converter. (17.5) Standard terminal boxes should be used. However, the design should take into account the ingress protection necessary for the location of the boxes.	Not addressed.	Not addressed.

CRITERIA	CIRIA C666	DNV-RP-A203	DNV-OS-D201	DNV-OSS-312	DNV – Wave Energy Converter Design	EMEC – Design Basis	EMEC – Certification Schemes	EMEC – Manufacturing
Riser / Power Collection / Transmission Cables								
Cable route selection and survey requirements	Not addressed.	Not addressed.	Not addressed.	Not addressed.	(21.3) The route of the cable must be planned to avoid hazards such as shipping lanes, fishing grounds, rocks, wrecks, and areas of high currents or shifting sands. Burying the cable may reduce the hazard but will increase costs.	Not addressed.	Not addressed.	Not addressed.
Criteria for crossings (other cables, pipelines, anchorage areas, navigational channels)	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	(17.2) In considering the routing of the cables the following should be taken into account: Submerged hazards; Fishing grounds; Fish breeding grounds; Shipping lanes; Areas of high tidal stream velocities; Shifting sands; Stability of seabed; Environmental conditions.	Not addressed.	Not addressed.
Component / material standards	Not addressed.	Not addressed.	(Ch.2,Sec.2.J) Section deals with requirements for cable selection during system design, including: Fire resistance; voltage rating; separation and protection, and temperature class. (Ch.2,Sec.9) Section deals with technical requirements for cables as electrical components, including: conductor cross section; insulating materials, wire braid, and protective sheaths.	(Sec.3.E101) Electrical systems are covered by DNV-OS-D201. Verification of the electrical system will be based on: Cable selection philosophy.	(21.5) The ISO 13628-5 Standard is to be employed. The standard gives recommendations for design and material selection.	(17.1) Underwater connectors should demonstrate satisfactory service of at least 5 years in similar applications. Connectors should: Not be of a push fit type, but have a positive locking mechanism such as bayonet fitting; Be arranged so they cannot be connected in the wrong position.	Not addressed.	(9.2) Glands and enclosures… will be suitable for the environment in which they will operate.

CRITERIA	CIRIA C666	DNV-RP-A203	DNV-OS-D201	DNV-OSS-312	DNV – Wave Energy Converter Design	EMEC – Design Basis	EMEC – Certification Schemes	EMEC – Manufacturing
Riser design	Not addressed.	Not addressed.	Not addressed.	Not addressed.	(20.1) Umbilical design and acceptance criteria shall generally be based on ISO 13628-5, Part 5, "Subsea Umbilicals". Guidelines given in OS-F201 "Dynamic Risers" on global load effect analysis should be adopted.	(17.3) The design basis shall determine the loading the cable can withstand. (17.4) Umbilicals shall be capable of transmitting… for the service life of the device. In considering possible degradation the following factors shall be considered: Material compatibility in the marine environment; Operating temperature; Terminations or interfaces of umbilicals. (17.6) Refer to the Bibliography for relevant standards for umbilicals and cables.	Not addressed.	Not addressed.

CRITERIA	CIRIA C666	DNV-RP-A203	DNV-OS-D201	DNV-OSS-312	DNV – Wave Energy Converter Design	EMEC – Design Basis	EMEC – Certification Schemes	EMEC – Manufacturing
Auxiliary Systems								
Supervisory control and data acquisition (SCADA)	Not addressed.	Not addressed.	(Ch.2,Sec.5.A301) All machines shall be provided with temperature detectors in their stator windings for monitoring and alarm.	(Sec.3.F101) Typical documentation for instrumentation and control systems is listed.	Section 19 covers instrumentation and control systems in detail, including the following topics: System monitoring and control; Control hierarchy and channel separation; Internal environment considerations; Software development; Telemetry, control, and communications links; Reliability issues; Hydraulic systems and controls; Air flow turbine control	Section 16 covers instrumentation and control systems. The following are of particular importance: (16.4) General requirements for control systems; (16.5) Requirements for safety and business critical control systems (20.1) The design basis shall consider whether monitoring can be done in-situ whilst at sea or whether it is necessary to recover the device from site and bring it back ashore.	(7.3.4.2) The control and protection system shall be proven as sufficient to keep the system operating within the design load conditions as specified in the certificate. Documentation required shall include: Functional description of control system; Instrumentation and equipment lists	Not addressed.
Emergency safety systems	Not addressed.	Not addressed.	Ch.2.Sec.2.H covers the following systems: (H200) General design; (H300) Main and emergency switchboard; (H400) Motor; (H500) Emergency stop	(Sec.3.G101) Typical documentation for fire protection and safety systems is listed.	(17.2.8) Consideration should be given to eliminating the use of batteries wherever possible. Design of UPS systems should be compatible with NORSOK E-001, and meet the requirements of BS EN 50091.	(15.4.2) The design of the device shall include details of emergency safety systems, such as: Emergency and navigation lighting; Fire detection, alarm, and extinguisher systems; Watertight doors	(7.3.4.10) Safety systems for consideration in certification should include all or some of the following: Fire protection; Fire resistance; Escape and evacuation mechanisms; Emergency stop. Also reference EMEC "Guidelines for Health & Safety in the Marine Energy Industry".	Not addressed.
Piping systems (working fluids, lubricants, and ballast water)	Not addressed.	Not addressed.	(Ch.2,Sec.2.I301(c)) Pipes shall not be installed above generators. If unavoidable, additional screening of flanges shall be required to protect against splash, spray, or leakage. (Ch.2,Sec.5.A206(a)) Lubrication of rotating machines shall be effective under all operating conditions.	Not addressed.	(17.3.4.2) Couplings are a source of leakage and particular attention should be paid to them and use of correct connector parts relative to the approved versions. (17.3.6.1) For preparation of turbine specs the following factors should be considered: Rotating parts, bearings, and seals	(15.6.1) Material used for pipes, valves, and fittings shall be suitable for their intended fluid and service.	(7.3.4.4) Scope for certification shall include in-place conditions for: lubrication systems	(8.4) Plumbers thread tape shall be prohibited. Threaded pressure containing fittings shall be sealed with an appropriate sealing compound.

CRITERIA	EMEC – Health and Safety	EMEC – Reliability	EMEC – Project Development	EMEC – Grid Connection	EMEC – Performance of Wave Energy	EMEC – Performance of Tidal Energy	EMEC – Wave Energy Tank Testing	GL – Ocean Current Turbines
Platform								
Common to Floating and Fixed Systems								
Site selection and hazards survey	Section 7 addresses site selection, initial site investigation (including hazard identification and risk assessment, and passage planning) and planning considerations including metocean factors, port facilities, accessibility and access routes, navigational risks, and cable routes.	Not addressed.	Chapter 1 addresses Site Screening including legislative and jurisdictional considerations, technical and physical considerations, environmental considerations, and health and safety considerations. (6.3) The project developer should assess the available data and their suitability to inform the initial feasibility of the project. Any data gaps and their relevance should be highlighted in order to identify, define and prioritize the requirements for further and more detailed surveys.	Not addressed.	(4.2) discusses initial site selection; however, the focus is on selecting a site to provide good performance assessment conditions and test results.	(4.2) A survey of the bathymetry of the test site shall be carried out to ensure that it is free from obstacles and topology that could affect the performance of TECs, or adversely affect the local quality of tidal currents. The site shall be surveyed in accordance with IHO Order 1 hydrographic survey standard.	Not addressed.	Not addressed.

CRITERIA	EMEC – Health and Safety	EMEC – Reliability	EMEC – Project Development	EMEC – Grid Connection	EMEC – Performance of Wave Energy	EMEC – Performance of Tidal Energy	EMEC – Wave Energy Tank Testing	GL – Ocean Current Turbines
Environmental data (metocean event definitions)	(7.2.1) Metocean factors that are recommended for consideration with respect to the safe development of the site, include: 100, 10, and 1-year return period values for wind-speed and significant wave height; wave height, current and tides; directional wave data for extreme values of wind, wave and current; wave height/period joint frequency distribution (wave scatter diagram); wave spectral parameters; wind/wave/current angular separation data; current speed and/or directional variation over the water depth; long tem wave statistics by direction; and frequency of weather events such as fog, ice and electrical activity.	(5.1) Numerous factors that affect reliability, main metocean factors are: wind speed and direction; wave height, period, and direction; tidal current velocity; tidal periods, water depth; daylight and visibility; sea ice; threat of storms; temperature; rain; lightning (5.2.2.1) Many sites considered for converters are near-shore or in shallow water. Most metocean data derived from hindcast models suited to deep, open water. Near-shore corrections should be considered before metocean data used to represent a site. Wave loading through the water column during storms is of particular importance. Local knowledge should be sought for local effects that may not appear in large-area data sets.	(5.3.1) Available Metocean data should be collected in order to gain an understanding of the marine climate in the area of interest. (6.3.1) Marine resource assessment – In order to confirm the existing marine climate and the associated power availability at the identified location(s), it is recommended to monitor the local ocean resource for a sufficient period of time. Refers to an as yet drafted document for guidance on the recommended equipment, methodology and duration of this resource monitoring. (6.3.3) Based on the environmental issues during the site screening and continues discussions with consultees, an environmental scoping study should be prepared. This will define the content and extent of the environmental studies to submit to the consenting authorities. The main elements of an environmental scoping review should include (but not be limited to): review of existing environmental conditions and restraints, compilation of issues raised by consultees, identification of data gaps, and identification of key potential environmental impacts.	Not addressed.	(4.4) Current measurements should be made at one or more locations in the test site area. The measurements should extend over at least 30 days. At a minimum, the measurements should be made at one level in the upper water column. However, measurements at further levels would be advantageous. The measurements should be analyzed to give information about the main tidal constituents and also any non-tidal currents. (4.5) Measurements of the tidal height should be made at the test site. The measurements should extend over at least 30 days and should be analyzed to give information about the main tidal constituents and also any non-tidal currents. (4.6) Contains recommendations for current modeling. (4.7) Contains recommendations for wave modeling. (4.8) A preliminary wave measurement program should be carried out to verify the wave model and to compare conditions at the test measurement site and the projected WEC sites. Measure over several months, preferably in winter.	(4.3) The effects of seasonal migration of currents need to be considered, since their potential capacity to relocate may exert an influence upon the prediction of long-term power capture. Tidal stratification might also need to be taken into consideration, and the scale of its existence should be inferred from numerical modeling. Wave-current interaction also exerts an influence upon the total current resource and the magnitude of this effect shall be assessed and where significant, taken into account. In general the area to be considered in this respect typically shall be of the order of 10 TECs diameters up and downstream and 5 diameters either side of the test site. (4.4) Contains requirements for data measurement of speed and direction at the resource assessment stage, including requirements for positioning recording devices, a 10-min resolution time series, accuracy, and minimum 30-day recording period. (4.5) Contains requirements for data analysis at the resource assessment stage.	Not addressed.	(4.4.2.1) In general, a combined recurrence period of 50 years is considered for extreme environmental actions during operations. During installation, operation, and fault occurrence normal environmental conditions with a recurrence period of up to 1-year shall be considered. For simplification, if joint probabilities of extreme situations are not known, load cases (A) through (H) are provided for consideration in ultimate load design. For example: Load Case (A) = 50-year extreme regular current, combined with long term mean wave and wind speed. Wave direction can be assumed either in line or opposite to the current.

CRITERIA	EMEC – Health and Safety	EMEC – Reliability	EMEC – Project Development	EMEC – Grid Connection	EMEC – Performance of Wave Energy	EMEC – Performance of Tidal Energy	EMEC – Wave Energy Tank Testing	GL – Ocean Current Turbines
Geotechnical data	(7.3) Site investigation data, often supported by laboratory testing, is required to identify: sea bed topography, nature and stability of the sea bed surface, geomorphology and engineering properties of the strata underlying the sea bed. The extent of investigations should be sufficient in area, depth and detail to adequately cover the device or array location and potentially the cable routes. The site and complexity of the proposed anchor point arrangements, piling or foundations positions and the anticipated sea bed soil conditions should also be considered in determining their extent.	Not addressed.	(5.3.4) An initial assessment of the geotechnical characteristics of the sea-bed at candidate sites should be undertaken where possible using existing data. (6.3.1) Existing bathymetry and se-bed geomorphology in the area should be investigated to refine the location and extent of the deployment area, assess the fixing and mooring requirements and outline a corridor for the cable route. If existing information does not provide the required level of detail, geophysical and geotechnical surveys may need to be undertaken. Landfall characteristics and onshore geotechnical conditions should be assessed in order to identify the likely technical requirements for the onshore works and the installation of the onshore section of the cable.	Not addressed.	Not addressed.	(4.2) Sub-bottom profiling might also be required in situations where there is a considerable volume of suspended sediment, or layers of liquefied mud that may affect the device installation.	Not addressed.	(4.3(7)) Additional parameters to be established at the site are: seismic action, soil morphology and properties, scour, sea bed movement.
Loads to consider (O&M, environmental, transport, installation)	(8.2) The following cases should be defined for each device as applicable: Intact case Damaged case, involving failure of a single component, i.e. failure of a mooring line or anchor point Design environmental conditions – 100 year wave + 100 year wind + 10 year current – 100 year wave + 10 year wind + 100 year current Directional combinations	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	(4.1(1)) Loading results mainly from sea currents and wave interaction, as well as operational loads. Additionally loads may occur from wind forces, sea ice and seismic action. (4.1.(4)) Loads for fracture/ultimate strength and stability analysis include loading during extreme external conditions, during normal operation, maintenance, during or after activation of the safety system and/or occurrence of any single fault situation as well as during transport or installation.

CRITERIA	EMEC – Health and Safety	EMEC – Reliability	EMEC – Project Development	EMEC – Grid Connection	EMEC – Performance of Wave Energy	EMEC – Performance of Tidal Energy	EMEC – Wave Energy Tank Testing	GL – Ocean Current Turbines
Fatigue assessment	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	(4.1(2)) The load assumptions have to be prepared in relation to the intended service life of the structure under consideration. Design life time assumed to be 20 years. (4.1(3)) Fatigue load analysis shall consider all conditions contributing to fatigue during transport, installation, and operation during the intended life-time. (4.4.2.2) Lists further assumptions for the fatigue load cases.
Corrosion control	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	(3.1.(1)) Follow requirements from GL "Guideline for the Certification of Offshore Wind Turbines", Chapter 3. (3.1.(2)) Consider GL "Guidelines for Corrosion Protection and Coating Systems", Chapter 6. (3.2.3(1)) All surfaces and cutting edges shall be protected permanently against surrounding media by application of appropriate coatings.

CRITERIA	EMEC – Health and Safety	EMEC – Reliability	EMEC – Project Development	EMEC – Grid Connection	EMEC – Performance of Wave Energy	EMEC – Performance of Tidal Energy	EMEC – Wave Energy Tank Testing	GL – Ocean Current Turbines
Access for operation and maintenance	(7.2.3) Details should be provided on permitted and prohibited underwater activities and equipment when a risk to the device or operating personnel exists. Consideration should be given to the use of external markings to inform personnel of the locations of safe access routes and hazardous regions. (8.3.2) Particular attention should be paid to design choices in the following areas: Safe working access; Safe working areas; Prevention of unauthorized access.	(5.1) Numerous factors that affect reliability, main factors concerning accessibility are: getting to and from the converter; getting on or off the converter; working on the converter safely and effectively	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	(2.2.1(2)) Access systems shall be designed according to international and local standards. GL "Regulations for the Construction and Testing of Accesses to Ships" may be used as a guide.
Specific to Floating Systems								
Structural analysis, allowable stresses, and loads	(8.2) Design engineers may utilize relevant codes and standards to create a safe design. Examples of appropriate publications are listed. Accurate assessment of the operating environment… will provide information necessary to calculate the structural loads the installation can safely bear.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	(3.1) Description of planned testing should include: Extreme motions; Identification of most demanding sea-state	(4.2) Contains formulas for estimating environmental load from current and wave sources (5.1(1)) The strength analysis shall be performed according to GL "Guideline for the Certification of Offshore Wind Turbines", Chapter 5.

CRITERIA	EMEC – Health and Safety	EMEC – Reliability	EMEC – Project Development	EMEC – Grid Connection	EMEC – Performance of Wave Energy	EMEC – Performance of Tidal Energy	EMEC – Wave Energy Tank Testing	GL – Ocean Current Turbines
Hull stability requirements	(8.4) HSE publication 2001/063 – Marine risk assessment addresses hazards including: Loss of structural integrity (e.g. hull); Loss of stability (e.g. ballast system failure). Also see Code of Safe Working Practices for Merchant Seamen	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	(4.1) Description of prototype models of test should include: Centers of gravity, buoyancy, mass moments, etc.	(2.2.5(1)) The construction shall be water tight to protect electrical and mechanical parts. (2.2.5(2)) As a minimum water leakage and oil leakage shall be considered in the design. (7.2) Reference GL “Rules for Classification and Construction Seagoing Ships, Machinery Installations, Section 4, Main Shafting”. Also lists other precautions especially for ocean current turbines. (4.4.7(2)) For floating structures standard methods from marine engineering may be used. In extreme conditions there may be high angles of inclination leading to unfavorable loading.
Mooring system	(8.3.1) Existing design rules may be adopted by the device designer. Examples of existing regulations are listed. Consideration should be given to safe and practical installation and access for maintenance. Design such that construction, assembly, and testing can place onshore as much as is possible. (8.4) HSE publication 2001/063 – Marine risk assessment addresses hazards including: Loss of position keeping (e.g. mooring failure)	Not addressed.	(6.4) Evaluation of the different design options should include: Mooring requirements, which will be based on the device, the geomorphology of the sea-bed, and environmental impacts	Not addressed.	(7.4) Wave buoys should be moored so that the are free to respond to the waves, but at the same time can survive the highest waves that are likely to occur at the site.	Not addressed.	(4.1) Description of prototype models of test should include: Mooring details (stiffness)	(4.4.8) Addresses mooring dynamics (6.1(2)) The analysis of anchoring and mooring systems shall be performed according to GL “Guideline for the Construction and Classification/Certification of Floating Productions, Storage and Off-Loading Units”.

CRITERIA	EMEC – Health and Safety	EMEC – Reliability	EMEC – Project Development	EMEC – Grid Connection	EMEC – Performance of Wave Energy	EMEC – Performance of Tidal Energy	EMEC – Wave Energy Tank Testing	GL – Ocean Current Turbines
Specific to Fixed Systems								
Structural analysis, allowable stresses, and loads	See floating systems.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	(3.1) Description of planned testing should include: Extreme wave loading of structure and foundations;	See floating systems.
Foundation design	Not addressed.	Not addressed.	(6.4) Evaluation of the different design options should include: Foundation requirements, which will be based on the device, the geomorphology of the sea-bed, and environmental impacts	Not addressed.	Not addressed.	Not addressed.	(4.1) Description of prototype models of test should include: Foundation details (stiffness)	(6.1(1)) The analysis of the structure and foundation shall be performed according to GL "Guideline for the Certification of Offshore Wind Turbines", Chapter 6.
Scour protection	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	(6.2(1)) The analysis of the scour protection shall be performing according to GL "Certification of Offshore Wind Turbines", Chapter 6. (6.2(2)) Global and local scour shall be considered. (6.2(3)) Measures may have to be taken to avoid scour around the system's foundation and anchoring points. (6.2(4)) In some cases, influence of the rotor vortex and its induced pressure fluctuations on the sea bed shall be considered. A minimum distance to the seabed shall be defined by the manufacturer for the location considered.
Power Conversion Systems								
Rotor / Nacelle Assemblies								

CRITERIA	EMEC – Health and Safety	EMEC – Reliability	EMEC – Project Development	EMEC – Grid Connection	EMEC – Performance of Wave Energy	EMEC – Performance of Tidal Energy	EMEC – Wave Energy Tank Testing	GL – Ocean Current Turbines
Basis of design	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	(4.4.1(1)) Design concepts of ocean current turbines are quite similar to wind turbine designs. The main loads to be considered and methods to do so are described in GL “Guideline for the Certification of Offshore Wind Turbines”, Chapter 4.
Loads to consider (actuation, hydrodynamic, shut down, transport, installation)	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	(4.4.1(2)) Additional effects have to be considered when calculating forces on ocean current turbines. (4.4.1(3)) Flow around the lifting device such as a horizontal rotor may change free surface level. (4.4.1(4)) Cavitation imposes additional loads on the structure and shall be avoided. (4.4.1(5)) Lists additional effects to consider.
Machinery components	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	(7.1) Analysis of machinery shall be performed according to GL “Guideline for the Certification of Offshore Wind Turbines”, Chapter 7. See also GL “Rules for Classification and Construction, Seagoing Ships, Machinery Installations.”
Displacer Assemblies								
Basis of design	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.
Loads to consider (actuation, hydrodynamic, shut down, transport, installation)	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.
Machinery components	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.
Yaw Control Systems								
Basis of design	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.

Appendix B – Device Design Criteria

CRITERIA	EMEC – Health and Safety	EMEC – Reliability	EMEC – Project Development	EMEC – Grid Connection	EMEC – Performance of Wave Energy	EMEC – Performance of Tidal Energy	EMEC – Wave Energy Tank Testing	GL – Ocean Current Turbines
Loads to consider (actuation, hydrodynamic, shut down, transport, installation)	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.
Machinery components	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.
Electrical Generators								
	Not addressed.	Not addressed.	(8.2) Technical studies to refine the design of the project should include: Development of generation profiles and quality of generation based on the selected technology	(4.2.1) In accordance with section DPC 7.4.1 of the Distribution Code, the generator shall supply its registered capacity under normal conditions within a frequency range of 49.5 Hz to 50.5 Hz. (4.5.1) Guidance on power quality issues can be obtained from a wind turbine standard (see BS EN 61400-21:2002). (4.5.2) Consider the effects of switching on/off as part of the routine operation (e.g. switching on/off individual generators with consequential inrush currents)	Not addressed.	Not addressed.	Not. Addressed.	(8.1(1)) In general electrical installations have to be designed and certified according to GL "Guideline for the Certification of Offshore Wind Turbines", Chapter 8.
Power Conditioning / Substations								

CRITERIA	EMEC – Health and Safety	EMEC – Reliability	EMEC – Project Development	EMEC – Grid Connection	EMEC – Performance of Wave Energy	EMEC – Performance of Tidal Energy	EMEC – Wave Energy Tank Testing	GL – Ocean Current Turbines
	Not addressed.	Not addressed.	(5.3.2) Early discussions with the operator of the transmission or distribution network should identify if a grid connection point is available in the planned area for the device. (6.4) Elements to take into account in concept design should include: Electrical design, including offshore and onshore electrical infrastructure (i.e. transformer, switchgear, connectors, etc)	Section 4 describes desired electrical parameters at the point of grid connection, including: Frequency, voltage range, power factor, and power quality. (5.3.2) As marine generators could be difficult to access, the use of circuit breakers instead of fuses should be considered, as these can be remotely reset. (5.3.4) There are advantages in locating protective devices onshore or on an offshore substation structure. (7.4) References *The Electricity Safety, Quality, and Continuity Regulations,* 2002, for guidance on earthing systems for marine generators.	(6.3) Electrical transducers shall meet the requirements of the following standards: Power transducers - IEC 60068-8 Current transformers - IEC 60044-1 Voltage transformers - IEC 60044-2	(5.1) Current and voltage transformers shall conform to Class 0.5, or better, as defined in IEC 60044- The accuracy of the power measurement device, if it is a transducer, shall conform to Class 0.5, or better, as defined in IEC 60688.	Not addressed.	(8.1(2)) Transformer and other auxiliary structures shall be defined as general offshore structures and designed according to GL "Rules for Classification and Construction, Offshore Installations".

Riser / Power Collection / Transmission Cables								
Cable route selection and survey requirements	Not addressed.	Not addressed.	(5.3.4) Sea-bed morphology will determine which areas are suitable for… the sub-sea cables. (6.3.1) Existing bathymetry should be investigated to outline a corridor for the cable route. If the existing information does not provide the required level of detail, further surveys may need to be done. (6.4) Elements to take into account in concept design should include: Indicative route; Protective measures.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.

Appendix B – Device Design Criteria

CRITERIA	EMEC – Health and Safety	EMEC – Reliability	EMEC – Project Development	EMEC – Grid Connection	EMEC – Performance of Wave Energy	EMEC – Performance of Tidal Energy	EMEC – Wave Energy Tank Testing	GL – Ocean Current Turbines
Criteria for crossings (other cables, pipelines, anchorage areas, navigational channels)	(7.2.4) Marine projects should be located in areas that do not endanger existing marine users. (7.2.5) Awareness of existing marine cables is an important consideration for site selection and routes for cable laying.	Not addressed.	(5.4.4) The presence and relevance of the following sea users and sub-sea infrastructure should be identified: Fishing; Commercial navigation; Recreational navigation (diving, surfing); MOD activities; Existing sub-sea cable and pipelines; Aggregate winning.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.
Component / material standards	Not addressed.	Not addressed.	(6.4) Elements to take into account in concept design should include: Cable electrical specification.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	(8.1(7)) If the electrical installation is located below sea level, pressure proof installations and bushings shall be used where necessary. The extent of this shall correspond to the water depth at which the device is installed. (8.1(8)) In compartments housing electrical installation, atmospheric control shall be applied.
Riser design criteria	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	(8.1(4)) Sea cables shall be designed and analyzed according to GL "Guideline for the Certification of Offshore Wind Turbines", Chapter 8.
Auxiliary Systems								
Supervisory control and data acquisition (SCADA)	(8.3.2) Particular attention should be paid to design choices in the following areas: Operational controls	Not addressed.	Not addressed.	(5.3.6) SCADA systems are likely to make use of optical fibers within or alongside power cables. Therefore, it is likely to be advantageous to use extra fibers to make the best use of protection relays.	(7.2) Discusses placement of instrumentation, including considerations for shallow vs. deep water sites as well as redundancy. (7.3) Discusses types of instrumentation, such as following buoys, acoustic dopplers, x-band radar, and pressure sensors.	(5.2) A device shall be installed to record variation in current velocity. Specifications for the device are then listed. (5.5) A digital data acquisition system shall be applied to gather measurements and to store pre-processed data. The uncertainty introduced by the system shall be demonstrated as being negligible compared to that due to the sensors.	(4.3) Description of data acquisition (DAQ) equipment and set up to include: DAQ hardware & software; Data dissemination rates; Acquisition sampling rates; Output file formats; Transducers used and measurements taken	(2.1(1)) A thorough analysis of… the monitoring devices shall be carried out. (2.1(4)) It is assumed that the device control system, shall meet the basis requirements listed in GL "Guideline for the Certification of Offshore Wind Turbines", Chapter 2.

CRITERIA	EMEC – Health and Safety	EMEC – Reliability	EMEC – Project Development	EMEC – Grid Connection	EMEC – Performance of Wave Energy	EMEC – Performance of Tidal Energy	EMEC – Wave Energy Tank Testing	GL – Ocean Current Turbines
Emergency safety systems	(8.3.2) Particular attention should be paid to design choices in the following areas: Safe remote control and operation, including emergency shut down	Not addressed.	Not addressed.	(7.1) Earthing systems are required for the following purposes: to allow protective devices to operate; to protect people and animals; and to protect against lightning; (10) The electrical system shall be designed so that: It shall be possible to prevent inadvertent re-energization, by locking disconnection devices.	Not addressed.	Not addressed.	Not addressed.	(2.1(1)) A thorough analysis of the protective devices shall be carried out. (2.1(3)) The outcome of the risk analysis shall be implemented in the protective devices.
Piping systems (working fluids, lubricants, and ballast water)	(8.4) Plumbers thread tape shall be prohibited. Threaded pressure containing fittings shall be sealed with an appropriate sealing compound.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed

CRITERIA	HMRC Part 1: Wave Power	IALA O-131	IEA OES Annex II	IEC 61400	IMCA AODC 35	ISO 2394:1998	DNV-OS-C301	DNV-OS-D101
Platform								
Common to Floating and Fixed Systems								
Site selection and hazards survey	Not addressed.	(1.2) Consultation between the stakeholders…and wave and tidal contractors should take place at an early stage. In general, development of offshore energy structures should not prejudice the safe use of Traffic Separation Schemes, Inshore Traffic Zones, recognized sea lanes and safe access to anchorages, harbors and places of refuge.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.
Environmental data (metocean event definitions)	Not addressed.	Not addressed.	Subtask II.2 (3) In most countries it is common to operate with a 100-year design situation. (5) Presents a list of measurements related to the weather conditions that are associated with the incoming power and operational conditions of the converter.	(6.1) The marine conditions described in this clause include waves, sea currents, water level, sea ice, marine growth, scour, and seabed movement.	Not addressed	Not addressed.	Not addressed.	Not addressed.

CRITERIA	HMRC Part 1: Wave Power	IALA O-131	IEA OES Annex II	IEC 61400	IMCA AODC 35	ISO 2394:1998	DNV-OS-C301	DNV-OS-D101
Geotechnical data	Not addressed	Not addressed.	Not addressed	(12.5) The soil properties at a site shall be assessed by a professionally qualified geotechnical engineer. Soil investigations shall be performed to provide adequate information to characterize soil properties throughout the depth of area that will affect or be affected by the foundation structure. The investigation in general shall include: geological survey; topographic survey of the sea floor; geophysical investigation; geotechnical investigations consisting of in-situ testing and laboratory tests. The soil investigations shall provide the following data: data for soil classification; shear strength parameters; deformation properties, including consolidation parameters; permeability; stiffness and damping parameters.	Not addressed.	Not addressed	Not addressed	Not addressed
Loads to consider (O&M, environmental, transport, installation)	Not addressed	Not addressed.	Not addressed	(7.3) Loads to be considered in the deign calculations: Gravitational and inertial loads; aerodynamic loads; actuation loads; hydrodynamic loads; sea ice loads; other loads such as wake loads, impact loads, and where relevant , earthquake loads.	Not addressed.	(9.5) Load cases should be arranged so that they produce the most unfavorable effect on the structure for the limit state considered.	(Ch.2,Sec.1.B102) In general a minimum wind velocity of 36 m/s shall be used for normal operating conditions and 51.5 m/s for severe storm conditions. In sheltered locations, consideration shall be given to a reduced wind velocity of not less than 25.8 m/s.	Not addressed
Fatigue assessment	Not addressed.	Not addressed.	Subtask II.2 (3) In order to determine the influence of fatigue the number and size of loads within each sea state must be known. A conservative estimate of the influence can be made by measuring the maximum load in each sea state and use the indicated number of oscillations in Table 3.12 for fatigue calculations.	Not addressed.	Not addressed.	Annex C discusses two models for fatigue analysis: the S-N line approach and the Fracture Mechanics approach.	Not addressed.	Not addressed.

CRITERIA	HMRC Part 1: Wave Power	IALA O-131	IEA OES Annex II	IEC 61400	IMCA AODC 35	ISO 2394:1998	DNV-OS-C301	DNV-OS-D101
Corrosion control	Not addressed.	Not addressed.	Not addressed.	(8) Provisions shall be made to ensure adequate protection of all components of the control and protection system against the effects of the marine environment. Guidance relating to corrosion protection is given in Appendix I.	Not addressed.	Not addressed.	Not addressed.	Not addressed
Access for operation and maintenance	Not addressed.	Not addressed.	Not addressed.	(14.2) In order to ensure safety of the inspection and maintenance personnel, the design shall incorporate: safe access paths and working places for inspection and routine maintenance.	(2.0.5.6) Fixed cables should be positioned so that they do NOT form a convenient hand grip.	Not addressed.	(Ch.2,Sec.2.B500) Discusses the operation and control of watertight doors and hatch covers. (Ch.2,Sec.2.D) Gives requirements for the arrangement of weathertight openings and their closing appliances. Includes minimum heights for coamings and sills.	Not addressed
Specific to Floating Systems								
Structural analysis, allowable stresses, and loads	Not addressed.	Not addressed.	Not addressed.	(7.1) The structural analysis shall be based on ISO 2394.	Not addressed.	(4.3(a)) Design and maintain the structure according to the rules in the following clauses for conditions associated with ordinary use and ordinary circumstances. (b) Design of the essential load-bearing members of a structure for specific exceptional actions which may be caused by accidents or similar occurrences. The structural layout should be checked to identify "key" structural elements, whose failure would cause the collapse of more than a limited portion of the structure close to the element in question. (c) Protection against foreseeable actions and elimination of errors. (d) Design of the structure in such a way that local damage does not lead to immediate collapse of the whole structure or a significant part of it.	(Ch.2,Sec.2.B400) Discusses calculation methods for the strength of watertight doors and hatch covers, including minimum thickness, minimum stiffness, and maximum stress.	Not addressed.

Appendix B – Device Design Criteria

CRITERIA	HMRC Part 1: Wave Power	IALA O-131	IEA OES Annex II	IEC 61400	IMCA AODC 35	ISO 2394:1998	DNV-OS-C301	DNV-OS-D101
Hull stability requirements	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	The entire document deals expressly with hull stability and watertight integrity requirements. This includes intact stability, damage stability, and freeboard.	Not addressed
Mooring system	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed
Unique to Fixed Systems								
Structural analysis, allowable stresses, and loads	Not addressed.	Not addressed.	Not addressed.	(7.1) The structural analysis shall be based on ISO 2394.	Not addressed.	See floating systems summary.	Not addressed.	Not addressed
Foundation design	Not addressed.	Not addressed.	Not addressed.	(11) The design and structural analysis of the foundation shall be performed in accordance with the ISO offshore structural design standards or other recognized offshore design standards. If offshore design standards other than the ISO standards are used, it must be demonstrated that at least the same level of structural reliability with respect to ultimate strength and fatigue is obtained.	Not addressed.	Not addressed.	Not addressed.	Not addressed
Scour protection	Not addressed.	(1.2) Depth monitoring devices to measure scour may need to be considered when approving wave and tidal energy locations.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed

Appendix B – Device Design Criteria

CRITERIA	HMRC Part 1: Wave Power	IALA O-131	IEA OES Annex II	IEC 61400	IMCA AODC 35	ISO 2394:1998	DNV-OS-C301	DNV-OS-D101
Power Conversion Systems								
Rotor / Nacelle Assemblies								
Basis of design	(2.2.4) Following the establishment of the primary power absorption characteristics, feasibility studies should be undertaken on the power take-off system of choice; feasible options include turbines or pumps.	(1.1) Many tidal concepts have fast-moving sub-surface elements such as whirling blades; these should be taken into account when identifying marking requirements.	Subtask II.2 (4) Defines main classes of Power Take-Off Systems: Oscillating Water Column Systems (Air Power); Overtopping Systems (water power); and Rotary Mechanical systems (Shaft power).	(9) The design of all mechanical systems within an offshore wind turbine shall meet the requirements stated in Clause 9. Provisions shall be made to ensure adequate protection of all mechanical systems against the effects of the marine environment. (9.1) All mechanical systems in the drive train shall be designed according to IEC/ISO standards wherever available. Otherwise, recognized standards shall be used. (9.4) Gears shall be designed using appropriate calculation methods as described in ISO 6336-1 to ISO 6336-3.	Not addressed.	Not addressed.	Not addressed.	Not addressed.
Loads to consider (actuation, hydrodynamic, shut down, transport, installation)	Not addressed.	Not addressed.	Not addressed.	Table 2 includes design load cases for situations including: Power production; Power production plus occurrence of fault; Start up; Normal shut down; Emergency shut down; Parked (standing still or idling); Parked and fault conditions; transport, assembly, maintenance and repair.	Not addressed.	Not addressed.	Not addressed.	Not addressed.
Machinery components	Not addressed.	Not addressed.	Not addressed.	Section 9 of IEC61400-1 addresses mechanical systems with sections addressing: hydraulic or pneumatic systems, main gearbox, yaw system, pitch system, protection function mechanical brakes, and rolling bearings.	Not addressed.	Not addressed.	Not addressed.	(B200) All components and systems covered by this standard shall be designed to operate under the environmental conditions provided. List, rolling, trim and pitch of floating installations according to tables B1 and B2. Environmental conditions for instrumentation are given in DNV-OS-D202 Pt. 2 Sec. 4.

CRITERIA	HMRC Part 1: Wave Power	IALA O-131	IEA OES Annex II	IEC 61400	IMCA AODC 35	ISO 2394:1998	DNV-OS-C301	DNV-OS-D101
Displacer Assemblies								
Basis of design	(2.2.4) Following the establishment of the primary power absorption characteristics, feasibility studies should be undertaken on the power take-off system of choice; feasible options include pneumatic or hydraulic primary conversion.	Not addressed.	Subtask II.2 (4) Defines main classes of Power Take-Off Systems: Linear Mechanical Systems; (Mechanical Power); Hydraulic systems (Fluid Power)	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.
Loads to consider (actuation, hydrodynamic, shut down, transport, installation)	Not addressed.	Not addressed.	Not addressed.	See nacelle assemblies. (9.3) Where auxiliary items are powered by hydraulic or pneumatic energy the systems must be designed to avoid potential hazards. Means of isolating or discharging accumulated energy must be included.	Not addressed.	Not addressed.	Not addressed.	Not addressed.
Machinery components	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	(B200) All components and systems covered by this standard shall be designed to operate under the environmental conditions provided. List, rolling, trim and pitch of floating installations according to tables B1 and B2. Environmental conditions for instrumentation are given in DNV-OS-D202 Pt. 2 Sec. 4.
Yaw Control Systems								
Basis of design	Not addressed.	Not addressed.	Not addressed.	See nacelle assemblies. (9.5) Any motors shall comply with relevant parts of Clause 10.	Not addressed.	Not addressed.	Not addressed.	Not addressed.
Loads to consider (actuation, hydrodynamic, shut down, transport, installation)	Not addressed.	Not addressed.	Not addressed.	See nacelle assemblies.	Not addressed.	Not addressed.	Not addressed.	Not addressed.

Appendix B – Device Design Criteria

CRITERIA	HMRC Part 1: Wave Power	IALA O-131	IEA OES Annex II	IEC 61400	IMCA AODC 35	ISO 2394:1998	DNV-OS-C301	DNV-OS-D101
Machinery components	Not addressed.	Not addressed.	Not addressed.	(9.6) The pitch system may consist of means to adjust blade pitch angle (e.g. hydraulic actuators, electric motors, gearboxes, brakes, and pinions) and means to guide the rotation (e.g. a bearing).	Not addressed.	Not addressed.	Not addressed.	(B200) All components and systems covered by this standard shall be designed to operate under the environmental conditions provided. List, rolling, trim and pitch of floating installations according to tables B1 and B2. Environmental conditions for instrumentation are given in DNV-OS-D202 Pt. 2 Sec. 4.
Electrical Generators								
	(2.2.4) To reduce the number of components and consequential losses, such as through a gearbox, a direct coupling is usually proposed. However, this restricts generator options.	Not addressed.	Not addressed.	(10.8) If a capacitor bank is connected in parallel with an induction generator, a suitable switch is required to disconnect the bank whenever there is a loss of network power.	Sections 1.1 through 1.12 provide tables on the safe voltage or current source to be used for a given situation or type of equipment.	Not addressed.	Not addressed.	Not addressed.
Power Conditioning								
	(2.2.1) Methods of reducing, or smoothing, extremes in power production should be pursued, either as a loss in relief (pressure valves) or transfer by short-term storage (accumulators).	(7) An electrical transformer station or other structure, if part of the device field, should be included as part of the overall marking. Otherwise it should be marked as a standalone device as described in Section 5.	Not addressed.	(10.10) The power quality characteristics of the turbine shall be assessed in accordance with IEC 61400-21. The procedures in IEC 61400-21 may be used to demonstrate compliance with requirements of the public distribution or transmission network.	Sections 2.1 through 2.10 show several uses of underwater equipment, each of which requires an isolating transformer to make the power from the source suitable for use by the device. (1.13(c)) All electrical supplies for use under water should be electrically isolated from the distribution system of the installation by, for example, isolating transformers. (3.2.2) Materials used for terminal blocks and cable markers should be chosen with toxicity in mind.	Not addressed.	Not addressed.	Not addressed.
Riser / Power Collection / Transmission Cables								
Cable route selection and survey requirements	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.

CRITERIA	HMRC Part 1: Wave Power	IALA O-131	IEA OES Annex II	IEC 61400	IMCA AODC 35	ISO 2394:1998	DNV-OS-C301	DNV-OS-D101
Criteria for crossings (other cables, pipelines, anchorage areas, navigational channels)	Not addressed.	(4) Power cables should be sufficiently trenched to avoid exposure from scouring / sand migration / trawling activities.	Not addressed.	(10.7) Cables shall be buried at a suitable depth to avoid damage by service vehicles. If not protected by a conduit or duct, cables shall be marked by covers or suitable marking tape.	Not addressed.	Not addressed.	Not addressed.	Not addressed.
Component / material standards	Not addressed.	Not addressed.	Not addressed.	(10.7) Where there is a possibility of… animals damaging cables, armored cables or conduits shall be used.	(2.0.4) It is important always to use low-toxicity cables and other materials. (3.2.1) Cable manufacturers should be consulted… before a cable is selected. Lists parameters that should be determined, such as: Normal current; Fault current and duration; Ambient temperature and pressure; Possible contamination; Mechanical strength required.	Not addressed.	Not addressed.	Not addressed.
Riser design criteria	Not addressed.	Not addressed.	Not addressed.	Not addressed.	(1.11) Likely to receive rough handling and to be exposed to water temperatures from 0 to 30 deg. C, and below 0 and up to 50 between the surface of the sea and the topside connection. (2.11) Supplied from a main isolation transformer on the surface and is the normal method of active protection.	Not addressed.	Not addressed.	Not addressed.

CRITERIA	HMRC Part 1: Wave Power	IALA O-131	IEA OES Annex II	IEC 61400	IMCA AODC 35	ISO 2394:1998	DNV-OS-C301	DNV-OS-D101
Auxiliary Systems								
Supervisory control and data acquisition (SCADA)	Not addressed.	Not addressed.	Not addressed.	Not addressed.	(2.0.3) In addition to passive protection, the system should provide active protection against shock. Active protection may be provided by a residual current device (RCD) or a line insulation monitor (LIM) coupled to a circuit breaker. (2.0.3.1) Commonly used RCDs have a typical operating time of 15 to 25 ms. A trip current of 30 mA at 20 ms has been found to be suitable. (2.0.3.2) A line-insulation monitor may be used on an umbilical cable as it enters or leaves the water to check for any developing electrical leakage. (2.0.3.2) A read-out of insulation level should be provided with warnings of low levels if appropriate.	Not addressed.	Not addressed.	Not addressed.
Emergency safety systems	Not addressed.	(5(a)) When structures are fixed to the seabed and extend above the surface, mark in accordance with IALA O-117 “Marking of Offshore Wind Farms” (5(b) Mark areas containing surface or sub-surface devices in accordance with IALA Buoyage System. (5(d)) How to mark individual devices extending above the waterline. Rest of Section 5 has additional situations requiring marking.	Not addressed.	(8.2) Where selection of control mode can be exercised, for example, for maintenance, each mode shall override all other control, except for emergency stop. (8.3) Protection functions shall maintain the wind turbine in a safe condition.	Not addressed.	Not addressed.	(Ch.2,Sec.2.B501) Frequently used watertight doors or hatch covers shall be arranged for emergency remote closing.	Not addressed.

CRITERIA	HMRC Part 1: Wave Power	IALA O-131	IEA OES Annex II	IEC 61400	IMCA AODC 35	ISO 2394:1998	DNV-OS-C301	DNV-OS-D101
Piping systems (working fluids, lubricants, and ballast water)	Not addressed.	Not addressed.	Not addressed.	(9.3) All pipes and/or hoses carrying hydraulic oil or compressed air shall be designed to withstand foreseen internal and external stresses.	(2.0.5.7) Terminal chambers should be sealed against entry of moisture.	Not addressed.	(Ch.2,Sec.2.A103) Piping systems… shall be in accordance with DNV-OS-D101 unless specified otherwise. (Ch.2,Sec.2.E) Specifically addresses ventilators and air pipes. (Ch.2,Sec.2.F) Specifically addresses inlets, discharges, and scuppers.	Section 2 (A 101) This section gives minimum requirements which apply to piping system, including bends, tees, valves, fittings, flanges, flexible elements, tec. Section 3, A 102) Requirements for ship-shaped units are given in DNV Rules for Classification of Ships, Pt.4, Ch.6. The requirements of this section are applicable to piping systems for tanks and dry compartments.

This page intentionally left blank.

Appendix C – Device Modeling and Testing Criteria

This page intentionally left blank.

CRITERIA	ABS 116	ABS 117	API RP 2A-WSD	API RP 2I	API RP 2L	API RP 2SK	API RP 2SM
Types of testing and test programs	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	(8) The primary objectives are the following: a. To determine maximum responses for design purpose, for example, motions, line tensions, forces at mooring interfaces, and so forth b. To quantify important parameters and thereby to calibrate computer programs c. To confirm, using a physical model, that no important facet of the operation has been overlooked.	(5.5) Recommendations for undertaking model tests are provided in API RP 2SK.
Physical small-scale model tests	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	(8) In order to obtain realistic results from model test, it is important to select the proper vessel and mooring model scales and testing facility (size and depth of model basin, wave, wind, and current generating capability). Often some of these parameters must be compromised to satisfy conflicting scaling laws and facility limitations. Because of this, scale errors should be minimized. Guidelines for wind tunnel tests can be found in SNAME T&R Bulletin 5-4. (A.3.2) Model test data may be used to predict wave forces for mooring system design provided that a representative underwater model of the unit is tested. Care should be taken to assure that the character of the flow in the model test is the same as the character of the flow for the full-scale unit.	Not addressed.
Open ocean prototype or large-scale model test	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.

Appendix C – Device Modeling and Testing Criteria

SUBJECT	CIRIA C666	DNV-RP-A203	DNV-OS-D201	DNV-OSS-312	DNV – Wave Energy Converter Design	EMEC – Design Basis	EMEC – Certification Schemes	EMEC – Manufacturing
Types of testing and test programs	Not addressed.	(9.7.1) Tests are required: To obtain input data for analysis; To verify analytical models; To verify function; To verify system reliability; The typical tests are termed: 1. Basic Tests, such as material properties 2. Prototype tests (qualification tests) of components and assemblies to verify the functional requirements. 3. Factory acceptance tests to verify manufacturing and assembly 4. Pre and Post-install tests of the full assembly. 5. Pilot application, represent the first use Section 9.7.2 through 9.7.6 describe each type of test in more detail	Not addressed.	(Section 2 B500) - The analytical approach should be supported and complemented by results obtained from testing to handle the uncertainties in the technology. The typical tests are termed: • Basic Tests, such as material properties • Prototype tests (qualification tests) of components and assemblies to verify the functional requirements. • Factory acceptance tests to verify manufacturing. • Model basin tests to test the global response of the device in survival and operational conditions. • Simulation tests for control systems or structural interactions • Pre and Post-install tests of the full assembly. Analyses of the device response and power performance should be validated against the actual test results found in model tests and pilot tests.	(Section 15.2) For wave energy devices with a dynamic response to wave loading and /or novel mooring configuration, a complete time domain simulation combined with tank testing may be necessary.	Not addressed.	Not addressed.	Not addressed.
Physical small-scale model tests	Not addressed.	Not addressed.	Not addressed.	(Section 3 B300) - Documentation for certification will include model test documentation.	(Appendix B3) – Hydrodynamic model tests should be conducted to: • Vary the waves to confirm that important hydrodynamic features are not overlooked. • Support theoretical calculations. • Verify general theory Model tests of survival performance should be conducted due to the strong non-linear effects of waves on structures.	Not addressed.	Not addressed.	Not addressed.
Open ocean prototype or large-scale model test	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.

SUBJECT	EMEC – Health and Safety	EMEC – Reliability, Maintainability and Survivability	EMEC – Project Development	EMEC – Grid Connection	EMEC – Performance of Wave Energy	EMEC – Performance of Tidal Energy	EMEC – Wave Energy Tank Testing	GL – Ocean Current Turbines
Types of testing and test programs	Not addressed.	Annex C – The importance of a structured program of system and component testing cannot be over emphasized. It is also important to distinguish between performance testing and reliability testing (where reliability is defined in Section 3.) The testing falls into two categories – development testing and production testing. The purpose of development testing is mainly to identify strengths and weaknesses in the design. The purpose of production testing is mainly to identify any manufacturing weaknesses. Testing, and in particular design for testability, should be an integral part of the design, development and production process.	Not addressed.	Not addressed.	This document outlines a methodology for assessing the performance of Wave Energy Conversion Systems at open sea test sites. (1) It is not intended to apply to testing in enclosed tanks or test basins. It is aimed primarily at WEC's that are post-prototype machines. Sections address: test site, measurements – general considerations, wave energy conversion system power output measurements, wave measurements, meteorological measurements, calculation of performance indicators, and reporting.	Not addressed.	Not addressed.	Not addressed.
Physical small-scale model tests	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	(1) This document is written to outline chapter headings that are to form a Scope that will be used as the basis for drafting the formal text of a tank testing standard for WECs. (2.1) When drafted will provide comment and guidance on the matching of appropriate physical scale to required parameters under investigation, and scale dependent effects that could influence measured quantities and their extrapolation to full scale values.	Not addressed.

SUBJECT	EMEC – Health and Safety	EMEC – Reliability, Maintainability and Survivability	EMEC – Project Development	EMEC – Grid Connection	EMEC – Performance of Wave Energy	EMEC – Performance of Tidal Energy	EMEC – Wave Energy Tank Testing	GL – Ocean Current Turbines
Open ocean prototype or large-scale model test	Not addressed.	Not addressed.	Not addressed.	Not addressed.	This document outlines a methodology for assessing the performance of Wave Energy Conversion Systems at open sea test sites. (1) It is not intended to apply to testing in enclosed tanks or test basins. It is aimed primarily at WEC's that are post-prototype machines. Sections address: test site, measurements – general considerations, wave energy conversion system power output measurements, wave measurements, meteorological measurements, calculation of performance indicators, and reporting.	(1) This document establishes a uniform methodology to ensure consistency and accuracy in the measurement and analysis of the power performance exhibited by tidal energy conversion systems TECS). This document also provides guidance in the measurement, analysis and reporting of the performance testing of TECS. Sections address: test conditions, test equipment, measurement procedures for TECS device performance, derived results, and reporting format.	Not addressed.	(10) Testing**.** Prototype testing shall be performed according to Chapter 11 of GL Guide for the Certification of Offshore Wind Turbines, adjusted for underwater conditions. Measurements needed for a new current turbine include: • Power curve • Power quality • Load measurement • Acoustic measurement • Gearbox prototype • Test of the systems behavior.

SUBJECT	HMRC Part 1: Wave Power	IALA O-131	IEA OES Annex II	IEC 61400	IMCA AODC 35	ISO 2394:1998		
Types of testing and test programs	This protocol presents three phases of scale model testing and two phases of prototype scale testing during the development and evaluation of a WEC concept. The protocol is an approach to manage the technical and cost risks associated with developing a new technology. Performance testing is predominant in Phase 1- Validation Model (Sect. 2.1) and Phase 2 – Design Model (Sect 2.2) tests. Survival testing is first considered in the Phase 3 Process Model tests (Sect 2.3) at a scale 1:3-15, in either large basin tests or benign outdoor sites. **(2.3.1) -** makes performance testing a primary consideration and storm & survival tests are secondary. **(2.3.2) -** discusses the secondary test objectives of gathering data on survival forces and stresses in components.	Not addressed.	(Annex II Task 2.3) - recommends a series of standard tests to evaluate wave energy concepts in terms of energy production and design loads. A survival testing limit is defined as wave conditions that only occur for 3 hours every 50 or 100 years. Task 2.4 covers measurements of power take off, forces, and speeds for various wave energy conversion device concepts. (Annex II Task 3) - has standards for presenting results. These include describing the test facility and the WEC, the experimental setup, and the results from standardized power production tests and survival tests. Power results include: power curve vs Hs, annual energy production, and annual average energy capture ratio. (Annex II Task 4) - discusses WEC performance assessment in terms of the annual energy per capital cost, the capital cost per kW rated power, and the rated power hours/year.	Not addressed.	Not addressed.	Not addressed.		

SUBJECT	HMRC Part 1: Wave Power	IALA O-131	IEA OES Annex II	IEC 61400	IMCA AODC 35	ISO 2394:1998		
Physical small-scale model tests	This protocol presents five phases of scale model testing for development and evaluation of a WEC concept. The protocol is an approach to manage the technical and cost risks associated with developing a new technology. (Section 2.3) - briefly discusses that due to Froude scaling, power is modeled at a ratio of (L) ^3.5. Thus even larger scale models (1:4) will produce only modest power output (1:128) compared to the prototype.	Not addressed.	Annex II, Subtask 1 is a listing of institutions with wave and current facilities for model testing in Canada, Denmark, UK, Portugal, France, Ireland, and Japan. Annex II Subtask 2 covers testing procedures. Task 2.1 Discusses model testing, model scaling laws. Task 2.2 Discusses ocean wave spectra and wave energy theories. From the sea energy spectrum, it is possible to define the significant wave height, the average wave period, the peak period, the energy period, and the power per meter of wavefront. The advisory panel has recommended a selection of representative sea states to be reproduced in model basins for testing WECs.	Not addressed.	Not addressed.	Not addressed.		
Open ocean prototype or large-scale model test	Not addressed.	Not addressed.	Task 2.5 discusses data requirements of prototype testing and issues related to comparison of test results at different sites. (Annex II) – Development of Recommended Practices for Testing and Evaluating Ocean Energy Systems.	Not addressed.	Not addressed.	(D.3) Conditions during testing may differ from the conditions for the intended structure in its actual environment. The conversion factor should be established by experimental or theoretical analysis. Influences accounted for by the conversion factor could include: Size effects; Time effects; Boundary conditions; Environmental conditions		

This page intentionally left blank.

Appendix D – Device Construction, Transportation and Installation Criteria

This page intentionally left blank.

CRITERIA	ABS 116	ABS 117	API RP 2A-WSD	API RP 2I	API RP 2L	API RP 2SK	API RP 2SM
Materials and components qualification or acceptance testing	Section 6 (1.1) The novel feature may require that various test or critical aspects of the design be scrutinized during construction to ensure a high level of quality. Types of testing that may be required as a condition of accepting the novel application include, but are not limited to: material testing; destructive testing such as bust test, fatigue testing and other types of failure testing; nondestructive or other proof testing for components, …	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	(6.3.1) The following rope tests should be conducted to determine rope properties: break test, static excursion test, dynamic extension test, tension-tension fatigue qualification test. The following rope tests may be conducted to demonstrate rope properties: torque and rotation test, axial compression fatigue test. (6.3.2) Rope tests performed on a prototype rope after the design is documented or on a sample rope taken during production. (6.3.9) For all of the rope tests except the break strength, the test results can be interpolated or extrapolated for ropes made of the same material, construction and termination. A scaling ratio of up to 2:1 in rope diameter can be used provided that the appropriateness of the chosen scale can be demonstrated. (7) A Quality Assurance (QA) program, as described in 7.6, should be followed when manufacturing both prototype and production ropes.

CRITERIA	ABS 116	ABS 117	API RP 2A-WSD	API RP 2I	API RP 2L	API RP 2SK	API RP 2SM
Structural fabrication of platforms	Not addressed	Not addressed.	(10) Welding and weld procedure qualifications shall be in accordance with applicable portions of the AWS Structural Welding Code AWS D1.1. (11) Fabrication, other than welding, should be in accordance with the Specification for the Design, Fabrication and Erection of Structural Steel for Buildings, American Institute of Steel Construction.	Not addressed.	Not addressed.	Not addressed.	Not addressed.
Machinery and equipment installations in or on platforms	Section 6 (1.1) The novel feature may require that various test or critical aspects of the design be scrutinized during construction to ensure a high level of quality. Types of testing that may be required as a condition of accepting the novel application include, but are not limited to: … sub-assemblies, and major assemblies; and functional testing covering Fault Tree Analyses and commissioning type test to ensure the system performs as intended.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.
Transport and offshore installation	Not addressed.	Not addressed.	(12) An installation plan should be prepared for each installation. This plan should include the method and procedures developed for the loadout, seafastenings and transportation of all components and for the complete installation.	Not addressed.	Not addressed.	Not addressed.	(8) Provides guidance for the development of procedures for handling, installation and recovery of synthetic fiber ropes.

CRITERIA	CIRIA C666	DNV-RP-A203	DNV –OS-C401	DNV-OS-D101	DNV-OS-D201	DNV-OSS-312	DNV –Wave Energy Converter Design	EMEC – Design Basis
Materials and components qualification or acceptance testing	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.
Structural fabrication of platforms			Chapter 2 contains sections addressing: welding procedures and qualifications of welders, fabrication and tolerances, non-destructive testing, tightness and structural testing, corrosion protection systems, and bolts and mechanical fastening.		Not addressed.			

CRITERIA	CIRIA C666	DNV-RP-A203	DNV –OS-C401	DNV-OS-D101	DNV-OS-D201	DNV-OSS-312	DNV –Wave Energy Converter Design	EMEC – Design Basis
Machinery and equipment installations in or on platforms	Not addressed.	Not addressed.	Not addressed.	Section 6 addresses pipe fabrication, workmanship and testing requirements which are intended to avoid piping failure due to poor manufacture and installation.	This standard addresses functional, safety, and overload performance tests for offshore electrical systems. The following sections are applicable to marine energy conversion devices. Sections 3 – 6 discuss electrical equipment, switchgear and controls, rotating machines, and power transformers. Sec. 4D - Inspection and Testing of switchgear. Sec. 5C - Inspection and Testing of rotating machines including generators. Sec 6B - Inspection and Testing of power transformers. Sec 7D - Inspection and Testing of Semi-conductor Converters. Sec 9H - Inspection and Testing of cables Sec 10B - Installation of equipment. Sec 10C - Installation of electrical cables onboard the platform. Sec 10D - Inspection and Testing of electrical system installation.	Not addressed.	Not addressed.	Not addressed.

CRITERIA	CIRIA C666	DNV-RP-A203	DNV –OS-C401	DNV-OS-D101	DNV-OS-D201	DNV-OSS-312	DNV –Wave Energy Converter Design	EMEC – Design Basis
Transport and offshore installation	(8.2) Metocean conditions can have a significant influence on construction activities and adverse conditions can lead to cost escalation at a critical time in the project cycle. The limiting environmental conditions for the tow route will dictate the availability of weather windows for completing the tow. A typical procedure for getting a device from an onshore construction facility to the offshore site is provided. Installation of moorings and umbilicals, towage of device to the site, connection and commissioning are typically restricted to a maximum significant wave height of 2 to 2.5m. The working limits of the tugs are defined by the safe working limits of personnel on the anchor handling decks, with significant wave heights of 2.5 to 3.0 m. Metocean considerations should support for an installation should support the cable laying stage.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	(22) Movement of partially completed structures should consider provisions from the DMV Rules for Planning and Execution of Marine Operations (load out, lifting, transportation, - dry or wet tow). (23) For activities requiring subsea operations (with objects lowered, pulled down or ballasted from the sea surface to its final position on the seabed), guidelines are provided in Part 2, Chapter 6 of the DMV Rules for Planning and Execution of Marine Operations.	(17.2) Installation of the cable to shore lists eight general considerations for routing the cable, including submerged hazards, fishing grounds, shipping lanes, stability of the seabed, and the like. (19) Deployment and Retrieval, includes a bullet list of eight deployment phases that should be included in a design analysis of the life-cycle costs.

SUBJECT	EMEC – Certification Schemes	EMEC – Manufacturing	EMEC – Health and Safety	EMEC – Reliability	EMEC – Project Development	EMEC – Grid Connection	EMEC – Performance of Wave Energy	EMEC – Performance of Tidal Energy
Materials and components qualification or acceptance testing	Not addressed.	Not addressed.	Not addressed.	Not addressed.	(8) Addresses project fabrication and installation with subsections addressing: scope; detailed design; contract strategy and tender process; project fabrication and installation; consultation; project fabrication and installation checklist	Not addressed.	Not addressed.	Not addressed.
Structural fabrication of platforms	Not addressed.	1) This document specifies techniques for planning and building quality into the manufacturing process. Includes sections addressing: contract review (including agreed inspection stages and certification); manufacture and workmanship; welding; inspection and testing of welds; assembly; electrical installations; surface coatings; factory and acceptance testing; and certification. Appendix 3 is a sample plan matrix for inspecting manufacturing operations.	Not addressed.	Not addressed.	Not separately addressed.	Not addressed.	Not addressed.	Not addressed.

SUBJECT	EMEC – Certification Schemes	EMEC – Manufacturing	EMEC – Health and Safety	EMEC – Reliability	EMEC – Project Development	EMEC – Grid Connection	EMEC – Performance of Wave Energy	EMEC – Performance of Tidal Energy
Machinery and equipment installations in or on platforms	Not addressed.	Section 9 includes a discussion of materials and inspections for electrical installations. Appendix 2 is a sample inspection certificate for electrical installations.	(8.6) The assembly instructions should be appropriately risk assessed to ensure due consideration of the specific hazards related to the actual work activity, tools and equipment used and the uniqueness of the work environment the activity is being undertaken within.	Not addressed.	Not separately addressed.	Not addressed.	Not addressed.	Not addressed.
Transport and offshore installation	Not addressed.		Section 9 provides health and safety guidelines during installation, commissioning and decommissioning.	Not addressed.	Not separately addressed.	Not addressed.	Not addressed.	Not addressed.

SUBJECT	EMEC – Wave Energy Tank Testing	GL – Ocean Current Turbines	HMRC Part 1: Wave Power	IALA O-131	IMCA AODC 35	IEA- Ocean Energy Systems Annex II	DNV-OS-D101	DNV-OS=C401
Materials and components qualification or acceptance testing	Not addressed.	(1.2.3.4) Provides for surveillance of manufacturing	Not addressed.	Not addressed.	Not addressed.	Not Addressed.	Not Addressed.	Not addressed.
Structural fabrication of platforms	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not Addressed.	Not Addressed.	This standard contains requirements for fabrication and testing of offshore structures with sections addressing: welding procedures and qualifications of welders; fabrication and tolerances; non-destructive testing; other tests; corrosion protection system; bolts and mechanical fastenings.
Machinery and equipment installations in or on platforms	Not addressed.	Not addressed.	Not addressed.	Not addressed.	(2.13) There are adequate guidelines available for protection practices for surface electrical distribution through national and international standards. In particular, the “Institution of Electrical Engineers Recommendations for the Electrical and Electronic Equipment of Mobile and Fixed Offshore Installations” and the “Regulations for Electrical and Electronic Equipment on Ships, latest edition, with recommended practice for their implementation issued by the Institution of Electrical Engineers gives sound advice.	Not Addressed.	(6) Provides pipe fabrication, workmanship, and testing requirements which are intended to avoid piping failure due to poor manufacture and installation.	Not Addressed.

SUBJECT	EMEC – Wave Energy Tank Testing	GL – Ocean Current Turbines	HMRC Part 1: Wave Power	IALA O-131	IMCA AODC 35	IEA- Ocean Energy Systems Annex II	DNV-OS-D101	DNV-OS=C401
Transport and offshore installation	Not addressed.	(1.2.3.5) Provides for surveillance of transport and installation. (2.2.3) During construction the system shall always stay in a safe condition, even when abandoned for long term due to bad weather. (3.1) The requirements laid down in the GL Guidelines for Certification of Offshore Wind Turbines, Chapter 3, shall be followed regarding manufacturing, quality management, materials, production, and corrosion control. For topics not considered in those Guidelines a list of GL Guidelines is presented. (9) Manuals shall be built up and certified in accordance with the Guidelines for Certification of Offshore Wind Turbines, Chapter 9, to include manuals for sea transport and offshore installation. (10) Marine operations shall be planned, performed and certified in accordance with Guidelines for Certification of Offshore Wind Turbines, Chapter 10.	Not addressed.	(4) During construction and decommissioning of an offshore wave or tidal energy extraction device or field, working areas should be established and marked in accordance with the IALA Maritime Buoyane System. Consider the use of guard ships in areas of high traffic density. Notices to Mariners, Radio Navigational Warnings – NAVTEX or broadcast warnings must be promulgated in advance of and during any offshore wave or tidal energy extraction device construction. Where individual wave or tidal devices extend above the surface careful consideration needs to be given to any additional temporary marking that may be required during construction or decommissioning. During construction, power cables between wave and tidal generators, between such generators and the transformer station, and the shore should be sufficiently trenched to avoid exposure from scouring or trawling.	(2.12)It should be recognized that power cables exist which cannot readily be disconnected. Detailed investigation and assessment of possible hazards should be carried out before diving operations commence and the necessary safety protection provided.	Not Addressed.	Not addressed.	Not Addressed.

This page intentionally left blank.

Appendix E – Device Operations Criteria

This page intentionally left blank.

Appendix E – Device Operations Criteria

CRITERIA	ABS 116	ABS 117	API RP 2A-WSD	API RP 2I	API RP 2L	API RP 2SK	API RP 2SM
Inspection planning and Scheduling	(1.4) ABS will outline the necessary elements of in-service survey and inspection. See 6.1.2 below. (3.5) Ensure the application can be monitored, inspected, and maintained consistent with existing practice. (6.1.2) For novel concepts, the following may special in-service requirements: Maintenance schedules; Inspection scope/frequency.	(7.6) Any operational constraints or additional maintenance or inspection requirements must be identified by the life-cycle risk management plan. During review of the plan, ABS may require additional in-service survey, inspection, and monitoring requirements.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.
Platform							
Floating	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.
Fixed	Not addressed.	Not addressed..	(14.1) Survey levels and frequency should be compiled and approved by a qualified engineer familiar with the structural integrity of the platform. (14.4.2) The time interval between surveys should not exceed the guideline intervals shown in Table 14.4.2-1 unless justified. A list of factors that either increase or decrease the survey intervals is given. (14.4.2) Justification for changing guideline survey intervals should be documented and retained. (14.6) Records of all surveys should be retained for the life of the platform. (14.6) Records should include detailed accounts of the survey findings. Descriptions of detected damage should be thoroughly documented and included with survey results.	Not addressed.	Not addressed.	Not addressed.	Not addressed.

Appendix E – Device Operations Criteria

CRITERIA	ABS 116	ABS 117	API RP 2A-WSD	API RP 2I	API RP 2L	API RP 2SK	API RP 2SM
Mooring System	Not addressed.	Not addressed.	Not addressed.	The following sections discuss chain and anchor jewelry: (2.2) inspection method (i.e. dockside or offshore); (2.3) inspection procedure (actual steps to follow); (2.6) inspection schedule; Sections on wire rope and anchor handling: (3.2) inspection method; (3.3) inspection procedure; (3.5) inspection schedule; Steel components for permanent moorings: (4.5) inspection objective, type, and schedule Fiber ropes: (5.2) inspection techniques (5.5) inspection and maintenance procedures	Not addressed.	(2.2.6) A mobile mooring can often be visually inspected during retrieval or deployment. To inspect a permanent mooring, divers or ROVs are often used.	(9.1) An individual log should be kept for each rope… including information such as rope tensions, relevant environmental conditions, and inspection/re-tensioning details. (9.2) The following provides an overview of the currently available inspection techniques for fiber ropes: (9.2.1) visual; (9.2.2) internal non-destructive; (9.2.3) destructive. (9.3) Inspection procedure for fiber rope should address following subjects: Visual inspection requirements; Description of rope strand damage requiring repair or replacement; Description of termination damage requiring repair or replacement; etc. (9.5.2) Regular inspection… should be performed over the service life of the mooring system.
Power Conversion systems	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.
Riser / Power Collection / Transmission Cables	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.
Auxiliary Systems	Not addressed.	Not addressed.	Not addressed.	Not addressed.	(1.3.k) Heliports… should be large enough to allow a mechanic performing routine maintenance to reach all parts of the aircraft safely.	(10.4) Although designed to be automatic, dynamic positioning systems must be continually monitored by an operator to ensure proper operation.	Not addressed.

Appendix E – Device Operations Criteria

SUBJECT	CIRIA C666	DNV-RP-A203	DNV-OS-D201	DNV-OSS-312	DNV – Wave Energy Converter Design	EMEC – Design Basis	EMEC – Certification Schemes	EMEC – Manufacturing
Inspection methods and frequency	(9.2) where possible, measuring devices placed on-site for previous phases of a project should be left in place and maintained to assist in providing continuous data to support O&M. License holders have found that the analysis of site recorded metocean data can help to predict the degree of maintenance likely to be needed. It is good practice for operations managers to be supplied with nowcast and forecast data on a 34-hour basis.	(8.2) The maintenance analysis shall ensure that the new technology includes a sound maintenance and condition monitoring philosophy relevant for the application.	Not addressed.	(Sec.1.E.107) Issue of the prototype certificate is based on successful evaluation of: Periodic inspection (Sec.2.A.301) Typical scope for certification comprises: Maintenance procedures (Sec.2.C.1101) In order to maintain the certificate the device will need to undergo regular survey. Typically this will involve an annual survey and a more comprehensive 5 year survey. Extent of the survey will be dictated by the design. (Sec.2.C.1102) Survey timing and methods will take account of inspection and maintenance programs.	(25.1.2) A system for continuous supervision of the devices must be provided. (25.2.1) Consideration should be given to… the extent, frequency, and choice of inspection methods. (25.2.4) A plan for in-service inspection should be developed as early as possible. (25.2.7) Lists factors governing the frequency of inspection. Use conservative intervals early in the operation of the device. After satisfactory operation is established, frequency may be lengthened to reduce operating costs.	Not addressed.	(6.5) Regular surveys should involve a shorter periodic survey and a more comprehensive longer periodic survey (other industries use annual and 5-year periods). The extent of the survey will be dictated by the design. Additional surveys shall be carried out if the device sustains damage or is significantly modified between regular surveys. (6.7) Inspection periods… shall be based on minimized risk to all stakeholders. (7.3.4.9) Maintenance and inspection plan shall include: Maintenance and inspection intervals.	Not addressed.
Platform								
Floating	(9,4) Annual monitoring reports will require submission to the licensing authorities for review.	(9.6.2) A system shall be used to follow up the data collection. Guidance notes are provided along with an example form for a data base checklist of failure mechanisms.	Not addressed.	(Sec.2.C.1201) Records should be kept of all complaints relating to the compliance of the device. (Sec.2.C.1202) Any safety related accident of the device shall be reported immediately together with proposed corrective actions. (Sec.2.C.1203) Major modifications must be reported without delay.	(25.1.2) Logging of operational data is essential. Key parameters to record are listed. Written logbooks should be stored for a number of years. (25.2.6) It is necessary to keep records of all maintenance work carried out. These records should be available to the device owner to aid investigation of failures.	Not addressed.	(6.3) Certification shall include methods and conditions of reporting. (6.4) The certification body shall keep a file of all relevant received material for at least 5 years after last date of receipt or until the last certificate expires. (6.5) There shall be a system to capture and report faults and failures. (6.10.5) Survey reports shall be issued by a surveyor appointed by the certification body. (7.3.4.9) Maintenance and inspection plan shall include: Description of quality recording and record keeping processes	Not addressed.
Fixed	See floating.	See floating.	Not addressed.	See floating systems.	See floating systems.	Not addressed.	See floating systems.	See floating systems.
Mooring System	Not separately addressed.	Not separately addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.
Power Conversion Systems	Not separately addressed.	Not separately addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.

SUBJECT	CIRIA C666	DNV-RP-A203	DNV-OS-D201	DNV-OSS-312	DNV – Wave Energy Converter Design	EMEC – Design Basis	EMEC – Certification Schemes	EMEC – Manufacturing
Riser / Power Collection / Transmission Cables	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.
Auxiliary Systems	9.3) Independent site measurements (from site buoys or other measuring devices) need to be taken in addition to any monitoring equipment built into generating devices.	Not separately addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.

Appendix E – Device Operations Criteria

SUBJECT	EMEC – Health and Safety	EMEC – Reliability	EMEC – Project Development	EMEC – Grid Connection	EMEC – Performance of Wave Energy	EMEC – Performance of Tidal Energy	EMEC – Wave Energy Tank Testing	GL – Ocean Current Turbines
Inspection methods and frequency	(10.6) Planned preventive maintenance should take place during the summer when both safety and schedule risks are as low as possible.	(8.5) Reliability strategy should include: Operations plan, inspection plan, and maintenance plans.	(9.2) An operation and management plan should make provisions for: Planning and implementation of preventative maintenance; Management of unplanned maintenance.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.
Platform			Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.
Floating	(9.4) Recommended that there is a document control and record keeping procedure. Lists typical documents that need to be controlled (9.19) Recommended that there is a procedure for reporting any incidents, accidents, and near misses, and that all contractors participate in the reporting. (10.3) Data on the operational performance of the device shall be recorded. Maintenance records shall be required for each device.	(12.1) A principal tool for managing operational feedback is a failure reporting and corrective action system.	(9.2) An operation and management plan should make provisions for: Review, monitoring, and auditing of technical performance; Review, monitoring, and auditing of environmental performance; Provision of information on performance to stakeholders and consenting authority (9.3) Health and safety plan should include: incident reporting and investigation procedures	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.

SUBJECT	EMEC – Health and Safety	EMEC – Reliability	EMEC – Project Development	EMEC – Grid Connection	EMEC – Performance of Wave Energy	EMEC – Performance of Tidal Energy	EMEC – Wave Energy Tank Testing	GL – Ocean Current Turbines
Fixed See floating systems.		See floating systems.	See floating systems.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	(1.2.3.7(1)) Periodic monitoring intervals are to be defined in the inspection plan and to be agreed with GL Wind. These intervals may vary depending on the condition of the device. (1.2.3.7(2)) The following must be reported or approved by GL Wind: Major repairs and damage; Any alterations; The extent of any of this work surveyed. (9) Manuals shall be built up and certified in accordance with GL "Guideline for the Certification of Offshore Wind Turbines", Chapter 9. (11) Procedures described in GL "Guideline for the Certification of Offshore Wind Turbines", Chapter 12, apply. (12(1)) Marine operations shall be planned, performed, and certified according to GL "Guideline for the Certification of Offshore Wind Turbines", Chapter 10. (12(2)) Operations shall be adjusted to local conditions.
Mooring System	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	(11) Periodic monitoring of mooring systems shall be considered.
Power Conversion systems	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.
Riser / Power Collection / Transmission Cables	Not addressed.	Not addressed.	Not addressed.	(10) The electrical system shall be designed so that any element can be safely disconnected… for maintenance	Not addressed.	Not addressed.	Not addressed.	Not addressed.
Auxiliary Systems	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.

SUBJECT	HMRC Part 1: Wave Power	IALA O-131	IEA OES Annex II	IEC 61400	IMCA AODC 35	ISO 2394:1998		
Inspection methods and frequency	Not addressed.	(6(b)) Operators of devices should have a reliable maintenance… regime in place.	Not addressed.	Not addressed.	Not addressed.	Not addressed.		
Platform								
Floating	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.		

Appendix E – Device Operations Criteria

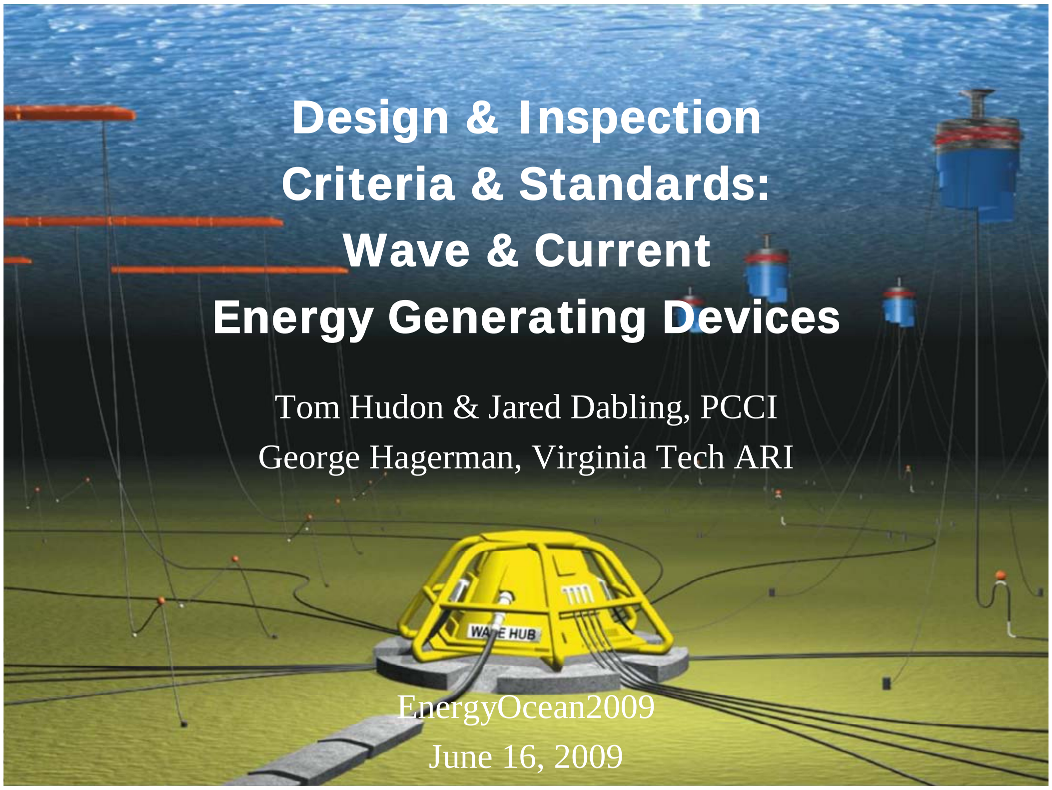
SUBJECT	HMRC Part 1: Wave Power	IALA O-131	IEA OES Annex II	IEC 61400	IMCA AODC 35	ISO 2394:1998		
Fixed	Not addressed.	Not addressed.	Not addressed.	(13.1) The operation, inspection, and maintenance procedures shall be specified in the manual. (13.2) External events detected as faults but critical for future safety may allow automatic return to normal operation. (13.3.3) Proper records shall be kept describing testing and results. (13.4.2) Operations and maintenance records shall be kept and should include: Turbine ID; Energy produced; Operating hours; Shutdown hours; Date and time fault reported and of service or repair; Nature of fault or service; Action taken; Parts replaced (13.4.3) The manual shall require the operator investigate the cause of any unscheduled automatic shutdown. (13.5) Each turbine model shall have a maintenance manual, which at a minimum consists of maintenance requirements and emergency procedures. Subjects which should also be covered include: Any requirement that inspection and maintenance shall be carried out by suitably trained personnel at the intervals specified; Maintenance inspection periods and procedures.	Not addressed.	(10.1) Lists situations when an existing structure shall be assessed as to its reliability. Assessments may also be required by authorities, insurance companies or owners, or demanded by a maintenance plan. (10.2) Assessment shall be based on principles outlined in clauses 1 through 9. (10.4) A special type of investigation is proof loading. (10.5) In the case of assessment of a damaged structure, the following stepwise procedure is recommended: (10.5.1) visual inspection; (10.5.2) explanation of the observed phenomena; (10.5.3) reliability assessment; (10.5.4) Additional information; (10.5.5) Final decision		
Mooring System	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.		
Power Conversion Systems	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.	Not addressed.		

SUBJECT	HMRC Part 1: Wave Power	IALA O-131	IEA OES Annex II	IEC 61400	IMCA AODC 35	ISO 2394:1998		
Riser / Power Collection / Transmission Cables	Not addressed.	Not addressed.	Not addressed.	Not addressed.	(3.0) Adequate records should be kept of the reasons for selection of electrical equipment, which should be available to a designer of future modifications.	Not addressed.		
Auxiliary Systems	Not addressed.	Not addressed.	Not addressed.	(8.3) Non-safe-life components… shall fail to a safe condition or their condition shall be automatically monitored. Safe-life designed components shall be inspected at adequate intervals.	(2.0.5.13) Records should be kept of maintenance carried out and modifications made to equipment. (2.0.5.14) Records should be kept of routine testing of active protection devices.	Not addressed.		

This page intentionally left blank.

Appendix F – Report User Guide

This page intentionally left blank.



PCCI
Marine and Environmental Engineering

Report Contents

- **Technology Context**
  - Taxonomy
  - Glossary
- **Regulatory Context**
- **Criteria Identification**
- **Existing Codes & Standards**
- **How existing codes & standards address identified criteria**
  - Design
  - Modeling & Testing
  - Construction, Transport, & Installation
  - Operations and IM&R
- **Regulatory Gap Analysis**
- **Recommended Regulatory Initiatives**

PCCI
Marine and Environmental Engineering

Report Contents

- **Technology Context**
  - Taxonomy *(Appendix A)*
  - Glossary
- **Regulatory Context**
- **Criteria Identification**
- **Existing Codes & Standards**
- **How existing codes & standards address identified criteria**
  - Design
  - Modeling & Testing
  - Construction, Transport, & Installation
  - Operations and IM&R
- **Regulatory Gap Analysis**
- **Recommended Regulatory Initiatives**

Step 1

Use taxonomy in Appendix A to find applicable criteria for given wave or current energy device

PCCI
Marine and Environmental Engineering

Report Contents

- **Technology Context**
  - Taxonomy *(Appendix A)*
  - Glossary
- **Regulatory Context**
- **Criteria Identification**
- **Existing Codes & Standards**
- **How existing codes & standards address identified criteria**
  - Design *(Appendix B)*
  - Modeling & Testing *(Appendix C)*
  - Construction, Transport, & Installation *(Appendix D)*
  - Operations and IM&R *(Appendix E)*
- **Regulatory Gap Analysis**
- **Recommended Regulatory Initiatives**

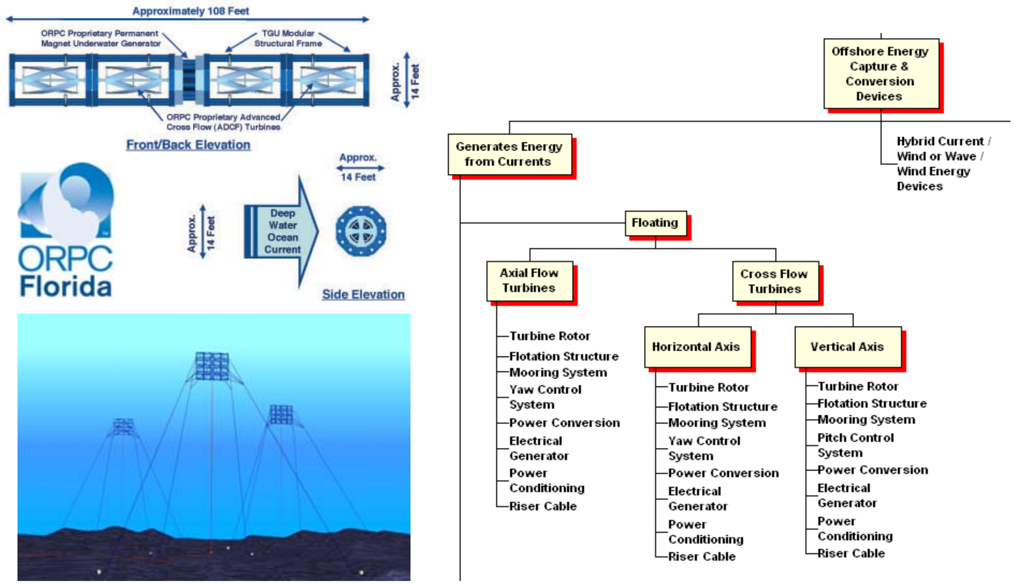
Step 1

Use taxonomy in Appendix A to find applicable criteria for given wave or current energy device

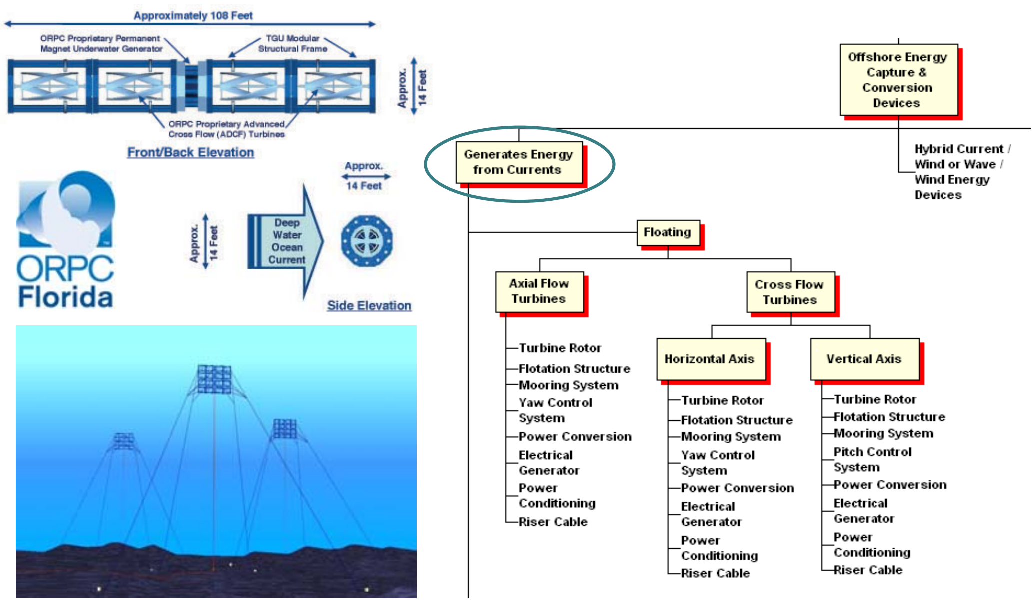
Step 2

Use tables in Appendices B – E to identify relevant existing codes and standards for applicable criteria

Step 1 – Find Device in Taxonomy

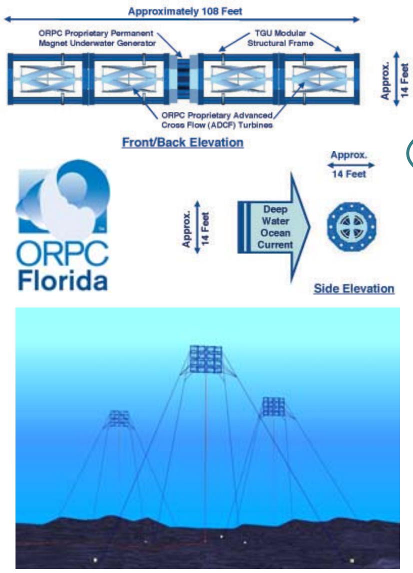


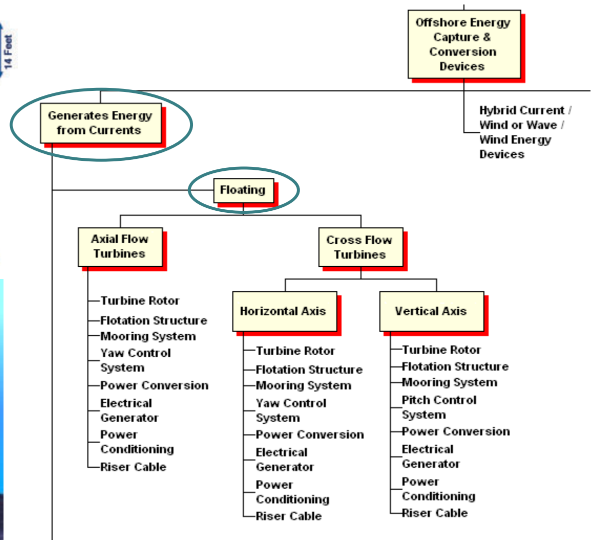
Step 1 – Find Device in Taxonomy



PCCI
Marine and Environmental Engineering

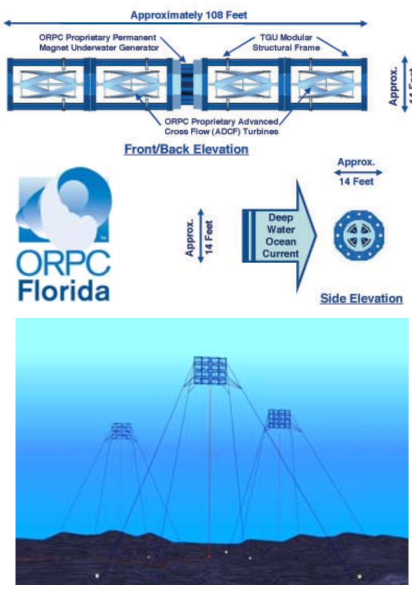
Step 1 – Find Device in Taxonomy

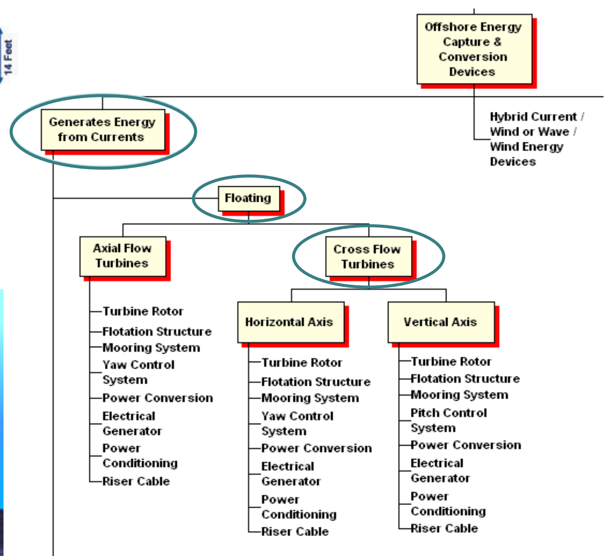




PCCI
Marine and Environmental Engineering

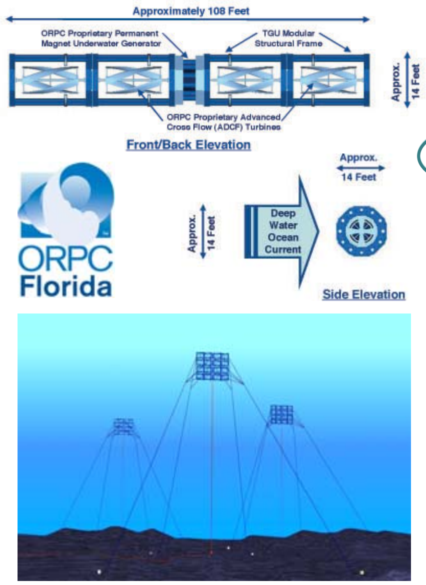
Step 1 – Find Device in Taxonomy

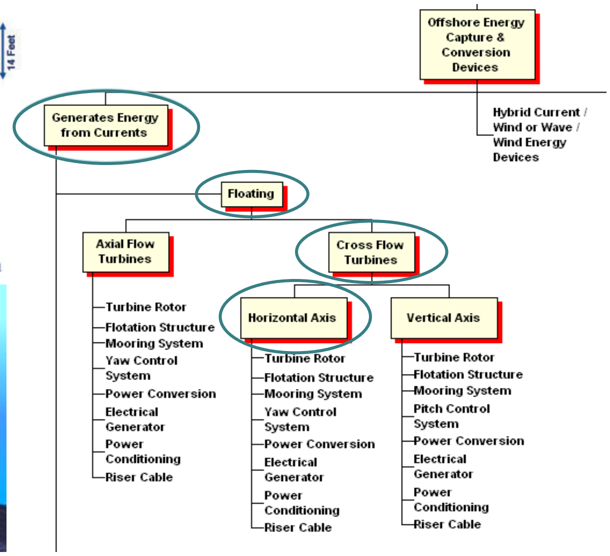




PCCI
Marine and Environmental Engineering

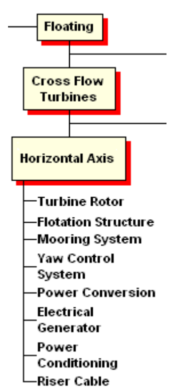
Step 1 – Find Device in Taxonomy





PCCI
Marine and Environmental Engineering

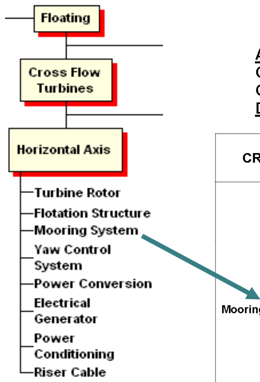
Step 2 – Find Criterion of Interest



PCCI
Marine and Environmental Engineering

Step 2 – Find Criterion of Interest

(in this case DESIGN → Mooring System)



APPENDIX B
OCEAN ENERGY DEVICE GUIDELINES
COMPARISON OF EXISTING CODES AND GUIDELINES FOR OCEAN ENERGY
DEVICE DESIGN CRITERIA

CRITERIA	GL – Ocean Current Turbines	EMEC – Health and Safety	EMEC – Project Development	EMEC – Performance of Wave Energy
Mooring system	(4.4.8) Addresses mooring dynamics. (6.1(2)) The analysis of anchoring and mooring systems shall be performed according to GL "Guideline for the Construction and Classification/Certification of Floating Productions, Storage and Off-Loading Units".	(8.3.1) Existing design rules may be adopted by the device designer. Examples of existing regulations are listed. Consideration should be given to safe and practical installation and access for maintenance. Design such that construction, assembly, and testing can place onshore as much as is possible. (8.4) HSE publication 2001/063 – Marine risk assessment addresses hazards including: Loss of position keeping (e.g. mooring failure)	(6.4) Evaluation of the different design options should include: Mooring requirements, which will be based on the device, the geomorphology of the sea-bed, and environmental impacts	(7.4) Wave buoys should be moored so that the are free to respond to the waves, but at the same time can survive the highest waves that are likely to occur at the site.

PCCI
Marine and Environmental Engineering

Step 3 – Look up details in identified standard

GL – Ocean Current Turbines
(4.4.8) Addresses mooring dynamics. (6.1(2)) The analysis of anchoring and mooring systems shall be performed according to GL "Guideline for the Construction and Classification/Certification of Floating Productions, Storage and Off-Loading Units".

Step 3 – Look up details in identified standard

GL – Ocean Current Turbines

(4.4.8) Addresses mooring dynamics. (6.1(2)) The analysis of anchoring and mooring systems shall be performed according to GL "Guideline for the Construction and Classification/Certification of Floating Productions, Storage and Off-Loading Units".

4.4.8 Mooring dynamics

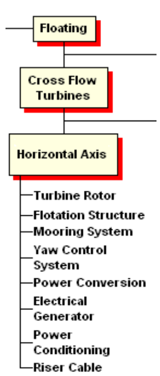
(1) Non linear dynamics of mooring systems shall be considered in system design.

(2) Interaction of the floating body with mooring and the power producing device shall be considered, especially periodic excitation from the rotor.

(3) Vortex induced vibrations on anchor cables considering current and wave influence have to be analysed.

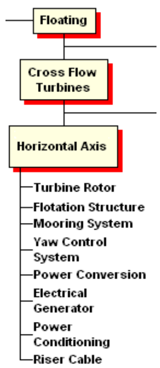
(4) Mooring and anchor forces have to be determined according to GL Rules for "Offshore structures" [2].

Step 3 – Repeat for Construction, Transport, and Installation



PCCI
Marine and Environmental Engineering

Step 3 – Repeat for Construction, Transport, and Installation

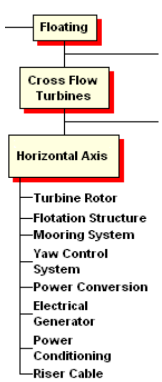


EMEC – Project Development

(8) Addresses project fabrication and installation with subsections addressing: scope; detailed design; contract strategy and tender process; project fabrication and installation; consultation; project fabrication and installation checklist

PCCI
Marine and Environmental Engineering

Step 3 – Repeat for Construction, Transport, and Installation



EMEC – Project Development

(8) Addresses project fabrication and installation with subsections addressing: scope; detailed design; contract strategy and tender process; project fabrication and installation; consultation; project fabrication and installation checklist

8.4 Project fabrication and installation

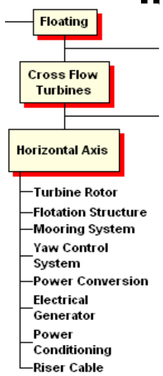
8.4.1 Project fabrication

Once the contract(s) is awarded for the different elements of the project, the project developer should ensure that the project infrastructure is manufactured according to the standards, timescales and cost agreed in the contract(s).

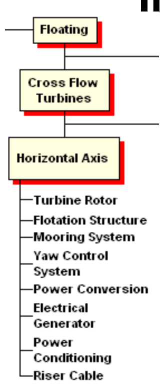
Fabrication materials and components, procedures for assembly, inspection, test and commissioning should comply with the provisions made in the Quality Plan based on relevant industry standards. Design requirements to mitigate H&S risks and environmental impacts identified during the detailed design phase of the project should be incorporated. Factory Acceptance Testing should be carried out to ensure that the end products comply with the project specification. Please refer to the *Guidelines for Manufacturing, Assembly and Testing of Marine Energy Conversion Systems*.

NOTE If more than one contract is awarded for the fabrication of the different project infrastructure, coordination between suppliers and manufacturing programmes, as well as system integration, will be critical and will need to be carefully managed.

Step 3 – Repeat for Operations and Inspection, Maintenance, & Repair



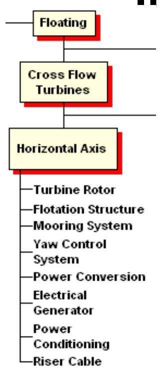
Step 3 – Repeat for Operations and Inspection, Maintenance, & Repair



EMEC – Certification Schemes

(6.5) Regular surveys should involve a shorter periodic survey and a more comprehensive longer periodic survey (other industries use annual and 5-year periods). The extent of the survey will be dictated by the design.
Additional surveys shall be carried out if the device sustains damage or is significantly modified between regular surveys.

Step 3 – Repeat for Operations and Inspection, Maintenance, & Repair



EMEC – Certification Schemes

(6.5) Regular surveys should involve a shorter periodic survey and a more comprehensive longer periodic survey (other industries use annual and 5 year periods). The extent of the survey will be dictated by the design

Additional surveys shall be carried out if the device sustains damage or is significantly modified between regular surveys.

6.5 Maintenance and expiration of certificates

In order to maintain the certification the marine energy converter shall undergo regular surveys.

This should involve a shorter periodic survey and a more comprehensive long periodic survey (in other industries annual and 5-yearly survey periods are used). The extent of the survey (areas, methods, frequencies) will normally be dictated by the design life, degradation mechanisms and the consequences of possible failure.

Periodic survey intervals shall be defined in the inspection plan and shall be agreed with the certification body.

NOTE 1 These intervals can vary depending on the condition of the marine energy converter.

Questions?

thudon@pccii.com

PCCI, Inc
300 North Lee Street, Suite 201
Alexandria, VA 22314-2640

1-703-684-2060 ext 1012