WES Knowledge Capture

Aquamarine Power Limited

Project Know-How

WES_KHO1_ER_Project Overview (APL)

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HIE
Highlands and Islands Enterprise
Iomairt na Gàidhealtachd 's nan Eilean

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Contents

Executive Summary

This document is intended as a brief guide to the contents of the reports produced for Wave Energy Scotland (WES) by Aquamarine Power Limited (APL) as part of Project Know-How. Project Know-How is part of the on-going knowledge capture work within WES and was commissioned to capture lessons, knowledge and key operational experiences from the wave energy sector in Scotland, and in particular the technology development companies based there.

These documents are to be shared with participants in WES funded development programmes, to prevent participants having to go through the same learning exercise. This approach meets a number of the WES objectives – ensure that the learning gained from support for wave device development and deployment to date, in particular the learning from Scotland's leading wave technologies, is retained and used to benefit the wave energy industry and to avoid duplication in funding, encourage collaboration and foster greater standardisation across the industry.

The Aquamarine Power Limited Know-How reports cover the experiences from the development and installation of the Oyster 1 and Oyster 800 Wave Energy Converters (WECs) at EMEC in Orkney, and include topics such as offshore operations; cathodic protection; supply chain experiences; scaled tank testing and the lessons learnt which lead to maintainability improvements.

This report provides a brief synopsis of each of the documents produced by Aquamarine Power, and also includes the high level lessons learnt summaries to act as a 'sign post' for the reader. A table in Section 6 gives details of the deliverables available from the project.

Note that additional reports, documents and data files referenced here and in the deliverables may not be currently available.

1 WP2 Offshore Operational Experience

File Name:

OYKNOW-REP-0001 - WES KC WP3 - Offshore Operational Experience - C2.pdf

Introduction

Through the successful execution of two full scale device installations (Oyster 1 and Oyster 800) and consecutive product improvement initiatives, Aquamarine Power gained a wealth of knowledge on numerous aspects of offshore operations including offshore planning, supply chain, vessel capabilities and weather limitations. Offshore operations are a common challenge shared by all developers, and the information presented here will be of value to them, the wider community, and the supply chain.

The report first considers the offshore experience gained from full-scale device installation, supporting the discussion on piling and installation experiences with experiences from Oyster 1 and Oyster 800. The focus then moves methodically through Operations and Maintenance activities, with attention given to vessel characteristics, weather considerations and the planning of maintenance activities, before highlighting experiences and lessons learnt in offshore activities and reporting. The key themes presented are generic to ensure relevance to a wider audience of WEC developers.

Objectives

The objective of this package of work was to disseminate the knowledge and learning gained in the following topics:-

a) Piling
    - The experience of Oyster 1 v Oyster 800, and further improvements

b) Supply Chain / Logistics for installation of WECs and maintenance
    - Supply chain experience and competence
    - Vessel capability requirements and availability

c) Use of model simulation for WEC towing and installation

d) Oyster 1 and Oyster 800 device installation

e) Offshore maintenance / repair of non-modular elements
    - Diver capability / manual handling restrictions
    - Diver operated tooling
    - On bottom times

f) Procedures, planning and preparation for offshore works

g) Weather dependency

Lessons Learnt - Extract

- Two methods of constructing multiple pile foundations have been demonstrated at the European Marine Energy Centre (EMEC)
- Installation of a large Oscillating Wave Surge Converter (OWSC) can be safely achieved, but careful consideration must be given to the installation weather conditions, device

dynamics (during installation) and ballasting arrangements. There are substantial challenges in the use of crane barges for this type of installation.

- Large WECs can be successfully installed onto the subsea using ‘float in / ballast down’ techniques without the need for large, expensive, crane vessels.
- Vessel capability on Orkney was sufficient to complete all maintenance activities on the Oyster test sites.
- Operations are inherently weather sensitive, and lack of planning can lead to inefficient time offshore.

2 WP3 Corrosion & Protection

File Name: OYKNOW-REP-0002 - WES KC WP3 - Corrosion and Protection - C2.pdf

Introduction

Oxygen, biological activities, pollution, temperature, salinity, suspended sediments and velocity are the known major factors which affect the corrosion behaviour of materials submerged in sea water. In this report Aquamarine Power documented the lessons learnt in design through the use of standard off-the-shelf components and materials, and the effect of material grades and compatibilities in disturbed water environments. Many common themes were identified which could benefit the wider wave community.

Objectives

The objective of this report is to share knowledge of the lessons learnt and the improvements made with respect to:-

a) Structural design approach
   - Through water column corrosion allowance
   - Where is Cathodic Protection (CP) effective?
b) Material compatibility
c) Splash zone effects
d) Off-the-shelf component suitability
e) Coatings and clad flanges
f) Flange and gasket combinations
g) Use and connection of anodes
h) Development of a reliable corrosion protection inspection technique

Lessons Learnt - Extract

- A combination of CP, coatings and corrosion allowance can provide a cost effective means of protecting offshore structures from corrosion.
- Be cautious about using dissimilar metals in close proximity as they may be prone to galvanic corrosion.
- Corrosion protection design for the splash zone can be feasible by using coatings and corrosion allowances for large structures. Smaller local components can be made of more corrosion resistant alloys (CRA).
- Different flange and seal combination will require different materials to ensure a leak resistant joint.
- Anodes should be installed on discrete parts without having to rely on electrical continuity between components in assemblies.
- A device called a bathycorrometer which uses a principle of stabbing probe circuit can be reliably used to survey CP systems.

3 WP4 Supply Chain

File Name: OYKNOW-REP-0003 - WES KC WP4 - Supply Chain - C2.pdf

Introduction

Throughout the development of the Oyster Technology, Aquamarine Power suffered from mixed experiences of the supply chain and poor component supply. Many of the components were purchased on the understanding that they were fit for purpose in subsea marine environments, and a number of these were not bespoke and may be considered by other wave developers.

Aquamarine Power often had to choose between expensive 'oil and gas' components that were over specified and over-priced, and the other extreme where the costs were more palatable but the product didn't meet the overall system requirements. This report documents a number of examples of lessons learnt as a result of material incompatibilities, corrosion on subsea wet-mate connectors, and experiences in the use of 316 Stainless Steel and high strength materials. The problems caused by these components led to significant cost and programme setbacks at Aquamarine Power, and the lessons learned will be pertinent to all other wave technology developers, particularly those making the transition to wet-testing.

Objectives

The objective of this report is to share the knowledge and lessons available from Oyster 1, Oyster 800 and the subsequent product improvement findings. Examples will include:-

a) Accumulator supply
b) Control and Instrumentation equipment including connectors
c) Cables
d) Isolation (ball) valves
e) 316 stainless steel components e.g. needle valves
f) High strength components (Hydrogen Induced embrittlement)

Lessons Learnt - Extract

- Supply of components labelled as subsea should not to be taken at face value.
- Metal shelled connectors have proven to be a reliable subsea connector for the near shore environment.
- Appropriate selection of valve supplier with suitable experience in the nearshore environment. Thorough Factory Acceptance Tests (FAT) required for supplied components.
- 316 stainless steel is not suitable as a reliable corrosion resistant alloy in seawater without CP. 316 may be used in conjunction with a reliable CP system.
- General awareness of hydrogen induced stress corrosion (HISC) and ensuring that suppliers are also aware of this issue. Generally advised to have a high and low tolerance when specifying material grades.

4 WP5 Tank Testing of WECs

File Name: OYKNOW-REP-0004 - WES KC WP5 - Tank Testing of WECs - C2.pdf

Introduction

In the current stage of the wave energy industry, experimental wave tank testing forms an integral part of WEC device development. The knowledge and expertise acquired by Aquamarine Power was developed in partnership with Queen's University Belfast (QUB), with whom the company had a long standing relationship, and this report documents the experiences and lessons gained from over 10 years of wave tank testing in the development of Oyster.

Experiences cover a range of activities through the whole design process, from early concept development through to full-scale model validation. The common themes presented include tank calibration, performance and load testing, installation and decommissioning testing, correlations between a scaled model and full-scale prototype, and the development of new concepts. In addition to the lessons learnt by Aquamarine Power, the report also gives a critical review and assessment of the existing tank testing standards documents.

Objectives

The scope of work outlined six principal categories to present the experimental wave tank testing knowledge and lessons experienced by Aquamarine Power. The objective of this report is to share the knowledge, lessons available and the improvements made within the following key areas:-

a) Wave tank geometry (advantages and disadvantages)
b) Wave making and calibration techniques
c) Instrumentation requirements – including calibration procedures
d) Experiences from data acquisition & standard processing techniques
e) Considerations for model design and fabrication
f) Health and safety procedures

The report is split into subsections and each subsection details the knowledge captured / lesson(s) learnt statements associated with each topic. Where necessary these statements are followed up with additional information and detail. Some knowledge capture statements are generic and apply to a broad range of tank facilities and techniques but the focus of this document is on the specific experiences of Aquamarine Power's on the testing of their nearshore, flap-type WEC (or Oscillating Wave Surge Converter (OWSC)), Oyster.

5 WP6 Maintainability Improvements

File Name:

OYKNOW-REP-0005 - WES KC WP6 - Maintainability Improvements - C2.pdf

Introduction

The experiences and lessons gained on the Oyster 1 project led Aquamarine Power to make some fundamental changes to the design philosophy to improve access and maintenance for Oyster 800. This package of work highlights the lessons learnt on the Oyster 1 project, and documents how these areas were improved for Oyster 800. The report also highlights where the changes made were effective and where they could be improved further.

The maintenance philosophies are considered, first examining the case study of the Oyster 1 experience and including a review of access issues to WEC components and activities such as cylinder exchange. General observations on the influence of the equipment, work vessel, and offshore personnel/dive teams are described, which are intentionally high level to be relevant to all the needs of all developers. The modularity and inherent maintenance features implemented for Oyster 800 are covered in detail, such as the cylinder and accumulator modules, while the poor reliability of the non-modular components and the modifications made post-installation to improve this are also described.

Objectives

The objective of this report is to share the knowledge, lessons available and the improvements made within the following key areas;

a) Oyster 1 – Access and maintainability lessons
b) Subsystem requirements – fundamental changes
    - Solution for addressing Oyster 1 maintainability limitations
    - Vessel capability drivers
    - Consideration of weather parameters
    - Local resource skill drivers
    - Local supply chain considerations
c) Modular approach to design and improved access (Oyster 1 v Oyster 800)
    - Cylinder module
    - Accumulator module
    - Ballast System
d) dInstallation and removal of modular sub-systems for maintenance
e) Maintenance strategy for Oyster 800
    - Time benefits for removal and installation
    - Cost reduction
    - Improved safety measures

Lessons Learnt - Extract

- Ballasting in a pre-determined direction on a flap type WEC is complex, being affected by the buoyancy and mass distributions, tidal height, wave height, wave period, and Power Take-Off (PTO) forces.
- Diver access and the space required for tool operation must be considered.
- A modular approach to maintenance of hydraulic system components can be made to work, but in order to be effective the speed of module replacement must be considered through the development of simple interfaces, better access and tooling, and the support of capable vessels and people.

6 Summary Table of Available Documents

The following table lists the documents referenced in this overview.

Filename	Short Title	No. Pages	File Size [MB]
OYKNOW-REP-0001 - WES KC WP2 - Offshore Operational Experience - C2.pdf	WP2 – Offshore Operational Experience	25	0.70
OYKNOW-REP-0002 - WES KC WP3 - Corrosion and Protection - C2.pdf	WP3 – Corrosion and protection	17	0.82
OYKNOW-REP-0003 - WES KC WP4 - Supply Chain - C2 .pdf	WP4 – Supply chain	17	0.45
OYKNOW-REP-0004 - WES KC WP5 - Tank Testing of WECs - C2.pdf	WP5 – Tank Testing of WECs	32	0.72
OYKNOW-REP-0005 - WES KC WP6 - Maintainability Improvements - C2.pdf	WP6 – Maintainability Improvements	19	0.74