Base Load Power Hub (BLPH)

Materials Selection Report

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1 INTRODUCTION

1.1 PROJECT OVERVIEW

Crosswind, a Shell and Eneco joint venture, was awarded the tender to develop the offshore Hollandse Kust Noord (HKN) wind farm, located 18.5km off the coast of Netherlands near the town of Egmond aan Zee. The consortium plans to have HKN operational in 2023 with an installed capacity of 759MW generating at least 3.3TWh per year. This is sufficient renewable power to supply more than 1 million Dutch households with green electricity.

Offshore wind farms produce intermittent electricity and balancing these dips and peaks and integrating this electricity into the national energy system requires new technologies. For this reason, the offshore wind farm will include several new technologies that could be implemented at full-scale in the future. The new technologies being explored include a floating solar park, a short-duration battery storage as well as long-term storage via green hydrogen produced by water electrolysis and subsequently consumed in a fuel cell. The combination of these individual measures, herein referred to as the Base Load Power Hub (BLPH) will ensure a continuous power supply regardless of the wind situation.

1.1.1 Project Location

The Hollandse Kust Noord (HKN) wind farm is located 18.5km off the coast of the Netherlands near the town of Egmond aan Zee.

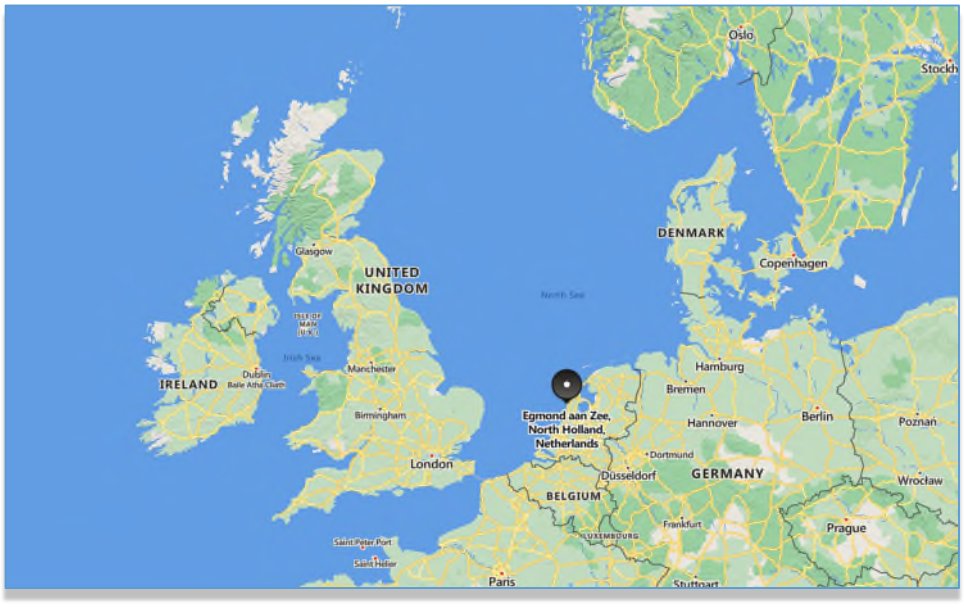


Figure 1 HOLLANDSE KUST NOORD WIND PARK Location Map

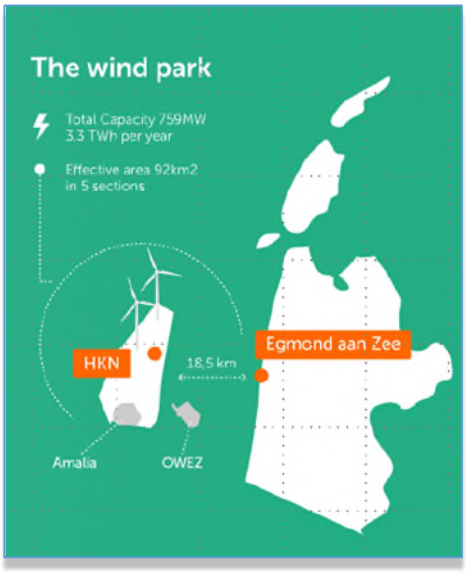


Figure 2 - Wind Park Details

The wind farm will consist of No. 69 x 11.5MW wind turbine generators each to be installed on a dedicated monopile structure. A 70th monopile located on coordinates E 590719.1, N 5841602.3 is reserved for installing the platform accommodating the BLPH. The monopile structure was designed and installed by Van Oord Offshore Wind (VooW) and therefore not part of the BLPH scope.

1.1.2 Project Concept

All components included in the BLPH will be integrated onshore on a topsides and installed in an offshore location within the boundaries of the HKN wind farm. At its simplest, the BLPH will store energy during periods of high electricity generation from renewable sources (a wind turbine generator and the floating solar PV farm) and release it during periods of low generation. In practice. It is expected that the energy stored will supplement generation from renewable sources to ensure that at least 1.0MW of power is exported to the electrical grid regardless of wind/solar availability.

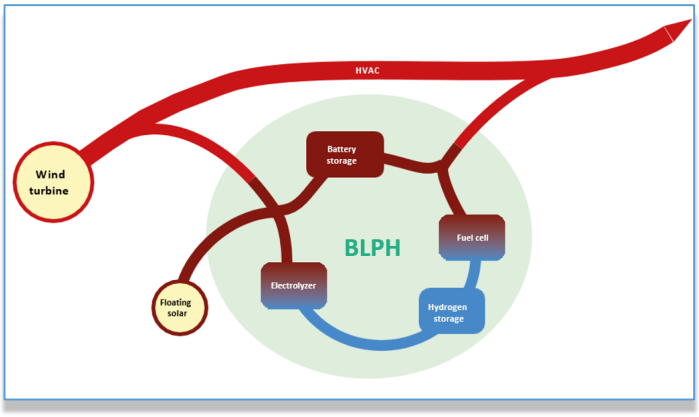


Figure 3 – BLPH Concept

Electricity in the BLPH will be stored in the form of electrons in a battery energy storage system (BESS) as well as converted into green hydrogen via water electrolysis. When the power output from the connecting wind turbine drops to below 1 MWe, the BLPH will return its stored energy to supplement the remaining power output. This will be by discharging the BESS, while stored hydrogen will be converted back into electricity using a fuel cell to extend the discharge duration.

The purpose of the BLPH s to function as a testbed for the integration of energy storage technologies with renewable generation. It is expected that equipment installed on the BLPH will operate as Normally Unmanned Installation for at least two (2) years with no or minimal maintenance and it will have its own independent control room with the ability to communicate with Crosswind's control room.

2 DOCUMENT SCOPE

This document is the EPC Material Selection Report for the BLPH (Base Load Power Hub) topsides installed on the monopile HKN70 (70th monopile of the Hollandse Kust Noord (HKN) Wind Farm), located 18.5km off the coast of the Netherlands near the town of Egmond aan Zee.

The purpose of this document is to define suitable materials for hydrogen (H_2) service and other services and to establish minimum requirements for external corrosion control for selected materials of the BLPH topsides. Recommendations for an appropriate external coating system shall be given.

Materials shall be selected for the following Topside Units of BLPH:

- Process Systems:
  - Interconnecting lines for the Electrolyser and Hydrogen Drying Package (Ref. [3])
  - Hydrogen Storage (Ref. [4])
  - Interconnecting lines for the Fuel Cell Package (Ref. [5])
- Utility Systems:
  - Water Treatment Plant (Ref. [6])
  - Instrument Air and Nitrogen Systems (Ref. [7])
  - Vent Systems (Ref. [8]).
- Valves and Instruments
- Bolting.

Materials for packages are excluded for the present Scope of Work.

2.1 REFERENCES

Note: unless specifically designated by date, the latest edition of each document has been applied, together with any amendments/supplements/revisions thereto.

Project Documents

Ref. [1] Base Load Power Hub (BLPH). *Basic Design Engineering Package* - Document No: K559-2254-PM-PLN-003

Ref. [2] Base Load Power Hub (BLPH). *Technical Data Sheet for H2 Storage Vessel - V-25001* - Document No: 123A90-DDL-MAC-DS-50027

Ref. [3] Rosetti Marino, Base Load Power Hub (BLPH). *Process Flow Scheme. Electrolyser and Hydrogen Drying Package* - Document No: 123A90-DDL-PR-DG-80003

Ref. [4] Base Load Power Hub (BLPH). *Process Flow Scheme. Hydrogen Storage* - Document No: 123A90-DDL-PR-DG-80004

Ref. [5] Base Load Power Hub (BLPH). *Process Flow Scheme. Fuel Cell Package* - Document No: 123A90-DDL-PR-DG-80005

Ref. [6] Base Load Power Hub (BLPH). *Utility Flow Diagram. Water Treatment Plant* - Document No: 123A90-DDL-PR-UFD-80006

Ref. [7] Base Load Power Hub (BLPH). *Utility Flow Diagram. Instrument Air and Nitrogen Systems* - Document No: 123A90-DDL-PR-UFD-80007

Ref. [8] Base Load Power Hub (BLPH). *Utility Flow Diagram. Vent Systems* - Document No: 123A90-DDL-PR-UFD-80008

Ref. [9] Base Load Power Hub (BLPH). Project No.: 2254. *Material Selection Report* - Document No: K559-2254-MT-REP-001

Ref. [10] Base Load Power Hub (BLPH). Project No.: 2254. - *Heat & Material Diagrams* - Document No: 123A90-DDL-PR-BL-80002,

Ref. [11] *Technical Query and Reply* "Request for Wind Farm Production Profile" - 123A90-PML-PM-TQ-00004_CPY REPLY TQ

Ref. [12] Base Load Power Hub (BLPH). *DS - Manual Valves* - Document No: 123A90-DDL-PP-DS-70003

Ref. [13] Base Load Power Hub (BLPH). *Piping Material Classes* - Document No: 123A90-DDL-PP-SP-70000

Ref. [14] Base Load Power Hub (BLPH). *TSS - Manual Valves & Strainers* - Document No: 123A90-DDL-PP-SP-70030

International Codes and Standards

Ref. [15] API RP 571: Damage Mechanisms Affecting Fixed Equipment in the Refining Industry, March 2020

Ref. [16] API RP 941: Steels for Hydrogen Service at Elevated Temperatures and Pressures in Petroleum Refineries and Petrochemical Plants, August 2020

Ref. [17] ASME B16.5: Pipe Flanges and Flanged Fittings, 2017

Ref. [18] ASME B31.3: Process Piping, 2022

Ref. [19] ASME B31.12: Hydrogen Piping and Pipelines, AMSE Code for Pressure Piping, B31, 2019

Ref. [20] ASME Boiler and Pressure Vessel Code - Section II Part A: Ferrous Material Specifications (Beginning to SA-450), Materials, July 2010

Ref. [21] ASME Boiler and Pressure Vessel Code - Section VIII Division 1: Rules for Construction of Pressure Vessels, July 2010

Ref. [22] ASME Boiler and Pressure Vessel Code - Section VIII Division 2 – Alternative Rules for Construction of Pressure Vessels, July 2010

Ref. [23] ASME Boiler and Pressure Vessel Code - Section VIII Division 3 – Alternative Rules for Construction of High Pressure Vessels, July 2010

Ref. [24] ASTM A193: Standard Specification for Alloy-Steel and Stainless Steel Bolting for High Temperature or High Pressure Service and Other Special Purpose Applications, November 2022

Ref. [25] ASTM A320: Standard Specification for Alloy-Steel and Stainless Steel Bolting for Low-Temperature Service, Nov 2022

Ref. [26] ASTM G88: Standard Guide for Designing Systems for Oxygen Service, November 2021

Ref. [27] ASTM G93: Standard Guide for Cleanliness Levels and Cleaning Methods for Materials and Equipment Used in Oxygen-Enriched Environments, 2019

Ref. [28] CGA: Publication Guides the Safe Design, Operation, and Maintenance of Oxygen Pipeline and Piping Systems, G-4.4, 2020

Ref. [29] CGA/ANSI, CGA G-4.1 Standard: Cleaning of Equipment for Oxygen Service, 2018

Ref. [30] CSA/ANSI, CHMC2: Test Methods for Evaluating Material Compatibility in Compressed Hydrogen Applications - Polymers, 2019

Ref. [31] EIGA: Hydrogen Pipeline Systems, IGC Doc 121/14, 2014

Ref. [32] IOGP S-563 Standard: Material Data Sheets for Piping and Valve Components, December 2021

Ref. [33] IOGP S-715 Standard: Supplementary Specification to NORSOK M-501 Coating and Painting for Offshore, Marine Coastal and Subsea Environments, 2020

Ref. [34] ISO 9223: Corrosion of Metals and Alloys - Corrosivity of Atmospheres - Classification, Determination and Estimation, Second Edition, May 2012

Ref. [35] ISO 10684 Standard: Fasteners - Hot Dip Galvanized Coatings (ISO 10684:2004 + Cor. 1:2008); German version EN ISO 10684:2004 + AC:2009, September 2011

Ref. [36] ISO 11114-2: Gas cylinders, Compatibility of Cylinder and Valve Materials with Gas Contents Part 2: Non-metallic materials, 2013

Ref. [37] ISO 12944-2: Paints and varnishes - Corrosion protection of steel structures by protective paint systems - Part 2: Classification of environments, 2017

Ref. [38] ISO 14687: Hydrogen Fuel Quality – Product Specification, 2019

Ref. [39] ISO 15156: Materials for Use in H_2Scontaining Environments in Oil and Gas Production, November 2020

Ref. [40] ISO 21457: Materials Selection and Corrosion Control for Oil and Gas Production Systems, 2010

Ref. [41] NORSOK M-501: Surface Preparation and Protective Coating, February 2012

Ref. [42] NORSOK M-710: Qualification of Non-Metallic Sealing Materials and Manufacturers, September 2014

Bibliography

Ref. [43] SAND2012-7321 (Scandia Hydrogen Programme): Technical Reference for Hydrogen Compatibility of Materials, 2012

Ref. [44] Materials Considerations in Hydrogen Production: Øvland, S. and Hansen, R.S. Hydro Oil & Energy, Research Centre Porsgrunn, 2007

2.2 DEFINITIONS AND ABBREVIATIONS

COMPANY or Client (CPY): Crosswind

CONTRACTOR (CTR): ROSETTI MARINO S.p.A.

PROJECT: HOLLANDSE KUST NOORD WIND PARK Project

AE	Acoustic Emission
API	American Petroleum Institute
ASME	American Society of Mechanical Engineers
ASTM	American Society of Testing and Materials
BESS	Battery Energy Storage System
BLPH	Base Load Power Hub
CA	Corrosion Allowance

CAPEX	Capital Expenditure
CE	Carbon Equivalent
CGA	Compressed Gasses Association
CSCC	Chloride Stress Corrosion Cracking
CPVC	Chlorinated Poly-vinyl Chloride
CRA	Corrosion Resistant Alloy
CS	Carbon Steel
EPC	Engineering, Procurement & Construction
DM	Damage Mechanism
DSS	Duplex Stainless Steel
EIGA	European Industrial Gas Association
EPC	Engineering Procurement Construction
EPCI	Engineering, Procurement, Construction and Installation
Ext-CSCC	External Chloride Stress Corrosion Cracking
FC	Fuel Cell
FEED	Front End Engineering Design
GRP	Glass Reinforced Epoxy
HB	Brinell Hardness
HGD	Hot Dip Galvanised
HE	Hydrogen Embrittlement
HIC	Hydrogen Induced Cracking
HKN	Hollandse Kust Noord
H&MB	Heat & Material Balance
HRC	Rockwell Hardness Number
HTHA	High Temperature Hydrogen Attack
HV	Vickers Hardness Number
IA	Instrument Air
ICP	Internal Cathodic Protection
IEC	Internal Epoxy Coating
IL	Internal Lining
IOGP	International Association of Oil and Gas Producers

ISO	International Organisation of Standardisation
LAS	Low Alloy Steel
LTCS	Low Temperature Carbon Steel
MDMT	Minimum Design Metal Temperature
MSR	Materials Selection Report
MW	Mega Watt
MWe	Mega Watt Electric
NNF	Normally Non Flowing
O_2	Oxygen
PFS	Process Flow Scheme
pH_2	Hydrogen Partial Pressure
pO_2	Partial Pressure of Oxygen
PTFE	Polytetrafluoroethylene
PWHT	Post Weld Heat Treatment
SASS	Super Austenitic Stainless Steel
SDSS	Super Duplex Stainless Steel
SGSI	Shell Global Solutions International
SS	Stainless Steel
STP	Standard Temperature and Pressure
SWI	Sea Water Intake
TCU	Thermal Control Unit
TDS	Total Dissolved Solid
TSA	Thermally Sprayed Aluminium
TSO	Transmission System Operator
UFD	Utility Flow Diagram
UV	Ultraviolet
VooW	Van Oord Offshore Wind
WTG	Wind Turbine Generator
WTP	Water Treatment Plant

3 PROJECT DATA

3.1 PROCESS SCHEME

In below Figure 1 (Ref. [1]), the process scheme of the selected BLPH concept including boundary limits is shown. The process can be summarized as follows:

- The Sea Water Intake (SWI) system supplies filtered sea water as Feedwater to the Desalination Unit for freshwater production.
- The electrolyser produces hydrogen at the required storage pressure.
- The electrolyser package includes drying and conditioning of the hydrogen product stream for storage and consumption in the Fuel Cell.
- The produced hydrogen is stored in the hydrogen storage system for time-shifting wind turbine generator power production.
- The Fuel Cell consumes hydrogen from the storage to produce power.
- The BESS acts as an electricity storage to balance the loads during hydrogen production and during power production by the Fuel Cell. The BESS storage capacity will also provide additional energy storage.

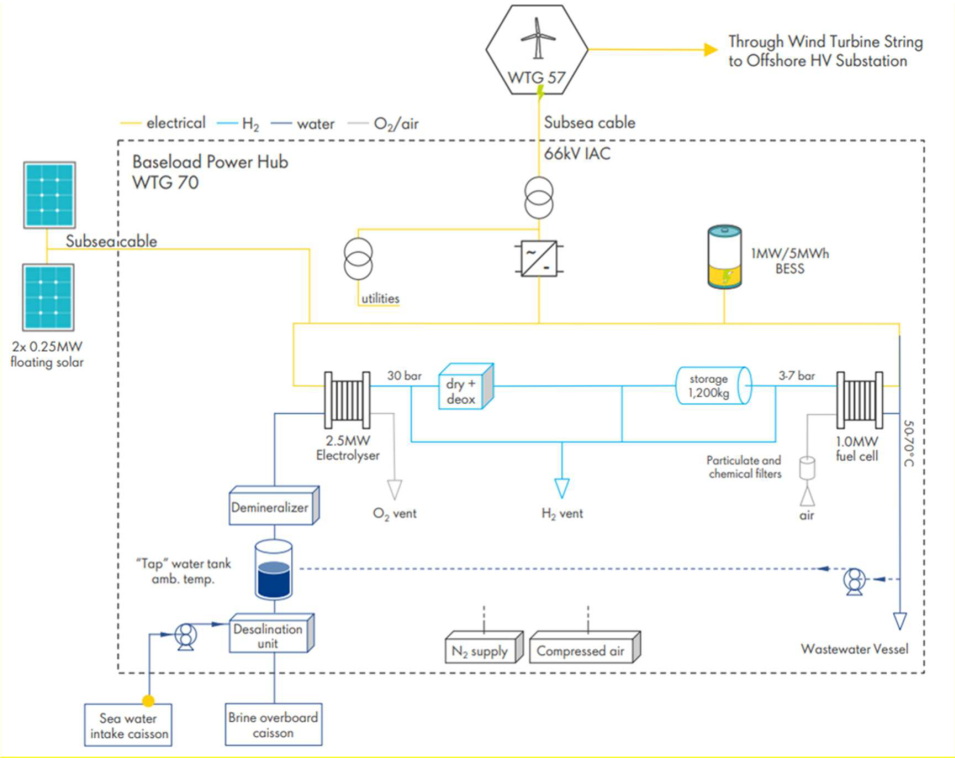


Figure 4 – Process Scheme of the selected BLPH Concept including Boundary Limits

3.2 DESIGN LIFE

Below Table 1 reports the design lives for the Monopile & Topside Structures and for the Topside Piping & Equipment. The total design life for Monopile & Topside Structures is 25.5 years, while Topside Piping & Equipment will be operated for 2 years, then removal and decommissioning will be evaluated.

The corrosion assessment and material selection for Topside Piping & Equipment which are scope of this report is based on 2-years operational life.

Table 1 - Platform Design Lives for Monopile & Topside Structures, Topside Piping & Equipment

DESCRIPTION	DURATION (YEARS)
Monopile & Topside Structures	
Construction Phase	2.5
Operational Life	2.0
Non-Operational Life	21.0
Topside Piping & Equipment	
Operational Life NOTE 1	2.0

NOTE 1: Topside assumed to be decommissioned and removed after 2 years.

3.3 DESIGN CASES

According to Heat & Material Diagrams (Ref. [10]), two design cases are foreseen:

- *Case 1*: Electrolyser is on and hydrogen is being stored, BESS (Battery Energy Storage System) is charging if required. FC (Fuel Cell) is off.
- *Case 2*: FC is on and hydrogen is being used, BESS is discharging if required. Electrolyser is off.

3.4 OPERATING CONDITIONS

Operating conditions for piping are reported in the Heat & Material Diagrams (Ref. [10]).

Conditions for storage vessels are reported in Technical Data Sheet for Hydrogen Storage Vessel (V-25001) (Ref. [2]) and summarized in Section 3.10.

3.5 HYDROGEN QUALITY

The hydrogen is produced to be stored and later to be consumed by the Fuel Cell (FC). The minimum hydrogen quality is determined by the FC and as reported in Ref. [1] is assumed to be according to ISO 14687 (Ref. [35]) Type I, Grade E, Category 3:

- Hydrogen Fuel Index: 99.9 %mol
- Total Non-hydrogen Gases: 0.1 %mol
- Water: Non-condensing at any ambient conditions
- Total hydrocarbons (except C1): 2 µmol/mol

- Methane: 100 µmol/mol
- Oxygen: 50 µmol/mol
- Total Nitrogen, Argon, Helium: 0.1 %mol.

High hydrogen purity shall be maintained. No water condensation is foreseen during normal operation. In case of upset conditions, the wet hydrogen is sent to vent system instead of storage vessels.

3.6 FRESH WATER QUALITY

As reported in Ref. [1], the EPCI CONTRACTOR shall align freshwater quality specification and operating conditions between Desalination Unit and Electrolyser Vendor. Following typical freshwater quality provides EPCI CONTRACTOR initial guidance for the respective interface conditions, final water quality is to be determined and confirmed by the Electrolyser OEM (Elogen):

- Pressure: 4-6 barg
- TDS (total dissolved solid): 540 mg/l
- Temperature: 10-25 °C
- Fouling index (SDI): - 3
- Hardness: 0.9 °Fr
- Oil: 0.1 mg/l
- TOC (total organic carbon): 3 mg/l
- DOC (dissolved organic carbon): 10 mg/l
- Free Chlorine: 0.01 mg/l
- Iron (Fe): 0.1 mg/l
- Manganese (Mn): 0.05 mg/l
- Aluminium (Al): 0.05 mg/l
- Conductivity: 703 µS/cm.

All other properties shall be as per drinking water. A water analysis is required to finalize the design of water treatment unit and to adjust the sizing (Ref. [1]).

3.7 DESIGN CAPACITIES

The objective of the BLPH is to provide 1MW of "gross" power for 99% of the time of the year. This means that during low wind (resulting in <1MWe), the combined output of WTG-57 + BESS + FC + Solar PV shall provide 1MWe of power to the wind farm (excluding the utility consumption of the BLPH platform).

In summary, the following minimum package requirements shall be applicable:

- Water Electrolyser : 2.5MWe
- BESS : 1.0MWe / 5.0MWhe
- Hydrogen Storage : 1,200kg (volumetric sizing @ 30barg)
- Fuel Cell : 1.0MWe
- Floating Solar PV: 0.5 MWe (this will be designed by Others).

3.8 ENVIRONMENTAL CONDITIONS

In the Basic Design Engineering Package (Ref. [1]), the following ambient temperatures are reported:

- Minimum Ambient Temperature: -8.4 °C
- Nominal Ambient Temperature: 10.5 °C
- Maximum Ambient Temperature: 25.0 °C.

3.9 LOW TEMPERATURE REQUIREMENTS

The following Table 2 reports the minimum design metal temperature (MDMT) to be considered for pressure retaining materials.

Table 2 – Minimum Design Metal Temperature (MDMT)

MATERIAL	MDMT [°C]
CS and LAS	-29
LTCS	-29°C to - 46°C
AISI 316/316L SS	-46°C to -196°C, but must be impact tested as per ASME B31.3 (Ref. [15]) when subjected to temperatures below -101 °C.

3.10 DATA OF HYDROGEN STORAGE VESSEL

The Technical Data Sheet for Hydrogen Storage Vessel (V-25001) (Ref. [2]) reports the following Design Data:

- Design conditions: 40 barg at -10 / 80 °C
- Volume: 95.44 m^3 (excluding heads)
- Material for Shell and Heads: SA-516-60
- Minimum Design Metal Temperature: - 29°C
- Operating conditions: 30 barg at 20 °C
- PWHT: as per ASME Sect VIII

It is to note that actual operating conditions are described by a range that covers operating pressures between 6 barg to about 30 barg and operating temperatures from ambient temperature to 65 °C. Indeed, storage vessels are cyclically loaded with hydrogen at 65 °C and 30 barg (Stream 2 in Case 1 of H&MB, Ref. [10]), then reach 20 °C because the metal is in contact with the colder external environment.

Further, Ref. [2] reports the Construction Code ASME Section VIII Div.2.

4 ASSESSMENT OF MATERIAL DEGRADATION MECHANISMS

4.1 POTENTIAL INTERNAL DAMAGE MECHANISMS

4.1.1 Introduction

General hydrogen and metallic materials evaluations are covered by several guidelines. At temperatures below 100°C, hydrogen embrittlement (HE) is the degradation mechanism (see Section 4.1.2).

At higher temperatures, generally above 200°C, high temperature hydrogen attack (HTHA) is the degradation mechanism for unalloyed and low alloyed steels (see Section 4.1.5). This effect is described in "Steels for Hydrogen Service at Elevated Temperatures" by API RP 941 (Ref. [13]).

4.1.2 Hydrogen Embrittlement (HE)

Hydrogen embrittlement (HE) is a generic term that encompasses numerus detrimental effects which materials may experience when exposed to hydrogen. These are generally caused as hydrogen can diffuse through steel as atomic hydrogen (H^+) and to a lesser extent as di-atomic hydrogen (H_2). H^+ and/or H_2 can then become trapped in a susceptible material, in a stressed area embrittlement and cracking can occur.

In other words, HE is the loss in strength, ductility, and/or fracture toughness of susceptible materials due to the penetration and diffusion of atomic hydrogen (Ref. [12]). HE can lead to brittle cracking. It can occur during manufacturing, welding, or from services that charge hydrogen into the metal.

Affected materials to HE include low-alloy steels, high-strength steels, 400 series SS, precipitation hardenable stainless steel, duplex stainless steel, and some high-strength nickel-based alloys.

As stated in Ref. [12], carbon steel (CS) can suffer HE if hardened by cold work or by welding. Typically, a CS has to have a hardness greater than Rockwell hardness number (HRC) 22 to be susceptible to HE cracking in the most severe environments. Higher strength/hardness can be tolerated in milder environments.

For HE to occur, the following five conditions must be satisfied (Ref. [12]):

- The material must be susceptible.
- Hydrogen must be present at a critical concentration within the material.
- The strength/hardness level must be high enough and the microstructure must be susceptible to HE.
- A stress above the threshold for HE must be present from residual stresses and/or applied stresses.
- The temperature must be in the embrittling and cracking range. HE generally diminishes with increasing or decreasing temperature away from ambient.

The effect of HE is described to occur in the temperature range from -100 to +100°C, reaching a maximum around room temperature. The yield strength of the materials is reported to be unchanged, but when entering the yield area, the material shows a brittle fracture. A guideline for handling of hydrogen at low temperatures is "Hydrogen Pipeline Systems" by EIGA (Ref. [28]).

In general, as strength increases, susceptibility to HE increases. Certain microstructures, such as untempered martensite, are more susceptible at the same strength level than tempered martensite. CS that is severely hydrogen charged will have lower fracture toughness than with no hydrogen.

4.1.3 Hydrogen Assisted Fatigue

Hydrogen service can significantly accelerate fatigue crack growth in Carbon Steel (CS) and ferritic/martensitic alloys. The presence of hydrogen reduces the threshold cyclic stress intensity factor as well as fatigue life, this is most prominent at ambient temperatures. The risk generally increases with increasing materials strength/hardness under cyclic loading.

Austenitic Stainless Steels are relatively unaffected by Hydrogen Assisted Fatigue.

4.1.4 Reduction of Tensile Strength and Ductility in Hydrogen Gas

H_2 gas will reduce the tensile strength/ductility and notched tensile strength of susceptible materials in high pressure environments. Premature failures of burst discs have been attributed to this phenomenon. All materials are affected with austenitic stainless steels less effected than most others.

4.1.5 High Temperature Hydrogen Attack (HTHA)

High Temperature Hydrogen Attack (HTHA) results from exposure of steels to H_2 gas at elevated temperatures and pressures. Dissociated hydrogen atoms react with carbon and carbides in the steel to form CH_4. This is a well understood damage mechanism in Refinery Environments and it is referred to API 941 (Ref. [13]).

CS which is not Post Weld Heat Treated (PWHT) is most easily affected by HTHA and PWHT reduces the risk. Corrosion Resistant Alloy (CRA) materials with increased Cr content further reduce the risk and 300 Stainless Steel (SS) series are immune.

Based on the present operating conditions (see Section 3.4 and 3.10), there is no risk of HTHA for the BLPH topsides installed on the monopile HKN70.

4.1.6 Gaseous Oxygen-Enhanced Ignition and Combustion

Many metals are flammable in O_2 and O_2-rich air (>25 % oxygen) services even at low pressures, whereas they are non-flammable in air. The spontaneous ignition or combustion of metallic and non-metallic components can result in fires and explosions in certain O_2-rich gaseous environments if not properly designed, operated, and maintained.

300 series SS have good resistance in low pressure O_2 environments and is recommended for services under 14 barg (API RP 571, Ref. [12]). There are no firm limits in API Standards on the use of SS in O_2 service above 14 barg, however risk of auto-ignition depends on O_2 pressure, velocity, temperature and piping design (Ref. [23], Ref. [25]). In such cases it may be prudent to use a Copper or Ni-based alloy which are essentially immune up to temperatures very close to melting points. Many nickel alloys are at risk of HE services though, so caution on concentration of H_2 should also be considered. Some materials such as alloy 400, alloy 800 or 310 SS will provide good resistance under all possible scenarios (provided properly cleaned). Other

considerations such as selection of non-metallics and cleaning are to be required in O_2 service and are discussed in Section 6.2.

4.1.7 Oxygen Corrosion

The presence of oxygen in water causes a steady corrosion on carbon steel (CS), affecting the entire exposed metallic surface. This type of corrosion reduces the thickness of the entire exposed surface at once and it is the typical mechanism of not passive metals.

Necessary conditions for this type of corrosion are an electrolyte (such as water) in direct contact with the metallic surface and the presence of an oxidizing species (such as oxygen). The oxygen reduces itself while oxidizing the metal atoms, generating corrosion products. Once all the oxidizing species are reduced, the corrosion reaction stops completely, which means that, if the source of oxygen is not continuous, so is the corrosion phenomenon.

No corrosion attack is expected on stainless steel (SS) due to oxygen presence, as long as the chloride concentration in the system is low. SS are passive metals which form a protective layer which is resistant to general corrosion attacks. In case chlorides are present, the protective layer can locally break giving place to localized corrosion attacks.

For the case under Study no oxygen corrosion is expected for the H_2 service, as the produced, stored and transported H_2 gas shows a high level of purity and since water is considered as non-condensing at any ambient conditions, see Section 3.5.

4.2 EXTERNAL DAMAGE MECHANISMS

4.2.1 Atmospheric Corrosion of CS

Atmospheric corrosion is the corrosion attack in the form of metal weight loss on CS in presence of condensed water oxygen saturated on the metal surface. Corrosion attack of this type depends on the atmospheric conditions such as temperature, humidity, environmental salinity, and the corrosive pollutant gases that may be present in that environment.

CS piping and equipment shall be externally protected against external atmospheric corrosion by suitable coating system. Since UV radiation may degrade an external polymer coating, UV-resistant paint system shall be selected.

Possible effect of the environment on material being transported to site should be considered and managed through proper handling, transportation and storage procedures and proper painting.

4.2.2 External Chloride Stress Corrosion Cracking (Ext-CSCC) of CRAs

The external environment may also enable the occurrence of external CSCC (Ext-CSCC). In this case, oxygen is present and traces of chlorides in the atmosphere may locally accumulate (e.g. marine environments, chloride-containing sand in desert areas or halide leaching materials used for thermal insulation…) and reach a critical concentration for Ext-CSCC; the triggering factor is the temperature. Above the critical temperature for Ext-CSCC onset, precautions shall be enforced for Ext-CSCC avoidance, e.g. by providing protective coatings.

Ext-CSCC initiates from sites of localized pitting or crevice corrosion. The propagation occurs when cracks grow more quickly from the pit or crevice than the rate of corrosion.

To reduce the risk of Ext-CSCC on exterior surfaces, all stainless steel piping and equipment shall be coated with appropriate product to protect surfaces from the wet chloride environment. Coating is required for all bare and insulated surfaces.

4.3 LOW TEMPERATURE BRITTLE FRACTURE

Brittle fracture is the sudden rapid fracture under stress (residual or applied) where the material exhibits little or no evidence of ductility or plastic deformation. Equipment operating at low temperatures may lead to brittle fracture of the material. Temperature, material's toughness, amount of both residual and applied stress including stress concentration are important parameters. Mitigation of brittle fracture will be achieved by the combination of process engineering and material selection with appropriate minimum design temperatures and with the correct toughness requirements.

For piping and equipment in low temperature service, the magnitude of the minimum design temperatures may drive the material selection process. Minimum Design Metal Temperature (MDMT) is specified as the lowest metal temperature expected during normal operation, extreme operation, start-up, emergency and normal shutdown, testing or depressurization.

Where low temperature service is expected, the first alternative to CS is LTCS, and the applicable range can often be increased by post-weld heat treatment. Where the design temperature is lower than the minimum permitted by the appropriate codes or Standards for LTCS, SS or Ni steel shall be specified.

5 MATERIALS SELECTION

5.1 MATERIAL SELECTION CRITERIA

The following Material Selection Criteria are reported in Ref. [1]:

- Material selection for piping and equipment shall be based on the FEED MSR (Ref. [9]).
- Piping used for Hydrogen service shall meet the requirements of ASME B31.12 (Ref. [15]) and provide resistance to HE.
- Storage Vessels (V-25001 A-F) shall be constructed from carbon steel (CS) and suitable for H_2 service.
- Flanges in both H_2 and non-H_2 service shall meet the requirements of ASME B16.5 (Ref. [14]).
- Drains and services not in H_2 service shall be constructed from CS with CA.
- Services where cleanliness is required e.g., demineralized water, shall be constructed from CRA or non-metallic materials including all tanks and pumps as detailed in the FEED MSR (Ref. [9]).
- Materials selection for electrolyser, fuel cells (FC) and other proprietary supplier equipment shall be by supplier and suitable for a 2-years design life in offshore environment. 304/304L SS and similar stainless-steel grades shall not be used in a marine environment due to risk of Ext-CSCC.
- Non-H_2 piping and equipment shall follow recognized industry Standards (e.g. ISO 21457, Ref. [37]).
- The number of welds & flanged joints in H_2 piping systems shall be minimized.

5.2 MATERIAL CANDIDATES FOR HYDROGEN SERVICE

5.2.1 Reference Standards

Reference Standards for the selection of materials in hydrogen service are:

- ASME B31.12 (Ref. [15]): Hydrogen Piping and Pipelines. This code is applicable to piping in gaseous and liquid hydrogen service and pipelines in gaseous hydrogen service. This code is applicable up to and including the joint connecting the piping to associated pressure vessels and equipment but not to the vessels and equipment themselves.
- ASME VIII Div.3-2010 (Ref. [20]): ASME Boiler and Pressure Vessel Code - Section VIII Division 3 (Alternative Rules for Construction of High Pressure Vessels), in particular the special requirements of Article KD-10 for vessels in high pressure hydrogen service shall be met.

The requirements of Article KD-10 are mandatory for the following vessels in hydrogen service:

- (1) *Non-welded vessels operating at temperatures less than 95°C*:
  - (a) With hydrogen partial pressure (pH_2) exceeding 6,000 psi (41 MPa).
  - (b) Constructed of materials with actual ultimate tensile strength exceeding 137 ksi (945 MPa) (see KM-230 and KM-243) and pH_2 exceeding 750 psi (5.2 MPa).
- (2) *Vessels of welded construction operating at temperatures less than 95°C*:
  - (a) With pH_2 exceeding 2,500 psi (17 MPa).
  - (b) Materials with actual ultimate tensile strength exceeding 90 ksi (620 MPa) and pH_2 exceeding 750 psi (5.2 MPa). It is worth noting that 620 MPa is maximum tensile strength for ASTM A-516 Gr. 70; therefore, any higher strength steel would need a different maximum tensile strength limit to be applied. It is here anticipated that, in the present case, ASTM A-

516 Gr. 60 is selected, with maximum tensile strength of 550 MPa, thus the limit of 620 MPa is respected.

For the case under Study, the requirements of the Article KD-10 (Ref. [20]) shall be met for all vessels in hydrogen service as defined by (b) in the above-reported list.

Each pressure component shall be evaluated for the specified fatigue cycles and shall meet the fracture toughness requirements in this Article. The requirements in this Article are in addition to the other requirements of this Division.

Requirements of Article KD-10 are non-mandatory for vessels operating above 95°C. The rules of this Article are applicable to the materials listed in Tables KCS-1 (carbon and low alloy steels) and KHA-1 (martensitic stainless steels), and to aluminium alloys 6061-T6 and 6061-T651 only.

5.2.2 Carbon Steel (CS)

CS can suffer from various forms of HE depending on the hydrogen pressure in the line. CS is commonly the material of choice in refinery hydrogen service. Reference Standards are reported in above Section 5.2.1.

When specifying grades of CS, it is recommended to apply controls to hardness and chemistry.

For limits on chemistry, EIGA 121/14 "Hydrogen Pipeline Systems" (Ref. [28]) follow the requirements of ISO 15156 (Ref. [35]) relatively closely. EIGA 121/14 (Ref. [28]) requires a maximum phosphorus content of 0.015% and a CE (Carbon Equivalent) of 0.35.

ASME B31.12 (Ref. [15]) states a maximum Vickers hardness in parent metal of 235 HV10 and in the weld metal of 200 HV10. Therefore, it is recommended to PWHT all CS piping in order to meet the hardness requirements.
Compared to ASME B31.12, API 571 (Ref. [12]) states that CS can suffer HE if hardened by cold work or by welding. Further it is reported that typically a CS has to have a hardness greater than Rockwell hardness number (HRC) 22 to be susceptible to HE cracking in the most severe environments. Higher strength/hardness can be tolerated in milder environments.

CS with such a low hardness and with limits on chemistry as described above will need to be specially procured.

For the present Project, CS with a maximum yield strength of 355 MPa shall be used.

Small molecule size of hydrogen gas can cause a greater risk to leakage than other gaseous species. Therefore, cast materials shall be avoided as they are generally more porous than forgings or components fabricated from plates.

SA 516 Steel Plates

SA 516 is a CS plate grade utilized primarily in welded pressure vessels for moderate to lower temperature service and where notch toughness is important. It is the most popular pressure vessel quality steel plate. Though it is produced in different grades (55, 60, 65, 70), A516 Grade 70, which roughly corresponds to the European version P355N, is the most widely used grade.

Tensile strength is one of the primary differences between grades. Grade 70 has a tensile strength between 485 – 625 MPa, which is the highest of all the grades.

Gr. 70 is a suitable grade for hydrogen storage. However, if requirements of a CE (Carbon Equivalent) of 0.35 and a maximum hardness of 235/200 HV10 must be fulfilled for welding, Grade 60 represents a better solution. It shall be mentioned that these requirements are very conservative, as they are generally applied for critical sour conditions.

5.2.3 Austenitic Stainless Steel (SS)

Generally Austenitic SSs are either less affected or relatively unaffected by HE. Stabilised "L" grades perform better than non-stabilised grades due to the risk of strain induced martensite in non-stabilised grades, therefore "L" grades should be used as standard as it is common for oil and gas services. While most 300 series SS perform well, 304L SS is more susceptible to HE rather than 316L SS and thus 304L SS is not recommended for the present project.

Given the lower susceptibility of 316L SS (or dual certified 316/316L SS) towards HE and there will be advantages in procuring 316L SS from stockists, rather than custom produced CS, this material should be used as the standard grade.

ISO 21457 (Ref. [37]) reports a maximum operating temperature for uncoated 316L SS in marine atmospheric environment of 50-60 °C, due to risk of Ext-CSCC (see also Section 5.8).

5.2.4 Martensitic Stainless Steel (MSS)

The majority of high strength martensitic SSs used in valve stems (e.g. 410, 430, 440, 17-4ph) are highly susceptible to HE. Therefore, it is recommended to avoid use of Ferritic SS, Martensitic SS and Precipitation Hardening SS.

5.2.5 Nickel Alloys (Inconel, Hastelloy etc.)

Test results compiled in SAND2012-7321 "Technical Reference for Hydrogen Compatibility of Materials" (Ref. [39]) show that nickel alloys such as Inconel 625 and Hastelloy C22 are affected by HE. Furthermore, ASME B31.12 (Ref. [15]) recommends that nickel-based alloys shall be avoided due to HE concerns.

Therefore, it is recommended that items as instrumentations, which commonly are in nickel-based alloys, shall be selected in 300 series SS or 6Mo SASS as per Section 5.2.3. External coating shall be specified for 316L SS to avoid Ext-CSCC and pitting corrosion in the Cl^- containing marine atmosphere (see Section 5.8).

5.2.6 Non-Metallic Materials

Graphite gaskets and packing are commonly used in H_2 service. Most elastomers are compatible with hydrogen. Their chemical resistance is given in below Table 3 (taken from Section 4.4.2 of Ref. [28]). Table 3 shows the permeation of hydrogen through elastomers at 25 °C.

Table 3 - H_2 Compatibility with Common Elastomers (Ref. [28])

MATERIAL	COMPATIBILITY	PERMEATION cm^{-3} S.T.P.mm.sec.$^{-1}$.cm^{-2} ($cmHg^{-1}$)
Natural rubber	B (Fair)	$492x10^{-10}$
Butyl rubber	A (Good)	$74 x10^{-10}$
Silicone rubber	B (Fair)	-
Neoprene (Polychloroprene)	A (Good)	$133 x10^{-10}$
Buna S	A (Good)	$399 x10^{-10}$
Viton (FKM)	A (Good)	-
Buna N (NBR)	A (Good)	-

Compatibility of above elastomers shall be verified to optimise the selection of non-metallic seals and special testing has to be performed according to relevant international Standards in order to reduce the risk of leakages. The main relevant Standards are:

- NORSOK M-710 (Ref. [42])
- ISO 11114-2 (Ref. [33])
- CHMC2 (Ref. [27]).

5.3 PROCESS SYSTEMS

5.3.1 Hydrogen Lines

As discussed in Sections 5.2.2 and 5.2.3, the most critical decision is whether to use (LT)CS or SS for the dry hydrogen lines. If CS is used it will require specialist procurement to meet the requirements of H_2 service, whereas standard 316L SS can be used. While 316L SS is normally approximately twice the cost of (LT)CS, having to specially procure (LT)CS, PWHT the welds and test for the low hardness, this cost benefit for (LT)CS is likely to disappear, particularly for small bore, thin wall lines which make up the majority of the topsides piping.

The cost saving from using (LT)CS will be eliminated by any H_2 specific requirements mandated by ASME B31.12 (Ref. [15]), which will likely be higher cost than SS. SS (grade 316LSS) can be used for H_2 piping with no special precautions.

Internal cleanliness is also an issue for CS piping, internal acid cleaning or similar will be required and filters will likely be required to protect electrolysers and fuel cell equipment.

5.3.2 Electrolyser and Hydrogen Drying Package

Reference is made to PFS – Electrolyser and Hydrogen Drying Package: 123A90-DDL-PR-DG-80003 (Ref. [3]).

Fresh water is provided to the Electrolyser Package by the Fresh Water Pump. Hydrogen produced in the electrolyser stack is fed to the internal dryer installation before the gas is fed to the hydrogen storage vessels. Hydrogen can be routed to the vent system during start-up and emergencies. The electrolyser stack is cooled by the Thermal Control Unit (TCU). The TCU container is mounted on top of the electrolyser container.

Inlet «Stream 1» contains the electrolyser feed water, which arrives from the Water Treatment Plant (Ref. [6]). This water is desalinated (fresh) water which has passed through the UV Water Filter in order to minimize biofouling in the downstream systems. The operating temperature of «Stream 1» is 24.7 °C with an operating pressure of 6 barg. The fresh water contains oxygen and is desalinated.
The fresh water stream requires cleanliness and therefore CS is not recommended, despite the short design life. 316L SS is an option for «Stream 1».

«Stream 2» is in contact with hydrogen gas, produced in the A-20000 - Electrolyser Package. Operating conditions of «Stream 2» are as follows (Ref. [10]):

- Vapour fraction: 1
- Operating temperature: 65.1 °C
- Operating pressure: 30 barg
- Mass density: 2.2 kg/m^3
- Hydrogen mol. fraction: 1.

Based on above operating conditions, CS is considered suitable provided the dehydration is adequate to prevent aqueous condensation (see also Section3.5). However, in line with points raised in Section 5.2.2 and 5.2.3, 316L SS shall be used as standard solution for hydrogen gas service (including «Stream 2»). External coating shall be specified for 316L SS to avoid Ext-CSCC and pitting corrosion in the Cl^- containing marine atmosphere (see Section5.8).

«Stream 3» (Electrolyser Oxygen Vent) from the electrolyser is included in a package by Vendor.

«Stream 4», which contains Electrolyser Water Effluent, is sent to Brine Discharge Caisson. Considering the short design life, CS + 3mm CA is the recommended material for «Stream 4».

Waste water is not recirculated (see page 2 of FEED MSR (Ref. [9])), therefore cleanliness is not required and CS + 3mm CA can be used due to short design life.

Table 4 - Materials for interconnecting piping of Electrolyser & Hydrogen Drying Package

STREAM NO.	SERVICE	INTERNAL DM	MATERIAL	NOTES
01	Water from WTP	O_2 Corrosion	316/316L SS	Chloride-free service
02	Hydrogen to Storage	HE	316L SS	Applicability of SS in line with Sect. 4.1

STREAM NO.	SERVICE	INTERNAL DM	MATERIAL	NOTES
03	To O_2 Vent	O_2 Corrosion Oxygen Enhanced Ignition	By Vendor	Cleaned O_2 (Sect. 6.2)
04	Electrolyser Effluent to Brine Discharge Caisson	O_2 Corrosion	CS +3mm CA	-
-	Water to Waste Water Tank	O_2 Corrosion	CS +3mm CA	NNF Waste water is not recirculated, therefore cleanliness is not required
-	To H_2 Vent	HE	CS +3mm CA	NNF No special precautions for H_2 required on atmospheric vents

5.3.3 Hydrogen Storage

Reference is made to PFS – Hydrogen Storage: 123A90-DDL-PR-DG-80004 (Ref. [4]).

As reported in Ref. [1], the materials for the hydrogen storage system shall be selected comprising the following items:

- Horizontal storage vessels
- Valve battery (pressure reduction valve arrangement fuel cell side).

As reported in Ref. [1], welded connections are recommended to minimise potential leaks of hydrogen.

Inlet «Stream 2» is in contact with hydrogen gas, produced in the A-20000 - Electrolyser Package. Operating conditions of «Stream 2» are as follows (Ref. [10]):

- Vapour fraction: 1
- Operating temperature: 65.1 °C
- Operating pressure: 30 barg
- Mass density: 2.2 kg/m^3
- Hydrogen mol. fraction: 1.

Operating conditions of outlet «Stream 5» (Hydrogen to Pressure Reduction for Fuel Cell) of Unit Hydrogen Storage are as follows (Ref. [4], Ref. [10]):

- Vapour fraction: 1
- Operating temperature: 65.1 °C
- Operating pressure: 30 barg
- Mass density: 2.2 kg/m^3
- Hydrogen mol. fraction.: 1.

According to Section 3.5, hydrogen purity shall be 99.9% and no water condensation is foreseen during normal operation. In case of upset conditions, the wet hydrogen is sent to vent system instead of storage. Therefore, hydrogen storage vessels always handle dry hydrogen.

Based on above operating conditions and in conformity with above Section 5.2.3, the recommended material for hydrogen gas «Stream 5» is 316L SS. External coating shall be specified for 316L SS to avoid Ext-CSCC and pitting corrosion in the Cl^- containing marine atmosphere (see Section 5.8).

The Design Data of Hydrogen Storage Vessels (V-25001) are reported in Section 3.10 according to Technical Data Sheet (Ref. [2]). The hydrogen service is a dry service and the vessels are operating at a low pressure of 30 barg. Therefore (LT)CS without a corrosion allowance (CA) is a valid option for the Hydrogen Storage Vessels V-25001.

A CA is not required for the Hydrogen Storage Vessels since water is considered as non-condensing at any ambient conditions (see Section 3.5), therefore the service is dry; moreover, the fluid is oxygen-free due to the high purity of the hydrogen. Thus, no oxygen corrosion or other damage mechanisms involving thickness loss are expected. The only possible damage mechanism to be considered for the case under Study is HE, i.e. a damage mechanisms not causing thickness loss, meaning that a CA has not be considered as a corrosion mitigation method.

As already mentioned in Section 5.2.2, as a CS plate grade SA 516 is recommended. Grade 60 and Grade 70 are both valid solutions. If the (LT)CS vessels shall meet chemistry and hardness requirements of Section 5.2.2, Grade 60 is the better solution. However, these requirements are quite rigid and could be relaxed, mainly because the operating pressure of the vessels is low (30 barg). Therefore, Grade 70 would be also a good solution.

Maximum strength of CS, where used, shall be limited to max 355 MPa as per Section 5.2.2.

During operation the H_2 storage vessels will be exposed to the cyclic loading/unloading of H_2 during the H_2 charging and discharging process. The charge/discharge cycles substantially depend on the periodicity of the wind field conditions. As reported in Ref. [11], for hydrogen vessel fatigue design, it is estimated that the number of full charge/discharge cycles (from full to empty) will be 180 times during the year. In other words, the following operating modes of the BLPH are expected:

- Fuel cell will utilise the full hydrogen inventory from the storage vessels 180 times per year (full discharge).
- Electrolyser will fully recharge the hydrogen vessels (from empty to full) 180 times per year (full charge).

CS may also be used in fatigue conditions, but present Project shall follow fracture mechanics criteria. Cyclic load to be calculated according to ASME Standards.

Below Table 5 reports the selected materials for the Hydrogen Storage Unit.

Table 5 - Materials for "Hydrogen Storage"

STREAM NO.	SERVICE	DM	MATERIAL	NOTES
02	Hydrogen to Storage	HE	316L SS	Applicability of SS in line with Sect. 5.1
05	Hydrogen from Storage	HE	316L SS	Applicability of SS in line with Sect. 5.1
-	To H_2 Vent	HE	CS +3mm CA	No special precautions for H_2 service
V-25001 A-F	Hydrogen Storage Vessels	HE	(LT)CS (SA 516)	Dry service, thus no CA is necessary. SA516 Grade 60, otherwise also Grade 70 is a valid solution

5.3.4 Fuel Cell Package

Reference is made to PFS – Fuel Cell Package: 123A90-DDL-PR-DG-80005 (Ref. [5]).

A single Fuel Cell Package A-80000 will be included on the upper deck to convert hydrogen gas to electricity. This will be a standalone, containerized Unit that's rated 1MW to meet all operational and safety requirements for use in a marine environment.

The Fuel Cell Package A-80000 will have the following tie-in points to the BLPH platform:

- Hydrogen Supply from the storage vessels
- Water drain to brine caisson
- Two power connections - 6.6kVAC and 400VAC (package utilities)
- The self-contained Package Control Unit (PCU)
- The self-contained fire detection, alarm, and suppression systems.

Operating conditions of «Stream 6» (Fuel Cell Hydrogen Feed) of Unit Fuel Cell Package are as follows (Ref. [5], Ref. [1]):

- Vapour fraction: 1
- Operating temperature: 66.3 °C
- Operating pressure: 6.5 barg
- Mass density: 0.5 kg/m^3
- Hydrogen mol. Frac.: 1.

Based on above operating conditions and in conformity with Inlet «Stream 5» (see above Sections 5.3.2 and 5.3.3), the recommended material for hydrogen gas «Stream 6» is 316L SS. External coating shall be specified for 316L SS to avoid Ext-CSCC and pitting corrosion in the Cl^- containing marine atmosphere (see Section 5.8).

«Stream 7», which contains Fuel Cell Water Effluent, is sent to Brine Discharge Caisson. Considering the short design life, CS + 3mm CA is the recommended material for «Stream 7».

Waste water is not recirculated (see page 2 of FEED MSR (Ref. [9])), therefore cleanliness is not required and CS + 3mm CA can be used due to short design life.

Below Table 6 reports the selected materials for the Fuel Cell Package.

Table 6 - Materials for "Fuel Cell Package"

STREAM NO.	SERVICE	DM	MATERIAL	NOTES
06	Hydrogen Feed to Fuel Cell	HE	316L SS	Applicability of SS in line with Sect. 5.1
07	Fuel Cell Water Effluent to Brine Discharge Caisson	O_2 Corrosion	CS +3mm CA	-
-	Water to Waste Water Tank	O_2 Corrosion	CS +3mm CA	NNF Waste water is not recirculated, therefore cleanliness is not required
-	To H_2 Vent	HE	CS + 3mm CA	NNF No special precautions for H_2 required on atmospheric vents

5.4 UTILITY SYSTEMS

5.4.1 Water Treatment Plant

Reference is made to UFD – Water Treatment Plant: 123A90-DDL-PR-UFD-80006 (Ref. [6]).

The Water Treatment Plant incorporates a dedicated Sea Water Intake and Return System comprising:

- Sea Water Lift Pump Caissons
- Sea Water Lift Pumps
- Biocide Dosing Unit
- Sea Water Coarse Filter Package & Ultra-Filtration Unit
- Brine Discharge Caisson.

Table 7 - Materials Selection of Piping for Water Treatment Plant

SERVICE	MATERIAL	NOTES
Seawater Intake	25% Cr SDSS	25% Cr SDSS is limited to max 30°C for chlorinated seawater. Titanium or GRE likely required at higher temperatures. In the present case, according to H&MB, operating temperature is around 22 °C, therefore SDSS is deemed suitable for the service.
Desalination Waste Waters and Drains	CS + 3mm CA	NNF lines
Fresh Water	316L SS	D/s desalination package. According to H&MB, operating temperature is around 24 °C; Cl^- shall be < 100-200 mg/l, especially if T > 60 °C may be reached.

Table 8 - Materials Selection of Equipment for Water Treatment Plant

TAG	EQUIPMENT	MATERIAL	NOTES
B-50013A/B	Sea Water Lift Pump Caissons	CS + CA + IL/IEC + ICP	GRP to be considered as alternative material
P-50001A/B	Sea Water Lift Pumps	25% Cr SDSS	-
A-50000	Water Treatment Package	By Vendor	-
T-55001	Waste Water Tank	GRP	CS + CA + IL/IEC + ICP to be considered as alternative material
B-50014	Brine Discharge Caisson	GRP	CS + CA + IL/IEC + ICP to be considered as alternative material

5.4.2 Instrument Air and Nitrogen Systems

Reference is made to UFD – Instrument Air and Nitrogen Systems: 123A90-DDL-PR-UFD-80007 (Ref. [7]).

Instrument Air (IA) Package comprising:

- Instrument Air Compressors
- Air Driers
- IA Receiver.

The centralized IA System will serve all BLPH continuous and intermittent consumers. Service Air will be required for maintenance purposes e.g., flushing of filters etc.

Nitrogen will be required for normal operation and maintenance purposes:

- Normal operation consists of:
  - Purge gas within the Hydrogen Vent System
  - Supply to the electrolyser and other package users for start / stop, safety, and idle operations.
- Maintenance purposes consists of:
  - Purging of hydrogen containing systems
  - Purging of piping prior to start-up and restart.

Table 9 - Materials Selection of Piping for Instrument Air and N_2 Systems

SERVICE	MATERIAL	NOTES
Instrument Air	316/316L SS	Cleanliness requirement
Nitrogen	CS + 3mm CA	Commonality with other CS Systems

Table 10 - Materials Selection of Equipment for Instrument Air and N_2 Systems

TAG	EQUIPMENT	MATERIAL	NOTES
A-63000	Instrument Air Package	By Vendor	316/316L SS recommended for cleanliness requirement
U-64000	Nitrogen System	By Vendor	-

5.4.3 Vent Systems

Reference is made to UFD – Vent Systems: 123A90-DDL-PR-UFD-80008 (Ref. [8]).

Vent System which will be comprised of two vents:

- The Oxygen Vent (included in a package by Vendor)
- The Hydrogen Vent.

The oxygen vent will be comprised of an oxygen vent stack and will be required for the continuous venting oxygen from the electrolyser when in use.

The Hydrogen Vent will be comprised of:

- A Hydrogen Vent Knock-Out Drum
- A Hydrogen Vent Stack.

The hydrogen vent will be required for all emergency relief and blowdown scenarios.

Table 11 - Materials Selection of Piping for Vent Systems

SERVICE	MATERIAL	NOTES
Oxygen Vents	By Vendor	Oxygen system cleaning required, see Section 6.2
Hydrogen Vents	CS + 3mm CA	No special precautions for H_2 required on atmospheric vents

Table 12 - Materials Selection of Equipment for Vent Systems

TAG	EQUIPMENT	MATERIAL	NOTES
V-43001	Oxygen Vent KO Drum	By Vendor	System cleanliness is required, see Section 6.2
Q-44004	Oxygen Vent	By Vendor	System cleanliness is required, see Section 6.2
Q-43004	Hydrogen Vent	CS + 3mm CA	No special precautions for H_2 required on atmospheric vents

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5.5 VALVES AND INSTRUMENTS

Per Section 5.2.4 most high strength martensitic SSs are highly susceptible to HE and should not be used in valves and instruments.

Nitronic material grades 50 and 60 show good performance in H_2, these should be considered in place of 17-4ph and martensitic alloys for use in areas such as valve stems. Nitronic 32 and 40 shall not be used.

Thus, focus should be on using Austenitic SS for such components with Nitronic 50/60 where high strength is required.

Hard facing alloys such as Stellite, if required shall be subject to individual review / approval based on H_2 track record and or test data. Stellite with at least 40% Cobalt is reported to be acceptable in H_2 service per EIGA 121/14 [Ref 6]. Given the clean service it is expected that austenitic SS should be suitable for majority of metal seated valves.

The majority of commonly used non-metallic materials for packing and gaskets appear suitable for use. Graphite should be permitted along with materials rated "A" for compatibility per Section 5.2.6. Per normal offshore design graphite gaskets shall not be used in seawater service.

Castings shall be avoided with a preference given to forgings, where castings are used, they should be subject to a high-pressure gas leak test as hydrogen can permeate through castings.

Certain instruments used in oil and gas / petrochemical industries tend to view Hastelloy C-276 as the best choice material. This is not the case in Hydrogen. While C276 could be used in H_2, testing is required as limited data is available. For the BLP Project use of C276 shall be avoided when possible and require approval/testing for use.

Diaphragms and bursting disks have been subject to failure in H_2 service. These shall be selected in 316L SS.

For the present Project, materials of valves are reported in the following relevant documents:

- 123A90-DDL-PP-DS-70003 Datasheet Manual Valves (Ref. [12])
- 123A90-DDL-PP-SP-70000 Piping Material Classes (Ref. [13])
- 123A90-DDL-PP-SP-70030 Technical Supply Specifications - Manual Valves & Strainers (Ref. [14]).

5.6 BOLTING

For the short operating life, all external bolting shall be in B7M in accordance to ASTM A-193 "Alloy steel and stainless steel bolting materials for high temperature service" (Ref. [21]) or in L7M in accordance to ASTM A320 "Alloy steel bolting materials for low temperature service" ([Ref. [22]).

CS bolting shall be provided with a protection from atmospheric corrosion by hot dip galvanised, "HDG", e.g. in accordance to ISO 10684 (Ref. [32]) or ASTM A-153. Alternative to HDG, chemically converted phosphating treatment, polytetrafluoroethylene (PTFE) based coatings or suitable paint protection can be considered.

Bolting in SS grades B8 (304) in accordance to ASTM A-193 (Ref. [21]) are not permitted for the present Project in pressure retaining application due to CSCC risks.

5.7 CONTROL OF INTERNAL DAMAGE MECHANISMS

5.7.1 Hydrogen Analysis

Hydrogen (H_2) purity shall be guaranteed especially to avoid possible poisoning of catalysts in the fuel cell. Further in order to have under control possible internal damages mechanisms (DMs), as Hydrogen Embrittlement (HE) and O_2 corrosion the hydrogen purity and the dew point shall be controlled and monitored.

The following is recommended:

- Hydrogen purity shall be controlled and hydrogen composition shall be measured to monitor potential detrimental contaminants like CO and chlorides.
- The dew point of the hydrogen gas shall be controlled and measured.

5.7.2 NDT Inspections

The adoption of NDT inspections is recommended for at least on H_2 vessel and a chosen section of the H_2 piping. A continuous control system with Acoustic Emission (AE) is suggested in order to control a possible Hydrogen Embrittlement (HE).

5.8 EXTERNAL CORROSION PROTECTION

As requested by Ref. [1], external coating for external corrosion protection shall be applied in accordance with a recognized industry Standard for offshore and meet the functional requirements as set out in the FEED MSR (Ref. [9]). As per Basic Design Engineering Package (Ref. [1]), the operational design life of the topsides piping and equipment is only 2 years, however the topside structure is designed for 25.5 years. The long structural design life requires offshore coating systems while the equipment could follow Vendor Standard coatings.

Thus, based on FEED MSR (Ref. [9]) and ISO 9223 (Ref. [34]), the following corrosion categories shall be specified for external coatings:

- CX (extreme corrosivity) for the main structure
- CX (extreme corrosivity) for all pressure retaining SS above 50°C
- C3 (medium corrosivity) for CS piping and equipment with a design life of two years.

For coating systems of this Project, since the operating life is limited, it is recommended to follow NORSOK M-501 (Ref. [38]) or IOGP S-715 (Ref. [30]) with pressure retaining Stainless Steel painted above 50°C design temperature. The below table recommends the applicable coating systems to be used for the main component parts of the Project. Where a temperature is quoted, this shall be read as the maximum operating temperature. Either NORSOK or IOGP systems can be used where stated.

Table 13 – Recommended Coating Systems

Application	NORSOK CSDS Number	IOGP Number	Coating Type	Notes
Structural items				
Structural carbon steel with max. operating T < 120 °C	System 1	System 1A / 1B	System 1: Zinc Rich Primer, min. 3 coats System 1B: Zinc Rich Primer + epoxy + topcoat	-
Structural carbon steel with max. operating T ≤ 80 °C in internal and fully dry and ventilated areas	System 8 Note: Manufacturer Standard coating system may be used if accepted by Project.	System 8	System 8: 1 coat two component epoxy, or Zinc rich epoxy + epoxy tie coat	-

Application	NORSOK CSDS Number	IOGP Number	Coating Type	Notes
Pressure vessels, equipment, piping and valves				
CS with max. operating T < 120°C, exteriors of equipment, vessels, piping and valves, non-insulated	System 1	System 1	System 1: Zinc Rich Primer, min. 3 coats	-
CS, insulated surfaces of tanks, vessels, piping	System 2A or System 2B	System 1D	System 2A: TSA or alloys of aluminium + sealer System 2B: Thermally sprayed zinc or alloys of zinc + Tie coat + Intermediate coat + Topcoat System 1D: Epoxy, Epoxy phenolic, Epoxy novolac	-
316/316L SS below 50°C, non-insulated	Coating not required	Coating not required	-	-
316/316L SS above 50°C, non-insulated	System 6A	System 6A	System 6A: Epoxy primer + two component epoxy + topcoat	-
316/316L SS below 150°C, insulated	System 6C	System 6C	System 6C: 2 coats epoxy phenolic (Epoxy, Epoxy phenolic, Epoxy novolac)	-

6 OTHER CONSIDERATIONS

6.1 FUGITIVE EMISSIONS

Due to the small molecule size of hydrogen, there is a greater leakage risk than other gasses. This leakage can be through seals, non-metallic or metallic materials. Additional leak testing above the normal for oil and gas facilities is likely to be required. Selection of low permeability non-metallics should be considered as to help reduce leaks alongside proper design.

One point raised in literature is the risk of leakage through cast materials, which are generally more porous than forgings or components fabricated from plate. The use of cast valves should be minimised, and hydraulic leak test castings is recommended in line with EIGA 121/14 (Ref. [28]).

6.2 O_2 SYSTEM CLEANING

System cleanliness is important for the safe operation of oxygen systems. Contamination with metallic fines or hydrocarbons such as oils and greases during construction or maintenance activities can lead to fires during subsequent start-up of the Unit per Section 4.1.6.

Piping and equipment in enriched oxygen service shall be cleaned to an International Standard e.g. CGA G-4.1 (Ref. [26]) or ASTM G93 (Ref. [24]).

APPENDIX A - MATERIAL SELECTION DIAGRAMS

NOTES

1. 2.5 MW PEM ELECTROLYSER, CONFIGURATION WILL BE VENDOR SPECIFIC. (02)
2. ELECTROLYSER AUXILIARIES ARE INCLUDED IN THE PACKAGE I.E. AC-DC RECTIFIERS, ELECTRO DEIONISATION, COOLING, IA, H2 DE-OXYGENATION AND DRYER. (02)
3. POWER SUPPLIED BY WTG (CW57 AND FLOATING SOLAR ARRAY).
4. HYDROGEN DRIERS, DE-OXYGENATION, WATER TREATMENT ARE VENDOR SPECIFIC. HYDROGEN DRIERS UTILIZE TEMPERATURE SWING ADSORPTION.
5. STREAM INFO IS PRESENTED IN H&MB (123A90-DDL-PR-BL-80002). (02)
6. OXYGEN VENT LINE WITHIN VENDOR PACKAGE SoW

A-20000
ELECTROLYSER
PACKAGE

By Vendor

03

NOTE 6

TO OXYGEN VENT Q-44004

123A90-DDL-PR-UFD-80008

NNF

TO HYDROGEN VENT
KO DRUM V-43001

123A90-DDL-PR-UFD-80008

02

FROM WATER TREATMENT PACKAGE (A-50000)

123A90-DDL-PR-UFD-80006

01

INSTRUMENT AIR
from IA PACKAGE (A-63000) (02)

123A90-DDL-PR-UFD-80007

NITROGEN PURGE
from N2 GENERATOR PACKAGE (A-64000) (02)

123A90-DDL-PR-UFD-80007

A-20000
SEE VENDOR DRAWING
doc. n. K559-2254-CWIWP4202302-C02-001

NOTE 1, 2, 3 & 4 (02)

FROM HYDROGEN
STORAGE INLET PT

123A90-DDL-PR-DG-80004

02

DRY H2 TO HYDROGEN
STORAGE VESSELS V-25001A/B/C/D/E/F

123A90-DDL-PR-DG-80004

TO WASTE WATER TANK T-55001

123A90-DDL-PR-UFD-80006

04

TO BRINE DISCHARGE
CAISSON B-50014

123A90-DDL-PR-UFD-80006

HOLDS

1. "DELETED"

LEGEND

- MAJOR PROCESS LINE
- MINOR PROCESS LINE
- INSTRUMENT SIGNAL
- VENDOR PACKAGE

LEGEND OF MATERIALS

- CS+3mmCA
- 316/316L SS

ABBREVIATIONS

- CA: Corrosion Allowance
- CS: Carbon Steel
- SS: Stainless Steel

REV.	DATE	DRN	CHKD	APPD	DESCRIPTION
02	22/08/24	SSE	CIM	DLO	ACCEPTED FOR CONSTRUCTION (AFC)
01	23/11/23	SSE	CIM	DLO	ACCEPTED FOR CONSTRUCTION (AFC)
00	18/09/23	SSE	CIM	DLO	ISSUE FOR REVIEW (IFR)

CROSSWIND

ROSETTI MARINO

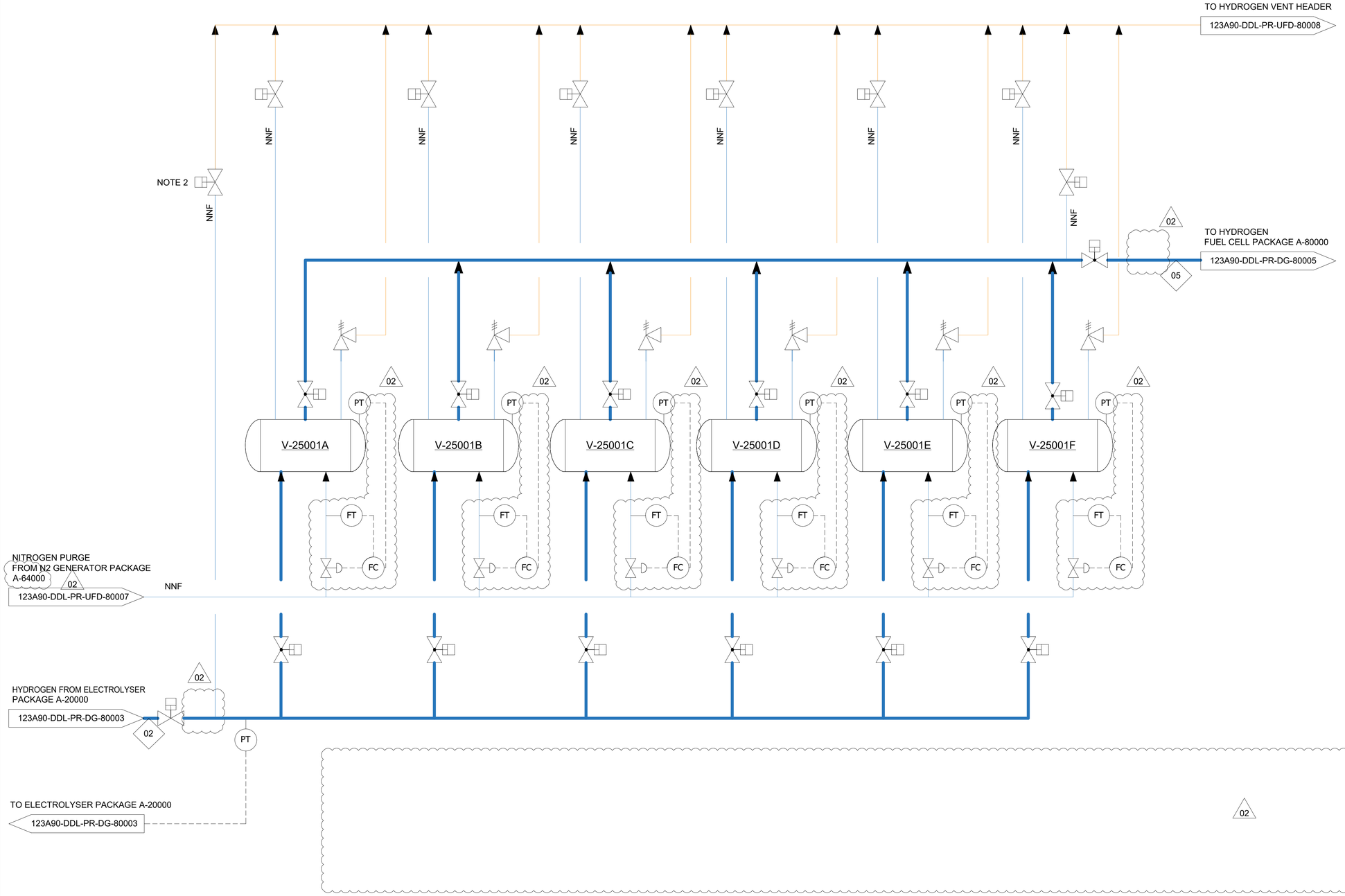
TITLE :
BASE LOAD POWER HUB (BLPH)
PROCESS FLOW SCHEME
ELECTROLYSER AND HYDROGEN DRYING PACKAGE

CONTRACT NO./TITLE CW-I-WP4-2023-05/HOLLANDSE KUST NOORD WIND PARK			SCALE
DRAWN	CHECKED	APPROVED	DATE

A1	DRAWING NO. 123A90-DDL-PR-DG-80003	SHEET 001	REV. 02

V-25001A/B/C/D/E/F
HYDROGEN
STORAGE
VESSELS

Shell: CS
(requirements for hydrogen service, as per Materials Selection Report)



NOTES

1. STREAM INFO IS PRESENTED IN H&MB (123A90-DDL-PR-BL-80002).
2. LINE REQUIRED FOR PURGING OF PIPE WORK.

HOLDS

1. "DELETED" 02

LEGEND

- MAJOR PROCESS LINE
- MINOR PROCESS LINE
- INSTRUMENT SIGNAL
- VENDOR PACKAGE

LEGEND OF MATERIALS

- CS+3mmCA
- 316/316L SS

ABBREVIATIONS

- CA: Corrosion Allowance
- CS: Carbon Steel
- SS: Stainless Steel

REV.	DATE	DRN	CHKD	APPD	DESCRIPTION
02	22/08/24	SSE	CIM	DLO	ACCEPTED FOR CONSTRUCTION (AFC)
01	23/11/23	SSE	CIM	DLO	ACCEPTED FOR CONSTRUCTION (AFC)
00	18/09/23	SSE	CIM	DLO	ISSUE FOR REVIEW (IFR)

CROSSWIND

ROSETTI MARINO

TITLE :
BASE LOAD POWER HUB (BLPH)
PROCESS FLOW SCHEME
HYDROGEN STORAGE

CONTRACT NO./TITLE	SCALE
CW-I-WP4-2023-05/HOLLANDSE KUST NOORD WIND PARK	

DRAWN	CHECKED	APPROVED	DATE

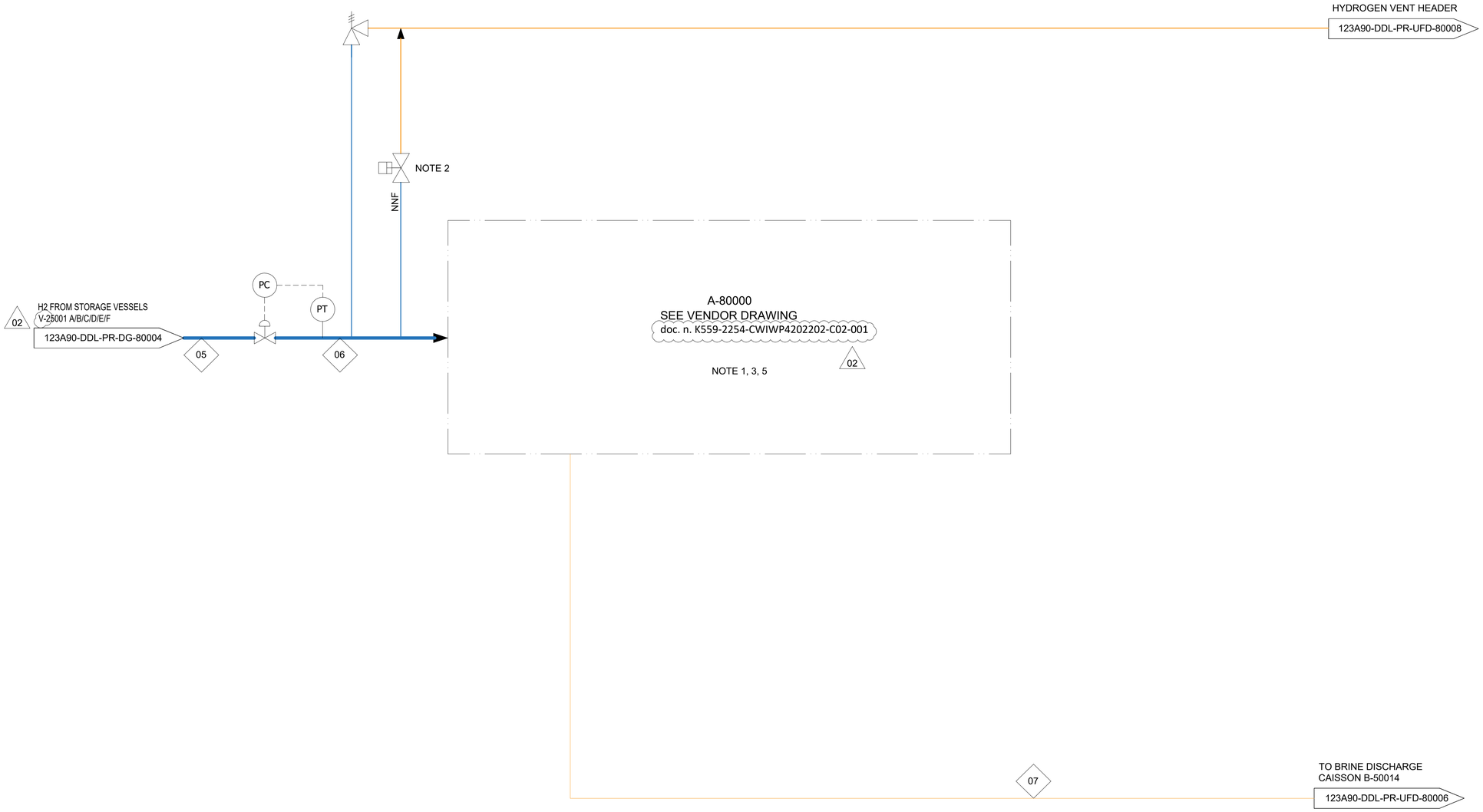
A1	DRAWING NO.	SHEET	REV.
	123A90-DDL-PR-DG-80004	001	02

NOTES

1. 1.0 MW PEM FUEL CELL, CONFIGURATION WILL BE VENDOR SPECIFIC.
2. LINE REQUIRED FOR PURGING OF PIPE WORK.
3. A PACKAGE INTERNAL RELEASE OF HYDROGEN (BY PRESSURE RELIEF, PURGE ETC.) IS VENTED OUT THE PROCESS AIR EXHAUST IN LEVELS BELOW THE LOWER FLAMMABLE LIMIT. VENTILATION AIR IS BLOWN OUT INTO THE SURROUNDING ENVIRONMENT, NO NEED FOR PHYSICAL CONNECTION
4. STREAM INFO IS PRESENTED IN H&MB (123A90-DDL-PR-BL-80002).
5. THE VENDOR PACKAGE WILL CONTAIN AIR INTAKE AND EXHAUST, SUITABLY SAFEGUARDED AND SEPARATED.

A-80000
FUEL CELL
PACKAGE

By Vendor



HOLDS

LEGEND

- MAJOR PROCESS LINE
- MINOR PROCESS LINE
- INSTRUMENT SIGNAL
- VENDOR PACKAGE

LEGEND OF MATERIALS

- CS+3mmCA
- 316/316L SS

ABBREVIATIONS

- CA: Corrosion Allowance
- CS: Carbon Steel
- SS: Stainless Steel

REV.	DATE	DRN	CHKD	APPD	DESCRIPTION
02	22/08/24	SSE	CIM	DLO	ACCEPTED FOR CONSTRUCTION (AFC)
01	23/11/23	SSE	CIM	DLO	ACCEPTED FOR CONSTRUCTION (AFC)
00	18/09/23	SSE	CIM	DLO	ISSUE FOR REVIEW (IFR)

CROSSWIND

ROSETTI MARINO

TITLE :
BASE LOAD POWER HUB (BLPH)
PROCESS FLOW SCHEME
FUEL CELL PACKAGE

CONTRACT NO./TITLE CW-I-WP4-2023-05/HOLLANDSE KUST NOORD WIND PARK			SCALE
DRAWN	CHECKED	APPROVED	DATE

A1	DRAWING NO. 123A90-DDL-PR-DG-80005	SHEET 001	REV. 02

B-50013A/B
SEA WATER LIFT PUMP CAISSON
CS + CA + IL/IEC+ICP (Alternative: GRP)

P-50001 A/B
SEA WATER LIFT PUMPS
25% Cr SDSS

A-50000
WATER TREATMENT PACKAGE
By Vendor

B-50014
BRINE DISCHARGE CAISSON
GRP (Alternative: CS + CA + IL/IEC+ICP)

T-55001
WASTE WATER TANK
GRP (Alternative: CS + CA + IL/IEC+ICP)

BIOCIDE DOSING LINE

A-50000
SEE VENDOR DRAWING
doc. n. 1724000448-PR-PID-00013

NOTE 2, 3, 4

TO ELECTROLYSER PACKAGE A-20000
123A90-DDL-PR-DG-80003

P-50001 A/B
NOTE 1

B-50013 A/B

FROM ELECTROLYSER PACKAGE A-20000
123A90-DDL-PR-DG-80003

FROM FUEL CELL PACKAGE A-80000
123A90-DDL-PR-DG-80005

FROM INSTRUMENT AIR PACKAGE AND RECEIVER A-63000
123A90-DDL-PR-UFD-80007

FROM HYDROGEN VENT KO DRUM V-43001
123A90-DDL-PR-UFD-80008

FROM ELECTROLYSER PACKAGE A-20000
123A90-DDL-PR-DG-80003

FROM HYDROGEN VENT Q-43004
123A90-DDL-PR-UFD-80008

B-50014

T-55001

NOTE 5
TO SHIP DISPOSAL

NOTES

1. SUBMERGED PUMPS WITH SCREEN.
2. A-50000 INCLUDES BIOCIDE DOSING UNIT
3. CLEAN IN PLACE (CIP) WITH CLEANING CHEMICALS.
4. SWRO INCLUDES PUMPS AND MEMBRANES.
5. WASTE WATER LOADED ONTO SHIP FOR SAFE PROCESSING ON SHORE.
6. STREAM INFO IS PRESENTED IN H&MB (123A90-DDL-PR-BL-80002).

HOLDS

1. DELETED
2. DELETED
3. DELETED.

LEGEND

- MAJOR PROCESS LINE
- MINOR PROCESS LINE
- INSTRUMENT SIGNAL
- VENDOR PACKAGE

LEGEND OF MATERIALS

- CS+3mmCA
- 316/316L SS
- 25% Cr SDSS
- CPVC

ABBREVIATIONS

- CA: Corrosion Allowance
- CPVC: Chlorinated Polyvinyl Chloride
- CS: Carbon Steel
- GRP: Glass Reinforced Plastic
- ICP: Internal Cathodic Protection
- IEC: Internal Epoxy Coating
- IL: Internal Lining
- SDSS: Super Duplex Stainless Steel
- SS: Stainless Steel
- TBC: To Be Confirmed

REV.	DATE	DRN	CHKD	APPD	DESCRIPTION
02	22/08/24	SSE	CIM	DLO	ACCEPTED FOR CONSTRUCTION (AFC)
01	23/11/23	SSE	CIM	DLO	ACCEPTED FOR CONSTRUCTION (AFC)
00	18/09/23	SSE	CIM	DLO	ISSUE FOR REVIEW (IFR)

CROSSWIND

ROSETTI MARINO

TITLE :
BASE LOAD POWER HUB (BLPH)
UTILITY FLOW DIAGRAM
WATER TREATMENT PLANT

CONTRACT NO./TITLE CW-I-WP4-2023-05/HOLLANDSE KUST NOORD WIND PARK			SCALE
DRAWN	CHECKED	APPROVED	DATE

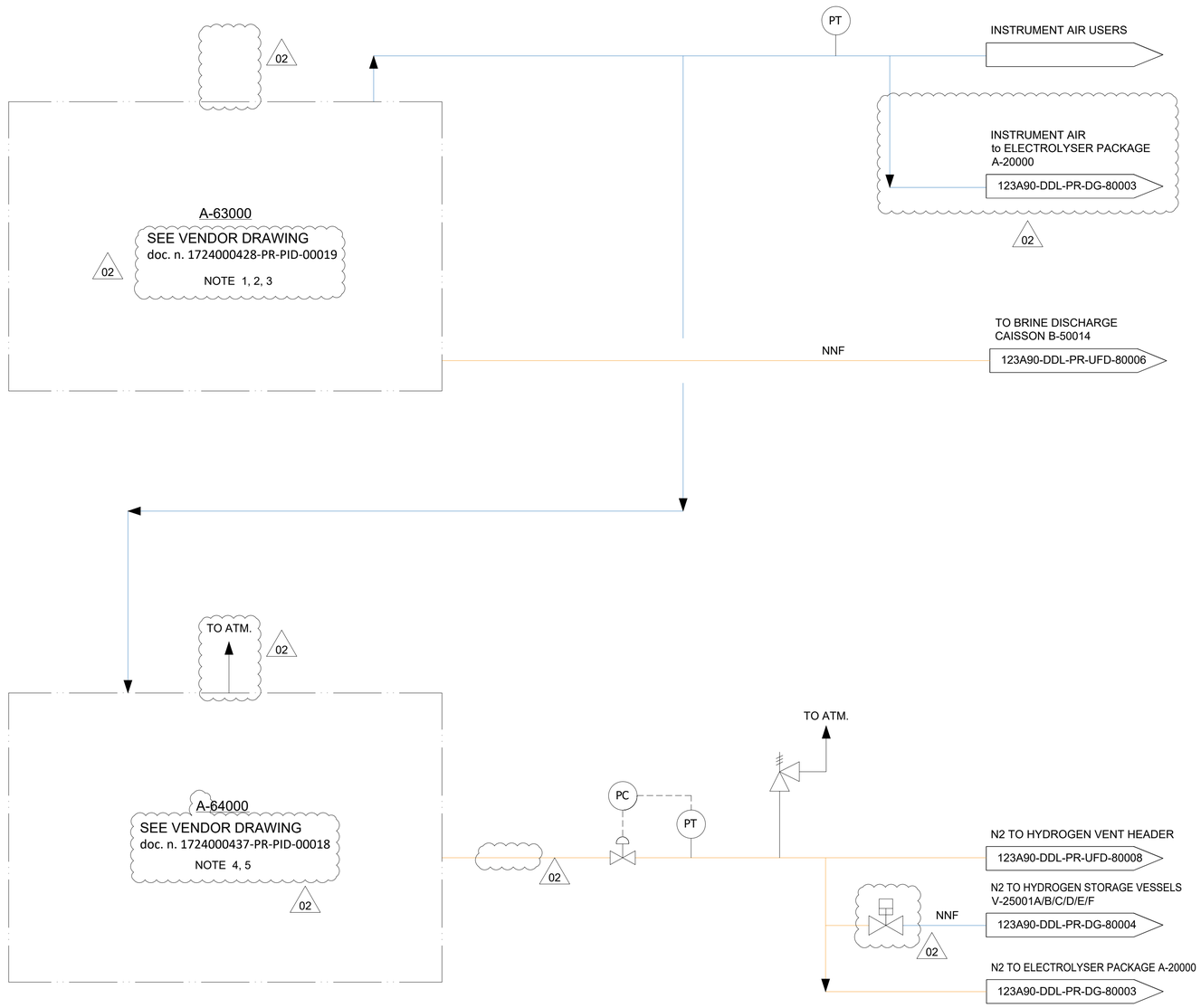
A1	DRAWING NO. 123A90-DDL-PR-UFD-80006	SHEET 001	REV. 02

A-63000
INSTRUMENT AIR
PACKAGE

By Vendor

A-64000
NITROGEN
GENERATION
PACKAGE
02

By Vendor



NOTES

1. INSTRUMENT AIR RECEIVER PROVIDES A MINIMUM OF 5 MINUTES HOLD UP VOLUME FOR ESSENTIAL USERS BETWEEN 9,5 AND 9 BARG OPERATING PRESSURE. 02
2. AIR SUPPLY PRESSURE CONTROLLED BY UPSTREAM CONTROL VALVE (WITHIN PACKAGE)
3. INSTRUMENT AIR PACKAGE A-63000 INCLUDES INSTRUMENT AIR RECEIVER V-63001
4. NITROGEN GENERATION PACKAGE A-64000 INCLUDES NITROGEN RECEIVER V-64001
5. NITROGEN RECEIVER PROVIDES A MINIMUM OF 5 MINUTES HOLD UP VOLUME FOR ESSENTIAL USERS BETWEEN 8 AND 7,5 BARG OPERATING PRESSURE.

02

HOLDS

1. "DELETED" 02
2. "DELETED"

LEGEND

- MAJOR PROCESS LINE
- MINOR PROCESS LINE
- INSTRUMENT SIGNAL
- VENDOR PACKAGE

LEGEND OF MATERIALS

- CS+3mmCA
- 316/316L SS

ABBREVIATIONS

- CA: Corrosion Allowance
- CS: Carbon Steel
- SS: Stainless Steel

REV.	DATE	DRN	CHKD	APPD	DESCRIPTION
02	22/08/24	SSE	CIM	DLO	ACCEPTED FOR CONSTRUCTION (AFC)
01	23/11/23	SSE	CIM	DLO	ACCEPTED FOR CONSTRUCTION (AFC)
00	18/09/23	SSE	CIM	DLO	ISSUE FOR REVIEW (IFR)

CROSSWIND

ROSETTI MARINO

TITLE :
BASE LOAD POWER HUB (BLPH)
UTILITY FLOW DIAGRAM
INSTRUMENT AIR AND NITROGEN SYSTEMS

CONTRACT NO./TITLE CW-I-WP4-2023-05/HOLLANDSE KUST NOORD WIND PARK | SCALE

DRAWN | CHECKED | APPROVED | DATE

A1 | DRAWING NO. 123A90-DDL-PR-UFD-80007 | SHEET 001 | REV. 02

V-43001
HYDROGEN
VENT KO
DRUM
LTCS+3mmCA

Q-44004
OXYGEN
VENT
316/316L SS

Q-43004
HYDROGEN
VENT
CS+3mmCA

OXYGEN FROM ELECTROLYSER
PACKAGE A-20000
123A90-DDL-PR-DG-80003

VENT HEADER

Q-44004
NOTE 1 & 2

FT

Q-43004
NOTE 1, 2 & 6

PT

V-43001
NOTE 5

LT

02

VENT HEADER

FROM ELECTROLYSER
PACKAGE A-20000
123A90-DDL-PR-DG-80003
NNF

FROM HYDROGEN
STORAGE VESSELS AND
HEADERS
123A90-DDL-PR-DG-80004
NNF

FROM FUEL CELL
PACKAGE FEED (A-80000)
02
123A90-DDL-PR-DG-80005
NNF

NITROGEN PURGE
from N2 GENERATOR PACKAGE (A-64000)
02
123A90-DDL-PR-UFD-80007

02

NNF

TO BRINE DISCHARGE
CAISSON B-50014
123A90-DDL-PR-UFD-80006

NOTES

1. VENTS SHOULD BE IN SAFE LOCATIONS.
2. HYDROGEN AND OXYGEN VENTS SHOULD BE SEGREGATED
3. STREAM INFO IS PRESENTED IN H&MB (123A90-DDL-PR-BL-80002).
4. DELETED 02
5. HYDROGEN KO DRUM WILL BE WINTERISED AS NECESSARY. 02
6. HYDROGEN VENT Q-43004 INCLUDES LIQUID SEAL DRUM, TO BE INSTALLED ON THE BOTTOM SIDE

HOLDS

1. "DELETED" 02
2. "DELETED"
3. "DELETED"

LEGEND

- MAJOR PROCESS LINE
- MINOR PROCESS LINE
- INSTRUMENT SIGNAL
- VENDOR PACKAGE

LEGEND OF MATERIALS

- CS+3mmCA
- 316/316L SS

ABBREVIATIONS

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- CS: Carbon Steel
- SS: Stainless Steel

REV.	DATE	DRN	CHKD	APPD	DESCRIPTION
02	22/08/24	SSE	CIM	DLO	ACCEPTED FOR CONSTRUCTION (AFC)
01	23/11/23	SSE	CIM	DLO	ACCEPTED FOR CONSTRUCTION (AFC)
00	18/09/23	SSE	CIM	DLO	ISSUE FOR REVIEW (IFR)

CROSSWIND

ROSETTI MARINO

TITLE :
BASE LOAD POWER HUB (BLPH)
UTILITY FLOW DIAGRAM
VENT SYSTEMS

CONTRACT NO./TITLE CW-I-WP4-2023-05/HOLLANDSE KUST NOORD WIND PARK | SCALE

DRAWN | CHECKED | APPROVED | DATE

A1 | DRAWING NO. 123A90-DDL-PR-UFD-80008 | SHEET 001 | REV. 02