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Partner Lloyd's Register – Deliverable D1.9.4

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DOCUMENT CONTROL

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REVISION HISTORY

A record of revisions and amendments to this document is given below:

Rev.	Date	Reason for amendments	Section changes from previous version
1	08-03-2023	DRAFT Document Issued	

List of abbreviations

ALARP	As Low As Reasonably Practicable
C&E	Cause and Effects
CAMS	Control, Alarm and Monitoring System
CCTV	Closed Circuit TeleVision
ESD	Emergency ShutDown
FAT	Factory Acceptance Test
FiFi	Fire Fighting
FMEA	Failure Modes and Effects Analysis
FS	Functional Safety
GA	General Arrangement
GW	Glycol Water
HAZID	Hazard Identification
HAZOP	Hazard and Operability
HP	High Pressure
HSE	Health and Safety Executive
IGC	International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk
IGF	International Code of Safety for Ship Using Gases or Other Low-flashpoint Fuels
IMO	International Maritime Organisation
LAH(H)	Level Alarm High (High-High)
LAL(L)	Level Alarm Low (Low-Low)
LOPA	Layer of Protection Analysis
LR	Lloyd's Register
PAH(H)	Pressure Alarm High (High-High)
PAL(L)	Pressure Alarm Low (Low-Low)
PCV	Pressure Control Valve
PFD	Process Flow Diagram
P&ID	Piping & Instrumentation Diagram
PPE	Personnel Protective Equipment
PRV	Pressure Release Valve

PSD	Process ShutDown
QRA	Quantitative Risk Assessments
RA	Risk Assessment
SIF	Safety Instrumented Function
SIL	Safety Integrity Level
SIS	Safety Instrumented System
SME	Subject Matter Expert
SMS	Safety Management System
SSOW	Safe Systems of Work
SWIFT	Structured ‘What-if’ Technique
UPS	Uninterruptible Power Supply
TAH(H)	Temperature Alarm High (High-High)
TAL(L)	Temperature Alarm Low (Low-Low)
TPRD	Thermal Pressure Relieve Device
VHF	Very High Frequency
VTS	Vessel Traffic System

Standard definitions[1]

Accident	An unplanned event involving fatality, injury, ship loss or damage, other property loss or damage, or environmental damage.
Allision	Striking of a moving vessel against a vessel or an object that is stationary.
Collision	Striking of a moving vessel against one that is also moving.
Consequence	The outcome of an unplanned event. This considers effects on natural and human systems, i.e. lives, livelihoods, health, ecosystems, economies, societies, cultures, services, and infrastructure.
Frequency	Number of times per period that an event occurs, i.e. once per year.
Hazard	Something with the potential to threaten human life, health, property or the environment.
Mitigation	An intervention to reduce either the frequency or consequence associated with a risk, or both.
Probability	The relative frequency that an event will occur, as expressed by the ratio of the number of occurrences to the total number of possible occurrences.
Risk	The combination of the frequency and the severity of the consequence.
Strike	Unintentional contact between two or more assets.

[1] As far as possible, definitions were taken from the UNTERM database and MSC-MEPC.2/Circ.12/Rev.2

Contents

1. Introduction

The shipping industry currently emits 3% of all the greenhouse gases in the world. Therefore, it is more than relevant that the shipping industry and the port authorities start to invest in decarbonisation, searching for the implementation of zero emission technologies. Today, there are quite a lot of obstacles in order to realise a full-scale use of zero emissions fuels on board of the ships and vessels. In order to tackle some of these obstacles, the ISHY project will investigate the following working fields:

- testing of the effectiveness of the low carbon propulsion technologies
- demonstrating the feasibility of H2 bunkering-facilities in a port
- prepare tools to support the transition to low-carbon propulsion systems for both retrofitting and building of new ships

To support the initiatives on alternative, low and zero-carbon fuels for the maritime industry, Work Activity A1.9 Hazard & Operability (HAZOP) Study shall be completed on the zepp.X150 Fuel Cell System designed by zepp.solutions on 10 March 2023.

1.1 Objective

Complete a HAZOP Study on the zepp.X150 Fuel Cell system designed by zepp.solutions to identify operational risks associated with its installation onboard a ship.

1.2 Scope

The HAZOP shall solely assess the Fuel Cell Systems and as such Fuel Storage and Conditioning Systems are considered outside the Scope of this Work Package.

2. Design Specification

Description	Value
Net rated power output	150 kWe
Efficiency at max. power	51% LHV
Efficiency at 50% power	57.5% LHV
Dimensions	1250 x 700 x 680 mm (L x W x H)
Volume	595 L
Mass	355 kg
Output voltage range	520-750 VDC (integrated DCDC converter output)
LV supply	12/24 VDC (max 500 W)
Communication	CANbus
Diagnostics	SAE J1939
Fuel type	Hydrogen gas
Fuel quality	ISO 14687:2019, SAE J2719
Oxidant	Ambient air
Coolant	Glysantin® FC G20 RM
Coolant temperature in	75 °C
Ambient operating temperature	−30-50 °C
IP protection	IP67

2.1 Technical description

Reference is made to zepp.solutions document, ISHY HAZOP, Teams Call, 10.03.2023. This was shared with the HAZOP Team in advance of the workshop. Due to its confidential nature it has been excluded from this document.

3. HAZOP

3.1 Objectives

The objectives of the HAZOP study are:

- to identify any operability hazards associated with the system
- to understand how the system can operate outside of its intended design parameters
- to review existing design safeguards
- to make recommendations where necessary

3.2 Methodology

A HAZOP study is a methodical technique used to identify hazards and operational issues associated with a process or the integration of a design into another system. It shall be completed in line with BS IEC 61882-2016, Hazard and operability studies (HAZOP studies) [2].

As illustrated in **Figure** 1, the system shall be divided into nodes, with guide words (e.g. High, Low, No) applied to parameters (e.g. Flow, Temperature, Pressure) to produce a comprehensive list of how it can operate outside of its intended design. The consequences of this would be determined and assessed with consideration given to any safeguards included within the systems design.

The process is as follows:

Deviation – The deviation is determined by the application of the guideword and parameter to the elements within the node. The team will discuss whether the deviation is possible, and shall only assess it, if deemed so.

Causes – The team shall establish possible causes for the deviation, if the consequences of the deviation are trivial the process can be terminated at this point (this will be recorded).

Consequences – The team shall consider harm to persons, environment, damage to equipment, loss of quality and loss of production / operation.

Safeguards – Existing safeguards in the design, C&E drawing, operating manuals shall be discussed, in particular the robustness of them and their suitability. The HAZOP is not a forum to engineer / re-engineer safeguards, any addition or modification to these will be captured under 'follow-up' Actions.

Recommendations – Can be suggested if any further information or studies on the design / safeguards are required.

Actions – A list of actions and persons responsible for them shall be collected throughout the HAZOP procedures.

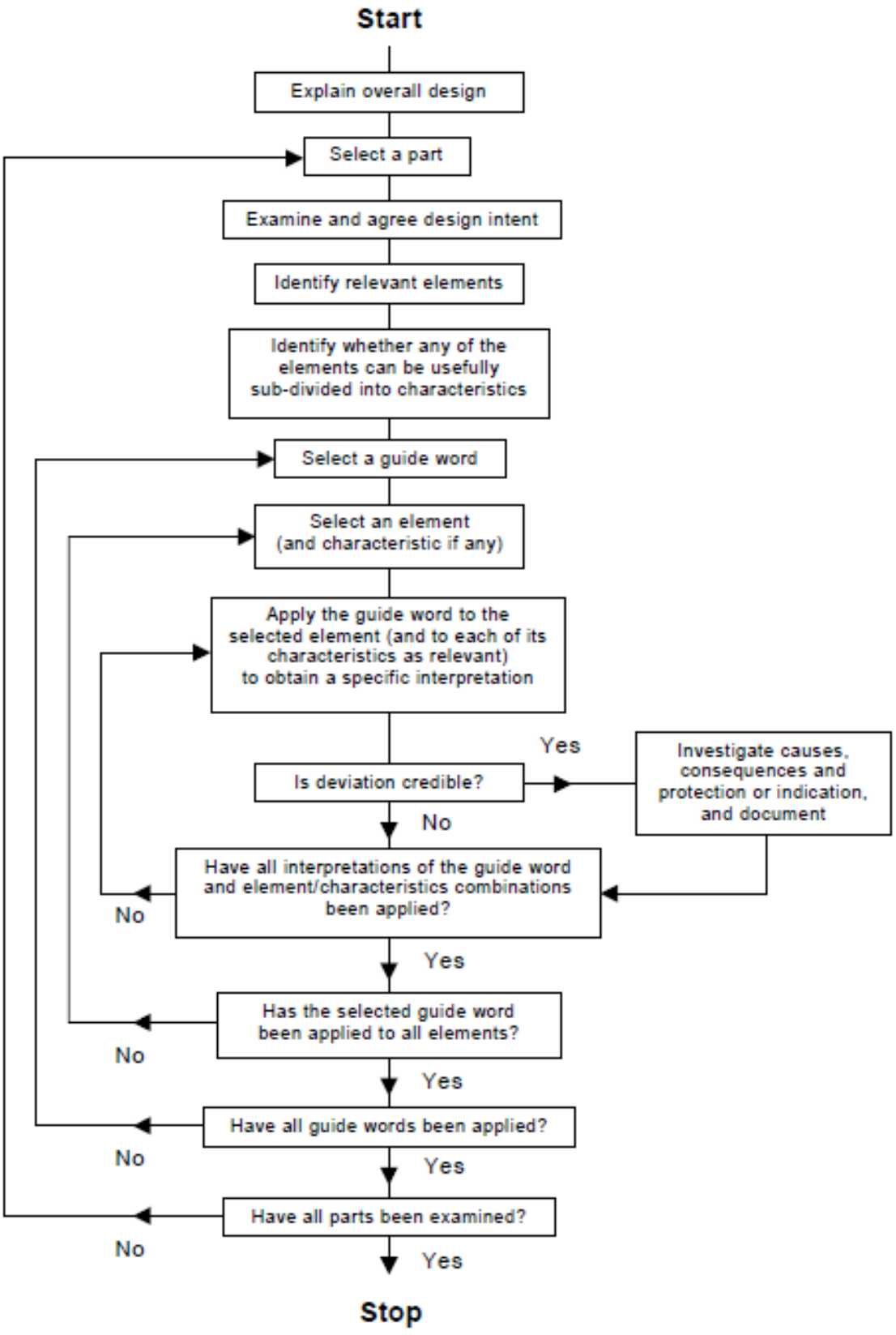

Figure 1 Flow Chart of the HAZOP Procedure (BS IEC 61882)

3.2.1 Deviation / Guidewords

The HAZOP technique is based on the identification of possible failures for each node with consideration given to the deviation. Deviation from the normal operation is defined as a combination of a guideword and a parameter, where the parameters typically considered are:

- Flow
- Level
- Temperature
- Pressure
- Composition

With guidewords typically being:

- More
- No
- Less
- Reverse
- Other than

3.2.2 HAZOP Worksheet

HAZOP worksheet consists of the items listed below:

- Deviation (guideword & parameter),
- Causes,
- Consequences,
- Safeguards (prevention, control and mitigation measures),
- Comments, and
- Recommendation (Action/by).

No.	Deviation	Cause	Consequence	Safeguard	Recommendation	
					Action	By

Table 1, Example format for HAZOP worksheet

3.2.3 Assumptions

The HAZOP study shall assume the following:

- The systems, equipment and layout is per the information shared prior to the workshop
- The systems shall be installed, operated and maintained in accordance with the manufacturers recommendations
- Only single failures / events will be considered, i.e. multiple failures shall not be considered credible, unless they can go undetected (hidden failures)
- The safeguards, including operational procedures discussed and included within the HAZOP Worksheet are in place and function as outlined
- The FC is providing the ship with a supplementary source of power
- If the system is to be installed onboard a ship it would undergo Type Approval

3.2.4 Node Definitions

The system has been divided into following nodes in Table 2 for effective review during the workshop.

Node No.	Description	Remark
1	Anode	
2	Cathode	
3	Coolant	
4	General Cabinet Design	

Table 2, Nodes for HAZOP Workshop

It is common to illustrate the Nodes on the PFD or P&ID, however this has been excluded from the report due to its confidential nature.

4. Workshop attendees

Subject to last minute changes, the workshop will be attended by the persons listed in Table 3.

Name	Company	Function	Role
Alex Pedgrift	LR	HRR Manager	Facilitator & Scribe
Jonas Brendelberger	zepp.solutions	Product expert – maritime	SME
Aditi Ahuja	zepp.solutions	Engineer	SME

Table 3: Provisional list of workshop attendees

4.1 Preparation

Prior to the study it is expected that the team members will have familiarised themselves with the following documentation:

- ISHY HAZOP, Teams Call, 10.03.2023
- ISHY_X3 System_PFD_Rev2 (not attached to this ToR due to its confidentiality)

5. Workshop agenda

Venue: Remote Meeting (MS Teams)

Day 10 March 2023

Times are GMT

12.00	Introductions
12.10	HAZOP Methodology Introduction
12.25	zepp.X150 System Introduction
13.00	HAZOP Node 1
14.00	HAZOP Node 2
15.00	HAZOP Node 3
15.40	HAZOP Node 4
16.00	'Wash-up'
16.30	Finish

6. References

[1] British Standards Publication - *Risk Management – Principles and Guidelines* - BS ISO 31000: 2018 - 2018

[2] British Standards Publication - *Hazard and operability studies (HAZOP studies)* - BS IEC 61882-2016 - 2016

Appendix 1 Tables

Appendix 2 Figures

Appendix 3 Drawings

Drawings have been removed due to their confidential nature