

**DOCUMENT TITLE: HAUV BATTERY EMERGENCIES**

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**ABBREVIATIONS**

| Abbreviation | Definition                           |
|--------------|--------------------------------------|
| ATM          | Atmosphere                           |
| AUV          | Autonomous Underwater Vehicle        |
| AVD          | Aqueous Vermiculite Dispersion       |
| HAUV         | Hybrid Autonomous Underwater Vehicle |
| HSE          | Health & Safety Executive            |

| Abbreviation | Definition                            |
|--------------|---------------------------------------|
| HSEQ         | Health, Safety, Environment & Quality |
| LiPo         | Lithium Polymer                       |
| Pt           | Port                                  |
| PPE          | Personal Protective Equipment         |
| PTW          | Permit to Work                        |
| RAC          | ROV Application Computer              |
| Stbd         | Starboard                             |
| TBT          | Tool Box Talk                         |

**REFERENCE DOCUMENTS**

| Ref No. | Document Title                                   | Document Number |
|---------|--|-----------------|
| [101]   | MODUS Risk Identification & Management Procedure | HS-PR-003       |
| [102]   | MODUS Management of Change Procedure             | HS-PR-009       |
| [103]   | Tool Box Talks                                   | HS-FM-001       |

## **1 INTRODUCTION**

### **1.1 SCOPE OF DOCUMENT**

The purpose of this document is to define the emergency preparedness and response processes to be followed in the event of the HAUV experiencing abnormal conditions with the LiPo batteries.

This document shall be applicable to all Modus HAUV work activities, including the assembly, disassembly and charging of the LiPo batteries.

## 2 HSEQ

### 2.1 WARNINGS, CAUTIONS & NOTES

This operating procedure will be interspersed warnings, cautions and notes, these are used to direct the readers attention to specific information.

#### 2.1.1 WARNINGS

A **WARNING** is used to alert the reader to operational or maintenance activities that may, under certain circumstances, represent a threat to safety and health. A warning precedes the paragraph or procedure which gives rise to such a threat.

#### 2.1.2 CAUTIONS








A **CAUTION** is used to alert the reader to operational or maintenance activities which, may under certain circumstances, cause damage to equipment and/or material. A caution precedes the paragraph or procedure to which it refers.




#### 2.1.3 NOTES

A Note contains information of a specific or general nature and is printed immediately after the paragraph to which it refers.

#### 2.1.4 SYMBOLS

The following symbols are used throughout this document:

|  |  |
|--|--|
|   | <b>WARNING</b><br>RISK OF PERSONAL INJURY.                     |
|   | <b>WARNING</b><br>FIRE HAZARD                                  |
|   | <b>WARNING</b><br>RISK OF PERSONAL INJURY DUE TO MOVING PARTS. |
|   | <b>WARNING</b><br>TAKE PRECAUTIONS AGAINST STATIC ELECTRICITY. |
|   | <b>WARNING</b><br>RISK OF ELECTRIC SHOCK.                      |
| <br> | <b>WARNING</b><br>RISK OF PERSONAL INJURY DUE TO HEAVY OBJECT. |

|   |   |
|---|---|
|  | <b>WARNING</b><br>WEAR PROTECTIVE CLOTHING AND EQUIPMENT. |
|  | <b>Caution</b><br>Risk of damage to equipment.            |
|  | Tool Box Talk Required                                    |

## 2.2 HSEQ

All work described within this document shall be performed in accordance with requirements given in the MODUS Business Management System (BMS) which is accredited in line with ISO:9001, ISO:14001 and ISO:45001 Standards.

The work shall in addition be performed in accordance with the requirements given in the Contract.

All internal documents for the project relating to this subject are referenced in the table of references at the front of this document and shall be read in conjunction with this procedure. Any additional task related safety awareness that needs to be highlighted will be addressed in the body of this document.

## 2.3 RISK ASSESSMENTS

All operations will be executed in accordance with the MODUS Risk Identification & Management Procedure, HS-PR-003, [101].

The MODUS specific Risk Assessment should identify the risks associated with specific elements of Modus operational activities. The Risk Assessment also identifies the controls required, which also consider the different human behaviour traits that are exhibited performing the same task under different conditions.

The risk assessment shall be completed by the Team Leader/Chairman and a minimum of two experienced personnel in the activity to be assessed. The risk assessment shall be accepted prior to commencement of the task(s) and communicated to the workforce to ensure understanding and compliance.

## 2.4 MANAGEMENT OF CHANGE

In the event of any unplanned circumstances which affect adherence to this procedure, to ensure the safety and efficiency of the operation, then the change shall be performed in accordance with the MODUS Management of Change Procedure, HS-PR-009, [102]. The change shall be with clear understanding between the involved parties.

## 2.5 TOOL BOX TALKS

Tool Box Talks are required at the beginning of each shift, if the task plan changes and if new people join the team. A TBT is not limited to these times and shall be delivered where appropriate. TBT's [103]: HS-FM-001, Tool Box Talks, are identified within Procedure Task Plans.

Relevant operating procedures and associated risk assessments must be reviewed and communicated during the TBT.

## **2.6 PERMIT TO WORK**

All Equinor controlled operations and related work will be controlled and co-ordinated by using the Equinor PTW system where required. The implementation of the Equinor PTW is the responsibility Equinor. Modus will ensure that all applicable works undertaken are conducted in full compliance with the Equinor PTW system.

## **2.7 PPE & SAFETY EQUIPMENT**

All personnel are to wear the correct PPE and be in possession of safety equipment as detailed in the relevant Risk Assessment(s)



### **3 OVERVIEW**

The central risk with LiPo batteries is fire. The batteries are unlikely to catch fire, but they can, through faults inside the battery, or from external damage.

Extreme events can affect the battery and this can be dangerous for the people around / adjacent to it. The Sabertooth battery is a LiPo battery with high stored energy. The LiPo cell technology contains components in itself, such as oxygen and fuel, to continue burning. There are fire extinguishers of the AVD type for Lithium batteries that can be used in an early stage or on single cells.

If an incident occurs on the platform, during storage or transport, the people in command must prioritise personal safety first and equipment damage second.

## 4 EMERGENCY PROCEDURE

### 4.1 BATTERY FIRE WITHIN THE VEHICLE/POD

If a Lithium battery overheats, hisses or bulges, immediately move the device away from flammable materials and place it on a non-combustible surface. If at all possible, remove the battery and put it outdoors to burn out. Simply disconnecting the battery from charge may not stop its destructive path.

The temperature of a lithium battery can quickly reach 500°C (932°F), at which point the cell catches fire or it explodes. This thermal runaway that occurs is known as “venting with flame.” or “Rapid disassembly” this can occur within milliseconds and may not be detected by the BMS temperature sensors until failure occurs.

If it is suspected that the battery is burning: Evacuate and seal of the room/space, to stop the toxic gas/smoke from spreading. If the vehicle is on the back deck of a vessel then all personnel must evacuate the area to windward of any smoke and toxic gas and follow the vessels emergency procedures.

### 4.2 FIRE OR EXTREME HEAT NEAR THE BATTERY OR VEHICLE

If possible take the battery / vehicle away from the vicinity of the fire or strong heat. If not possible, stay clear of the battery and monitor until the conditions have gone back to normal +24h. When the vehicle or battery is safe, check the battery for damages before connecting the battery test cable and checking the battery status. If the battery has been contaminated with smoke, the recommended action is not to use it.

### 4.3 MAJOR MECHANICAL IMPACT

If the battery is dropped from a high altitude during loading of equipment or other high impact incidents and the status of the battery is unknown, do the following:

|    |  |
|----|--|
| 1. | Immediately move the vehicle or the battery to a non-critical building or a non-critical area outside.   |
| 2. | Rope-off an area of 20m and leave the vehicle or battery to rest for a minimum of 6h.  |
| 3. | Connect and start the vehicle with the “start key” or use the battery test cable to monitor the status on the battery.                                     |
| 4. | If it is all OK, remove the rope and move the vehicle / battery to the original location.  |
| 5. | Let the equipment rest for an additional 18h and then check the status again if OK.  |
| 6. | Disassemble the battery to cell module level.  |
| 7. | Check for bends, cracks other damages due to the high impact. Pay extra attention to the cells' corners and tabs. If OK, reassemble and start the battery. |
| 8. | Check the battery with SW tool and if OK, it is safe to use.   |

#### 4.4 SUBSEA VEHICLE EVENT

The battery modules are located in a 1 ATM pressure housing. The most likely events are a complete flooded main pressure hull or a small leak.

If water intrusions are in the magnitude of 5-10L, one should consider that hydrogen gas may have been produced inside the pod.


##### 4.4.1 FLOODED MAIN PRESSURE HULL

In the event of a complete flooded main pressure hull (most likely due to an implosion of the pod or a major leak due to a collapsed o-ring), it is unlikely that there will be a build up any internal pressure due to the nature of the leak.


If the port pod is flooded, a magnitude of 30L of water can enter. The vehicle will probably be operational with port pod flooded. Hydrogen gas will be produced but will evacuate through the leak during ascension. Most likely issue due to flooding is that no pressure is built up in the pod.

Look on the HMI connected to the vehicle Wi-Fi at the surface for the errors reported.

#### PORT POD LEAK

|  |   |
|--|---|
|  | <b>WARNING - DANGER TO PERSONNEL AND EQUIPMENT</b><br>Hydrogen gas may be present in the pod, which may cause a potential fire hazard. Do not use any tool or equipment that could ignite the Hydrogen gas in close proximity to vehicle. |
| 1.   | Recover the vehicle to the trolley  |
| 2.   | Remove the Pt. Side top cover   |
| 3.   | Secure rear or front lid with wood or equivalent between lid and plastic frame.   |
| 4.   | Loosen air bleed screw  |
| 5.   | Let it bleed for 1 minute   |
| 6.   | Remove lid and let water out.   |

#### STARBOARD POD LEAK

|   |  |
|---|--|
|  | <b>WARNING - DANGER TO PERSONNEL AND EQUIPMENT</b><br>Hydrogen gas may be present in the pod, which may cause a potential fire hazard. Do not use any tool or equipment that could ignite the Hydrogen gas in close proximity to vehicle.  |
| 1.  | If the starboard pod is flooded, a magnitude of 70L of water can enter. It is likely that the vehicle will quickly become non-operational due to the flooded main electronics such as the low voltage power supplies and computers.<br>The vehicle will sink to sea floor, hydrogen gas will be produced but will evacuate through the leak opening and be replaced with water until chemical / electrical / mechanical conditions are in balance. |
| 2.  | Recover the vehicle with an ROV i.a.w the vehicle emergency recovery plan  |
| 3.  | Recover the vehicle to the trolley   |
| 4.  | Remove the Stbd. Side top cover  |
| 5.  | Secure rear or front lid with wood or equivalent between lid and plastic frame.  |
| 6.  | Loosen air bleed screw   |


|    |                               |
|----|-------------------------------|
| 7. | Let it bleed for 1 minute     |
| 8. | Remove lid and let water out. |

#### 4.4.2 SMALL LEAKS INSIDE THE MAIN PRESSURE HULL

A more likely event is small leaks that can occur normally due to damaged or degenerated O-rings, dirt on or corroded O-ring surfaces. Normally this kind of leak can be seen during the vacuum test. If this event occurs during the dive, the four leak detectors, one in each end of main pressure pods, will trigger the RAC to go to emergency surface. Around 1-5 cl is enough to trigger the leak detectors if the vehicle is in normal attitude. Once the vehicle is at the surface, connect to it via Wi-Fi and follow the procedure as described in the see "Flooded Main Pressure Hull" in section 4.3.1.

The most common cause of a small leak is a damaged or deteriorated O-ring or O-ring seal. In Sabertooth, there are a lot of sealing surfaces especially on the starboard lids.

Recommended procedure:

|   |  |
|---|--|
| 1.  | Vacuum check the hull that reports a leak. Is the leak detectable using vacuum?<br>If yes continue, if no Helium or other methods need to be used. |
| 2.  | Replace one lid to "tool lid" then vacuum test. Vacuum OK = leak on replaced lid.  |
| 3.  | If no, replace other lid then vacuum test. Vacuum OK = leak on replaced lid.   |
| 4.  | If no, the leak is on pressure hull.   |
| 5.  | Once identify leak on the unit, lid 1 or lid 2 or pressure hull.   |
| 6.  | On the lids, disassemble the connectors, replace the o-rings and reassemble the connectors.  |
| 7.  | If the pressure hull is leaking, check o-ring surfaces for scratches/dirt etc. Replace where necessary.  |
|  | <b>Caution</b><br>Risk of damage to equipment.<br><br>Always replace O-rings when connectors have been disassembled.                               |