International Association of Oil & Gas Producers

REPORT 478

JANUARY 2018

Performance of saturation diving emergency hyperbaric evacuation and recovery

Acknowledgements

IOGP Diving Operations Subcommittee

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Revision history

VERSION	DATE	AMENDMENTS
2.0	January 2018	Updated section 9 (Emergency drills and training) New Appendix A: HEP template New Appendix B: HEP Safety Critical Element Analysis New Appendix C: Example Matrix of Permitted Operations Minor edits to sections 5 and 8
1.0	September 2014	First release

Contents

1. Introduction

IOGP provided recommendations for assisting companies with the management of diving operations in Report 411, *Diving Recommended Practice* in 2008. Industry experience and understanding of the importance of methods for the successful evacuation of saturation divers has developed since then.

This Recommended Practice is about the evacuation and recovery of saturation divers maintained on-board a vessel or facility. It also includes divers deployed in submersible compression chambers (diving bells) and habitats when the need for evacuation is required. An evacuation and recovery operation is considered complete when all divers have completed the required decompression, any therapeutic treatment and bend watch and are safely back at atmospheric pressure.

Divers in saturation are constrained by a pressure boundary which requires careful decompression or else significant risks to the health of the divers may occur. To prevent the occurrence of fatal incidents, the pressure boundary and the atmosphere inside the pressure vessel must be maintained by suitable equipment and competent personnel. This Recommended Practice is also about the capability to evacuate divers to a place of safety while providing the necessary life support.

This report has been prepared by the Diving Operations Subcommittee (DOsC) of IOGP. Input and feedback was obtained from Diving Companies, Diving Trade Associations, Classification Societies, Regulators and diving personnel, for which the IOGP Diving Operations Subcommittee is appreciative.

2. Scope

This report provides guidance for managing emergencies requiring the evacuation of saturation divers to a place of safety. It provides a framework to assist companies to manage hyperbaric evacuation at their worksites.

The framework also provides guidance on the development of a structured Hyperbaric Evacuation Plan (HEP). The Hyperbaric Evacuation Plan assists operational staff with understanding their roles and responsibilities. It also includes elements such as the location, provision and status of all equipment required during execution of the plan. Such a structured plan should provide opportunity for consistency in the industry and so should minimize the possibility for diverging approaches and misunderstandings.

This report recommends minimum performance criteria for key areas of the evacuation, and the use of two management tools: Matrix of Permitted Operations (MOPO) and the SCE List. These tools will assist operational staff in evaluating the status of operational controls as situations change and any actions that may then be required.

The report does not provide technical solutions. Many technical solutions are produced by Regulators, Industry Associations and Classification Societies as industry guidance.

3. Hyperbaric Evacuation Plan

Every Saturation system should have a Hyperbaric Evacuation Plan for divers in saturation (HEP).

The HEP should be based on the worst case scenario of evacuation from a diving vessel or facility with its full complement of diving bell(s) deployed and requiring recovery and evacuation of all saturation divers including those deployed in any welding habitat.

4. Validation, audit and review of the Hyperbaric Evacuation Plan

The HEP should be validated by a Statement of Fitness (SOF), written approval from the contractor's Asset Manager or activity Manager (project manager or operations manager) that confirms that the relevant requirements of the HEP have been met and that an effective system for evacuation is in place. The saturation system may be then be used for saturation diving.

The HEP should be subject to audit as part of the contractor's HSE Diving Safety Management System. The audit should verify that the HEP implementation remains fit for purpose.

5. Contents of the Hyperbaric Evacuation Plan

An HEP is an operational document that provides key information in the event of a hyperbaric evacuation. It should be clear, clean and concise.

An example template is given in Appendix A.

The HEP should be supported by documentation on:

a) details of all the required health and safety critical tasks and the key personnel with their allocated location, roles, responsibilities, and competencies to achieve them:

    1) Asset custodian (SOF signatory)
    2) Divers
    3) HEP Custodian
    4) HEP Owner
    5) HRF Team
    6) Maintenance Team
    7) Operational Leader (if not VM) and Operational support crew
    8) Recovery Team
    9) SPHL crew
    10) Support Team
    11) Vessel Master (VM)

b) a list of Safety Critical Elements (SCE), their location, status and required controls. This SCE list should be specific to the area of operation, the vessel or facility. See Appendix B for further details on SCE

c) a list of all SCEs that are classified as single point failures and the mitigation provided

d) design standards for the hyperbaric evacuation system (HES)

e) maintenance and inspection requirements

f) personnel manning levels and their required training and competency

g) a description of planned emergency drills, and their frequency and logging

h) the specification of the on-board life support equipment, its capacity and the limit duration for the occupants of a lost diving bell(s), habitat or hyperbaric evacuation system

i) a plan for the support, recovery and transfer of the occupants of a lost diving bell or abandoned habitat

j) a procedure for the launch, support, recovery of chamber occupants and support crew of the Hyperbaric Evacuation System(s)

k) the recovery to, and transfer into, a dedicated Hyperbaric Reception Facility (HRF), either fixed or portable, for final controlled decompression

l) a plan that details the capability of providing specialized medical intervention at the location and inside the facility should it be required

m) a Matrix of Permitted Operations (MOPO).

6. Performance capabilities

6.1 Hyperbaric Evacuation System:

All self-propelled hyperbaric lifeboats (SPHL) should be maintained in a state of immediate readiness and with any pressure boundaries maintained to provide safety and optimum evacuation performance. A selection process should be based on the following capabilities:

- **Dual SPHL**: Each SPHL should provide 100% evacuation capability and redundancy for the saturation diving team.
- **Single SPHL**: SPHL should provide 100% evacuation capability.

The Hyperbaric Evacuation System (HES) should have a proven capability of achieving the following, based on the vessel's best speed in median weather conditions for the region and the time of year:

a) The total elapsed time between the instructions to evacuate divers from the chamber complex until the time when the SPHL is launched should not exceed 15 min.

b) The total elapsed time for the SPHL to have transited 100 metres away from the evacuated launch site should not exceed 30 min.

c) Vessel(s), equipment and marine services necessary to protect and support the SPHL(s) should be at the SPHL location within 12 hours of the launch of the SPHL.

d) Transfer of all occupants from the SPHL(s) to the designated Hyperbaric Reception Facility (HRF) should be achieved within 54 hours or 75% of the SPHL survival endurance capability.

If these performances are not achievable for a specific operation, mitigating actions will have to be agreed in advance between the Operator and the Diving contractor.

6.2 Recovery of divers from a lost and stricken bell

A successful recovery of divers from a lost and stricken bell should be achievable within 75% of the maximum accepted and proven life support capability endurance of that lost diving bell.

A successful recovery and transfer of occupants of a lost habitat should be achievable within 75% of the maximum accepted and proven life support capability endurance of that habitat.

7. Equipment

7.1 Evacuation of divers from the diving bell

For evacuation of divers from the diving bell, a dual entry Submersible Decompression Chamber (SDC) should be considered that provides access to the SDC in the event of a blocked internal door (unconscious or paralysed divers in the bell).

7.2 Codes and standards for design, construction, test and maintenance

IMO Resolution A.831 (19), *Code of Safety for Diving Systems* and IMO Resolution A.692 (17), *Guidelines and Specifications for Hyperbaric Evacuation Systems* should be applied to hyperbaric evacuation facilities.

All Hyperbaric Reception Facilities (HRFs) should be designed, constructed, tested and maintained to certifying authority and appropriate industry requirements with a recognized classification society. (A goal for the industry would be to have HRFs designed, constructed, tested and maintained in class with a recognized classification society.) These facilities should have no overdue surveys and should be free of all overdue Conditions of Class and/or Conditions of Authority.

7.3 Launch and recovery equipment

The system should be capable of being launched independently of the vessel's supply system. This capability should use gravity or stored mechanical energy such as accumulator banks.

Recovery systems should be managed in accordance with the man riding requirements of IOGP Report 376, *Lifting & hoisting safety recommended practice*.

7.4 Critical System Monitoring and Tracking

Critical System Monitoring and Tracking (CSMT) equipment should be provided. The CSMT equipment should be a system capable of monitoring, tracking and communicating critical system information from the SPHL to a specified location. This information will assist the recovery support crew on the SPHL's status and location.

The following should be covered in the design of a CSMT:

a) to have satellite communication capability from inside and outside the SPHL

b) the CSMT to be a stand-alone system, providing battery-backed data acquisition, recording and transmission of parameters from the SPHL via a global satellite communications network

c) to have a high availability terrestrial server system that will receive all data from SPHLs. This should be distributed globally via the Internet to allow remote monitoring and incident management from any location (either on land or at sea)

d) the CSMT to be operable in a hot-standby mode continuously

e) to provide assured readiness by the use of periodic self-test diagnostics.

Critical mission data to be recorded and transmitted should include:

a) identification of the SPHL and its occupants

b) live GPS coordinates of the SPHL

c) time-stamped historical log of any evacuation event

d) emergency signalling data (e.g. 'real' or 'drill' status, critical condition status from the SPHL crew)

e) environmental data (air temperature, seawater temperature, heave/pitch/roll maxima)

f) chamber depth

g) chamber temperature

h) chamber oxygen partial pressure

i) chamber carbon dioxide partial pressure

j) on-board gas storage bottle pressures (HeO_2 and O_2)

k) rate of change of depth

l) chamber relative humidity

m) status of engine (running/stopped), battery condition, cooling/heating system status, and fuel tank levels.

8. Operational factors

8.1 Matrix of Permitted Operations (MOPO)

The diving contractor should produce a Matrix of Permitted Operations (MOPO). The MOPO is an information tool to assist supervisors and line managers during the planning and coordination of operations and activities. Copies of the MOPO should be available on the vessel.

The MOPO should include:

a) the operation or activity operating envelope and safe operating limits

b) all operational activities associated with the vessel that could impact the integrity of the HES

c) Actions necessary for the crew to take if situations arise that could compromise safe operations.

The MOPO should specify all 'line of fire' (in the trajectory of moving hazards) scenarios and their controls. Single SPHL systems should be protected from line of fire risks, e.g. overhead lifts or the operation of a diving vessel alongside a platform with the SPHL facing the installation – problematic in the event of a dynamic positioning (DP) incident.

A MOPO template is provided in Appendix C.

8.2 Operation in a harbour

When the DSV is in harbour, no single SPHL system should be placed alongside a quay unless it is identified in the HEP and the site has the required personnel and equipment to launch the SPHL. The HEP should not impact upon the normal vessel evacuation of marine personnel.

The SCE List and HEP should identify the control of seaboard harbour obstructions (e.g. any obstructions on the side of the ship opposite of the quay, where a SPHL could be launch to the water) and depth for a launch.

8.3 Managing Safety Critical Elements in operation

SCE must function on demand. The HEP should include risk control and mitigation measures to manage risks arising from impaired SCE(s). These risks should be properly identified, documented, implemented and monitored.

9. Emergency drills and training

An Emergency Drills Matrix with a guidance section laying out the actions recommended of each member of the diving project, marine and shore side personnel in the event of an emergency occurring during operations should be provided.

The diving contractor should develop generic emergency training scenarios and procedures. Trials and drills should be undertaken to train personnel and to test the efficiency of the procedures, the interfaces and the equipment that affect the successful execution of the Hyperbaric Evacuation Plan (HEP).

A functional drill to a specific design of HRF, including proven SPHL fit up and testing to the maximum working pressure, should be carried out and verified by a 'competent person' to validate a 'mating method statement' (MMS).

All SPHLs should be launched and verified 'fit for purpose' by a competent person within a period that does not exceed six months.

Only SPHLs with validated MMS, having been mated and function tested to a specific design of HRF, should be included in an approved Hyperbaric Evacuation plan (HEP).

SPHL to HRF compatibility

Rigour is required in the lifeboat pre-mating trial survey and development of the mating sequence described in the specific SPHL to HRF 'mating method statement' (MMS).

An appropriate level of detail should be recorded in the MMS to ensure a high level of confidence in future mating repeatability. Such data would typically include: organization and logistics, gas and electric supply, crane capacity, quayside laydown (reception) area characteristics, transport.

The MMS should be 'validated' by undertaking a mating trial that includes a 60-minute TUP (Transfer Under Pressure) compartment pressure leak test of the mating spool and clamp with the HES in place using a suitable gas.

The process should result in a 'mating compatibility certificate' (MCC) being issued by the 'competent person' responsible for the trial. The certificate's purpose is to validate the MMS.

Once compatibility has been established, it is repeatability that holds a risk.

Control of risk

Risks that can influence mating repeatability include:

- alteration to the SPHL that influence the MMS
- alteration to the HRF design that influence the MMS
- dissembling of the pressure compartments
- loss of mating method statement/technical competence/know-how.

Time per-se does not introduce a quantifiable risk to repeatability.

Maintaining the confidence of repeatability

To approve the HEP for a planned diving operation, evidence of mating (i.e. a mating method statement, validated by mating trial certificate) and documentation of repeatability should be provided.

Industry practice requires the SPHLs to be launched every six months. In connection with this, a survey of the SPHL should be performed, and a statement issued by the DSV that no change to the SPHL that impacts the MMS has been undertaken. This statement should be sent to the proposed HRF provider and accepted by them.

Similarly, the responsible person for the HRF should issue, every six months, a statement that no changes to the HRF design or recorded data that impacts on established MMS have been undertaken.

- This statement should be sent to the DSVs carrying relevant SPHLs and accepted by them.
- This statement should also confirm that the necessary technical competency in the MMS is retained and available.
- If the pressure compartments have been dissembled, a confirmation of re-established integrity of the HRF should be issued.

10. Glossary

Bendwatch

Period of time required for divers to be in the vicinity of a recompression chamber following decompression.

Habitat

Remote temporary fixed structure allowing access by divers to carry out work activities such as welding under pressure in a dry environment.

Hyperbaric Evacuation System (HES)

Whole plant, equipment process, procedures and personnel necessary to accomplish hyperbaric evacuation.

Hyperbaric Reception Facility (HRF)

Facility for the transfer, life support, decompression and bendwatch of divers from the Self Propelled Hyperbaric Lifeboat (SPHL) with dedicated on-board support crew to normobaric pressure. A HRF includes a Transfer Under Pressure (TUP) capability for transferring personnel and equipment in and out of the facility.

Normobaric

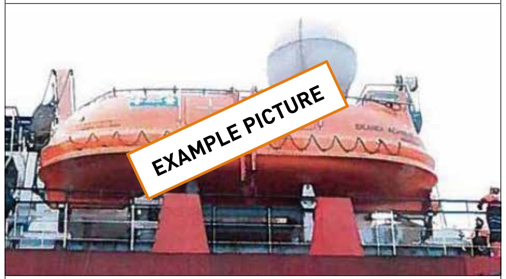
Barometric pressure equivalent to sea level pressure.

Safety Critical Element (SCE)

Item of equipment or process whose purpose is to prevent or limit the consequences of a High Risk Hazard that if realized could result in the fatality of one or more diver's or support crew.

Appendix A: Project Hyperbaric Evacuation Plan – Suggested template

Vessel SPHL (Enter image here)



Vessel Call Sign

SPHL Make
Length
Width
Height
Hook Centres
Weight (Unladen)
Weight (Laden)
Located on DSV (Port / Starboard)
Max Speed
Fuel Tank Endurance
Max Chamber Depth Rated
Max No. Divers
Max No. Crew
Towing Arrangements
Chamber Type / Volume

TUP Mating

Specifications

Trunk
Position
Type
Taper Angle
Taper Edge
Outer Diameter
Inner Diameter
'O' Ring
Additional Door

SPHL Self Support Capability

Gas Volumes

Oxygen
Heliox
Air
CO_2 Absorbent

KG

Thermal Control
Emergency Panel Connection
Standard Norsok / IMCA D 051
Comms / Power
Estimated Consumables Endurance

Project Details

Client?
Project No?
Project Name?
Vessel Locations?
Mobilization Port?
De-Mobilization Port?
Designated HRF Location?
Worksite Depths?
Worksite Storage?
Nautical Miles to designated HRF?
Duration of SPHL @ 3 knots?

Life Support Package and Equipment

Life Support Package located?
LSP Generator located?
Diving Gas located?
Diving Consumables located?

Confirmed Successful Vessel SPHL / HRF Matings

Units	Date	Comments
NHC		
NUI		
Mobile Systems		
Other		

SPHL Evacuation at sea – Option 1

Describe Plan (include references to relevant procedures)

SPHL Evacuation at sea – Option 2

Describe Plan

Evacuation in Port

Quayside heating and cooling?
Describe Plan
Will SPHL be in Harbour or on Quayside?
Quayside Cranage
Transportation Plan if by road
Power/Life Support capability in transit / Police escort

Specialized Support Personnel and Consumables

How will support personnel and consumables be expedited to HRF?
Describe Plan
Nearest Airport / Road transportation?

Emergency Contact Numbers

Contractors Emergency Response
Contractors Medical Support
NHC Aberdeen
Project Manager
NUI Bergen
Diving Gas
MIMIR Marine Hull
Aberdeen Coastguard
Bergen Coastguard
Police Scotland
Local Agents / Cranage / Haulage

Supporting Documentation

Contractors Manuals
Insert details

SPHL Lifting Operations

Approved Certified Lift Plan in Place?
Certified Lift Beam located?
Certified Bridle Rigging located?
SPHL Cradles located?

SPHL Transit Timings/*Offshore Rescue Vessel (Delete as Appropriate)*

Mobilization Port to designated HRF location / *crew competence and manning level to effect rescue*
Offshore worst case location to designated HRF / *Suitable deck space / Accommodation / LSP / SPHL onboard*
Describe other options of alternative HRF locations / *Life Support Package Locations / Crane if applicable SIMOPS or primary mission of proposed rescue vessel*
Identify all offshore worksites that vessel will visit with divers in saturation during this project and confirm time / distance from designated HRF @ 3 knots

HRF State of Readiness

PROJECT CAN CONFIRM THAT DESIGNATED HRF IS / IS NOT BEING UTILIZED FOR OTHER ACTIVITIES DURING LIFE OF PROJECT HRF REQUIREMENTS

Manning levels for HRF standby mode
Manning levels for HRF critical mode
Medical support
Time required to make HRF Operational

Emergency Response Plan – Describe?
Media Management / Single Point of Contact?
Other known DSVs working in area?

CONTACT DETAILS

Available services at HRF location?
On-site medical support?
Water?
Ambient lighting?
Security?
Electrical Supply?
Waste Management?
Accommodation for support personnel?
Toilet facilities?

Contractor Sign off boxes		

Appendix B

Hyperbaric Evacuation Plan (HEP) Safety Critical Element (SCE) analysis

IOGP Report 478 defines Safety Critical Elements (SCEs) as an item of equipment or process whose purpose is to prevent or limit the consequences of a High-Risk Hazard that, if realized, could result in the fatality of one or more divers or support crew.

IMCA information note D 15/14 considers relevant parts of the Failure Mode and Effects Analysis (FMEA) an appropriate tool for identifying SCEs for the Hyperbaric evacuation part of the contingency.

Using this approach, related to SCE in Hyperbaric Evacuation, the SCE listing below is an example of single point failures with no secondary means of measures during the Contingency mode.

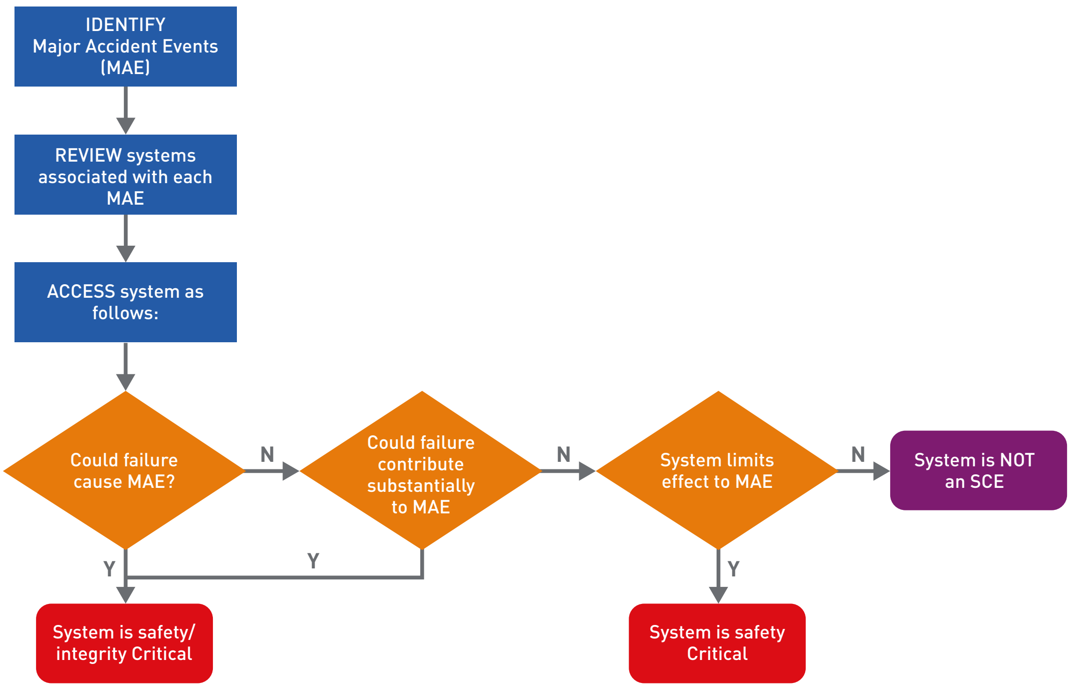


Figure B.1: Suggested SCE Identification Process

Based upon the process shown, a list of SCE could be developed as below:

- SCE-01 – Fire Fighting Systems available in launch area and extern firefighting on lifeboat
- SCE-02 – Life support systems
- SCE-03 – Hull Structure
- SCE-04 – Towing and Lifting Appliances
- SCE-05 – Human Interaction
- SCE-06 – Vessel, equipment and marine services to protect Launched SPHL(s)
- SCE-07 – Handling and Infrastructure of receiving HRF
- *SCE-xx – To be filled in if required*

Table B.1: Example SCE summary

SCE	Location of Critical System Components	Status, Operational or not (when tested)	Possible mitigating actions? (Yes/No)
SCE-01 – Fire Fighting Systems available in launch area, in SPHL and HRF	**Launch area:**		
	External water spray system	Operational	Potential utilization of local firehose
	Fresh air supply system		
	Fire extinguisher(s)		
	SPHL		
	Fire extinguisher(s) Inside chamber	Operational	Not realistic
	External Water spray system		
	FIFI systems		
	HRF		
	Fire extinguisher(s)	Operational	Fire hose
	Local fire brigade		
SCE-02 – Life support systems	**SPHL**		
	Power supply	Operational with main engine	Generator secondary
	Gas supply	On-board Gas	Connect LSP
	ECU/LSP	Scrubber/heater/cooler	LSP is back up
	Fresh water supply		
	LSP		
	Portable Generator	Operational	Power supply from multiple sources
	Water tank		
	ECU/LSP		
	HRF		
	Fresh water supply		
	Power supply		
	Gas supply		
	ECU/LSP		
SCE-03 – Hull and Chamber structure	SPHL Flange		
	HRF Flange		
SCE-04 – Towing and Lifting Appliances	General Structure Structural integrity	Operational	
SCE-05 – Human interaction	Personnel inside and outside of SPHL Chamber		
SCE-06 – Vessel, equipment and marine services to protect Launched SPHL(s)	Part of HEP	Operational	
SCE-07 – Handling and Infrastructure of receiving HRF	Ability to receive with mobile unit, quay strength checked, large enough area to receive an SPHL.	Operational	
SCE-xx – To be filled in if required			

Appendix C

Example Matrix of Permitted Operations (MOPO)

This table is an example overview of Matrix of permitted operations (MOPO) for Hyperbaric evacuation of saturation divers THIS MOPO DOES NOT OVER-RIDE THE MASTER'S DECISION TO STOP A JOB OR NOT TO COMMENCE IF HE/SHE THINKS IT IS UNSAFE	**Compromise to Safety Critical Elements (SCEs) DSV/SPHL**	Fire Fighting Systems available in launch area and extern firefighting on lifeboat	Failure to Life support systems	Failure Hull and chamber Structure	Failure to Towing and Lifting Appliances	Human Interaction compromised	Vessel, equipment and marine services to protect Launched SPHLs	To be filled in if required		**Compromise to Safety Critical Elements (SCEs) for HRF**	Unavailability of HRF	Handling and Infrastructure of receiving HRF	Unavailability of auxiliary support equipment to HRF	Docking with SPHL towards Quay	To be filled in if required		**Site specific Operations**	Launch area compromised/Blocked	1 bell in a 2 bell dsv compromised	SPHL towards platform	Collision Imminent	Inclement weather conditions	To be filled in if required
Saturation Diving Operations																							
Saturation Diving Ops with correction		1	2		3	4	5				6	7	8	9					10	11	12	13	

LEGEND

Activity Permitted with Additional Controls / corrective measures implemented (See Notes)

Activity not permitted in these circumstances

NOTE

1. Provided a suitable fire hose could be arranged for as substitute to permanent sprinkler in the launch area.
2. If SPHL has primary and secondary power supply/heating cooling.
3. Secondary means to be provided.
4. For DSV, primary and secondary means already in place and for SPHL possible change out of personnel must be evaluated.
5. If secondary means of this capacity is available and or possible to be mobilized within time criteria.
6. If secondary HRF is available with acceptable criteria.
7. If alternative infrastructure could be sourced within acceptable timeframe.
8. If auxiliary support system could be sourced and delivered within timeframe of receiving the SPHL.
9. If transportation and landing facilities for SPHL is mobilized within reach of SPHL launch davids (alternative mobilize crane) and system to keep acceptable environmental condition inside SPHL during the stay out of water.
10. If second bell is out of service for longer period than 75% of survival time, source a back up DSV within such timeframe.
11. Evaluate risk of collision and compromised SPHL.
12. Evaluate risk and take action if risk is higher than acceptable.
13. Dependent of Vessel's Activity Specific Operating Guidelines (ASOG).

xx To be filled in if required.

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