OceanGate

Manned Submersible Cyclops 1

Pilot Training Manual

Prepared by OceanGate Inc.

Author: [redacted]

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This document contains information necessary for the safe operation of Cyclops 1 following her significant modification in 2014/2015. It shall include the mechanical, electrical and associated sub systems, which relate to the submersible and provide detailed procedures to allow for the safe operation of the submersible systems.

Amendment History

SECTION NUMBER	AMMENDMENT	AUTHOR

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Introduction

This document is issued to all pilots and Cyclops 1 operations personnel and shall be made available to any outside contractors or inspecting bodies involved in the day to day running of the operation.

The contents of this manual should provide an adequate level of information for Oceangate submersible pilot training.

- Safety Precautions
  - When working on or around Cyclops 1 all personnel must comply with all current safety regulations and Oceangate Inc. Health and Safety policy. All personnel are reminded that when on deck and working on or around Cyclops 1 they are to wear appropriate PPE consisting of hardhat, safety boots, coveralls, eye and ear protection and lifejackets when applicable.
  - All personnel are to comply with the Man-Aloft regulations. There are several high-energy systems that personnel must be aware of. These consist of Electrical, HP Air and HP Oxygen systems. There are also several items of equipment that can move automatically without warning; they include Thrusters, Sonar and Manipulators. During all deck driven operations, a pilot will be inside Cyclops 1 and a second member of the team will be outside of the submersible to ensure there is no risk to potential passerby.

Glossary of Terms

Payload	Weight which can be carried and remain within standard emergency operating parameters.
PPE	Personal Protection Equipment
PHS	Portable handling system "A-Frame"
MSLARS	Mobile Subsea Launch and Recovery System
UWT	Underwater Telephone
VHF	Very High Frequency
UHF	Ultra High Frequency
DISSUB	Distressed Submersible
FSW	Feet Sea Water
MSW	Meters Sea Water
NM	Nautical Miles
PSI	Pounds per Square Inch
VBT	Variable ballast tank
MOSHIP	Mother Ship

Unit Conversions: Metric & Imperial Measurements

- General

1 centimeter (cm)	= 0.3937 in
1 meter (m)	= 3.28084 ft
1 kilometer (km)	= 0.6214 mile
1 inch (in)	= 2.54 cm
1 feet (ft)	= 0.3048 m
1 mile	= 1.6093 km
1 mile	= 0.868976 nm
1 nautical mile	= 1.150779 mile
1 nautical mile	= 10.126859 cables
1 cable	= 0.098747 nm
1 fathom	= 1.8288 m

- Surface Area

1 sq. cm (cm^2)	= 0.1550 in^2
1 sq. meter (m^2)	= 0.3861 $mile^2$
1 sq. in (in^2)	= 6.4516 cm^2
1 sq. yard (yd^2)	= 0.8361 m^2
1 sq. mile ($mile^2$)	= 2.59 km^2

- Volume and Capacity

1 cubic cm (cm^3)	= 0.0610 in^3
1 cubic meter (m^3)	= 1.3080 yd^3
1 liter (l)	= 0.2200 gal
1 cubic inch (in^3)	= 16.387 cm^3
1 cubic yard (yd^3)	= 0.7646 m^3

- Weight

1 gram (g)	= 0.0353 oz
1 kilogram (kg)	= 2.2046 lb
1 ton (t)	= 0.9842 ton
1 ounce (oz)	= 28.35 g
1 pound (lb)	= 0.4536 kg
1 ton	= 1.016 t

- Pressure

1 bar	= 14.503774 psi
1 psi	= 0.068948 bar
10 msw	= 1 bar

Responsibilities of Key Crew Members

- Submersible Pilot
  - The pilot will be fully qualified to dive Cyclops 1 in accordance with the OceanGate Pilot Training program.
  - The pilot has overall responsibility within Cyclops 1 for themselves and all crew onboard.
  - The pilot will be deemed fit to dive by the Director of Marine Operations prior to commencement of any diving operations.
  - The Pilot shall report to the Director of Marine Operations in order to ensure the maximum overall crew experience while maintaining safe and methodical decision making in water in accordance with a pre-determined dive profile.
  - The pilot will dive Cyclops 1 when required by the Director of Marine Operations.
  - The pilot will perform pre-dive checks before the dive according to the pre-dive checklist in order to obtain approval from the Director of Marine Operations before proceeding with the launch.
  - The pilot will ensure that Cyclops 1 and all associated systems and equipment are in full working order prior to each dive.
  - The pilot will ensure that post-dive checks are performed after each dive according to the post-dive checklists.
  - The pilot will report any defects found during pre/post dive checks or during the dive to the Director of Marine Operations and Equipment Technician.
  - The pilot will ensure that Cyclops 1 and any additional crew are ready to dive at the appointed hour.
  - The pilot will liaise with the Director of Marine Operations and Equipment Technician to ensure that all repairs and maintenance are completed prior to a dive.
  - The pilot will assist with any Cyclops 1 maintenance tasks and its associated equipment.
  - The pilot will attend any pre-dive briefings in order to be fully instructed as to the scope of the dive.
  - The pilot will assist after the dive in the preparation of the dive report.
  - The pilot will regularly assess and maintain the submersible's trim and ballast conditions.
  - The pilot will assist in the training of new pilots.
  - Crew Briefing

    The Pilot will provide a pre dive safety brief to all crew prior to shutting the hatch that will include a brief outline on communications and how to bring Cyclops 1 to the surface in the event that the pilot is incapacitated. Lists of items to be included in the briefing are as follows:
    - A demonstration of the safety equipment available in Cyclops 1.
    - Instruction on keeping watches/rings etc. clear of viewports.
    - Instruction on the methods used to surface Cyclops 1 and how to use the UWT in the unlikely event the Pilot is incapacitated.
    - No unnecessary movements in Cyclops 1 when close to an item of interest (i.e. coral or a wreck) without informing the pilot first.
    - No flammable items lighters/matches or aerosols allowed in Cyclops 1.

- Director of Marine Operations
  - The Director of Marine Operations is in control of all launch and recovery operations, also the direction of the Vessel Master (Captain) to make necessary maneuvers to ensure the safety of Cyclops 1 and all personnel involved. The vessel master has overall control of the entire Operation.
  - The Director of Marine Operations is responsible for maintaining control of the operation throughout the dive to ensure the safety of Cyclops 1 and the team while maintaining a satisfactory completion of the dive task.
  - The Director of Marine Operations will ensure the safety of Cyclops 1 from all vessels and hazards in the vicinity of the operations site from commencement of the launch until recovery is complete.
  - The Director of Marine Operations will ensure that Cyclops 1, the safety boat(s), and all associated equipment are fully serviceable prior to the dive.
  - The Director of Marine Operations will ensure that all diving operations are carried out in accordance with the US Coastguard and Charter Vessel Owners Association.
  - The Director of Marine Operations will liaise with the project clients, master of the vessel for the positioning of the ship/MSLARS at the project site and advise the Cyclops 1 pilot of his position relative to the desired dive site.
  - The Director of Marine Operations will ensure that all equipment and stores used by the operational team are in a condition satisfactory in performance, maintenance, and calibration.
  - The Director of Marine Operations has the right to terminate the proposed dive if he/she considers that any equipment would prejudice the safe and satisfactory performance of the operation.
  - The Director of Marine Operations will ensure that all specific certification relative to Cyclops 1 and associated equipment are available and up to date.
  - The Director of Marine Operations has the right to terminate the operation if they consider that any individual is unfit to carry out their role in the dive task at hand.
  - The Director of Marine Operations will conduct a pre dive safety brief with the project client, vessel master and all Cyclops 1 operational staff. This will ensure that all concerned are familiar with the purpose of the operation, proposed method of achieving its completion and it will also highlight to all who the key individuals are.
  - The Director of Marine Operations will ensure that the vessel/MSLARS being used for a launch and recovery platform is compliant with the relevant Merchant Shipping regulations.

Crew Training

Cyclops 1 pilots will undergo several methods of training, covering a broad range of topics from operations to systems including classroom, technical, and practical exercises on Cyclops 1 and its support systems.

During training, Staff Trainee Pilots will receive instruction and exams from the Director of Marine Operations that will test their knowledge of various systems and operations.

The Trainee Pilots will also complete practical exams, demonstrating their skills in operating Cyclops 1. The Director of Marine Operations will provide a training log and record of all examinations.

Skills Acquired at the Conclusion of Pilot Training:

- Be able to operate Cyclops 1 in a safe and professional manner
- Know and understand all aspects of dive operations
- Understand and comply with the Cyclops Operations Manual
- Be well versed on the Technical specification and systems
- Be compliant in the Emergency and Company Specific Procedures
- Maintain high standards in the performance of their duty

Recurrent training will be conducted to maintain Pilot proficiency.

Any pilot not having dived in any specific submersible in a 6-month period will receive recurrent training by Director of Marine Operations.

New hires with previous Submersible experience will be required to show proficiency in all the training outcomes prior to being certified for solo piloting operations.

Operating Restrictions and Limitations

- ### Submersible Buoyancy

  Under normal circumstances, Cyclops 1 shall be capable of achieving positive buoyancy by means of the air ballast system.

  Payload checks are to be carried out after all refits, maintenance periods, and after large items of equipment are fitted.

  OceanGate Inc. at its Everett HQ holds a record of the payload state.

  The payload state shall be entered for each dive in the pre dive log, which will be signed by the pilot and countersigned by the Director of Marine Operations.

  Reserve buoyancy of **200lbs** lift always to be observed.

- ### Submersible Stability

  The stability of Cyclops 1 is checked after any refits, maintenance periods, and after large items of equipment are fitted.

  A figure is calculated for the distance between the center of gravity and the center of buoyancy in the dived state. This distance represents the inherent stability of Cyclops1.

  The subsequent addition or removal of weight will affect the stability of Cyclops 1 depending on the position in which changes are made. A maintenance log is kept at Everett HQ of any changes in weight or buoyancy and their position on Cyclops 1 noted.

  Any potential buoyancy added above the center of buoyancy will increase the stability and vice versa.

  Any weight added above the center of gravity reduces the stability and vice versa.

  When on the surface, a maximum of 1 person shall be allowed on the top fairing of Cyclops 1 at any time.

- ### Operational Restrictions and Limitations
  - Documentation and Clearances
    The Director of Marine Operations will review the dive schedule and make sure all permits have been acquired. Permits and clearance often require a long lead-time, so should be obtained as soon as a potential dive operation is anticipated.
  - Environmental Conditions
    The Director of Marine Operations will ensure that weather conditions, anticipated sea states, currents, tides and sub-sea conditions are acceptable. Weather and conditions should be monitored and recorded on the dive plan to determine daily effects.

- Surface Conditions on Site
  - Visibility
    Cyclops 1 is not to be launched if the surface visibility is less than 1 nautical mile. If the visibility deteriorates while Cyclops 1 is in the dived state, the Director of Marine Operations will decide whether to abort the dive task and recover to deck or to keep it submerged until conditions improve.

  - Sea State
    Cyclops 1 is not to be launched if the sea state is greater than 3 (see appendix for graphic) or if the weather forecast indicates it will deteriorate while Cyclops 1 is planned to be in the water. If the weather deteriorates while Cyclops 1 is submerged the Director of Marine Operations will decide whether to abort the dive and recover to deck or to keep it submerged, until conditions improve.

    See below image for indication of sea state.

Sea State	Description	Wind Force (Beaufort)	Wind Description	Wind Range (knots)	Wind Velocity (knots)	Average Wave Height (ft)
0	[illegible]	0	Calm	<1	0	0
	[illegible]	1	Light Air	1-3	2	0.05
1	[illegible]	2	Light Breeze	4-6	5	0.18
2	[illegible]	3	Gentle Breeze	7-10	8.5 10	0.6 0.88
3	[illegible]	4	Moderate Breeze	11-16	12 13.5 14 16	1.4 1.8 2.0 2.9
4	[illegible]	5	Fresh Breeze	17-21	18 19 20	3.8 4.3 5.0
5	[illegible]	6	Strong Breeze	22-27	22 24 24.5 26	6.4 7.9 8.2 9.6
6	[illegible]	7	Moderate Gale	28-33	28 30 30.5 32	11 14 16 [illegible]
7	[illegible]	8	Fresh Gale	34-40	34 36 37 38 40	[illegible] 21 23 25 28

  - Bottom Conditions on Site
    Tidal/Current – Cyclops 1 shall not operate if the bottom tide/current is in excess of 2 knots.

  - Water Depth
    Cyclops 1 shall not exceed her initial classification pressure, which equates to a maximum water depth of 500 meters.

  - Operations in the Vicinity of Structures, Platforms, or Barges
    When working in the vicinity of structures, platforms and barges, the respective platform manager or barge superintendent shall be informed of Cyclops 1 dive objectives. Clearance should be obtained and all necessary permits should be in place to ensure the safety of the vehicle.

The platform manager and vessel masters shall be made aware of the limitations of Cyclops 1 relative to shipping movements, anchor handling, crane operations, weather, visibility, tide, etc.

- Operating Alongside an ROV
  If a joint dive is necessary, special safety rules will apply to avoid damage to personnel and equipment; the measures are as follows:
  - A joint briefing should be conducted with the ROV Operations Manager to define the precise work tasks and operating areas.
  - Visibility should exceed 2 meters.
  - Tidal current should be less than 1 Knot and the surface vessel and ROV should operate down tide of Cyclops 1.
  - Tracking systems must be operational and both vehicles have working transponders.
  - Both vehicles have working sonar's.
  - Safe headings shall be determined in the event of one of the vehicles losing control.
  - The ROV Superintendent has direct contact with the Director of Marine Operations.

- Operating Alongside Divers
  If a joint dive is necessary, special safety rules will apply to avoid damage to personnel and equipment.
  - A joint briefing should be conducted with the Diving Supervisor to define the precise work task and operating areas.
  - Visibility should exceed 2 meters.
  - Tidal current should be less than 1.0 Knot and the surface vessel and divers should operate down tide of Cyclops 1.
  - Tracking system must be operational.
  - The Diving Supervisor has direct contact with the Director of Marine Operations and has contact with Cyclops 1 via UWT.
  - Safe heading shall be given to Cyclops 1 in the event of a diver emergency.

Submersible Theory

- ### Buoyancy

  When Cyclops 1 is in "Neutral Buoyancy" – that is, tending neither to rise nor sink – its weight exactly equals the weight of the volume of water that it displaces (Archimedes' Principle); thus, by changing either the weight or volume of the submersible, it can be made positively or negatively buoyant.

  There are two main systems by which buoyancy can be controlled on Cyclops.
  - HP Air
  - Ejectable leg assembly (emergency release only)

  Cyclops 1 must be able to surface using any one of its systems by achieving positive buoyancy (with a minimum reserve) at the depth at which it is operating.

  In order to ensure that these systems are fully effective, the submersible must be carefully adjusted with regards to total weight and volume before launching. This requires adjustment of all weights that have been altered since the previous dive and, if necessary, the adjustment of lead weight or buoyancy material (not currently fitted) external to the pressure hull.

  Once in the water, the systems controlling buoyancy act as follows:
  The submersible will become positively buoyant and rise if its weight is reduced or if its volume is increased without any increase in weight. This applies when HP air is blown into the VBT thereby reducing the weight of the submersible.

- ### Archimedes Principle

  Archimedes principle states that when an object is wholly or partially immersed in a liquid, the up-thrust it receives is equal to the weight of the liquid displaced. Upward Force (U) = Volume (V) x Density (D) of liquid displaced

  Consider that an object immersed in a liquid will experience an upward force, which will attempt to force it out of the liquid. This force is due to the displaced liquid attempting to re-occupy the space taken over by the object.

- ### Center of Buoyancy and Center of Gravity

  The center of gravity of Cyclops 1 is below the center of buoyancy. It is common knowledge that dense objects sink in fluids with lower densities. If the center of gravity of Cyclops 1 is below its center of buoyancy, this means that the majority of the weight rests below the center of buoyancy. This implies that the volume of Cyclops 1 below this point is denser than the same volume of displaced water. Thus, the lower portion of Cyclops 1 will tend to sink while the upper portion will tend to rise, preventing her from rolling.

System Description

- ### Pressure Boundaries, Exo-Structure, and External Fittings

The pressure boundary maintains watertight integrity of Cyclops 1 and its associated equipment to the maximum operating depth of 500 meters of seawater (MSW). The term "Pressure Boundary" refers to the entirety of the pressure hull. The exo-structure forms the framework enabling various fixtures and fittings to be attached to Cyclops 1.

The pressure hull, designed according to BS5500, consists of a ring-stiffened cylinder with a tapered section at the aft end. The hull is constructed in 3 sections and joined by bolted O-ring sealed flanges. The 9 internal T-section frames are made from the same material as the hull and an overall corrosion allowance of 1mm has been incorporated in the calculations for the shell plating. The ring stiffeners are utilized as attachment points for pipe work, cable trays and oxygen ducting.

A single point lift system is attached to the hull adjacent to frames 4 and 5. Mounting lugs are also provided on the hull for the aluminium exo-structure, the lower skids and drop weight assembly.

The viewport is accommodated in a machined steel ring and welded into the hull; fastenings then secure the acrylic dome.

The conning tower viewport, bolted to a mount made from SS316, is hinged and spring closed. A circular neoprene lip seal under the bottom side of the viewport mount seals the conning tower to the SS316 flange welded to the hull. The hull is fitted with 12 penetration plates machined from 40 mm plate.

- ### Hull Materials

The shell is fabricated from 20 mm steel plate to BS-EN 10028-3 P355NL 1/1.0566. Frames, mounting lugs and tori-spherical dished end, and the conning tower cylinder are made from 16mm plate to BS-EN 10028-3 P355NL 1/1.0566. Hull joint flanges, hatch reinforcement, lifting lugs and minor penetration bosses are made from 40mm plate to BS-EN 10028-3 P355NL1/1.0566. Bow viewport ring 100 mm plate is made out of BS-EN 10028-3 P355NL1/1.0566. Refer to BS-EN 10028-3 for full spec.

The aft hemisphere is pressed from 16 mm plate with a 4 mm thinning/corrosion allowance incorporated in the calculation. The design has been conducted according to section 3.6.4 of BS5500. The completed hull is stress relieved prior to final machining of mating faces and window seat according to the weld procedure.

The pressure hull was manufactured, inspected, and tested in accordance with the ABS Rules for Building and Classing Underwater Vehicles, Systems and Hyperbaric Facilities, 1990. The pressure hull, including all pressure boundary items, underwent a pressure test to 631 m in the pressure tank at Slingsby in Kirbymoorside in March 1998. Three cycles, each one lasting 30 minutes, were performed and strain gauges were fitted on 23 places inside the pressure hull.

- **Main View Port**

  The forward main viewport has a diameter of 1444 mm manufactured from acrylic material. It has a 150º angle with a thickness of 94 mm. The viewport is held against the hull by means of a clamp ring bolted to the conical hull flange. Sealing is achieved by an O-ring at the chamfer of the outer diameter of the acrylic and the conical flange. The surface of the hull flange is epoxy painted (same as hull paint). Special care has to be taken when disassembling; this should be only performed with the viewport lying in a suitable size of tire. Spherical ports do give better all-round vision but have an element of distortion; however, they provide the ideal, all round visual required by the pilot.

- **Hatch**

  The submersible has one hatch with an inside diameter of 520 mm. The hatch has handles on both port and starboard sides, making the operation of opening and closing simple. The viewport enables the pilot to control the submersible for surface piloting if the forward facing camera and/or sonar malfunctions.

  The conning tower viewport has a diameter of 613 mm manufactured from acrylic. It has a 150º angle with a thickness of 40 mm.

- **Trim and Ballast System**

  The trim and ballast system on Cyclops 1 contains elements of the HP Air system, as well as to include a lead weight in the form of an ejectable unit, which is used in conjunction with the hydraulic hand pump within Cyclops 1. There are also fixed and portable lead ballast, which can be removed or installed prior to a dive depending on payload conditions.

  The 200lb lead drop weight is situated on the underside of Cyclops 1; it can be ejected in case of an emergency.

  There is a bladder installed on the upper section of the hull on Cyclops 1, which acts as a ballast tank, this in conjunction with the HP air system assists with the desired submerged state of Positive-Neutral-Negative.

  The bladder itself is manufactured by Wing Inflatable's and has a fully blown volume of 170lt.

  The bladder is installed on the underside of the top fairing by use of secure fasteners. The maximum allowable volume is restricted to 170 liters. The volume is controlled by two pressure relief valves on each corner of the bladder. The relief valves are set to relieve at 3psi above ambient.

  There are 2 fill points on the top of the bladder to allow for the system to be filled with air. The fill point which is used for standard Blowing conditions is situated aft of the conning tower, the second fill point on the bladder is situated on the port side forward. This secondary fill point is used for Emergency Blow only.

The valve used to fill the system is situated on the HP air panel on the Starboard side of Cyclops 1. The flow of air from the external cylinder's goes to the blow valve passing through ¼" tubing then onwards to the inlet valve atop the bladder itself.
The Emergency blow valve inside Cyclops 1 is situated on the upper penetrator above the pilot's console.

There is a vent system installed to the bladders to adjust Cyclops 1 ballasting condition whilst submerged. There are 2 vent valves fitted, one forward and one aft, to allow the air to escape to ambient. These are controlled via a 3-way valve situated on the Starboard HP air panel.

HP Air System

The HP Air system on Cyclops 1 has a maximum working pressure of 3000psi.

There are both main and reserve HPA banks on Cyclops 1. Port is the main bank and Starboard is generally the reserve bank. However, the roles of each bank may switch every six months.

Each bank consists of 2 x 45 liter cylinders, with individual bottleneck valves for isolation.

As part of the Pilot pre-dive log, the reserve shall be opened and the pressure noted. The hull stop shall be shut again and the system is then bled via the built in breathing system (BIBS). Upon completion, the Main HP Air hull stop shall be opened for dived operations.

Both the main and reserve HP air supplies enter Cyclops 1 through the upper penetration plate amidships of the vehicle.

Both supplies are piped to the HP Air panel located on the Starboard Side within Cyclops 1. The pressure is visually noted via the inline HP Air gauge, it then branches off to the vent valves, blow valves, and BIBS.

The pressure supplied to the vent and blow lines is not regulated and it receives the working pressure of the system.

The Built in Breathing System (BIBS) passes through an LP Regulator on the HP Air panel and it is set manually to reduce the pressure down to 140psi. An isolation valve when in the open position supplies the pressure to the 5 diving regulators that make up the BIBS.

Image showing the HP Air panel on the starboard side.

HP Oxygen System

The HP Oxygen system consists of one main and six reserve cylinders each with a capacity of 13 liters (78 liters total reserve). These cylinders are vertically mounted within Cyclops 1.

The main O2 cylinder is situated on the Starboard side and has a maximum charge pressure of 2000psi. The remaining reserve cylinders are located as follows: two on the port side and four on the starboard side aft of the Pilot Station. They have a maximum charge pressure of 2000psi.

Each cylinder has its own individual isolating valve at the neck of the bottle.

During pre-dive Pilot checks, the reserve cylinders shall be opened individually to confirm the system pressure. A minimum system pressure of 2000psi should be present to allow for 96 hours of life support capability in the event of an emergency. During dived operations, the main cylinder shall be opened and the reserves shall remain shut.

Once the main cylinder has been opened the flow of oxygen will pass through a fixed pressure regulator, this in turn reduces the pressure down prior to going to the flow meter. The flow meter shall be set manually using the needle valve to supply a flow of half a liter per minute per person. The Pilot, who will be monitoring the Oxygen levels inside Cyclops 1 using Analox meters, will adjust the flow rate accordingly throughout the dive.

The Oxygen charging point for the O2 system is situated internal of Cyclops 1 on the Port side adjacent to the first reserve cylinder.

Image showing Starboard O2 system.

Life Support and Atmospheric Monitoring

Within Cyclops 1, there are two Analox Sub Aspida atmospheric monitors, which allow the pilot to monitor the atmospheric levels within the submersible.

The Analox systems continuously monitor atmospheric CO_2 and O_2 levels within the submersible.

One of the Analox meters is powered via the onboard 9V power supply; it also has an internal battery backup in the event of power failure within the submersible.

The 2nd meter is solely run on its internal two AA batteries and used as back up only.

Both meters should be fully charged and turned on prior to commencement of any dive operations to confirm functionality (the second Analox to be turned off once it has shown to be working). The upper alarm limit for O_2 is 23% and lower set to alarm at 19%. CO_2 upper limit is set to alarm at 0.5%.

There is one scrubber unit installed within Cyclops 1 behind the Pilot seating area. This is filled with Sofnalime CO_2 absorbent high performance diving grade.

During high humidity conditions approximately 1 inch of Silica will be put in the base of the scrubber can prior to filling with the Sofnalime, this will assist in reducing the condensation levels within the submersible.

The scrubber fan unit is powered via the 12V system.

As part of the emergency requirements within the submersible, we carry an alternative means of "scrubbing" the atmosphere. This is in the form of Lithium curtains, which are dry stored in Ammo boxes and deployed during emergency dive operations only. Within Cyclops 1, we carry enough Lithium curtains to allow for 96 hours of atmospheric scrubbing capability.

In addition to the above, we also carry emergency supplies for all 5 crew members for 96 hours:

- Emergency rations (i.e. food and water)
- Heat reflective blankets
- Dive masks
- Nose clips

Emergency Hydraulic System

The Emergency Hydraulic System consists of a hydraulic hand pump and the Cyclops lower frame and leg assembly.

The pump itself has a maximum working pressure of 3000psi and is filled with oil via the fill point atop the unit.

To operate the system and in turn eject the frame and leg assembly we use the following procedure:

- Turn the Hydraulic pump selector handle to the Close position.
- Open both the release drop weight hull stops (EMER WT DROP).
- Turn both quarter turn valves on the HPA panel to Drop
- Insert the hand pump into the pump.
- Start to pump, once pressure is seen on the Hydraulic pressure gauge (located on the Starboard HPA panel) continue pumping until the frame and leg assembly have ejected and the moment of Cyclops 1 will change to a positive one.

  The frame and leg assembly are held in situ via a pin and spring mechanism. The C- catch and yolk assembly remain with Cyclops when the frame and leg assembly have been ejected.

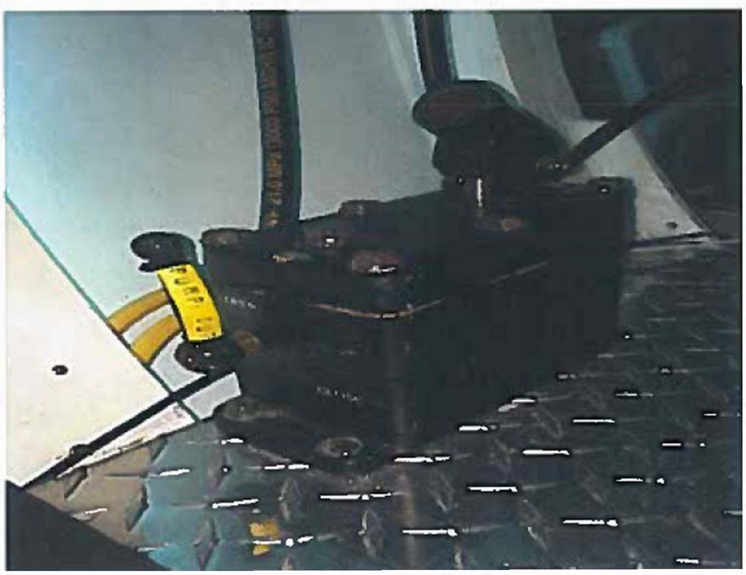


Image showing the Emergency Hydraulic Pump

Electrical System

Cyclops 1 is divided into two separate power systems. The 120V battery busses supply power for thrusters and non-critical computer systems. There is also an isolated 24V electrical system used for computers and sensitive equipment.

- ### 120 Volt

  Main power for the submersible systems is provided by two banks of ten Optima 12V Absorbed Glass Mat Marine/RV batteries located inside the hull under the flooring sections. Each bank of 10 batteries is wired in series so that each bank may provide 120V DC to operate the systems.

  It is standard practice for both banks to be run simultaneously, however, there is the option to run them individually. Each bank has its own contactor clearly designated by the switches on the main control panel on the Port side.

  Each battery bank is activated through a separate contactor, which when active routes the battery power through the main fuses and to the distribution panels.

  The 120V from the battery bank is then used to provide main power to the thrusters through the rear penetrators.

  The rotary selector switch in the lower left section of the control panel views battery voltage and current draw of the 12V, 24V and 120V systems.

  Two of the batteries are designated as reserves in order to operate the 12 and 24-volt systems in the event of an emergency. These two batteries, in addition to being run in series with the rest, also have switched lines running into the 12V and 24V bus panels. The meter at the bottom of the control panel may be used to check the voltage from the designated emergency batteries. In order for the correct measurement to be made, the three-position on the selector switch on the lower right of the control panel must be in the "battery" position.

  120V battery power is also routed to two Vicor DC/DC converters located behind the main control panel of Cyclops 1, one supplies the 12V and one the 24V system voltages.

- ### 12 Volt and 24 Volt

  The meter at the bottom of the control panel may be used to measure the voltage output from both the 12V and 24V converter. In order for the correct measurement to be taken, the three-position selector switch on the lower right of the control panel must be in the "converter" position.

  The 24V system provides power to the following:

  - Pan and Tilt
  - Sonar 1
  - Sonar 2

The 12V system provides power to the following:

- Under Water Telephone (UWT)
- Interior Dome Camera
- VHF
- Scrubber
- Monitor 2
- Interior lights

A portion of the equipment used in Cyclops 1 (i.e. the alarm controller and environmental monitoring equipment) are automatically powered without the use of switches and will be addressed in the relevant sections of this manual.

- Isolated 24V System

The isolated voltage is supplied by two dedicated batteries which are separate from the 120V banks. The batteries are located in the aft of Cyclops 1. To enable the voltage, there are control switches located on the port side of Cyclops 1 on the left side of the computer storage shelf. The top switch enables 24V to the remainder of the switches on the panel.

The isolated 24V system provides power to the following:

- Control computer
- Media computer
- DVL
- PHINS
- Sphere low voltage

Alarm System

Cyclops 1 is equipped with various alarm systems to alert the Pilot to possible issues with the equipment.

The alarm control box is located behind the starboard control panel and is powered by the main batteries of Cyclops 1. The control box is wired with its own inline 120-12V DC/DC converter. This way, the alarms are activated as soon as main power is switched on and no need for an individual alarm breaker. The individual water detect and hatch sensors have internal batteries and are always on.

A brief sound indication will notify the pilot of water alarm activation prior to the LED indicator. LEDs behind the panel will change from a solid red to a flashing red when an alarm is activated providing a visual indication to the Pilot.

The hatch alarm is in two sections: a magnet affixed to the hatch and the receiver unit located in the conning tower. The receiver unit contains a 9V battery, which powers the component and relays the signal to the control box within the submersible. A reed switch inside the receiver unit remains closed when the hatch is closed; this is due to the magnet on the hatch making contact. When the magnet is removed, i.e. the hatch is open; the reed switch no longer provides a closed circuit and activates the flashing LED on the control box.

There are two water detection alarms located within Cyclops 1.One sensor is located under the forward crew floor panel and the second sensor is located under the flooring just aft of the pilot seating area. Both alarms are suspended approximately 0.25" above the lowest point on the curvature of the hull. The sensors have two contact points, which when connected via submergence in water will create a closed circuit and activate the flashing LED on the control box. Each sensor will activate a separate LED on the control box.

There are also alarm systems installed within the external Control Spheres monitoring temperature, humidity, water detection and pressure. The Pilot has visual indication of these alarms on the diagnostics page on the control screen of monitor-1 and is monitored throughout the dive.

Communication System

For topside communications, Cyclops I has to option to run either the Ocean Technology Systems Aquacom STX-101 or Subphone 580 system. Prior to each expedition either system shall be selected for the duration rather than carry both units onboard Cyclops.

The OTS unit is powered by the 12V system, which acts as a charger for the internal battery of the Aquacom. On its own, the battery has an approximate life of 20hrs.

There are 4 channels available on the system and its power draw is 5A @12V. The range of the Aquacom is 3000m.

The Sub-phone 580 system, which can operate off of the same 12V power supply cabling and switch as the Aquacom. There is a 10,000m range for the Sub-phone.

Both communication devices require a transducer mounted on the upper port on Cyclops 1. Likewise, a transducer is required on the support vessel, which is most commonly mounted adjacent to the tracking transceiver since both will only operate when submerged and mounted as far away from away from propeller wash as possible.

OTS Aquacom STX-101 unit.

Navigation, Video, and External Lighting

- Tracking

  When Cyclops 1 is submerged, topside support vessel tracks her via an acoustic system consisting of a transceiver and a transponder. The Link-Quest Tracklink 1500 consists of several components: the sub mounted transponder, the topside mounted transceiver, and the topside tracking pc/software.

  The transponder is mounted in a clamp on the top/aft section of Cyclops I. This unit is powered by an internal battery pack. The transponder must also have the correctly labeled plug on the connector, as an alternate plug will not have the internal connections that allow the unit to wake up. The transponder will go into a sleep state after several minutes of inactivity, so there is no need to remove the connector after operations until the transponder is stored.

  The transceiver portion of the tracking system is mounted to the support vessel. The placement of the transceiver will likely vary depending on the ship's configuration. The key element is that the device is submerged transducer side down on a rigid structure several feet or more under the MOSHIP (preferably clear of any thruster wash). The transceiver connects to a portable power supply, which also provides power for the PC aspect of the system.

- Video

  The video system currently used on Cyclops 1 is a forward facing camera unit that can take images at 30 frames per second. This unit receives power from the onboard 12V system but in the unlikely event of power failure it can run on its own internal battery.

  There is one permanently mounted internal of Cyclops 1 in the upper section of the Forward Viewport looking ahead of the vehicle.

  The image produced is fed directly to the Pilot monitor 2 on the Starboard side.

- Lighting

  The source for external lighting on Cyclops 1 consists of two Teledyne Bowtech 20,000 Lumen LED floodlights. There is also the option to utilize two Deep Sea Power and Light Sealite Spheres. These lights are controlled by individual switches found on the main port control panel and receive fused power from the 120V system.

- Sonar

  Cyclops I uses one or more BlueView sonar devices for detection of underwater objects. Regardless of the sonar head used, they are both supplied with power from the 24V system. The Sonar 1 and Sonar 2 switches in Cyclops correspond to the cable that is connected to the sonar head on the external mount.

  Both sonars are mounted to an electric pan and tilt unit, which is controlled via the BlueView controls on monitor 1.

The specifications of the available sonars for Cyclops 1 are as follows:

- P900
  - 45-degree field of view
  - Range 100m
  - Frequency 900k Hz
  - Update rate up to 15Hz
  - Power consumption @24v = 29w
  - Depth range 1000m
- M450
  - 90-degree field of view
  - Range 300m
  - Frequency 450khz
  - Update rate up to 25Hz
  - Power consumption 24W
  - Depth 1000m
- 1350
  - Capable of providing 3D image scans
  - Update rate up to 30Hz
  - Frequency 1.35 MHz
  - Power consumption 45w
  - Depth range 1000m

- Compass

  The main compass onboard is provided through the IXblue PHINS system providing a true heading of the vehicle, this is displayed on the Pilot monitor.
  There is also a Spartan AHRS-8 digital compass installed. This unit is a fully temperature compensated system, which is individually calibrated for heading accuracy.
  The Spartan provides real-time noise characterization and active gyro-drift compensation for heading, pitch, and roll, this is completely standalone from the Phins system.

  Both systems are integrated into Cyclops 1 through the DVL system, providing heading reference on the Pilot's consol.
- DVL

  Cyclops 1 is outfitted with a 600KHz Rowe Technologies SeaPilot Doppler Velocity Log (DVL) system that is rated to 3,000 meters. The unit provides compass heading, pitch/roll, water temperature, pressure, and also has the capability to record and display water profiling and bottom-track data. All information provided by the unit is displayed on the Pilot's console.

- **PHINS**

  PHINS is an inertial navigation system providing position, true heading, attitude, speed, depth and heave. Its high accuracy inertial measurement unit is based on iXBlue's fiber-optic gyroscope technology coupled with an embedded digital signal processor that runs an advanced Kalman filter. PHINS is compatible with doppler velocity log (DVL)

Images depicting location and size of integrated PHINS system within Cyclops 1.

Propulsion

- Cyclops Spherical Glass Housing

  Cyclops makes use of two 17" glass spheres for multiplexing propulsion power and data outside of the life space pressure hull. Note that only thruster command and feedback are accessed via the spheres, no payload data is involved.

  The glass (1/2" thick) is manufactured by Nautilus Marine of Germany and is rated to 6000-meter depth. Holes are precision drilled to allow communications and power cable access.

  As the sphere architecture for Cyclops is asymmetrical, we refer to the spheres as "primary" and "secondary". The primary sphere includes a direct data connection to the hull (via fiber optic line), while the secondary communicates to the hull only through the primary.

Image showing one of the control spheres.

- Basic sphere components consist of:
  - o Motor controllers for the thrusters, which are brushless DC motors operating at 120V. Each sphere controls 2 thrusters and thus contains 2 controllers.
  - o A multichannel D/A-A/D (DAC) device for converting between analog and digital signals. Each DAC has enough input/output channels that only 1 is required to control both thrusters in each sphere. The specific DAC used is Ethernet based; thus access to all of its channels can be performed over a single Ethernet cable.
  - o Temperature, pressure, and humidity sensors for monitoring the sphere internal environment. These are also routed to the DAC device in each sphere.
  - o Fiber-enabled Ethernet switch. In the primary sphere only, this multiplexes the DAC in the primary sphere with the DAC in the secondary sphere and connects that pair with a computer inside the hull via a single fiber-optic cable.

- Sphere connectors/penetrators are all from SubConn/MacCartney Inc. These include:
  - High-power connectors for thruster power.
  - Low-power connectors for auxiliary power.
  - Standard Ethernet connectors for cross-sphere data and low power transfer.
  - Fiber-optic connector for all sphere-hull data (primary only).

  For cooling, the spheres are partially filled with mineral oil. This helps conduct heat generated by the motor drives to the walls of the sphere and then into the ocean. It also reduces risk of implosion should the spheres fail by reducing entrained air. To maintain sphere integrity at low external pressures (e.g. in air or near surface) the sphere internal pressure is drawn down by a vacuum pump after oil filling.
- Thrusters
  Cyclops 1 has 4 Innerspace 1002HL Hexscreen Electric Thrusters.

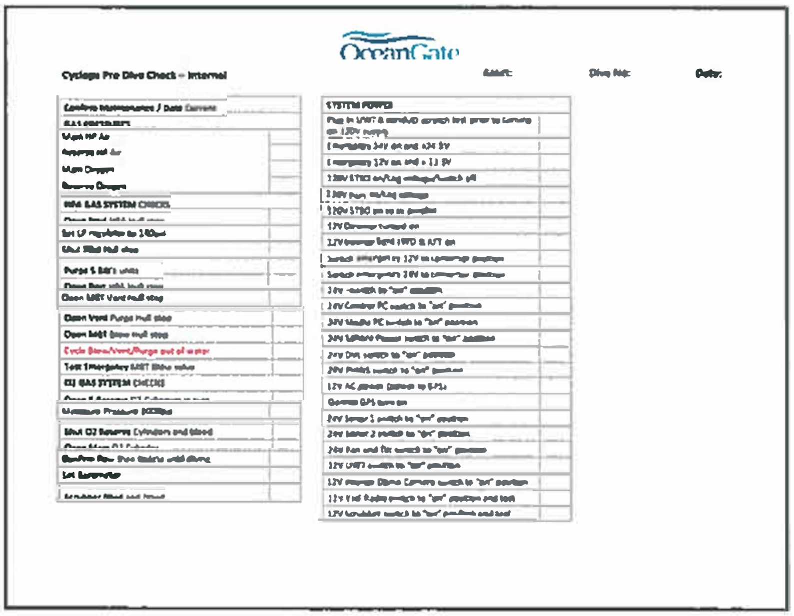
  One or both banks of the onboard batteries can power these thrusters. Power is routed in through the rear penetrator of Cyclops 1. The control and operating system is customized and discussed more in detail in the sphere parameters.

Pilot Logs

As part of the pre/post dive checks the Cyclops Pilot carries out, logs are generated to confirm that all systems have been fully tested; functioning and relevant pressures and power levels are at sufficient levels.

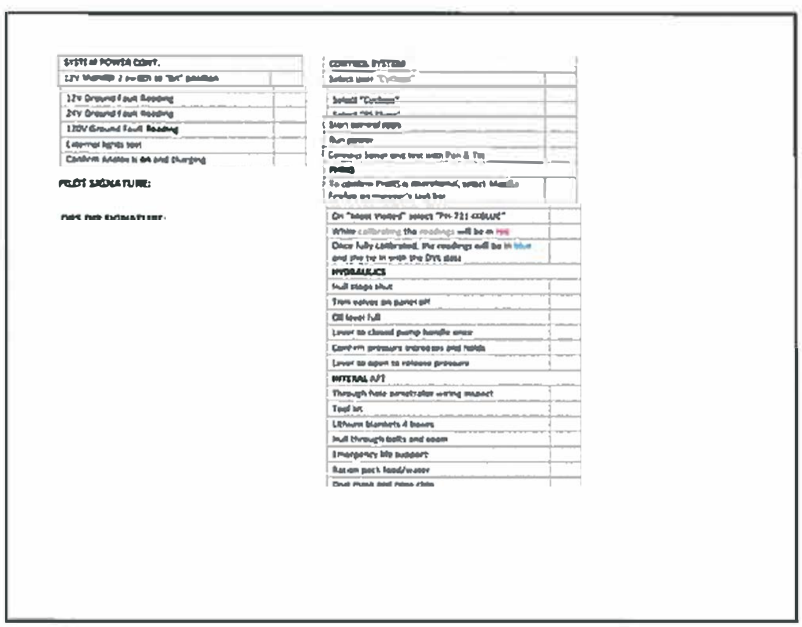
These logs are scanned and held on the OceanGate database for future reference.

Images showing an example of a Cyclops Pre-Dive Checklist


OceanGate

Cyclops Pre Dive Check – Internal

Cycle Blow/Vent/Purge out of water


PILOT SIGNATURE:

HYDRAULICS

Oil level full

General Launch and Recovery Operational Procedures

- MSLARS
  - MSLARS Launch

    Before commencing with the launch sequence, the Director of Marine Operations will ensure that the following conditions are satisfied:
    - A pre-dive brief of Pilot, marine crew and all key personnel has been carried out as required.
    - All stations are manned and equipment operational.
    - If working in the vicinity of platforms or other vessels, clearance shall be obtained from the respective platform manager or vessel master.
      A support boat is on station fully equipped and with a stand-by surface swimmer on-board.
    - Cyclops pre-dive checks have been carried out and logs signed off by the Pilot and countersigned by Director of Marine Operations.
    - All crew are to be transferred to MSLARS via the support boat.
    - Pre dive safety briefing for the crew members to be conducted by the Pilot prior to shutting hatches.
    - The LP cylinder pressures are to be confirmed as being no lower than 150 Psi prior to commencement of the operation.
    - Confirmation will be made that all transit plates have been removed from the underside of MSLARS.
    - MSLARS operator to confirm that MSLARS pre-dives are complete.
    - All tied down straps are to be removed and placed in the support boat.
    - Ensure all four of the surface buoys are secured to each of the corners of MSLARS.
    - Additional buoyancy in the form of a Mine Recovery bag to be secured to one of the buoy lines (optional depending on sea state).
    - Upon confirmation that all parties have clearance to proceed with the launch, all surface personnel will disembark from MSLARS deck. The support boat will remain no closer than five meters from MSLARS prior to it submerging.
    - Vessel master and Director of Marine Operations will confirm the MOSHIP is clear of the launch area and all towlines to MSLARS have enough slack prior to commencement of the launch.
    - The Director of Marine Operations will confirm Cyclops 1 pilot is ready to dive via the VHF surface communication and upon confirmation they will instruct MSLARS Operator to "vent MSLARS."
    - The Cyclops pilot will be informed "MSLARS is venting now" from the topside communications operator.
    - The vent rate will be controlled and may vary depending on sea states.
    - Once MSLARS and Cyclops 1 have fully vented, MSLARS operator will confirm with the Director of Marine Operations that MSLARS is fully vented.
    - Upon confirmation from topside communications that MSLARS has vented, the Pilot will clear MSLARS and commence with the Dive mission.
    - Cyclops 1 pilot will confirm that the submersible is clear of MSLARS.

- MSLARS Recovery
  - Vessel master and Director of Marine Operations will confirm the MOSHIP is clear of the recovery area and all towlines to MSLARS have enough slack prior to commencement of the recovery.
  - The Director of Marine Operations will confirm Cyclops 1 is ready to recover via the UWT and upon confirmation they will instruct MSLARS Operator to "Close up on the control unit".
  - The Cyclops pilot will be informed, "Clear to land on MSLARS" from the topside communication operator.
  - The Pilot will then inform the Director of Marine Operations he/she is in position in the fully locked position and ballast tank is fully blown via the UWT.
  - The Support boat will clear from MSLARS recovery station no less than five meters away.
  - Upon instruction that the Support boat is clear, the Director of Marine Operations will instruct the MSLARS operator to blow MSLARS tanks and bring her to the surface.
  - Cyclops 1 pilot will be informed once MSLARS tanks have been fully blown and it is safe to open the upper hatch on the surface.
  - The support boat shall close up on MSLARS install the boarding ladder once the hatch has been opened.
  - The decision to attach ratchet straps to secure Cyclops 1 to the deck of MSLARS between dives will be determined by the Director of Marine Operations.

- A-Frame Vessels
  - Before commencing with the launch sequence, the Director of Marine Operations will ensure that the following conditions are satisfied:
    - A pre-dive brief of Pilot, marine crew and all key personnel has been carried out as required.
    - All stations are manned and equipment operational.
    - Cyclops 1 securing straps are removed and tow and lift lines attached (also drogue and steadying lines if applicable).
    - If working in the vicinity of platforms or other vessels, clearance shall be obtained from the respective platform manager or vessel master.
    - A support boat is on station fully equipped and with a stand-by surface swimmer on-board.
    - Cyclops 1 pre-dive checks have been carried out and signed by the Pilot and countersigned by Director of Marine Operations.
    - The MOSHIP is in the vicinity of the dive site and on the correct course and at the correct speed for launch.
    - For launches underway from 'A' frame vessels a launch and recovery speed of 2-3 knots is normal.
    - No other surface vessels are hazarding the operation.
    - Visual signals for submersible and diver operations to be displayed on the vessel.
    - The launch sequence that follows varies according to the handling system used.

- Typical Launch Sequence A-Frame Vessels
  - On instruction from the Director of Marine Operations, the A-Frame operator lifts Cyclops 1 off the deck.
  - The A-Frame is now rammed out and the lift line is adjusted as required.
  - The towrope fitted to the aft of Cyclops 1 is paid out sufficiently to keep the submersible and pendant in the vertical plane. The deck crew stands by to guide the towrope through stern leads to ensure towrope is maintained ready as Cyclops 1 passes through the A-Frame and into the water.
  - The lift line is lowered away until Cyclops 1's thrusters are submerged in the water.
  - The Director of Marine Operations signals to the handling gear operator to veer rapidly until the submersible enters the water.
  - The Pilot checks the lights, Insulation Resistance, thrusters and the submersible's watertight integrity once the water level is above the viewport.
  - Once the Pilot has confirmed all checks are complete, the Director of Marine Operations instructs the support boat to land the surface swimmer on to the upper deck of Cyclops 1. The Pilot shall confirm the thrusters Deadman's switch is off prior to the deployment of the swimmer.
  - The Director of Marine Operations signals the surface swimmer to release the lift line.
  - The towline is paid out until Cyclops 1 is approximately 15 meters astern and the tow is maintained until the launch position is achieved.
  - When in position, the ship's speed is reduced and the Director of Marine Operations signals for the tow line to be paid out until slack.
  - Once he/she has confirmed that Cyclops 1 thruster's Deadman's switch is off, the surface swimmer releases the towline from the submersible and is recovered to the support boat.
  - The Director of Marine Operations instructs the MOSHIP to move clear of the submersible.
  - The towline can be retrieved by the MOSHIP and flaked out ready for recovery.
  - Where applicable, the surface swimmer detaches and recovers the drogue (if required for steadying Cyclops during tow), attaches the surface marker buoy and deploys any items of equipment required for the submersible operations. The support boat recovers the surface swimmer.
  - The Director of Marine Operations gives Cyclops 1 permission to bring the thruster's back on and gives clearance to vent.
  - On board the MOSHIP, the A-Frame is rammed in and the lift line secured to restrict movements and thereby avoid constant abrasive action.
  - The dive is then continued as per the pre-dive brief.
  - It may be decided during calm water deployment that the MOSHIP holds station during the launch and Cyclops 1 motors away from the MOSHIP when the lift line has been released.

- Recovery Sequence – A-Frame Vessels
  Before commencing with the recovery sequence, the Director of Marine Operations is to ensure that the following conditions are satisfied:
  - No other vessels are in the area hazarding the operation.
  - Personnel are closed up as required.
  - The support boat is on station (at the submersible marker buoy if fitted) with the surface swimmer and boat driver on board.
  - The A-Frame is rammed out and lift line is at its required length.\
- Typical Dynamic Recovery – A-Frame Vessels
  - The Director of Marine Operations instructs the pilot that he is clear to ascend.
  - Once on the surface, VHF contact is established and full air buoyancy is attained.
  - The surface swimmer transfers from the diving boat to Cyclops and, if applicable, detaches the buoy line and stows any equipment. The swimmer remains with Cyclops.
  - The ship is manuevered to pass 15 to 20 meters from Cyclops on the recovery course.
  - The Director of Marine Operations instructs Cyclops to turn on to a recovery heading as required.
  - The support boat returns to the MOSHIP and the surface swimmer collects the end of the towline.
  - As the MOSHIP draws level with Cyclops 1, the Director of Marine Operations instructs the Pilot to turn the thruster's Deadman's switch off. Once this is confirmed, the support boat driver takes the towline across to the surface swimmer who attaches it to the aft submersible tow point, ensuring it does not foul any part of the submersible. As the ship passes Cyclops 1, any slack line is taken up on the tow winch and Cyclops 1 is taken on tow.
- Typical Static Recovery Sequence – A-Frame Vessels
  - The Director of Marine Operations instructs the pilot that he/she is clear to ascend.
  - Once on the surface, VHF contact is established and full air buoyancy is attained.
  - The surface swimmer transfers from the support boat to Cyclops 1 and, if applicable, detaches the buoy line and stows any equipment. The surface swimmer remains with Cyclops 1.
  - The ship is maneuvered into position approximately 30 meters astern of Cyclops 1 and maintains this position.
  - The Director of Marine Operations instructs Cyclops 1 to turn on to the reciprocal heading to the ship.
  - Once the Pilot has confirmed that the thruster's Deadman's switch is off, the support boat driver collects the towline from the stern of the ship and takes it to the surface swimmer who attaches it to the aft tow point, ensuring it does not foul any part of the submersible.
  - Any slack line is taken up on the tow winch; the ship moves ahead and turns on to the recovery heading. The support boat maintains station close to Cyclops 1 while it is on tow. If required, the surface swimmer will attach a drogue line. The support boat then pays out the towline and deploys the drogue astern of Cyclops 1.
  - The towline is winched in until Cyclops 1 is below the lift line.
  - The MOSHIP maintains steady course and speed unless otherwise instructed by the Director of Marine Operations.

- The surface swimmer attaches the lift line to the lift hook and is collected by the support boat.
- When instructed by the Director of Marine Operations, the A-Frame operator lifts Cyclops. The A-Frame is rammed in with the lift line being hauled in at the same time.
- The towline is kept taut to ensure that Cyclops 1 is stable throughout the process.
- Cyclops 1 is lowered on to the deck and secured.
- The Pilot opens the hatch when informed it is clear to do so.

- Crane Vessels

  Launch from a MOSHIP using a crane should only be carried out in sheltered or calm waters, as any swell makes the operation hazardous. This limitation may be relaxed in some circumstances, but only at the discretion of the Director of Marine Operations and depending on the size and stability of the MOSHIP.

  - Typical Launch Sequence Using a Crane
    - Pre-dive check routines are to be completed.
    - Fenders are to be available for positioning between Cyclops 1 and the MOSHIP side.
    - The MOSHIP takes up position over the dive site and is stopped, with sea on the bow to minimize rolling in such a manner as to ensure that the vessel does not drift towards Cyclops 1 when in the water. For vessels fitted with thrusters, position can be maintained.
    - The support boat is launched with the driver and the surface swimmer positioned by the ship's side close to, but not beneath, the launch position
      To prevent damage or injury to Cyclops 1 or the Surface swimmer, a suitably rated nylon strop is to be used between the Crane hook and the Cyclops 1 lift point.
    - Handling lines are attached to the forward and aft upper securing pad eyes on Cyclops 1 and the standard towline secured to the aft towline securing point.
    - The Director of Marine Operations informs the Vessel Master that Cyclops 1 is ready for launch and awaits clearance to continue.
    - After confirmation that Cyclops 1 is clear for launch, the crane driver lifts, slews and lowers Cyclops 1 into the water.
    - In the event the MOSHIP has thrusters near the launch/recovery position, prior to fully lowering Cyclops 1 into the water the Vessel Master is to confirm thrusters have stopped. This is to eliminate any possible danger to the surface swimmer while in the water.
    - Cyclops 1 pilot checks the hatch seal and the ground fault detector (GFD).
    - Upon confirmation all checks are complete, the Pilot is to inform the Director of Marine Operations that the thruster's Deadman's switch is in the off position
    - Upon instruction from the Director of Marine Operations, the surface swimmer enters the water and removes the tag lines and then the aft towline. All lines are recovered on-board.
    - With the surface swimmer back on top of the submersible, the main lift strap is removed from the Cyclops 1 lift point when the Director of Marine Operations directs them to do so.
    - The support boat collects the surface swimmer and stands by to assist as an additional fender to Cyclops 1 if required.
    - Cyclops 1 is instructed to switch on thrusters and is free to maneuver clear of MOSHIP.
    - The MOSHIP may also move to assist the clearance at the instruction of the Director of Marine Operations.

- When Cyclops 1 is clear of the MOSHIP and in the dive position with the marker buoy fitted (if applicable) and when the support boat has collected the surface swimmer, Cyclops 1 is given clear to vent.

- Recovery Sequence – Crane Vessels

Recovery by a MOSHIP using an over-side crane should only be carried out in sheltered or calm waters, as any swell makes the operation hazardous.

The limitation may be relaxed in some circumstances, but only at the discretion of the Director of Operations and depending on the size and stability of the MOSHIP. The typical recovery sequence when using a crane is as follows:

- The support boat is launched with driver and surface swimmer and takes up position by the Cyclops 1 marker buoy (if fitted) or as directed by the Director of Marine Operations.
- When Cyclops 1 is on the surface with full positive buoyancy achieved, the Surface swimmer boards Cyclops 1 after the Director of Marine Operations has instructed the Pilot to switch off the thruster's deadman's switch.
- The surface swimmer disconnects the surface marker buoy (if applicable).
- The surface swimmer remains with Cyclops 1.
- Cyclops 1 will be informed by the Director of Marine Operations to switch on thrusters and is clear to manoeuvre when the swimmer is in position.
- The MOSHIP manoeuvres to take up position.
- During surfacing operations, the tag lines, aft towline and main lift strap will have been rigged to the crane hook, swung overboard, and lowered to the waterline.
- Cyclops 1 will manoeuvre alongside the vessel and under the lift hook.
- The support boat will manoeuvre between the vessel's side and Cyclops 1 to act as fender as long as the personnel are not in harm's way.
- Director of Marine Operations will instruct the swimmer to connect the lift strap.
- As for launch the MOSHIP; the Vessel Master will stop thrusters on instructions from the Director of Marine Operations.
- When requested the surface swimmer enters the water and connects the towline.
- With lines connected and with the surface swimmer back in the support boat, slack is taken out of the lift wire, handling lines are manned and Cyclops 1 is lifted on-board the MOSHIP
- When positioned correctly on the cradle or deck, Cyclops 1 is secured. When informed to do so, the pilot may open the hatch and the crew can disembark.

Dived Operations Without MSLARS

- ### Cyclops Dive Procedure

  Following the launch of Cyclops, the Director of Marine Operations will give the order "clear to vent". The Pilot acknowledges this order and proceeds to dive Cyclops 1 in accordance with the following techniques:

  - Shallow Water Dives (less than 150 meters)
    - Pilot opens vents and reports, "venting now" to the Director of Marine Operations.
    - Support boat informs the Director of Marine Operations when Cyclops 1 leaves surface if he has no visual.
    - Once Sub-Surface:
      - Vents are shut.
      - UWT communications check carried out with MOSHIP.
      - VHF radio is switched off or volume turned down to prevent interference.
      - External lights switched on as necessary.
      - Through-hull penetrators, viewports and bilges checked regularly for ingress of water.
      - Ensure Sonar is functioning properly and that the pan and tilt are facing towards the seabed.
      - Depth is to be reported every 15 meters.
      - Thrusters may be used in the vertical mode to vary the descent rate.
      - At 25-30 meters from bottom, a controlled amount of HP air is blown into the ballast tank to slow the descent rate.
      - At a suitable distance from the seabed, the main propulsion can be used to further slow the rate of movement and, if applicable, to locate a suitable landing area.
  - Deep Water Dive (greater than 150 meters)

    The procedure for a deep-water dives differ only slightly from that of a shallow water dive in that:
    - Sonar is used as an echo sounder until the bottom is within range of the actual echo sounder.
    - Depth is reported to the MOSHIP every 30 meters.
  - All Dives

    Once on the bottom the Pilot reports to the MOSHIP "on bottom" and notes in the Dive Log, the following:
    - Depth
    - Visibility with lights on and off
    - Bottom conditions
    - Tide/current direction and strength
    - The Pilot then proceeds with his work task as instructed at the pre-dive brief

- Surfacing Procedures without MSLARS
  - Upon completion or termination of the Cyclops 1 mission, the Director of Marine Operations will order, "stand by for recovery".
    - The Director of Marine Operations shall ensure that the following conditions are satisfied:
      - No other vessels are in the area hazarding the operation.
      - Required deck personnel are closed up.
      - The support boat is on station (at submersible marker buoy if fitted) with surface swimmer as necessary.
      - The MOSHIP is on station.
      - The Director of Marine Operations shall give the instruction to Cyclops 1 "clear to ascend."
      - The Pilot will start surfacing procedure by either increasing buoyancy by use of: the HP air ballast system, thrusters, or a combination of both. The rate of ascent must be limited to a maximum of 18 meters (60ft) per minute.
  - Shallow Water Ascent – Pilot's Procedure
    - The Pilot should inform the MOSHIP "off bottom".
    - The Pilot should inform the MOSHIP of his depth every 15 meters.
    - If using air, control the ascent rate to 18 meters per minute by venting air from the ballast tank as it expands. Thrusters may be used to assist.
    - At 40 meters from the surface, the Pilot shall request final clearance to surface and await authorization before taking the submersible any shallower.
    - Cyclops 1 Pilot or additional crewmembers keep an upward lookout throughout the ascent to check for wires, obstructions or shadows etc.
    - On reaching the surface, the Pilot shall establish contact with the Director of Marine Operations on VHF.
    - Cyclops 1 shall blow HP air into the ballast tank as necessary to achieve full buoyancy.
    - During the ascent, the Pilot will endeavor to obtain a sonar contact of the MOSHIP.
  - Deep Water Ascent – Pilot's Procedure

    This procedure is basically the same as for the shallow water ascent, but the following differences must be incorporated:
    - Depth to be reported every 30 meters.
    - At 45 metres from the surface, the Pilot shall request final clearance to surface and await authorization before taking the submersible any shallower.
    - During the ascent, the Pilot will endeavor to obtain a sonar contact of the MOSHIP.

Communications

- Surface Communications
  - Surface communications are to be maintained between the MOSHIP and Cyclops using VHF on channel **76** and channel **16** is to be used as emergency only.
  - The MOSHIP will also maintain listening watch throughout operations on the appropriate local frequency (UHF/VHF) for the handling of traffic within the area.
    It is imperative that radio traffic should be kept to an absolute minimum during operations.
- Underwater Communications
  - An underwater communications log is to be constantly maintained between the MOSHIP and Cyclops 1 when in water. Communications are to be kept to an absolute minimum to enable the Cyclops 1 crew to devote their full attention to the designated work task.
  - In the absence of any other traffic, a communications check is to be initiated from the MOSHIP every 15 minutes. The Director of Marine Operations may extend this interval if communications are bad or when particular tasks would be hindered by the 15-minute rule. However, an extension of the interval must be considered the exception rather than the rule. The interval may be shortened.
  - In the event of loss of underwater communications for 30 minutes beyond the time interval set for that dive, i.e. if at 15 minute intervals, then 15 plus 30 minutes), the Pilot is to initiate emergency surfacing procedure in accordance with the loss of communications procedure.
  - Any variation from the 15-minute communications is to be clearly marked in the Communications Log.
- Emergency Underwater Communications Equipment
  - A serviceable portable underwater communications set complete with power supply and transducer assembly is to be kept on board the MOSHIP for use in the event of an emergency and should be tested during the first dive of the operation and regularly thereafter.

Emergency Procedures

- Procedure in the event of a Delayed Submersible Recovery
  - Restrictions for conducting manned submersible operations are laid down by Lloyds, DNV GL, M.S.A. and other classification bodies.
  - These restrictions state that manned submersible operations shall not be conducted in sea conditions in excess of Sea State 6 – In reality; however, this operating limitation may be increased or decreased depending on individual MOSHIP/submersible capabilities.
  - The Director of Marine Operations may decide to delay recovery because of excessive wind or sea conditions and informs Cyclops 1 of the reason for delayed recovery.
- MOSHIP Equipment Failure
  - If equipment failure on the MOSHIP prevents recovery, Cyclops 1 will undertake the following actions, until the situation is resolved:
    - All non-essential services to be shut down to maximize battery endurance.
    - Regular communication checks will be made incorporating Life Support situation reports.
    - Warm clothing and thermal blankets shall be worn.

      Note: Cyclops 1 has Life Support for 5 men/women for 96 hours.
- Submersible Issues

  If equipment failure in the submersible, or temporary snagging, requires a delay until a tide change allow extrication, Cyclops 1 Pilot will follow actions detailed above until the situation is resolved.
  - Seawater Ingress and Flooding
    - The main causes of Sea Water Ingress into Cyclops 1 are likely to be for any one, or combination of, the following reasons:
      - Broken front viewpoint or hatch viewport.
      - Leak at O-ring face of the main view port, conning tower hatch or the interface rings making up the Cyclops 1 chamber.
      - Fractured pipe open to sea.
      - Failure of penetrator seating or sealing arrangement.
    - Action in the Event of Water Ingress
      - The actions following the discovery of any breach in watertight integrity of Cyclops 1 will in all cases be dependent on the severity and nature of the incident.
      - In all but a catastrophic situation, any breach in watertight integrity can be effectively contained and a controlled assessment will be made to determine whether to continue with the dive.
    - Compartment Bilge Alarm
      - Check water level at sensor, there are 2 sensors installed within the Cyclops 1 chamber.
      - The leak is to be located and if appropriate the relevant hull valve(s) shut. If leak cannot be stopped by system isolation, and depending on the severity of the flooding, the submersible Pilot will either instigate Emergency Surfacing Procedure or commence a controlled emergency ascent.

- Control Sphere Water Alarm
  - No visual indication of the presence of seawater is possible. On hearing or seeing a visual Control Sphere water alarm on the Pilot's control console, the Pilot shall follow the Emergency Surfacing Procedure.
- Submersible Flooding

  In the event of flooding occurring to Cyclops 1 the following action shall be taken:
  - Inform Director of Marine Operations of situation.
  - MOSHIP to ensure it provides clear sea space above Cyclops 1 position.
  - Launch the support boat if not already in the water.
  - Cyclops 1 Pilot to use HP air ballast system to attempt to achieve positive buoyancy.
  - Weather conditions permitted, standby to evacuate Cyclops 1 when on the surface.
  - Surface team will prepare emergency buoyancy lift bags and the surface swimmer will fit to Cyclops 1 when she arrives on surface.

- High Pressure Air (HPA) or Oxygen Leak
  - Symptoms of Internal Leak:
    - Hissing noise
    - Rise in internal pressure (Verified on the barometer).
    - Crew notice pressure difference in ears.
    - Drop in HP air or 02 storage pressures.
    - Rise or fall in percent of 02 in the atmosphere on Analox meter.
    - Change in barometer reading.
  - Symptoms of External Leak
    - Noise of escaping air bubbles heard on the UWT.
    - Drop in air storage pressures in cylinders (with no resulting rise in internal pressure).
  - Action for Internal Leak

    If the leak is HP Air, the balance of the atmosphere will have been upset and pressure will increase. Actions to be taken are as follows:
    - Attempt to isolate and rectify leak.
    - If no success, follow emergency surfacing procedure.
    - If the leak is 02, avoid any action, which might cause a spark. Do not operate breakers or switches. Normal breathing can clear a small increase in 02.
    - Isolate the 02 cylinders within Cyclops 1.
    - **In extreme circumstances, whilst ascending at shallow depths, undo one hatch handle and hold on to the other hatch handle to prevent hatch blowing open.**
  - Action for External Leak
    - Follow emergency surfacing procedure.
    - Advise Director of Marine Operations of the situation.
    - Decision whether to terminate dive will be taken by the Pilot and the Director of Marine Operations depending on the nature of the mission, HP air remaining being the determinable factor.

- Smoke

  In the event that a crew member smells smoke but no fire is visible, the Cyclops 1 pilot will take the following action:
  - If electrical, attempt to isolate the problem function. If not possible, take all power off the electrical circuits. Pilot to ensure Cyclops is clear of possible entanglement prior to shut down.
  - Utilize crew members to investigate source of smell
  - Inform surface control at earliest opportunity
  - The decision to continue with the dive is at the discretion of the Pilot and the Director of Marine Operations. Ensure that O2 supply is back in operation if isolated.
- Fire

  The most likely cause of fire in Cyclops 1 is the burning of electrical equipment. For all fires, however, the following action is to be taken:
  - If electrical, attempt to isolate the problem function. If not possible, take all power off the electrical circuits. Pilot to ensure Cyclops is clear of possible entanglement prior to shut down.
  - Shut off Oxygen supply if fire is coming from the vicinity of the onboard Oxygen cylinders
  - If deemed essential, use the fire extinguisher to extinguish the fire
  - All crew on board Cyclops 1 are to utilize Built-In Breathing System (BIBS) and diving masks if deemed necessary.
  - It must be noted that the compartment internal pressure will increase if personnel go onto BIBS.
  - Inform surface control of the situation at earliest opportunity.

    Note: Combustibles such as matches and lighters etc. are not allowed inside Cyclops 1 during a dive. Great care must be exercised to ensure that no combustible materials are left inside the submersible during and following maintenance, and that all oil leakages are cleaned up.
- System Failure Whilst Submerged
  - The Pilot will keep the Director of Marine Operations informed of any systems failures and remedial action taken. If the failure is considered dangerous, follow emergency surfacing procedures.
- Snagging

  The most likely scenario for snagging occurring to Cyclops 1 would be for heavy rope or wire to be wrapped around the thruster areas or the landing gear.

  In the event of this situation occurring the Pilot is to inform the Director of Marine Operations immediately and should he be unable to free the obstruction the following action shall be taken:
  - Inform surface control of situation.
  - Reduce submersible electrical load to a minimum.
  - Crew are to put on warm clothing and don thermal blankets within Cyclops 1.
  - Monitor Life Support Systems and atmosphere analysers.
  - Maintain UWT contact with topside.

    In this situation, divers or an ROV system would be mobilized to assist Cyclops 1 to remove the snag. Director of Marine Operations to follow the Emergency call out plan unless the MOSHIP has the required resources on hand.

- Emergency Surfacing Procedures

  The decision to make an emergency XRAY ascent must take into account the following:
  - If working in or around platforms, structures or vessels; a clear ascent may not be possible and an attempt could severely aggravate the situation. In this instance, Cyclops 1 will have to be moved clear before the ascent by the use of thrusters, if operational, or by becoming neutrally buoyant and drifting.
  - In the event of an emergency, which necessitates Cyclops 1 surfacing immediately, the following action is to be taken:
    - Blow HP air into ballast tank to obtain lift.
    - Broadcast XRAY, XRAY, XRAY clearly on UWT.
    - Check VHF is switched on.
    - If emergency is of an electrical nature, take power off all circuits.
  - When on the Surface:
    - Obtain maximum buoyancy by blowing HP air into the ballast tank.
    - Jettison the frame and leg assembly (if necessary).
    - Attempt communication with the MOSHIP and support boat and pass continual reports on the VHF.
    - Crew are to don life jackets if necessary (do not inflate while in the submersible).
    - Adjust trim if necessary.
    - Await instructions from the Director of Marine Operations.
    - In extreme circumstances, if evacuation is necessary once on the surface, undo and open the hatch.
    - Pilot follows the crew into the water or support boat.
    - Only one crewmember to remain on the upper deck at any one time, all remaining crew should be in the support boat or in the water holding on to Cyclops 1.
    - Shut and dog the hatch after evacuation of Cyclops 1.
    - Stay within vicinity of Cyclops 1 until rescued by the support boat.
  - Action by Director of Operations on Receiving XRAY, XRAY, XRAY:
    - Dispatch support boat to expected Cyclops 1 surfacing position.
    - Prepare MOSHIP for full recovery.
    - Deploy any additional workboats along with the support boat.
- Distressed Submersible

  A distressed submersible is unable to surface without external assistance. The circumstances that would prevent Cyclops 1 from attaining positive buoyancy and therefore being unable to surface are:
  - Snagging to seabed or subsea obstruction.
  - Flooding to the Cyclops 1 compartment.
  - Loss of air ballast system and thruster control.

  Should an incident arise where Cyclops 1 cannot attain positive buoyancy and therefore be unable to surface, an emergency situation, but not necessarily a rescue situation, will exist. The factors effecting any given emergency situation and, consequently the action thought necessary to rectify any given situation, will vary according to the nature and severity of the incident.

Offshore procedures will, in the initial stages following a submersible accident, be governed by the time available to act in respect of the nature of incident, weather conditions and submersible subsea endurance. Preliminary preparations will be made to provide outside assistance.

Action in Cyclops 1

- Cyclops 1 has the ability to jettison the frame and leg assembly. The result of this action would be to increase positive buoyancy. This is to be carried out after attempting to fill the ballast bag and thrusting.
- Should these jettisoning measures not be appropriate or not work, Cyclops 1 will inform the Director of Marine Operations and await assistance, maintaining constant UWT communication watch, and make plans for an extended wait for rescue.

- Distressed Submersible Recovery
  - In a situation where Cyclops 1 should need to be lifted from the seabed, an appropriate vessel or system will be mobilized to assist.
- Emergency Recovery Lift Point
  - Cyclops 1 is currently fitted with a recovery/ lift strop secured to the main lift point.
  - Depending whether diver or ROV intervention is being used, one or two recovery lines will be attached to the strap. The strap is designed to lift Cyclops 1 completely from the water. If this action is not available, Cyclops 1 shall be lifted to the following:
    - The surface only, where flotation bags will be attached and a Personnel Evacuation effected.

      OR
    - To air diving depth where a heavy lift arrangement can be attached to the Cyclops 1 main lift point and the submersible lifted on-board the recovery vessel.
- Loss of Communications
  - Dived
    - If the Pilot totally loses communications with the surface for 30 minutes in excess of the regular communications interval, the dive is to be terminated and Cyclops 1 will surface following emergency surfacing procedures.
  - Action in Cyclops if surface communications are not clear and are garbled:
    - Attempt to signal using the following pings
      - Ping 1: Ping I can hear and understand your message
      - Ping 2: Affirmative / I am locked in position on MSLARS
      - Ping 3: Your message was not understood
      - Ping4: I am surfacing immediately (to be treated as for X-Ray until further information received).

        If no success, emergency surface after the time interval has elapsed
  - Surfaced
    - If VHF communications are lost on the surface, the UWT is to be used if possible or use mobile phones if signal permits.

    - If communications remain unsatisfactory, Cyclops 1 is to remain at full buoyancy until recovery is affected.
    - Surface crew will follow the emergency assist plan if communications with Cyclops 1 are not achievable in the original dive time shedule.

- Casualty Handling Operations

  The casualty handling equipment comprises of the following:
  - 1 x Military issue man removal strap
- MSLARS Buoyancy Issues
  - In the event of a malfunction with MSLARS buoyancy whilst under tow, the option to add additional buoyancy in the form of two Flotation bags will assist in maintaining the stability of the launch platform until the necessary repairs have been carried out.
  - The MSLARS has various attachment points on the upper deck, which will allow for the surface support personnel to attach and secure the bags to the hull. Once the bags are attached, a fill line shall be run from the support vessel and will subsequently be filled.
  - If the MSLARS has an issue which results in the slow sinking whilst undertow, then an attempt to release the tie down points and deploy Cyclops 1 will be carried out at the discretion of the Director of Marine Operations.
- Cyclops Recovery to MSLARS

  In the event that Cyclops loses all power and is unable to navigate into position on the submerged MSLARS, the following procedure will be followed:
  - Upon Cyclops 1 informing the Director of Marine Operations that she has lost control of all propulsion systems, the surface boat will be launched with the two divers dressed for an Emergency recovery.
  - Cyclops 1 once given clear to surface, will carry out a controlled ascent and fully blow her ballast tank once on surface.
  - The support boat will tow Cyclops using the aft tow point until she is centered above MSLARS.
  - The support boat will deploy the divers to attach the emergency towlines to the lower fwd and aft emergency recovery points on Cyclops.
  - These emergency recovery lines once attached to Cyclops are fed through the MSLARS deck eyes and taken back to the surface vessels.
  - The forward emergency towline will be taken to the surface tow vessel and the aft emergency towline handed to the support boat.
  - A coordinated effort between the 2 surface vessels to pull Cyclops directly over MSLARS landing skids shall be carried out.
  - It may be beneficial for the tow vessel to come ahead slowly to assist with the centering of Cyclops.
  - Once in position the diver closed up on the fwd end of Cyclops shall indicate to the Cyclops Pilot to vent the submersible slowly.
  - The aft diver will assist with maneuvering the submersible as it vents while the surface vessels take in the slack lines.
  - Once the submersible has been guided into its locked position the diver shall indicate to the Cyclops Pilot he is to blow air into the ballast tank to fully lock Cyclops into MSLARS.
  - If necessary, the divers should use ratchet straps to assist with the final positioning of Cyclops.

- Once all stations are happy the divers shall be recovered from the water and MSLARS brought to surface.

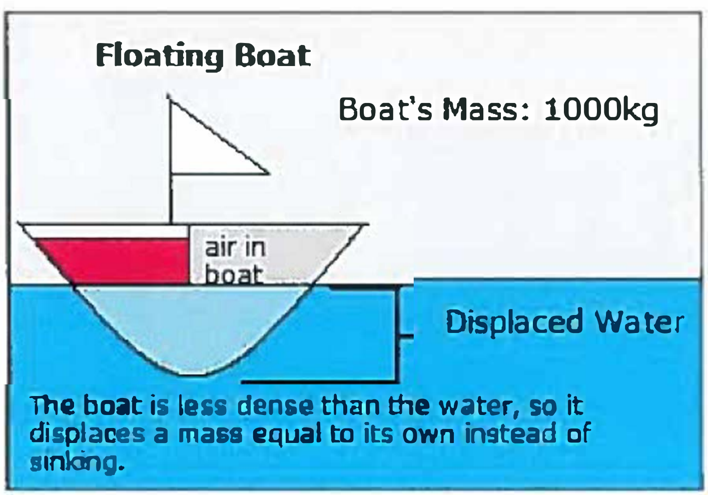
Appendices

Basic Submersible Theory

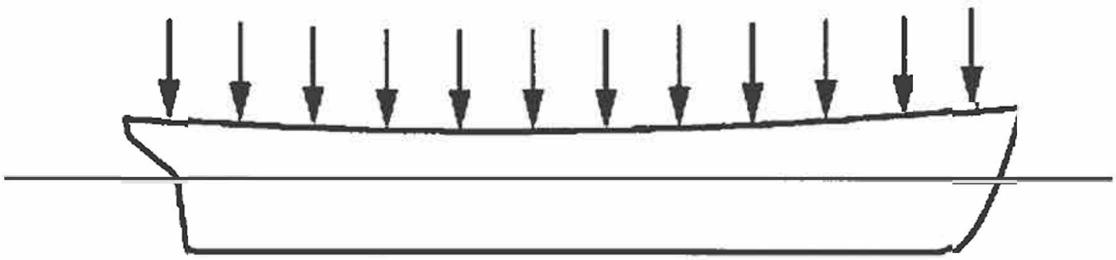
- **Specific Gravity**
  - The ratio of the mass of a solid or liquid to the mass of an equal volume of distilled water.
  - Pure water is the standard measure.
  - The ratio of pure water to pure water is 1:1 (1litre = 1kg).
  - Therefore, pure water has an SG of 1.000
  - Normally seawater has an SG of 1.017 and 1.027
  - Therefore, SG 1.017 = 1.017kg and SG 1.027 = 1.027kg

- **Salinity**
  - The salinity of seawater varies from one location to another.
  - For instance, oceans that have little or no tide generally have a high evaporation rate, therefore there is more salt than is in the open ocean so the SG is higher.
  - Note: Areas close to river outlets or close to mountainous areas have a lower SG due to fresh water run-off.

- **Archimedes Principal**
  - When an object is wholly or partially immersed in a liquid, the upthrust it receives is equal to the weight of the liquid displaced.

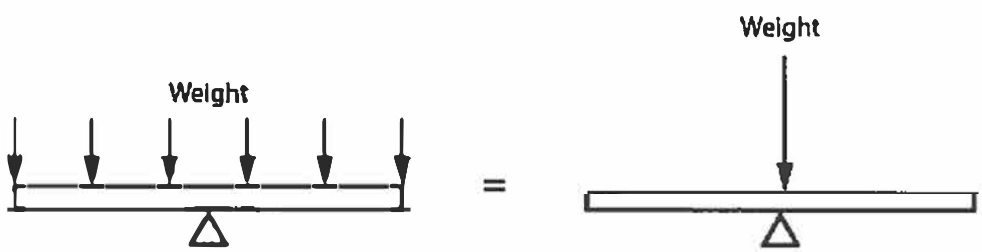


- **Buoyancy**
  - Because the density of the fluid displaced by identical objects is greater in salt water, the object is thrust up by a greater force in salt water rather than fresh.
- **Center of Gravity and Buoyancy**
  The weight of a vessel is distributed along its length, acting downwards over the entire structure.



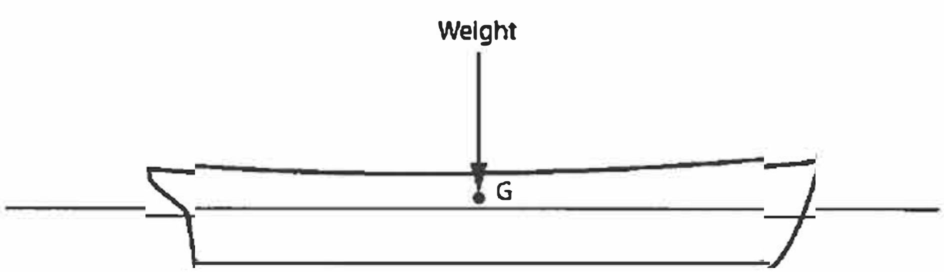
However, we consider all the weight to be acting vertically downwards through one point, which we call the Centre of Gravity (G). Consider a plank of wood, placed on a seesaw. Moving the plank back and forth you will find the point where the plank is balanced: this point is the Centre of Gravity.

If the plank is perfectly even through its length, the center of gravity will be exactly in the middle. If is not even G will be in such a position that the weight on one side will balance the other.

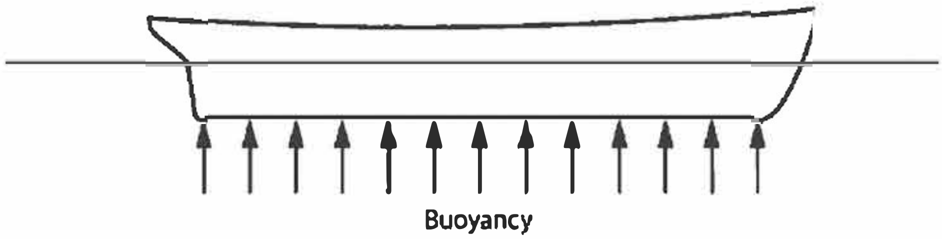


Note: The triangle in the diagram above represents the fulcrum or pivot point.

A ship is the same: all the weight is assumed to act downwards through the Centre Of Gravity (G).

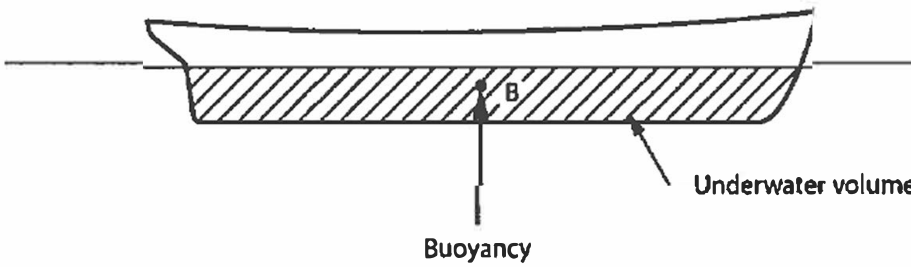


Having considered the weight of a vessel, we now look at the buoyancy opposing that weight. The hull of the ship is supported by water along its entire length.

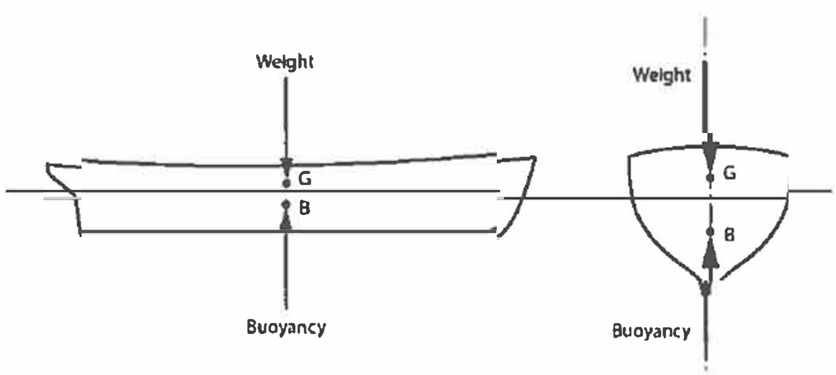


Just as the weight of the vessel was assumed to act downward through the Centre of Gravity, the buoyancy force is assumed to act vertically upwards through a single point as well.
This point is known as the Centre of Buoyancy (B).

This Centre of Buoyancy is the center of the underwater part of the vessel's hull.



The two forces, weight and buoyancy are equal and opposite. For a vessel floating at an even keel or upright G and B are in the same vertical (center) line. This will be true if we consider the vessel lengthways (longitudinally) or across the vessel (transversely).



- **Submersible Buoyancy**

  Under normal circumstances most Manned Submersibles shall be capable of achieving positive buoyancy by means of their air ballast system.

  Payload checks are to be carried out after all refit, maintenance periods and after large items of equipment are fitted.

  OceanGate Inc. at its Everett HQ holds a record of the payload state.

  The payload state shall be entered for each dive in the pre dive log, which will be signed by the pilot and countersigned by the Operations Director.

  Reserve lift buoyancy on all submersibles must always be observed prior to a dive.

- **Submerged Stability Theory**

  Having first established whether Cyclops 1is buoyant (negative or positive), we must consider whether the originally upright submersible, will remain upright.

  A submersible in stable equilibrium will, if given a small angular displacement, return to its original position. A submersible in unstable equilibrium will not return to its original position and the displacement will increase. In neutral equilibrium the submersible will neither return to its original position nor move further away from it.

  The conditions for submerged equilibrium are therefore simple.

  If the centre of gravity 'G' was to rise above the centre of buoyancy 'B', the couple caused by a small displacement would cause the submersible to rotate. For the consideration of the submersibles submerged stability it is sufficient to show that the distance BG is positive.
  When submerged, for a given condition B and G are assumed to be fixed points, and therefore submerged stability is the same in roll and in pitch.

  With the BG defined for a given scenario the effect on the BG can be considered over a range of subsurface conditions

- **Surface Stability Theory**

  The condition for the angular stability of Cyclops 1 is a little more complicated than when submerged. This is because when the submersible under goes an angular displacement about the horizontal axis, the shape of the immersed volume changes, moving the centre of buoyancy relative to the body. As a result, stable equilibrium can be achieved even when G is above B.

Diving Theory

- **Atmospheric Pressure**

  The atmosphere exerts a pressure on the earth's surface. The same way as water exerts pressure produced by the weight of air above the Earth.

  The atmosphere being gaseous means it is compressible. Therefore, its density varies relative to height.
  The greatest density on the earth's surface is at sea level.
  Pressure at Sea Level is approximately 1 Bar.

- **Water Pressure**

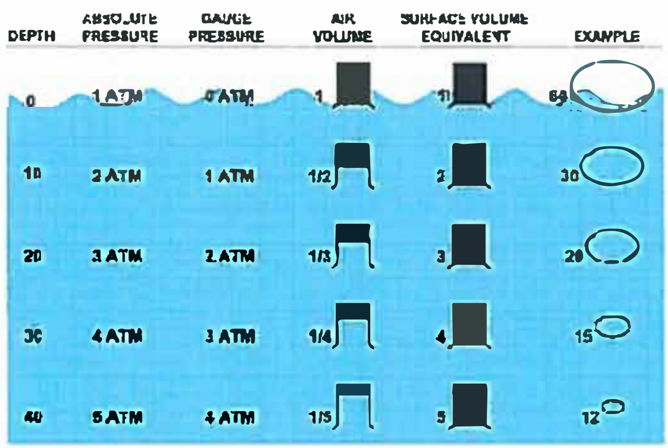
  As water is considered to be incompressible water pressure will increase by 0.1 Bar for every meter of a submersible descent.

- **Boyle`s Law**

  Boyle`s Law states, "If the temperature remains constant, the volume of a given mass will vary inversely as its absolute pressure."

  If the volume is decreased by one half, then the pressure and the density are doubled.

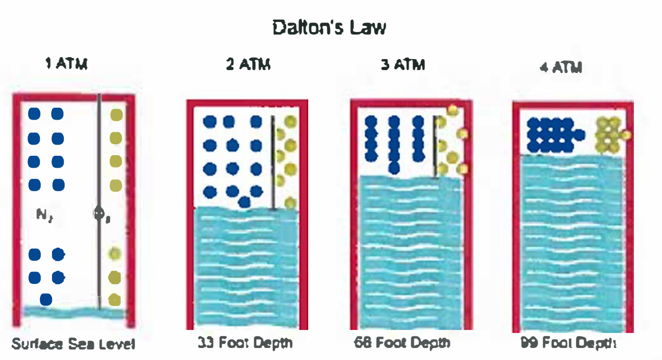
  As can be seen in the table below this shows the effects of pressure at depth.



Note: This chart gives a clear indication that at depth there is an unusable amount of gas in a submersibles system the deeper you go.

- **The Gases we are interested in**
  - **Oxygen (O2)**
    - No taste, color or odor.
    - It forms 21% of our atmosphere.
    - It is often used as a breathing gas instead of air.
    - The limits required to sustain life are:
      - Minimum 0.2 Bars Abs
      - Maximum 2 Bars Abs
      - For submersible operations the upper allowable limit is 23%
      - For submersible operations the lower allowable limit is 19%
  - **Nitrogen (N2)**
    - No taste, color or odor.
    - It forms 79% of our atmosphere.
    - It is not capable of supporting life.
    - Under High pressure it may lead to "Nitrogen Narcosis" at depth greater than 40msw
  - **Carbon Dioxide (CO2)**
    - It is a poisonous gas.
    - Seated at rest a person produces 0.22 lpm.
    - Light exercise a person produces 0.58 lpm.
    - No taste, color or odor except in high concentrations.
    - For submersible operations the upper limit should be 0.5%
    - At atmospheric pressure up to 3% can be breathed with no effect.
    - At 4% it causes CO2 Poisoning (Hypercapnia)
- **Basic Gas Laws**
  - **Dalton's Law**

    "In a mixture of gases, the partial pressure of each gas present is equal to the pressure that gas would exert if it alone occupied the original volume"



Gas Calculations

- Cyclops 1 minimum O2 pressure to achieve emergency 96 hours per person.
  - 6 Reserve Cylinders * 13 liters each = 78 liters' total
  - Consumption = 0.3 liters per person per minute
  - 0.3 liters/min/person * 60 min = 18 liters/person/hour
  - 18 liters/person/hour * 96 hours = 1728 liters/person
  - 1728 liters/person * 5 crew members (max) = 8640 liters' minimum quantity
  - 2000 psi x 78 liters / 14.5 psi = 10,758 liters of O2 (max capacity of onboard supply)

Number of Crew	Minimum O2 Reserve Pressure (PSI) (@ .3 liters/min/person)
1	321.23
2	642.46
3	963.69
4	1284.92
5	1606.15

<u>Built-In-Breathing System</u>

BIBS pressure required for 5 crew members for a 30-minute period
The average consumption of air consumed per minute is 8 liters.
8 liters/min * 60 min/hour = 480 liters/person/hour
480 liters/person/hour* .5 hours * 5 people= 1200 liters
Reserve bank = 90 liters

1200 liters/90 liter = 13.33 bar
13.33 bar *14.5 Psi = 193.33 psi

<u>High Pressure Air (HPA)</u>
<u>Minimum pressure required to fully blow the Ballast tank</u>

HPA Calculations at Maximum Depth

i) 2 Reserve Bottles * 45 liters each = 90 liters
ii) VBT Maximum volume = 170 liters
iii) 170 liters VBT Max. Volume + 90 liters' reserve volume = 260 liters
iv) Max Cyclops depth = 1640.42 ft (500 m)
v) Expected depth = 1640.42 ft/ (32.81 ft/bar) = 50.00 bar
vi) 260 liters* 50.00 bar = 13,000.16 total liters
vii) 13,000.16 liters/90 liters = 144.48 bar
viii) 144.45 bar * 14.5 Psi = 2094.47 Psi

Depth (m)	Pressure (Psi)
100	160.485
200	306.274
300	452.064
400	597.853
500	743.642

OceanGate

Submersible Pilot Training Task Book

Issue Number: 01

Date Issued On: 8/18/17

Author: David Lochridge

Approved By: ____________

This task book belongs to: [redacted]

Submersible Pilot Qualifying Date: ____________

Table of Contents

Summary

This document is part of the physical documentation of the Submersible Pilot Training Program required of all OceanGate submersible pilot trainees.

This task book is to be used in conjunction with both the Pilot Training Manual and OceanGate Operations Manuals.

For the benefit of both student and training staff, the purpose of this task book is to record the achievements of each student and show the work that remains to be carried out.

The practical tasks will be signed off once they have been completed to the satisfaction of the Director of Submersible Operations.

The Director of Submersible Operations will, on completion, sign off on lectures and successfully completed written and oral exams.

Many of the practical exercises require completion during the period of a single dive. Once the student has fully mastered the techniques and demonstrated required knowledge, a senior pilot or the Director of Submersible Operations will assess the student and sign the level completion page in the relevant task book section.

The last page of each level has a signoff sheet for completion by the Director of Submersible Operations once the student has successfully carried out the relevant checkout.

A certificate of competence will be issued to the student on successful completion off all written, theory and check out dives.

Lecture Evaluations

Submersible Pilot Theory: Level One

TASK	NAME OF INSTRUCTOR	SIGNED	DATE
Responsibilities of Submersible Pilot	[redacted]		21st Sept 2017
Submersible Buoyancy	[redacted]		21st Sept 2017.
Archimedes' Principle	[redacted]		21st Sept 2017
Center of Buoyancy and Gravity	[redacted]		21st Sept 2017.
Submersible Stability	[redacted]		21st Sept 2017
Pre/Post Dive Checks	[redacted]		31st Aug 2017
HP Air Systems	[redacted]		31st Aug 2017
02 Systems	[redacted]		31st Aug 2017
Life Support Systems	[redacted]		31st Aug 2017
Communication System	[redacted]		31st Aug 2017
Video and External Lighting System	[redacted]		31st Aug 2017
Emergency Hydraulic System	[redacted]		31st Aug 2017
Standard dive procedures	[redacted]		21st Sept 2017
Snagging	[redacted]		21st Sept 2017
Fire	[redacted]		21st Sept 2017
Distressed Submersible	[redacted]		21st Sept 2017
HP Air leak	[redacted]		21st Sept 2017
02 leak	[redacted]		21st Sept 2017
Emergency Surfacing Procedures	[redacted]		21st Sept 2017
Launch procedures MS. LARS	[redacted]		21st Sept 2017

Date of Evaluation Completion: 21st [redacted]

[redacted]anGate
Director of Marine [redacted]ations

Practical Tasks: Level One

TASK	NAME OF INSTRUCTOR	SIGNED	DATE
Internal Pre/Post Dive checks	[redacted]	[redacted]	31st Aug 2017
External Pre/Post Dive checks	[redacted]	[redacted]	31st Aug 2017
Atmosphere Control	[redacted]	[redacted]	31st Aug 2017
HP Air System Operation	[redacted]	[redacted]	31st Aug 2017
02 System Operation	[redacted]	[redacted]	31st Aug 2017
Communications	[redacted]	[redacted]	31st Aug 2017
Buoyancy Control	[redacted]	[redacted]	21st Sept 2017
Surface Maneuvering	[redacted]	[redacted]	31st Aug 2017.
Sub-Surface Maneuvering	[redacted]	[redacted]	21st Sept 2017
Emergency Hydraulic Systems	[redacted]	[redacted]	21st Sept 2017
HP Air leak	[redacted]	[redacted]	21st Sept 2017
02 Leak	[redacted]	[redacted]	21st Sept 2017
Fire in the Submersible	[redacted]	[redacted]	31st Aug 2017
Snagging	[redacted]	[redacted]	31st Aug 2017
Emergency Surfacing Procedure	[redacted]	[redacted]	21st Sept 2017.
Emergency Life Support	[redacted]	[redacted]	21st Sept 2017

Date of Evaluation Completion: 21[redacted]7

Director of Marine Operations

Lecture Evaluations

Submersible Pilot Theory: Level Two

TASK	NAME OF INSTRUCTOR	SIGNED	DATE
Operating Restrictions and limitations			
Dive plans			
Pilot's log and Ballast Calculations			
Gas Calculations			
Electrical Distribution			
Alarm System			
Navigation System			
Procedures in event of delayed submersible			
Seawater Ingress and flooding			
Casualty handling			
Launch procedures A-Frame			
Launch procedures Crane			

Date of Evaluation Completion: ________________

Practical Tasks: Level Two

TASK	NAME OF INSTRUCTOR	SIGNED	DATE
Electric System Operations			
Submersible Navigation			
Standard Dive Procedures			
Dive Planning			
Controlled Ascents			
Controlled Descents			
Search Techniques			
Alternative Methods of Power and Control			
Delayed Submersible Procedures			
Seawater Ingress and Flooding			
System Fault Finding			
Casualty Handling			
MS. LARS Operations			

Date of Evaluation Completion: ________________

Pilot Certification Signoff

OceanGate

Student Name [redacted]

Has successfully passed the final examination for Submersible Pilot Level 1.

Date 9/21/2017 Examine[redacted]

Signed [redacted] irector of Marine Operations

OceanGate

Student Name ______________________________

Has successfully passed the final examination for Submersible Pilot Level 2.

Date__________ Examiner______________________________

Signed______________________________________