UPGRADING THE ELECTRICAL AND ELECTRONIC SYSTEMS OF THE MANNED RESEARCH SUBMERSIBLE CLELIA

Robert Tusting, Mike Adams, Gregory Kennedy,
Frank Caimi, Benhur Chiong, and Joseph Spytek

Harbor Branch Oceanographic Institution, Inc.
5600 U.S. 1, North
Fort Pierce, Florida 34946

ABSTRACT

During 1992, the manned submersible PC-1204 was renamed CLELIA and upgraded by Harbor Branch Oceanographic Institution, Inc. to provide the underwater research community with a moderate-cost, high-capability, shallow-water submersible. This paper will discuss the changes made to the electrical and electronics systems to improve the capabilities of the vehicle to perform observations, collect specimens and samples, and obtain qualitative scientific data. The emphasis has been to retain the subsystems that have proven to be robust and reliable, to replace obsolescent subsystems which are difficult to maintain, and to add a number of 1990's technologies to make the CLELIA the most effective manned submersible capable of operations to a depth of 1000 ft.

INTRODUCTION

Harbor Branch Oceanographic Institution, Inc. has been operating manned and unmanned research submersibles for over 22 years. Our primary goal is to provide state-of-the-art manned submersibles for the best underwater observation, photo/video documentation, measurement, and in-situ quantitative sampling capabilities covering a wide range of marine and fresh-water disciplines. Occasionally, when the need arises, our facilities are made available for other tasks, for example, the CHALLENGER recovery operation (1). The latest addition to our undersea research capabilities is CLELIA, a three-person submersible with an operating depth of 1,000 ft. (Refer to Figure 1.) CLELIA, originally designed and built by Perry Oceanographics in 1978, for the support of the offshore oil and gas industry, is one of five PC-1200 series submersibles. This design has also been successful as a work, observational, and research vehicle. Many of these vintage vehicles are still in service worldwide.

Harbor Branch acquired CLELIA in 1992 to complement the two 3000-ft. JOHNSON-SEA-LINK (J-S-L) research submersibles (2-5). We spent a major part of 1992 refitting and outfitting her with the latest scientific and safety equipment. CLELIA's first year of operation, 1993, took her to the Bahamas, the Florida Keys, and the Gulf of Maine for 170 training and scientific dives. Planned cruises during 1994 include the Great Lakes as part of the Large Lakes of the World Initiative. The scientific results of these cruises will be reported elsewhere.

BACKGROUND

Although the J-S-L submersibles are acknowledged to be the best research vehicles in their depth class (3000 ft. maximum), there have been a number of research projects in shallower water (i.e., Great Lakes and Continental Shelf) which would favor a vehicle which:

- Is smaller, lighter, and can operate from a ship-of-opportunity.
- Can provide more dive-days per dollar.
- Has improved observational capability in low-visibility water (i.e., most of the Great Lakes).

Early in our refitting plans, we elected to retain many of the well-designed, robust, and proven systems and to replace those which have become obsolescent (unavailability of service and spare parts, etc.). In addition, we have added the special observational, measurement, and sampling capabilities our scientific users need for productive and quantitative science. This paper will summarize the changes made to the electrical and electronic systems. Some of the technology developed has already found applications in unmanned undersea systems.

MAIN POWER SYSTEM

The main power system consists of batteries, cabling, circuit protection and switching components, and monitoring circuits. All of the original components except the battery pods have been replaced to provide higher current capacity, improved maintainability and better monitoring of the batteries. The batteries are located in two one-atmosphere pods on either side of the hull as shown in Figure 2. Forty 12-volt, deep-cycle batteries are connected in series/parallel to provide 120 VDC at approximately 240 amp.-hr. total (available stored energy of 29 kW-hr.). A schematic diagram of one of the two battery pods is given in Figure 3.

The two parallel strings of batteries within each pod are isolated from each other and the main power bus by 600 amp diodes. In addition, the two battery pods are completely isolated electrically until they are switched into the 120-volt main power bus by double-pole circuit breakers within the hull. The pilot can select power from port, starboard, or both battery pods. Cables, connectors, and circuit protection device ratings have been selected to allow up to 150 amps to be drawn from either battery. One hundred and seventy five amp fuses are provided within each battery pod, and custom cable assemblies and connectors, rated at 300 amps, are used to connect the batteries to the main power bus within the vehicle.

Sealed lead-acid batteries are used to reduce the probability of an acid spill and reduce the amount of hydrogen gas released during charging. The word "sealed" is somewhat misleading; sealed lead-acid batteries (including those with gelled electrolyte) release a small but significant amount of hydrogen, although the amount generated is considerably less than for conventional lead-acid batteries. The possible problems associated with hydrogen generation within sealed housings are greatly reduced by the following redundant design features of CLELIA's power system.

- Current-regulated battery chargers are used to ensure that each individual battery string is charged at a rate less than that recommended by the battery manufacturer.
- Voltage regulation is also provided so that the batteries are not charged at a voltage higher than recommended by the battery manufacturer.
- The fuses within the battery pods are enclosed in sealed metal housings.
- Hydrolytic catalytic converters are provided in each pod to safely convert hydrogen and oxygen to water vapor (twenty per pod).
- Air-purging ports are provided in each pod so that a small flow of dry, low-pressure air is maintained during all charging operations. It is not necessary to open the battery pods for venting during battery charging operations.
- Gas detectors are incorporated in both battery pods which provide an indication of the internal hydrogen gas content. Automatic alarms are set to trip if the H_2 level exceeds 1%.* (Refer to a later section for details.)

Higher-energy-density batteries are being evaluated which should increase the total energy storage to approximately 35 kW-hr. Standard operating procedures require that there is a reserve battery capacity of at least 7 kW-hr. at the end of a dive.

AUXILIARY POWER SYSTEMS

24 VDC. Regulated twenty-four volt DC power is obtained from the main 120-VDC power system by custom-made, higher-power, DC-to-DC converters. Two completely separate 1200-watt assemblies are implemented by parallel operation of VICOR, VI-200 series converters (6). They can be used individually or connected in parallel to provide a total of 2400 watts @ 24 VDC. The submersible's control, instrumentation, and scientific systems

* The lower explosive limit for hydrogen in air is approximately 4%.

(with the exception of the alarm systems and a few 12-volt devices) operate from the 24-V supply.

12 VDC. Twelve-volt DC power is also obtained from the 120-VDC bus by two 100-w VICOR DC-to-DC converters. As with the 24-V system, the converters can be used individually or connected in parallel to provide up to 200 watts at 12 VDC.

115 VAC. Alternating current power for the sonar system and scientific equipment is provided by two 250-watt Avionic Instruments inverters connected in parallel to supply 500 watts of regulated 60-Hz power (6). Input power is obtained from the 24-VDC bus.

Electrical Penetrators/Cables. All of the electrical penetrators and cables supplied with the vehicle have been replaced. All hull-mounted electrical penetrators have stainless steel bodies and have been tested in accordance with Section 11.17.8 of the 1990 ABS Rules.

PROPULSION

Main Motor. The main propulsion is a 10-hp DC motor driving a 36"-diameter, 36"-pitch propeller through a reduction gear. The motor controller is a pulse-width-modulator which uses high-power SCRs to efficiently provide speed control. The Perry design is robust and reliable, and no modifications have been made other than some repackaging of the control into a smaller pilot's console. Primary steering control is provided by a hydraulically actuated rudder and an electromechanical autopilot.

Thrusters. CLELIA is provided with four thrusters as shown in Figure 1 and 2. One horizontal thruster is located at the stern and another at the bow for horizontal maneuverability. A pair of thrusters is mounted on a tilt mechanism so that they can provide vertical or forward/aft thrust. Simple and reliable bi-directional, on/off control is provided by the original relay controller. Replacements for the power relays have been located since the original manufacturer is no longer in business.

New thrusters have been designed and installed which use a permanent-magnet, 1150-rpm, 1-hp brush-type DC motor. The motor is directly coupled to a 10-inch diameter by 5-inch pitch custom propeller to eliminate the weight and efficiency loss of a gear box. Propeller fairings provide a nearly equal forward and reverse thrust of approximately 85 lb.

MONITOR SYSTEMS

Electrical System. A 3 1/2-digit multimeter has been added which allows the pilot to monitor the performance of the various safety and electrical systems. These include:

- Total current delivered from the 120-V bus
- 120-V bus voltage
- 24-V bus voltage
- 12-V supply voltage
- Inverter output voltage
- Hydrogen level port battery pod
- Hydrogen level starboard battery pod

The hydrogen gas detectors are powered by an isolated DC-to-DC converter which is energized whenever either battery pod is connected to the submersible. A low-battery-voltage sensor and indicator is being implemented.

Alarm System. The original multiple alarm system has been modified to additionally indicate a 25% lower-explosive-limit condition in either battery pod. Water-entry into either battery pod or the main hull is detected. A DC-to-DC converter replacement for the alarm battery is planned to simplify maintenance.

Ground-Fault Detection. The electrical ground fault detector circuit has been retained but is being modified to replace the battery with a small DC-to-DC converter.

COMMUNICATIONS

Radio. Communications on the surface are provided by a hand-held VHF transceiver. An external antenna has been found to be unnecessary, eliminating one hull penetrator.

Underwater Telephone. The obsolescent underwater telephone has been replaced with a new one provided by Orcatron Manufacturing, Ltd.

NAVIGATION

Sonar. An EDO, Model 258, high-resolution, color sonar system has been installed to replace the aged and obsolescent unit. Smaller obstacle-avoidance sonars are being evaluated for 1994 operations.

Autopilot. The original gyro-stabilized autopilot allows a constant-heading course to be steered while the pilot is occupied with other tasks.

Compass. A KVH Industries digital flux-gate compass has been installed with a mechanical compass maintained as a back-up.

Knot Meter. A rotor-type, digital-reading knot meter is provided. This is the same type as that used on the J-S-L submersibles for the past ten years (7).

Altimeter. An acoustic altimeter provides the pilot with a constant display of height-above-bottom.

Depth. Vehicle depth is provided by two mechanical pressure gauges calibrated in water depth.

Strobe. An Xenon strobe light is provided to aid in locating the vehicle when it is on the surface.

Acoustic Tracking. A Model 4327A acoustic beacon/transponder is provided for locating and tracking the vehicle while submerged using the shipboard Trackpoint II Positioning System. This acoustic system has been connected into a differential GPS to provide accurate, real-time tracking of CLELIA. This Integrated Mission Profiler was developed in collaboration with Creative Underwater Technologies. In addition to absolute positioning, it has proven to be a powerful tool for station fixing, site location, and directing transects.

External Lights. CLELIA is equipped with four 600-w Underwater Snooper Lights. Two will be replaced with 400-w high-efficiency, metal halide lights to increase the total illumination (9). Additional lighting can be provided to meet the requirements of special mission requirements.

CAMERA EQUIPMENT

Video. CLELIA is equipped with a MOS high-resolution, color video camera mounted on an electrical pan and tilt unit. A pair of lasers, for image scaling, is standard equipment. General photographic lighting is provided by four 250-watt quartz halogen lights. Provisions for continuously-variable intensity control are being made. The video recording format is Hi-8, provided by a Sony CVD-1000, computer controlled, video deck. Two 4" color, liquid-crystal monitors are mounted in a heads-up display. A Sony EVO-9700, Hi-8 editing station is available on the support ship. Spare penetrators are available for additional cameras which may be required for special missions or scientific projects.

Still Photography. Standard equipment includes a Benthos, Model 374, 35-mm camera and 100-w sec. strobe. An HBOI developed 85-mm telephoto camera system with laser focus is presently being constructed and will be available for the 1994 season. This will be a compact version of the telephoto/macro camera that has been standard equipment on both J-S-L submersibles for several years (8). Color film processing (E-6) is available onboard the support ship.

MANIPULATIVE AND SAMPLING EQUIPMENT

CLELIA is equipped with the basic sampling capabilities as those provided on the J-S-L submersibles (10). Prospective users of CLELIA are encouraged to talk with her Chief Pilot, Mike Adams, for specific details and special requirements. Some of the standard features include:

Manipulator. CLELIA is equipped with an HBOI seven-function manipulator functionally identical to those used on the J-S-L submersibles.

Suction Pump. A 3/4-hp electrically-driven suction pump is standard equipment for use with various scientific and sampling equipment.

Rotary-Bin Sampler. A smaller version of the J-S-L type sample holder is standard equipment. The bucket volume is 8 liter and there are twelve buckets.

Core Samplers. Punch-core and box-core samples are regularly used, although with CLELIA fewer samples per dive are available than with the J-S-Ls.

CTD. A stand-alone, internally-recording Sea-Bird CTD is standard equipment. Computer facilities for downloading data are customarily provided onboard the support ship.

CONCLUSIONS

CLELIA has been extensively outfitted to provide a highly effective underwater observational, photographic, and manipulative vehicle. Safety, reliability, simplicity, and versatility have been emphasized during the refitting process so that she can be operated and maintained by a crew of four. During her first operating year, CLELIA did not lose any dives due to equipment malfunctions.

The effectiveness of CLELIA is enhanced by a large acrylic view port (refer to Figure 1) which is within 1/2 meter off the bottom and allows two scientists/observers to simultaneously observe and operate the state-of-the-art sampling equipment. Photographic capabilities permit large sophisticated camera systems to be operated within the one-atmosphere hull as well as the external photo/video cameras.

ACKNOWLEDGMENTS

The authors would like to thank Annell Nelson for her care in preparing this manuscript and Tim Askew for his efforts in reviewing it. This paper is HBOI Contribution No. 983.

REFERENCES

1. Askew, T.M. JOHNSON-SEA-LINK Submersible's role in the Challenger Recovery. Proc. OCEANS '87, pp. 1225-1229.
2. Youngbluth, M.J. Manned Submersibles and Instrumentation: Tools for Oceanographic Research. Proc. SUBTECH '83, pp. 335-344.
3. Askew, T.M. Submersibles for Science —JOHNSON-SEA-LINK I and II. Proc. OCEANS '84, pp. 612-616.
4. Clark, M.K. Continuation of a 'Sedimental Journey' Planned in the Great Lakes. Sea Technology, May, 1986, pp. 23-26.
5. Cooper, R.A. and I.G. Babb. Manned Submersibles Support a Wide Range of Underwater Research in New England and the Great Lakes. Proc. OCEANS '88, pp. 112-118.
6. Tusting, R.F. and L.D. Taylor. Power Distribution and Conversion in Undersea Systems. Sea Technology, July, 1992 pp. 58-61.
7. Tusting, R.F. An Improved Digital Knot Meter for Submersibles and Remote Vehicles. Proc. INTERVENTION '87 pp. 94-97.
8. Tusting, R.F. Enhancement of Undersea Measurement and Vision Systems Using Lasers. Proc. INTERVENTION '90, pp. 284-290.
9. Olson, M.S., D.G. Rimer and S.B. Parker. ROV Lighting with Metal Halide. Proc. INTERVENTION '89, pp. 182-189.
10. Tietze, R. and A.M. Clark. Remotely Operated Tools for Undersea Vehicles. Proc. ASME Symposium: Current Practices and New Technology in Ocean Engineering, 1986, pp. 219-223.

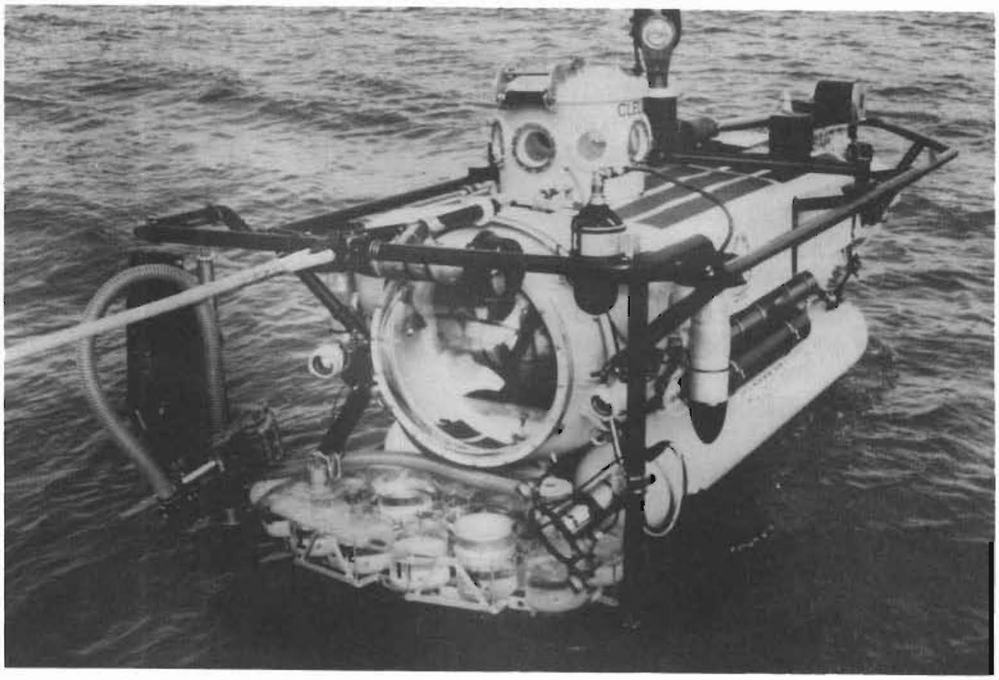

Figure 1. Photograph of CLELIA showing some of her operational and scientific equipment.

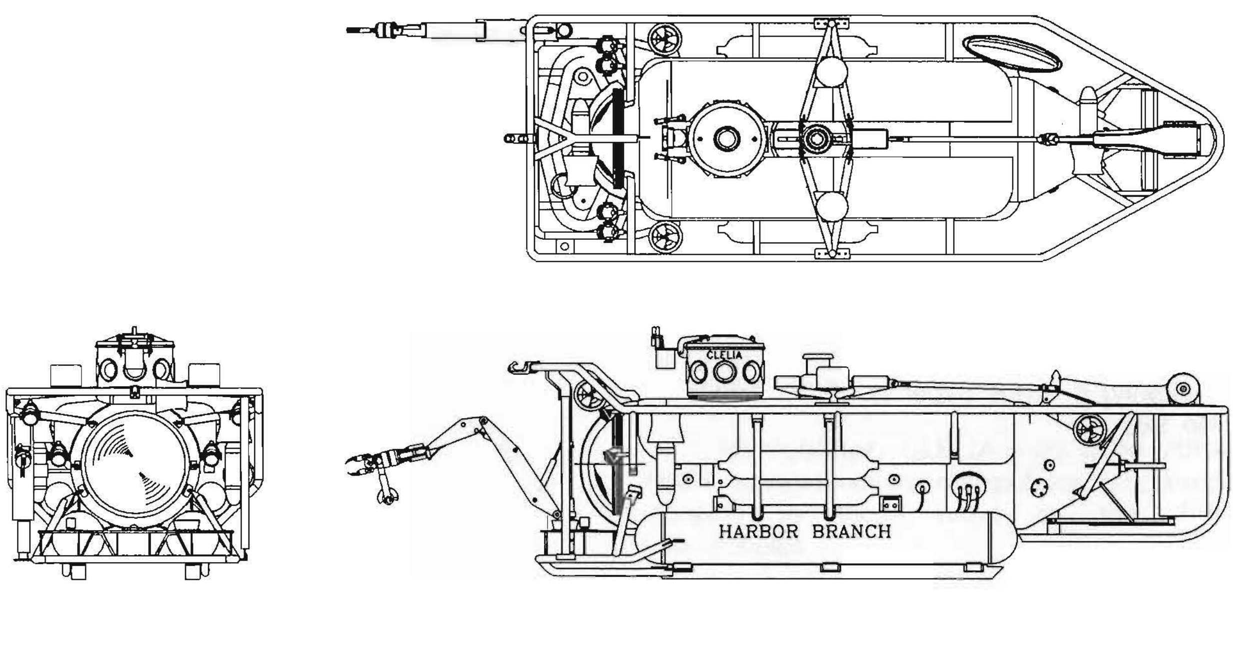

Figure 2. Outline drawing of CLELIA.

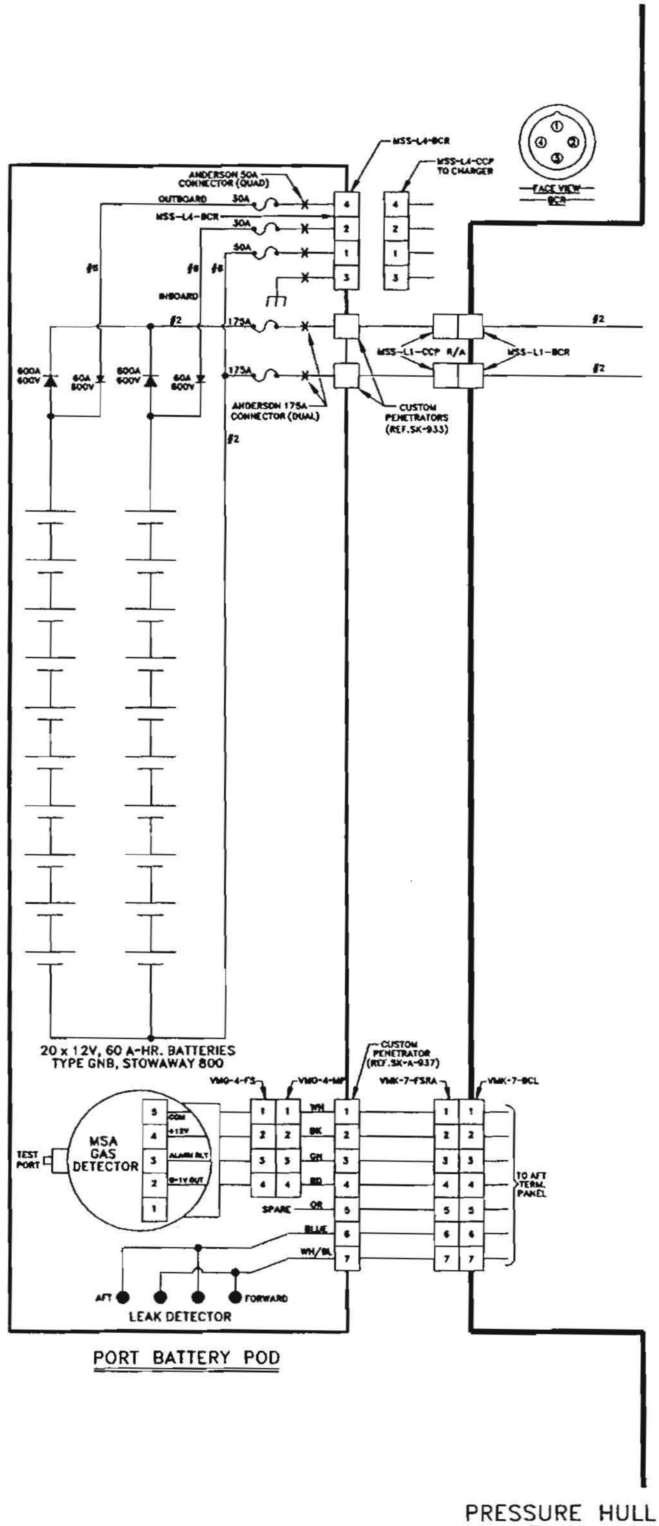

Figure 3. Schematic Diagram of Port Battery Pod.