Training Regimen for Exosuit Atmospheric Diving System

Considerations for Next-Generation Scientific and Commercial Applications

By Michael Lombardi • James Clark

The Exosuit is a cast-aluminum rotary joint atmospheric diving system (ADS) designed and built by Nuytco Research Ltd. (Vancouver, Canada). This ADS allows pilots to operate safely down to a water depth of 1,000 feet, while still retaining exceptional dexterity and the flexibility necessary to perform delicate work.

The fundamental premise of any ADS diving system is that cabin pressure is maintained at a surface equivalent, thereby eliminating the pressure maladies associated with wet diving. The Exosuit utilizes a unique series of rotary joints with only half the friction under pressure of previous ADS joint designs. This remarkable improvement allows the diver/pilot to articulate the suit with improved dexterity and perform tasks more effectively than prior-generation suits.


Michael Lombardi dives the Exosuit ADS in a test tank at Nuytco Research Ltd.

(Photo Credit: James Clark)

Many ADS developments of the modern era evolve from the lineage developed by Dr. R. T. (Phil) Nuytten. Nuytten's original rotary joint patent in 1985 provided the breakthrough that allowed modern ADS systems to evolve as practical subsea equipment.

After Nuytten's rotary joint had been proven and incorporated into the Newtsuit, ADS became a useful tool for certain underwater tasks. Two notable projects demonstrate the capabilities of this technology. Recovery and replacement of the ship's bell from the SS Edmund Fitzgerald in 1995 required special rigging, ultrathermic burning and the coordination of ADS work with submersible operations. Between 2009 and 2011 a series of construction tasks undertaken at NYCDEP Shaft 19, the principal water supply aqueduct to New York City, evolved to become the most complex ADS project ever undertaken. Despite these accomplishments, shortcomings in ADS technology and the tooling that is readily available historically offers limited applications for atmospheric diving.

Phil Nuytten introduced his concept for the Exosuit in the year 2000, and his new design incorporated improved technology, as well as numerous modifications derived from his practical experience with a variety of ADS systems. A decade of development by Nuytco Research culminated in beta testing of the Exosuit during 2009.

The existing thruster-powered Exosuit is now expected to be followed by Nuytten's concept for an untethered swimmable ADS, which is in development. In 2013 Nuytco completed the first production Exosuit for delivery to the Diving Division of J. F. White Contracting Co., a general contractor based in Framingham, Massachusetts.

Exosuit Specifications

The Exosuit is depth-rated at 1,000 feet, with A536 aluminum alloy castings and a weight of 650 pounds (without pilot), depending on configuration. Its life support system comprises two redundant oxygen systems, with a total capacity of 50 hours, and a 50-hour carbon dioxide scrubber. Propulsion is provided by four 1.6-horsepower thrusters (expandable to eight), magnetically coupled with direct drive.

(Photo Credit: Michael Lombardi)

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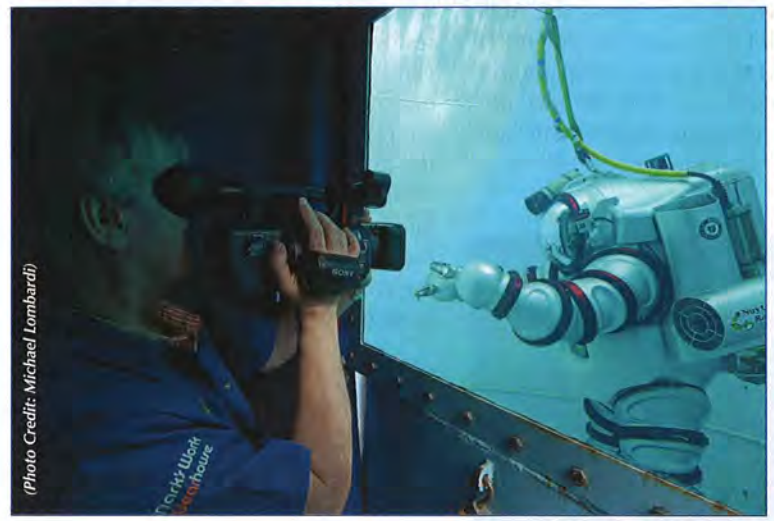

(Photo Credit: Michael Lombardi)

(Top) Ed O'Brien (diving safety officer, Woods Hole Oceanographic Institution) manages the topside interface and control system for the Exosuit during a training dive. (Middle) Lombardi works through pre-dive checks before being locked into the suit. (Bottom) Dr. Phil Nuytten, inventor of the Exosuit, observes and records video of a test pilot.

The telemetry/control system consists of the PLC-based distributed control system by Kyoto, Japan-based OMRON; gigabit Ethernet over fiber-optic; remote (topside) control of thrusters, thruster trim, lights and tooling; and remote AMS (atmospheric monitoring system). Communications work through a full duplex intercom over copper, IP intercom out and acoustic through water communications for backup. The umbilical is 1250 LF nominal, OD 0.980-inch nominal and neutrally buoyant, and has minimum 27-inch bend radius, breaking strength of 7,200 pounds, and a power requirement of 50 amps, 50 to 60 hertz.

Emergency equipment includes an umbilical jettison capability, thruster jettison capability and emergency battery. Ancillary equipment includes an HD H.264 Blu-Ray Codec camera; Imagenex (Port Coquitlam, Canada) miniature 852 scanning sonar; and two Nuytco Newtsun LED lights at 150 watts and 9,600 lumens each.

Training Program

The initial Exosuit pilot training and acceptance program for this long-awaited ADS system occurred July 2013. The Exosuit training program was offered by Nuytco Research Ltd. at their facility in North Vancouver. It spanned seven days and provided classroom instruction, topside operations and in-water test tank practice for 10 individuals. The training program was organized and adapted to a variety of pilots representing a wide range of experience and application interests.

System Familiarization. Classroom lectures (approximately six cumulative hours) provided an understanding of the development motives and history of ADS, as well as system-specific instruction for the control system, rotary joint maintenance, and an overview of system telemetry. While this training took place in a controlled shop and classroom environment, system familiarization continued throughout the week with direct oversight and interaction by experienced Nuytco technicians and ADS pilots. This provided ample one-on-one time for questions, specific subsystem familiarization and troubleshooting.

Fit Test. Each participant rotated through a fit test protocol (approximately 30 minutes per pilot). This procedure included instruction on donning the suit, lock-in process, familiarization with internal suit systems and their functions, and a time allowance to rehearse placing and removing the pilot's arms into the suit arms. The fit test proved to be a limiting factor for some individuals.

Adjustment can be made to the Exosuit by way of torso extension rings, and boot extensions, but the rigid suit can create limitations for certain pilot physiques. It should be noted that following the fit test procedure, only eight of 10 participants undertook in-water instruction, though all continued practicing both topside functions. One pilot candidate had calf muscles too large to enter the leg segment, and the other could only insert one of his arms into the suit arm. Individuals progressing with training had their bodyweight recorded to provide a convenient reference for ballast adjustments during pre-dive ADS setup.

Primary and Redundant Life Support Functions. All trainees were guided through a dry run (approximately 30 to 45 minutes per pilot) of primary and redundant life support system functions after being locked into the suit. The 1-atmosphere enclosed cabin space requires particular attention to atmospheric management. The Exosuit system is generally intuitive, including the regulation of oxygen supply via both an adjustable bellows and needle valve bypass, and an electric fan circulates cabin gas through the carbon dioxide scrubber system. The pilot is tasked with maintaining a constant oxygen fraction of approximately .21 bar while under a -1 pound per square inch vacuum. Deviations from this oxygen percentage are continuously monitored topside, with data transmitted through optical fiber in the umbilical, and the pilot can be instructed to adjust the bellows to match metabolic consumption during work or rest.

Pre- and Post-Dive Procedures and Maintenance. A detailed pre- and post-dive checklist is provided with the Exosuit. The checklist was modified slightly throughout this initial training program to reflect trainee input and considerations for actual field operations. The checklist sequentially scrolls through pilot systems and verification procedures, as well as topside systems and operations at the control center, then rigging checks and procedures for the suit lift and deployment/recovery. This procedural checklist was worked through in detail (approximately 1 hour pre-dive, 30 minutes post-dive) during every training dive (approximately 15-person dives at 60 to 90 minutes each over three days of in-water training tank practice). Many of the procedures became intuitive after this repetition, and participants generally agreed that the system was intuitive for pre- and post-dive tasks with relatively quick turnaround between pilot excursions.

> *"The Exosuit represents the next generation of ADS technology."*

Deployment and Retrieval Procedures. Exosuit deployment and retrieval will vary depending on the platform or vessel utilized for operational support, but efforts were made to standardize rigging the suit with pilot aboard for lift from or to the suit staging frame which also opens the ADS torso for pilot entry and exit. Attention was devoted to team manning requirements to ensure safe and effective deployment. Crew requirements will vary depending upon the work platform or vessel; however, it was evident that the minimum manning requirement is five people. This team consists of a dive supervisor, a tender, deck foreman/winch operator, crane/launch-and-recovery system operator, and pilot. Personnel assumed each role during our training and benefited by practicing coordination during each deployment and retrieval procedure.

In-water Function and Operations. Each pilot trainee was afforded at least two in-water rotations (approximately 60 to 90 minutes each) in a test tank on site. While brief, this provided adequate time to learn basic suit functions with an emphasis on directional mobility using the thrusters. Exercises were performed such as deploying and restowing a knife, attempting to touch various tank features with either hand pod manipulator, maintaining a vertical position in midwater, and attempting to break a conventional shackle or retrieve a dime from the bottom of the tank. Additionally, emergency procedures for donning a BIBS-style breathing mask to bypass the scrubber fan were rehearsed.

Generally, all pilot trainees commented on the relative simplicity of suit functions, though it was universally acknowledged that considerable practice time in the water would be required to rehearse special tasks or to manipulate tooling for upcoming work. Probably the best indication of Exosuit function was illustrated by the training results achieved by one professional engineer. This individual was a recreational scuba diver with only a half dozen open-water dives, but after his Exosuit training rotations he could retrieve a dime from the bottom of the tank and was eager to perform more complicated and meaningful work.

Considerations for Practical Applications

Throughout the training program, discussions continued regarding potential mechanisms to provide access to the Exosuit, particularly for the scientific community. The concept is supported by J. F. White, as it would broaden the market for this technology, and afford benefits to new areas of study in ocean exploration. The training program clearly offered a brief overview of how pilots with variable and diverse professional backgrounds were able to adapt easily to and operate the Exosuit.

The aptitude attained with time in the water as a diving professional may be needed to carry out delicate tasks or while piloting the Exosuit in difficult working conditions. Recognition of situational and spatial awareness in the underwater environment comes only with prior experience. Scientific pilots with little ADS experience may not be able to perform working tasks (beyond casual observation) efficiently, but they will also not face the critical time limitations imposed with conventional wet diving techniques while operating at the same depths. If the scientific diver underwent a preliminary training program similar to the one held in Vancouver and then completed additional practice shifts with particular tooling or collection apparatus, significant results could be achieved at the outset, and pilot capabilities would only improve with experience. This topic will be the subject of future study and evaluation.


(Photo Credit: Michael Lombardi)

A test pilot is lifted by crane and deployed in the test tank in Vancouver.

Exosuit operations and maintenance became intuitive after a few day of training, but limitations should also be recognized. Performing a range of tasks, either scientific or commercial, will require development and testing of custom tooling that can be actuated by the pilot. These efforts are underway.

Conclusion

The Exosuit represents the next generation of ADS technology. It has proven during its initial testing to be simple and intuitive to operate, and basic operations can be carried out by new pilots varying in their underwater experience.

At the conclusion of training at Nuytco in Vancouver, J. F. White ordered a second Exosuit and will continue program development with the intent of expanding the range of end-users.

Practical limitations of the Exosuit have been recognized, but specific tooling is now being developed to expand the variety of in-water ADS capabilities beyond the underwater construction traditionally performed by J. F. White. Efforts are now underway to deploy the Exosuit for scientific, engineering and commercial applications.

Acknowledgments

The authors extend their thanks to the team at Nuytco Research Ltd. for their diligent efforts and hospitality during this very successful training program. We also wish to acknowledge J. F. White Contracting Co. for their foresight in working with Nuytco to bring this new generation of ADS technology to the commercial marketplace, while considering the added potential for scientific applications.

References

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