Evolution of The NOAA Minimum Manufacturing and Performance Requirements for Closed Circuit Mixed Gas Rebreathers

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Abstract

The NOAA Diving Program (NDP) and NOAA’s Undersea Research Program (NURP) together support more than 25,000 dives per year. Under the Outer Continental Shelf Lands Act, NOAA has the mandate to increase the safety and efficiency of divers through advanced diving technologies. To increase the allowable working depth to 300 feet for NOAA-supported scientific dives the NDP and NURP initiated a program to investigate the introduction of closed circuit mixed gas rebreathers (CCRs) into NOAA dive programs. During this investigation it was discovered there was no consensus standard covering CCRs; the European Union Standard was not issued at that time. To answer this need, a NOAA-sponsored working group generated a safety standard titled NOAA Minimum Manufacturing and Performance Requirements for CCRs. This paper will discuss the purpose, development, intended use, and status of the requirements.

Introduction

The National Oceanic and Atmospheric Administration (NOAA) has two major programs that utilize diving to conduct undersea research - the NOAA Diving Program (NDP) and the National Undersea Research Program (NURP). The goal of both of these federal programs is to help NOAA describe and predict changes in the Earth's environment, and to conserve and wisely manage the Nation's coastal and marine resources.

The NDP primarily supports intramural research programs conducted by personnel within NOAA's three major line offices: the National Marine Fisheries Service (NMFS), the National Ocean Service (NOS), and the Office of Oceanic and Atmospheric Research (OAR). Although not a major line office, NOAA Marine and Aviation Operations, which provides operational support for the aforementioned major line offices, also utilizes divers and therefore, falls under the auspices of the NDP.

NURP supports extramural research programs conducted by scientists from various academic and marine research institutions throughout the nation through six regional centers and one institute for undersea technology. These NOAA partners operate on funds provided by NOAA grants, and the grants require that all operations be performed in a safe and environmentally responsible manner.
Background

In the late 1990’s, the NDP began receiving formal requests from several NOAA offices to undergo training in closed circuit mixed gas rebreathers (CCR) from commercial vendors. The requests were reviewed by the NOAA Diving Safety Board (NDSB) and all were approved. Upon further investigation into the rebreathers being used for training, it was discovered that very few had undergone any type of testing other than that conducted by the manufacturers’ themselves.

One of the basic tenets of the NDP is that all diving equipment used by NOAA personnel be thoroughly tested and evaluated for reliability and functionality. For life-support equipment, such testing must be completed by an independent, third-party that is not affiliated with the manufacturer. The requirement for such testing is both ethically and legally justified under the NDP charter as outlined in the NOAA Administrative Order 209-123 that states: “The purpose of the NOAA Diving Program is to train, certify, and equip scientists, engineers, and technicians to perform a variety of underwater tasks in support of NOAA's mission and to ensure that all diving operations are conducted safely, efficiently, and economically.” The same document also lists several goals directly tied to the testing of equipment – they are: 1) to provide safe, state-of-the-art, and well maintained dive equipment, 2) to investigate and implement new diving technologies and techniques, and 3) to provide equipment, personnel, and expertise to NOAA field operations, as needed.

Concerned by the lack of independent testing of CCRs, the NDP invoked a moratorium on further rebreather training until appropriate testing was completed and the NDP was satisfied the units were safe. The moratorium was imposed in 2001, and concurrently the NDP initiated a test and evaluation (T&E) program to investigate commercial-off-the-shelf (COTS) rebreathers for potential use by NOAA personnel.

CCR Investigation

In 2001 the NDP conducted a survey of all NOAA divers to determine what capabilities and features they most desired in a rebreather. Based on the results of the survey, four COTS closed-circuit rebreathers were identified as candidates for the T&E program. They included: the Olympic Submarine CCR 2000, Steam Machine Prism Topaz, Cis-Lunar Mk 5P and the Ambient Pressure Valve Buddy Inspiration. Two of the units, the CCR 2000 and the Topaz, had already been tested, or were in the process of being tested, by the US Navy Experimental Diving Unit (NEDU) in Panama City, FL for possible use by US Navy personnel. The Topaz had already completed unmanned testing and was scheduled to undergo manned testing in early 2002. The CCR 2000 was eliminated from consideration early in the process due to quality and assurance (Q&A) issues, and therefore did not undergo either unmanned or manned testing.

In 2002, the NDP approached the NEDU about conducting unmanned and manned tests on the Cis-Lunar Mk5P and the Ambient Pressure Valve Buddy Inspiration rebreathers. In preparation for testing of the two units it was necessary to determine what tests needed to be
performed and what criteria would be used to determine acceptable results for each test. With assistance from several experts in the field of rebreathers, a NOAA test protocol was developed based on criteria used by NEDU for evaluating equipment for the US Navy. Although not as stringent as that used by the US Navy, the NOAA criteria were considered reasonable and appropriate for the type of work expected to be performed by NOAA divers.

The MK5P completed both unmanned and manned testing. The Inspiration only completed unmanned testing. The NEDU declined to conduct manned testing on the Inspiration due to concerns over potential hazards created by the location of the batteries within the breathing loop. NEDU completed testing of the two units in late 2002 and summarized the results in two reports: 1) NOAA Diving Program Underwater Breathing Apparatus: Unmanned Evaluation, TA02-07, NEDU TR#03-02, February 2003, and 2) NOAA Diving Program Underwater Breathing Apparatus: Manned Evaluation, TA02-07, NEDU TR03-07, March 2003. The NDP immediately released copies of the reports to the two manufacturers.

Consensus Standards

Following testing of the two units by NEDU, the NDP decided to develop minimum manufacturing and performance requirements for CCRs. It was at this point that NURP joined forces with the NDP to help co-develop these minimum requirements. A team of experts comprised of NOAA personnel, rebreather users, University Diving Safety Officers, and outside consultants, worked for almost two years to produce the document, “The NOAA Minimum Manufacturing and Performance Requirements for Closed Circuit Mixed Gas Rebreathers.” The purpose of the standard is to establish minimum qualification criteria by which closed circuit mixed gas rebreathers (CCRs) will be evaluated for potential use by NOAA, NOAA sponsored, or otherwise NOAA authorized, personnel. The criteria outlined in the document were selected to provide NOAA management with a fair assurance that the equipment will not endanger the diver, will not limit his ability to perform the work, and will do what the manufacturer claims it will do. The goal of the document is to ensure that NOAA authorized CCRs are reliable and operator friendly, and meet or exceed reasonable performance standards.

Also during this time, NURP contracted the U.S. Navy Coastal Systems Station, in Panama City, FL, to further investigate the battery used in the Inspiration rebreather. The results of the investigation are in the report: John Camperman et. al., U. S. Navy Coastal Systems Station, Safety Evaluation Lithium Manganese Dioxide Batteries in a Diving Life Support Recirculator, September 24, 2003. The investigation found that under normal dive conditions, i.e., hyperbaric environment, the Lithium Manganese Dioxide battery used in the Inspiration, produce 1,2-dimethoxyethane, a compound that is harmful by inhalation to humans, above the maximum allowable level of 0.02 ppm. The study further substantiated the position that the breathing loop must be free of any materials or components that could provide a source of ignition, or that may off-gas noxious or hazardous gases or otherwise are potentially harmful for human life support, e.g. batteries or PVC coatings.
Framework For The Requirements Document

The NDP/NURP team established a framework for a rebreather standard based on requirements for high quality and reliability, safety features, and reasonable performance measures that would allow a NOAA-supported diver to perform scientific tasks at the specified depth. The resulting standard was designed to be free of bias toward or against any particular design or manufacturer and was not meant to create a competition among manufacturers, but to establish safety requirements that all manufacturers must meet.

The NOAA Minimum Manufacturing and Performance Requirements for Closed Circuit Mixed Gas Rebreathers involves three basic requirements: 1) be manufactured and tested to an acceptable quality control program, 2) possess certain components and/or perform certain functions deemed necessary and appropriate for CCRs by NOAA, and 3) meet minimum performance criteria during unmanned and manned testing by a NOAA-approved independent, third-party.

The following is an outline of the NOAA Minimum Manufacturing and Performance Requirements for Closed Circuit Mixed Gas Rebreathers:

Introduction

The introduction states the purpose, rationale, and goal of the standard. It also outlines to whom the standard applies.

Qualification Criteria

1. Manufactured and Tested to an Acceptable Quality Control Program
2. Capabilities/ Components And Performance Requirements.
   2.1 Capabilities/ Components
   2.2 Performance Requirements
Appendix A: Required Testing
A.1 Unmanned Tests
A.2 Manned Tests
A.3 Report

Consensus Review Process

The draft requirements document was reviewed (sometimes several times) by members of the NDP Diving Safety Board, NDP Technical Advisory Committee, and members of the NURP Diving Council. These three groups were condensed into a single working group that produced the first draft of a consensus document at a workshop held in Long Beach, CA following the AAUS Symposia in March 2004. The document was sent to selected individuals and organizations either nominated by the working group or those who asked to review the document during the 2004 AAUS Symposia. Finally, it was posted for public comment with a deadline for comments of January 1, 2005.
During this process, reviewers submitted extensive questions and comments and each comment was considered for inclusion. However, many of the comments suggested additional testing that was more appropriate for the purchasing phase, or that should be part of an operational procedure. The decision was to limit the focus to one of addressing minimum standards.

During the process of drafting these requirements, the European Standard EN 14143, Respiratory Equipment-Self contained re-breathing diving apparatus had not been published. The European Committee for Standardization issued their standard in September of 2003, (just after the first draft of our requirements was in review) and became the only European Standard for CCRs in March of 2004. The authors of this paper compared EN 14143 to the NOAA draft and felt that the NOAA requirements are generally consistent with the requirements of EN 14143. In several instances the actual language or specifications of the EU standard was used verbatim rather than reinventing the wheel. The biggest difference between the two documents is in manned testing where the European standard only requires diving to a depth of 3 meters, whereas NOAA requires diving to a depth of 100 meters.

**Future Efforts**

This paper provides background information on how the proposed NOAA CCR standard was developed and introduces its main components. A copy of the actual standard is not included in this document because at the time of this writing the proposed standard was still posted for public comment. The deadline for submission of this paper coincided with the 1 January 2005 deadline for comments from the public on the draft requirements. By the time this paper is presented at the 2005 AAUS Symposium, comments from the public will have been considered. NOAA’s goal is to have a final document that has been adopted by the NDP to discuss at the symposia.

Applications for approval are to be submitted to: Director, NOAA Diving Program, 7600 Sand Point Way, NE, Seattle, WA 98115-0070

The documentation for each CCR submitted for approval must include a description of how and when each requirement in this standard was satisfied, and the certification reports from NOAA approved independent third party witnesses.

**Conclusion**

The production and adoption of these CCR standards is only the first step in the process. NOAA’s goal is for these minimum requirements to be incorporated into a consensus U.S. National Standard that will form the basis for reciprocity with other national and international standards. The current version of the standard is available through the NOAA Dive Program website at http://www.ndc.noaa.gov/pdfs/NOAA_CCR_Standards_Final.pdf.
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