

Under Pressure: Testing Before Deployment is Integral to Success at Sea

Rigorous Pressure Testing Can Uncover Problems Before They Become Costly

By Kevin Hardy

Vice President

Steve Weston

High Pressure Facilities Manager and

John Sanderson

Director of

*New Product Development
DeepSea Power & Light
San Diego, California*

“Nature sides with the hidden flaw” is a fitting corollary to Murphy’s law. Success below the high seas comes largely from detailed planning and careful preparation. Capt. Don Walsh, pilot of the bathyscaphe Trieste I, in its historic two-man dive to the floor of the Challenger Deep in the Mariana Trench, recently said, “Successful operations depend upon a skill-to-luck ratio. While luck is important, you always want skill to be more than 50 percent.”

Pressure testing has a long and storied history and remains one of the most useful tools designers have available. It is a critical part of preparation, but often one of the first steps to be cut when resources get stretched. With the limited availability of ship time, combined with the high cost of ship operations and equipment and long lead time of grant and project funding, it makes financial sense to validate system integrity before deployment. Equipment should not see pressure for the first time on its first deployment. External pressure testing is a critical environmental test that is part of routine mechanical testing protocols. Ideally, pressure testing should simulate the actual conditions of operation and complement a

full systems test that includes electronics and software validation.

This article will summarize current pressure testing paradigms and protocols used with pressure testing facilities, based on the experience of operating the DeepSea Power & Light high-pressure chambers, some of which operate to 30,000 pounds per square inch under computer control. This article is limited to a discussion of external hydrostatic pressure testing.

Advantages

There are distinct advantages to pressure testing. “It should work” are not words an end user wants to hear when his instrument or vehicle is hanging below a quick release over some very deep water. Pressure testing is the best means to validate housing integrity before expensive electronics are placed inside. It can reveal hidden mechanical flaws such as extruded aluminum tubing with an unfused seam or an unacceptably thin wall section that

was created during the extrusion process. Molded nonmetallic pressure-resistant connector parts can have assorted flaws. Even soft rubber-molded cable



(Above) A new pressure housing design was intentionally taken to crush depth to confirm the expected failure mechanism.

(Right) Steve Weston poses with this new American Society of Mechanical Engineers-certified 20-inch chamber at DeepSea Power & Light, which can operate to 20,000 pounds per square inch and includes multiple feedthrough ports.





(Photo courtesy of Southwest Research Institute.)

Southwest Research Institute prepares a submersible for a hydrostatic test. The facility operates ocean simulation chambers with diameters up to 90 inches and pressures to 30,000 pounds per square inch.

terminations and urethane overmolds can have voids that show up only under pressure when the void collapses and the wires short out. Pressure compensation systems might have problems with

component bulk modulus that compromise smooth operation when needed most.

While pressure testing can appear to be time-consuming and adds some

cost, in practice it saves time and adds confidence for a successful operation by eliminating failure modes, some potentially catastrophic. A tenured faculty member recently sent a borrowed instrument with a stated six-kilometer-rated housing to 8.4 kilometers, guessing there was sufficient safety margin in the design. Pressure testing was not a convenient option. The device made it to the bottom, and it is still there.

Pressure testing is useful at three key junctures of development: component validation, system validation and proof testing. Component validation qualifies a part for integration into a system. System validation tests the full assembly to the maximum defined static pressure of the "design depth," and it should include cyclic testing to be certain the material can survive repeated deploy-

SEACON®
UNDERWATER ELECTRICAL AND FIBER OPTIC CONNECTORS

Leaders in...
...Underwater Connector Technology

SEA CON® Brantner & Associates, Inc
+1 (619) 562-7071
www.seacon-usa.com

SEACON Advanced Products, LLC
+1 (979) 865-8846
www.seacon-ap.com

SEACON (europe) Ltd
+44 (0) 1493 652733
www.seaconeurope.com

SEA CON Global Production
+52 (664) 626-2726
Toll-Free USA (888) 562-7072
www.seaconglobal.com

Exhibiting at Underwater Intervention 2009 March 3rd - 5th New Orleans, Louisiana Booth #803

Rules of Thumb

1. Expect at least a half day to set up and breakdown, depending on test requirements.
2. Failure is an option; that is why we pressure test things. Have a plan to cope with failure. If expensive components do not need to be inside the housing for the initial test, save the aggravation.
3. If there is something that is delicate, should not be touched or needs a little extra care, let the operator know. They appreciate your directness. For one, DeepSea encourages customers be present for complex test plans or to operate their external test equipment.
4. Wet things can be slippery. Use gloves that maximize grip strength, and pay careful attention to handling. Use of pressure facilities is at your own risk. Operators do not assume any liability for damage to your equipment.
5. Operators do not allow clients to operate the pressure system. However, most welcome on-site detailed direction and assistance in testing.
6. It is recommended that a witness be present for any test. Simple pressure testing may be dropped off and picked up later.
7. Review any liability waivers for clarity.
8. Discuss the training and experience of the facility operators.
9. Agree on payment terms before coming to the facility. Understand that most quotes for pressure testing are estimates based on your desired testing protocol. Delays are inevitable as procedures get more complex.
10. Provide a well written plan, including a bill of materials and checklists. Do not make the operator guess. If not present, review the plan with the operator before the test day to prevent a needless delay while the operator tries to determine exactly what was intended.

ment. A test to “crush depth” confirms failure mode. At DeepSea, at least one article of every new housing design is validated by taking the part to implosion—which can be quite exciting for the operators. This may be a costly test, but important information can be gleaned by analyzing the failure mode and comparing calculated versus actual implosion pressures. Proof testing is an in-process quality control test to “rated depth” after manufacture or overhaul.

Also on the plus side, pressure chambers are run by knowledgeable and experienced technicians. Should a part fail, it is easy to pick up the pieces for forensic engineering. Feedthroughs allow data logging and external power supplies. It is a lot easier to get in and out of a chamber than to access the deep sea—and a lot less expensive.

Limitations

There are limitations to pressure chambers. Sometimes the ocean is the only place large enough to pressure test a fully assembled system. Jacques-Yves Cousteau tested the integrity of his new two-man diving saucers by lowering them into the Mediterranean Sea.

Roster of Pressure Facilities

If your firm offers a pressure chamber for outside testing, readers will benefit from knowing about it. Please send information on your facility to Marine Technology Society fellow Brock Rosenthal at brock@o-vations.com, who has offered to post it to his Web site and maintain it. Please include:

- Contact info (company, contact name, address, phone, e-mail, Web site)
- Chamber size(s)
- Pressure capabilities
- Other features, such as manual or automatic control, feed throughs, data logging, temperature, working fluid and if your site is a secure facility

Tests of sympathetic implosion require the “infinite” volume of the sea, as pressure chambers rapidly lose pressure with the loss of any amount of volume due to the largely incompressible nature of water. The chamber walls may also artificially cause interactions that could dampen or amplify the shock wave.

Pressure pumps are often positive displacement piston pumps powered by compressed air.

The action is reciprocal, and pressure is added in incremental increases. It is not smoothly linear, even under computer control.

CAE

Computer-aided engineering (CAE) programs, such as DeepSea Power & Light's freeware UnderPressure, provide designers a first-order analysis of simple housing integrity against the affects of external pressure. Advanced users will want to study the program for opportunities to modify default material properties to match their actual material. Other simulation programs, such as COMSOL Inc.'s (Burlington, Massachusetts) COMSOL 3.5 and SolidWorks Corp.'s (Concord, Massachusetts) COSMOS, provide motion, stress or thermal models, but are costly and are not routinely available to the average designer.

Testing Paradigms

Pressure testing should simulate the actual conditions of operation. Dwell time at the surface before a dive may produce a low-pressure leak that seals with increased pressure. Zooming rapidly to high pressure in a chamber may mask this weakness. Alternately, a high-pressure test may cause a void or other weakness around a seal to collapse. The high pressure will maintain the seal, but the housing will leak dur-

ing a low-pressure soak test following the proof test. One should also keep in mind that an undulating autonomous underwater vehicle (AUV) or a wire-lowered conductivity, temperature, depth instrument package sees cyclical pressure stresses, while plastics may creep under long-term exposure to high pressure. Pressure testing should model the most extreme of expected conditions.

Testing Protocols

When working with a testing house, it is important to define the test plan in writing. The plan should be offered to

the testing facility with enough time for them to carefully review and comment on the testing. They have lots of experience, and they are, after all, their chambers. One should include the proposed test dates and be sure to discuss their in-house shop loading to ensure his or her desired window fits within their availability.

The testing protocol should outline the following items.

Purpose. What are the important variables to measure? What defines a pass or fail? Is this component validation, system validation or proof testing?

Standards and Certifications. Are there defined standards to be tested against, such as those of the American Bureau of Shipping, Underwriters Laboratories or U.S. Government specification? If so, be sure to provide a copy to speed up the process.

Safety Factor. What are the design limits, including the safety factor? How were these determined? Safety factors are a matter of choice.

For example, Woods Hole Oceanographic Institutions' deep submergence vehicle Alvin requires testing to 50 percent over its rated depth. Un-

“When working with a testing house, it is important to define the test plan in writing. The plan should be offered to the testing facility with enough time for them to carefully review and comment on the testing.”

manned systems may only require testing to 10 percent over their rated depth.

Can Blocking be Used? If this is the first time an empty housing is being taken to the design depth, the interior implodable volume should be filled to 90 percent or more with an incompressible material or hard wood to limit the amount of energy released by a failure. A 98 percent fill may be required if the system is being taken intentionally to failure.

Measurement Techniques. How are variables to be measured? The test may look to simply confirm that no seals leak, but other tests may measure volumetric displacement, strain gauge, deflection, acoustic emission or count pressure cycles. Define the test equipment that will be needed and where it will come from. Ask the operator what equipment they might have or suggest.

Calibrations. Are gauges, meters and other measurement devices in current calibration?

Environmental Simulation. Define the rate of pressurization and depressurization, number of cycles, hold times at pressure and at sea level, water temperature, fresh or saltwater and test pressure.

Electrical Interface. Specify the voltage and current requirements for any power-on testing and specify the required connectors the test house may need to interface to the project. Note that this may incur additional costs and preparation time if the test facility has to procure special nonstandard connectors to support the test or fabricate a custom adapter plate.

Pressure Compensation. Is there oil or other hazardous material that may need to be dealt with? How will it be



Visit us at Subsea Tieback
Booth 466
www.CnavGPS.com

- S u p p o r t - 24/7 Support and global integrity monitoring
- A c c u r a t e - One decimeter accuracy
- F l e x i b l e - Hardware and service options to fit your needs
- E a s e - Simple to install & operate
- R e l i a b l e - Two Signal Networks / No single point of failure

CONTACT US AT:

LAFAYETTE – CORPORATE +1 (337) 210-0000	HOUSTON +1 (713) 468-1536
MEXICO +52 (938) 381-8973	BRASIL +55 (21) 22102555
EUROPE +44 (1284) 388-631	SINGAPORE +65 (62) 95-9738
SOUTH AFRICA +27 (21) 702-1870	ANGOLA +244 (222) 330202

contained? Provide the material safety data sheet to the operators. Is there compressed air to deal with? Specify the venting plan intended during depressurization.

Hazards. If the housing fails and water gets inside, are there materials, like lithium batteries, that will react vigorously with water? If a seal fails and the interior becomes positively pressurized, is there a way to relieve the interior pressure safely?

Sample Size. How many tests are needed for the statistics sample size?

Conclusions

Pressure testing is a critical part of preparation and a key to success at sea. It is a critical environmental test that should always be part of routine design and manufacturing validation. Pressure testing should simulate the actual conditions of operation. It provides the operator and deck crew confidence in the system being deployed.

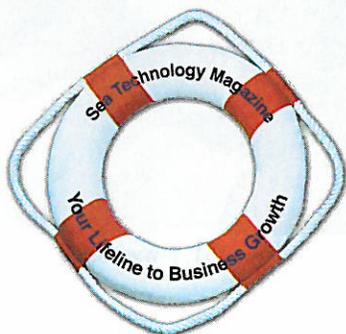
Acknowledgments

The authors would like to gratefully recognize the lessons they learned from

Kevin Hardy is vice president of DeepSea Power & Light, where he has worked in both engineering and marketing capacities. He spent 34 years at Scripps Institution of Oceanography as a senior development engineer, using pressure facilities extensively.

Steve Weston is DeepSea Power & Light's high-pressure facilities manager and director of ceramics development. His hollow ceramic spheres provide flotation for Woods Hole Oceanographic Institution's hybrid remotely operated vehicle and were cycle tested 10,000 times to 30,000 pounds per square inch.

John Sanderson is DeepSea Power & Light's director of new product development. Sanderson retired from the U.S. Navy with the rank of Lieutenant Commander after 27 years of operating and maintaining nuclear submarines.



the U.S. Navy Arctic Submarine Laboratory in Point Loma, California.

Thanks to Matt James of the Southwest Research Institute, DeepSea's ocean sales manager Peter Weber and Brock Rosenthal of Ocean Innovations for their for review and valuable contributions to this article.

References

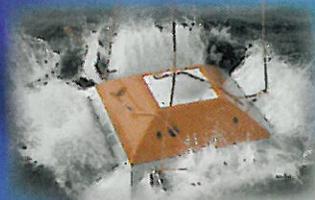
For a full list of references, please contact Kevin Hardy at Kevin_Hardy@deepsea.com. For fur-

ther information on DeepSea Power & Light's pressure test facilities, please contact Edward Vega at Edward_Vega@deepsea.com, or for information on Southwest Research Institute's chambers, contact Jesse Ramon at jesse.ramon@swri.org. ■

Visit our Web site at www.sea-technology.com, and click on the title of this article in the Table of Contents to be linked to the respective company's Web site.

Accurate Data Absolute Recovery

You rely on the ability to collect accurate data and retrieve your instruments safely. As the world leader in design and manufacture of oceanographic products, Flotation Technologies understands the value of data recovery, ADCP technology and oceanographic operations. Our products for ADCPs are put to the test and pass every day.



Visit flotec.com for our full line of ADCP deployment products including mid-water, deepwater and low drag buoys; in-line frames and trawl-resistant bottom mounts.



FLOTATION TECHNOLOGIES™

A company with depth

U.S. Tel: 1.800.639.7806
Int'l Tel: +1.207.282.7749

flotec.com

A Deep Down company

Welcome to the family...

Deep Multi-Sealite®

NEW!

LED Multi-Sealite®



www.deepsea.com 1-800-487-3775

See us at Underwater Intervention, booth 428.
Ask about our new pressure testing facility!

SEA TECHNOLOGY[®]

The Worldwide Information Leader for Marine Business, Science & Engineering

FEBRUARY 2009, Volume 50, No. 2

For more information on any of these subjects, visit our Web site at www.sea-technology.com, and click on the article titles in the Table of Contents or e-mail the editorial staff at oceanbiz@sea-technology.com.

- 10 MULTISCALE SEISMIC IMAGING OF ACTIVE FAULTS AT SEA**
Dr. Rafael Bartolome, Dr. Claudio Lo Iacono and Dr. Eulàlia Gràcia (Consejo Superior de Investigaciones Científicas) explain how high-resolution seismic technologies reveal the geometry and structure of the seismogenic Carboneras Fault Zone in southern Spain.
- 19 UNDER PRESSURE: TESTING BEFORE DEPLOYMENT IS INTEGRAL TO SUCCESS AT SEA**
Kevin Hardy, Steve Weston and John Sanderson (DeepSea Power & Light) show how rigorous pressure testing can uncover problems before they become costly.
- 27 A MULTIDISCIPLINARY DATA INTEGRATION, ANALYSIS AND VISUALIZATION SOLUTION**
Chris Malzone (Myriax Inc.) demonstrates how one can overcome the integration of multi-variant, multisource data through Eonfusion.
- 35 UNDERWATER INTERVENTION INTERNATIONAL CONFERENCE 2009**
—Conference Preview
- 41 REAL-TIME CURRENT MEASUREMENTS IMPROVE VESSEL SAFETY AND PORT EFFICIENCY**
Stephen P. O'Malley (OceanTechUSA Inc.) and Chris McGrath (National Oceanic and Atmospheric Administration) explore how the ATON system provides port decision makers with a reliable and cost-effective alternative in real-time current monitoring.
- 50 OCEAN BUSINESS 2009: SOUTHAMPTON, ENGLAND**
—Conference Preview
- 53 EXPERIMENTAL AND COMPUTATIONAL FATIGUE ANALYSES OF MARINE COMPOSITES**
K. Turget Gursel, Engin Unal (Ege University) and Gokdeniz Nesor (Dokuz Eylul University) investigate E-glass fiber-reinforced polyester composites with adhesive joints in atmospheric and marine environments.
- 57 UNDERWATER TEMPERATURE LOGGERS: SELECTION AND DEPLOYMENT CONSIDERATIONS**
Paul Gannett (Onset Computer Corp.) outlines a guide to logging water temperatures with portable, battery-powered data loggers.
- 61 TRANSDUCER TECHNOLOGY ENHANCES STORM WATER MANAGEMENT**
Dale Beardsley (Pressure Systems Inc.) tells how enhanced observations of swash zones lead to increased dune recovery and better measurement of beach erosion.
- 63 ALUMINUM AUTONOMOUS NAVIGATOR FOR INTELLIGENT SAMPLING: THE ALANIS PROJECT**
Massimo Caccia, Marco Bibuli and Gabriele Bruzzone (Italian National Research Council) review the design, construction and preliminary trials of an unmanned multipurpose vehicle for water and seafloor monitoring.

For more information on these news items, visit our Web site at www.sea-technology.com.

Editorial	7	Offshore Oil & Ocean Engineering	85
Soundings	9	International	87
Capital Report	69	Books	89
Ocean Research	71	Contracts	91
Ocean Business	73	Meetings	90
Marine Resources	78	People	92
Product Development	76	ST Looks Back	93
Marine Electronics	80	Professional Services Directory	94
Navy Currents	82	Soapbox	97
Environmental Monitoring	83	Advertiser Index	98

COVER—A Nortek acoustic Doppler velocimeter, as seen through a fisheye lens, is used to measure currents and waves in Mallorca, Spain. (Photo courtesy of Eduardo Infantes Oanes.)

NEXT MONTH—U.S. Navy accepts portable underwater tracking range...Application of a pressure vessel to a magnesium alloy underwater vehicle...A physicomimetics control framework for swarms of autonomous surface vehicles...Meeting the threat of maritime improvised explosive devices...Monitoring the Eastern Alboran Sea using high-resolution glider data.

© Copyright 2009 by Compass Publications, Inc. *Sea Technology* (ISSN 0093-3651) is published monthly by Compass Publications, Inc., Suite 1001, 1501 Wilson Blvd., Arlington, VA 22209; (703) 524-3136; FAX (703) 841-0852. All rights reserved. Neither this publication nor any part of it may be reproduced, stored in a retrieval system, or transmitted in any form or by any means, electronic, mechanical, photocopying, recording, or otherwise, without the prior permission of Compass Publications Inc. Periodicals postage paid at Arlington, Virginia, and additional mailing offices. Subscriptions may be purchased at the following rates: domestic, \$50 one year; \$70 two years; foreign air mail, \$155. Single copies \$4.50 plus postage and handling (current issue only). POSTMASTER: send address changes to Compass Publications, Inc., P.O. Box 37, Stonington, ME 04681. Canada Publications Number 40013321. Canadian return address BleuChip International, P.O. Box 25542, London, ON N6C 6B2, Canada. CUSTOMER SERVICE, Katie Clark, Tel. 1-800-989-5253 or 1-207-367-2396.

UNIVERSAL DECK BOX UDB-9000

Universal Control for your subsea devices from shallow water to deep sea



TELEDYNE BENTHOS
A Teledyne Technologies Company

The UDB-9000 works with all Benthos acoustic releases, transponders and modems, including the SMART products.

TELEDYNE BENTHOS
A MEMBER OF TELEDYNE MARINE
49 Edgerton Drive
North Falmouth, MA 02556 USA
T: +1 508.563.1000 F: +1 508.563.6444
E: benthos@teledyne.com

www.benthos.com

THE INDUSTRY'S RECOGNIZED
AUTHORITY FOR DESIGN,
ENGINEERING AND APPLICATION
OF EQUIPMENT AND SERVICES
IN THE GLOBAL OCEAN COMMUNITY

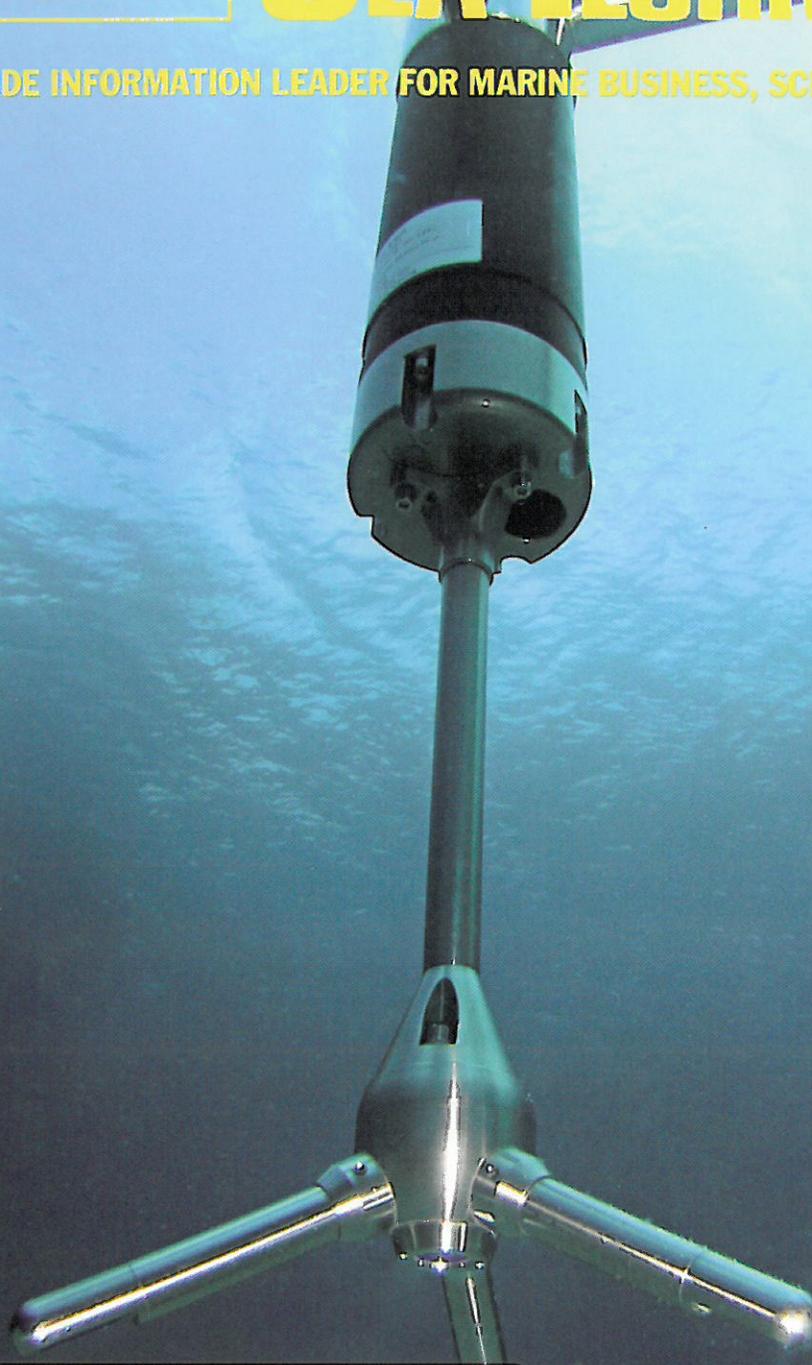
SEA TECHNOLOGY

FEBRUARY 2009

SINGLE ISSUE PRICE \$4.50

www.sea-technology.com

WORLDWIDE INFORMATION LEADER FOR MARINE BUSINESS, SCIENCE & ENGINEERING



**INSTRUMENTATION:
MEASUREMENT
PROCESSING &
ANALYSIS**

www.sea-technology.com