Prifysgol Cymru
Y Drindod Dewi Sant
University of Wales
Trinity Saint David

DEVELOPMENT AND EVALUATION OF A SAFE SYSTEM OF WORK FOR WATER PRESSURE AND IMMERSION TESTING IN PREPARATION FOR UKAS 9001 AUDIT: ENHANCING IMMERSION TEST PROCEDURES AND QUALITY ASSURANCE

AUTHOR: ALBERT WILLETT PROJECT SUPERVISORS: EWA KAZIMIERSKA AND PHIL HILTON

Introduction

Water pressure and immersion testing assess how effectively munitions and equipment prevent water ingress during real-world use. Immersion testing simulates shallow-water events such as accidental drops or fording(Figure 1), while water pressure testing uses controlled hydrostatic pressure to replicate deeper or high-pressure underwater environments like those experienced by underwater EOD equipment(Figure 2 and Figure 3). These methods ensure equipment meets the requirements of DEF STAN 00-035 (Test CL29)[1], MIL STD 812 (AECTP Method 307) and form part of the wider environmental qualification process used throughout the CADMID life cycle. Accurate testing is critical. Water ingress can degrade explosives, damage electronics, and lead to failures. Past incidents, including the 2016 Mali mortar accident demonstrate the severe consequences of poor sealing[3].

Figure 1- fording test facility[2]

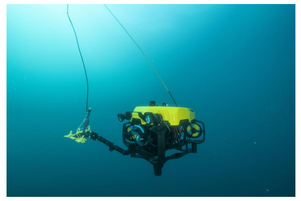
Figure 2- Exail Underwater EOD robot[4]

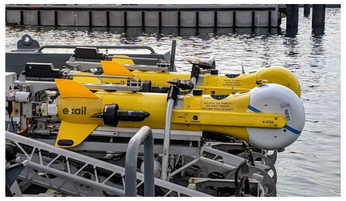
Figure 3- Exail K-Ster C Underwater EOD robot [4]

This poster as well as the overall report is broken down into three key work packages:

- **Work Package 1** – Review of current equipment, identifies hazards, completes risk assessments, and produces a full Safe System of Work to ensure compliant, safe testing in accordance with DEF STAN 00 035.
- **Work Package 2** – Demonstrates how test CL29 under replicates real conditions, as dynamic, impact and slamming loads exceed static pressures justifying reassessment and improvement of testing methodology.
- **Work Package 3** – The identification of improved test equipment to deliver the increased test severities identified in work package 2.

Work Package 1

After a successful restoration project, the Environmental Test Centre continues to operate a hydrostatic pressure chamber and large immersion tanks to meet the requirements of DEF STAN 00 035 CL29, MIL STD 812 and UKAS accreditation to ISO 9001.

Water pressure test capability

- Maximum test article size 1.4 m × 0.7 m × 0.7 m
  Maximum pressure of 95p.s.i (655kPa) equivalent water depth of 63m

Immersion test capability

- Maximum test article size 1.4 m × 0.7 m × 0.7 m
- Maximum submersion depth of 1.5m

Figure 4 – Water pressure test chamber

Restoration of Equipment
The programme of work required to restore the test facility included equipment restoration (Figure 4 and 5). Updated risk assessment and creation of improved Work instruction.

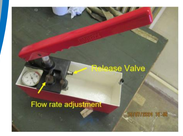

Figure 5 – Hydraulic hand pump

Aims and Objectives

Restore current test equipment to achieve UKAS 9001 accreditation
Restore the test equipment at ETC, Create a comprehensive safe system of work and achieve UKAS 9001 accreditation

Redefine immersion test severities
Quantify the contribution of hydrodynamic, hydrostatic and transient forces.
Demonstrate the under representation of real environmental stresses in DEF STAN 00 035 CL29.

Develop improved pressure-based test methods using differential and vacuum techniques
Establish increased test severities for Method 1 (positive pressure chamber) and Method 2 (vacuum differential testing) as more representative alternatives to static depth testing.

Support standardisation of dynamic immersion severities across defence platform
Produce evidence-based severity levels using worked examples and recommend pressure equivalents for shallow, deep fording and underwater systems.

Work Package 2

Work package 2 investigates the limitations of DEF STAN 00 035 CL29 which focuses on static hydrostatic pressure and under replicates real service loads. The additional loads experienced include Hydrodynamic forces: Flow, vehicle motion and currents. Temporary forces induced by water entry include impact/slamming spikes that can exceed static loads by over 100% in short durations.

Worked example of an unpackaged 30 mm ammunition at various submersion depths vs the static pressure.

Static Submersion

- A 1.0 m static water depth at a pressure of 9.81 kPa creates a 6.93 N force on the crimp.

Forces experienced during Fording

- At 1.0 m with a river flow of 1.5m/s & vehicle motion of 5kph induces a pressure of 11.89 kPa and an 8.40 N force on the crimp.
- A 1.5 m static water depth experienced during deep fording with additional river flow and vehicle motion produces a pressure of 16.79 kPa and a force on the crimp of 11.87 N.

Impact forces

- Impact/slamming forces experienced from a 2 m drop induce a short duration 15.88 N force on the crimp.

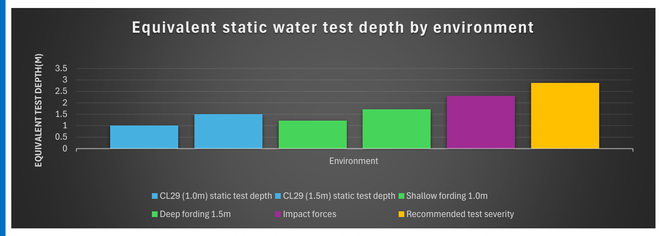

Figure 6 – static water pressure test depth comparison chart

Alternative Test Methodologies

DEF STAN 00-035 Test CL30

Uses a negative pressure differential achieved by either heating the submersion solution to 60°C and the test article is at 25°C. This allows for the gasses trapped within the test article to expand and any leaks will be identified by bubble release. Alternatively, the pressure differential can be achieved by using a vacuum chamber. This method induces a pressure of 9008Pa which does not replicate real world conditions however the 2.866m static depth recommended test severity can be achieved by reducing the external pressure to 73.2kPa. The advantages of this method is that the test item does not experience water ingress if it was to fail.

AECTP Method 307

Using the same principle found within DEF STAN 00 035 Test CL30, AECTP Method 307 induces a positive pressure differential by conditioning the test article rather than the submersion solution. A pressure differential of 27°C increases the 1.0m submersion depth to 1.13m. Using this principle a pressure differential of 66°C would replicate the 2.866m static water pressure depth.

Industry test standards

The test severity found within the defence industry do not consider the additional forces found demonstrated above. These forces are considered in other test standards like those found with ISO 6425 and ISO 22810. These are both used within the watch industry which uses over pressurisation to assess seals. For premium watch manufactures the best practice is to apply an additional 25% pressure. This safety factor is what is applied to justify the 2.866m static water pressure depth for items that will experience accidental immersion.

Work Package 3

Modernization of Test Equipment-
A systems engineering approach with updated User Requirements, System Requirements should be used incorporating findings from WP1, WP2 and UKAS audit actions.

Key User & System Requirements

- Pressures ≥125% service environment
- Automated pressure control
- Data logging, remote monitoring, digital-twin integration.

Functional Needs

- Maintain pressures up to 3375 kPa
- Maintain stable water temperature
- Provide secure operator interface and interlocks,

Solution Options

1. Hydrostatic(figure7) and Vacuum chamber using 2 independent chambers for Method 1 and Method 2
2. Hybrid system: Supports both pressure and vacuum modes (Figure 8)

Figure 7 – hydrostatic test chamber[5]

Figure 8 – Dual Mode test chamber[5]

Proposed solutions

Method 1 increases immersion test severity by applying 28.086 kPa external pressure in a controlled water pressure chamber, equivalent to 2.866 m freshwater depth for items normally exposed up to 1.5 m. T
Method 2 uses a vacuum chamber, submerging the item in water and applying a 73.2 kPa vacuum to create the same pressure differential as Method 1. Any seal failure immediately produces visible bubbles.

Test severities greater than deep fording
DEF STAN requires test depths up to 275m m with the 125% safety margin this increases to 344m, supporting specialist underwater systems such as UXO clearance ROVs.
Radiography and CT scanning data should be with FEA and Digital twins to improve seal integrity assessment, failure detection, and predictive maintenance.

Conclusion

The combined findings from Work Packages 1–3 demonstrate that immersion testing must evolve from static depth-based methods to a risk driven, more representative test methodology. Evidence shows that real world conditions are dominated by transient hydrodynamic loads rather than static pressure, and that vacuum assisted techniques protect the test item from water ingress. Integrating the findings from WP1,2 and 3 establishes a unified direction for future standards by adopting differential pressure methods, enhancing automation, and aligning test practices with modern engineering principles like digital twins and condition-based maintenance.

Future work

Future research should focus on gathering comprehensive in service failure rate data and information on seal degradation to better understand conditions that most frequently cause water ingress. This evidence would help validate and refine the equivalent static depth and dynamic loading models developed in this study (WP2) for a wider variety of test articles. Further work should also advance digital twin technologies to predict seal performance over the full asset lifecycle, accounting for ageing, thermal cycling and fatigue. Establishing standardised dynamic immersion severities across defence platforms would improve consistency, while integrating machine vision systems for automated bubble and leak detection would enhance sensitivity, repeatability, traceability and support ongoing condition monitoring.

Future Demand for Immersion and Water pressure testing

The demand for underwater Explosive Ordnance Disposal (EOD) equipment is expected to increase in response to ongoing instability in the region surrounding Iran and the Strait of Hormuz, a pattern previously observed during the Iran–Iraq conflict of the 1980s. Implementing the recommendations within this report will enhance confidence that such equipment is properly validated against realistic operational conditions. Furthermore, it will enable the adoption of modern engineering practices, including condition-based maintenance and digital-twin technologies, thereby improving reliability, reducing lifecycle risk, and supporting more informed through-life management.

All content within this poster is assessed in greater detail within the full report which contains the full list of references. References for the key points and photos found within this poster are found below:

[1 Defence Equipment and Support, Defence Standard 00-035 part 3 Iss 7, Glasgow: UK Defence Standardization, 2025.]
[2 U.S. Marine Corps Website , "Marines," U.S. Marine Corps Website , 31 July 2015. [Online]. Available: https://www.marines.mil/Photos/igphoto/2001265909/. [Accessed 15 Feb 2026]
[3 Dutch Safety Board , "onderzoeksraad," August 2022. [Online]. Available: https://onderzoeksraad.nl/wp-content/uploads/2023/11/reopened_investigation_2022_mortal_accident_mali.pdf. [Accessed 5 Feb 2026].
[4] N. Gain, "NAVAL NEWS," NAVAL NEWS, 02 April 2024. [Online]. Available: https://www.navalnews.com/naval-news/2024/04/belgian-navys-eod-capabilities-enhanced-with-exail-r7-rovs/. [Accessed 20 February 2026]
[5] Amade-Tech, "Amade-Tech," Amade-Tech, 2025. [Online]. Available: https://www.amade-tech.com/product/ocean-depth-and-pressure-simulation-test-tank/. [Accessed 5 February 2026].