IDEST Worldwide Limited
Company Number 16357221

0248

PRESSURE AUDIT DEVICE – PERFORMANCE AND PROOF TEST

IDEST a UKAS Accredited Certification Body No. 0248 for ISO/IEC 17024:2012

1 Introduction

Further to the IDEST report T017 regarding accuracy of working gauges and over pressure control devices IDEST identified a potential need for a minimally intrusive means of monitoring actual test pressures achieved in real world hydrostatic test equipment.

The team proposed fabricating a sample adapter to insert between the hydro test system and cylinder under test. The sample adapter would have a standard threaded port to facilitate the attachment of a pressure gauge.

A Hydrotechnik 'Watchlog' Bluetooth compact pressure sensor was selected for the pressure transducer. This offers a range from 0 to 700 Bar with accuracy ±0.5% full scale, with the benefit of wireless connection allowing remote monitoring from a safe distance.

The purpose of the Pressure Audit Device (PAD) is to allow IDEST inspectors to independently monitor the actual test pressures achieved by technicians during inspections. And, if the hydro test system is run to cut-off, to measure the activation pressure of the over pressure control device. Per ISO 18119 a 'control device' shall provide pressure relief to ensure that the pressure applied to the cylinder under test "*shall not exceed the test pressure by 3% or 10 bar, whichever is lower".*

To safely deploy the PAD in IDEST Centres the PAD itself must be proof tested to 1.5 times the desired maximum working pressure.

A prototype adapter was manufactured to evaluate concept, performance and safety.

This report documents the design, evaluation and proof testing.

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1.1 Aim of the Pressure Audit Device (PAD)

Recent work on digital gauges highlighted the potential difficulties of achieving the accuracy requirements of the Standards that govern hydrostatic cylinder testing. The requirements are broadly that the operator:

1. Can read the test pressure to at least ±1% accuracy.
2. Can repeatably achieve an actual test pressure that is greater than target but does not exceed target upper limit (target plus 3 % or 10 bar, whichever is lower).
3. The pressure control activates reliably below target upper limit (target plus 3 % or 10 bar, whichever is lower).

Where centres use analogue gauges the IDEST inspector experiences the same challenges as the centre operator when trying to assess the actual pressures achieved during testing.

For this reason, IDEST conceived creating a digital Pressure Audit Device (PAD) to facilitate a minimally intrusive means of independently monitoring hydrostatic pressure during the inspection.

1.2 Goals of the PAD design

The goals for the PAD design are:

- Easy to install and remove from the Centre's hydro test system
- Meets the pressure reading accuracy requirements (< ±1% fsd)
- At least 400 bar working pressure
- Wire free connection to the remote pressure display
- Significant safety margins through design engineering
- Proof tested to 1.5 times maximum rated working pressure
- Water resistant for compatibility with jacketed volumetric testing (IP67)

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2 The PAD design

The minimally invasive installation and removal criteria means a 'no tools' connection to the test system is required. This drove the concept toward a pressure sample adapter with suitable threads such that it can be inserted between the centre's hydro test system and the cylinder under test.

The final PAD design consists of the following:

- Machined stainless steel male / female adapter with threaded sample port
- Digital Bluetooth wireless pressure sensor
- iOS or Android app running on a mobile device

Figure 1: PAD prototype

2.1 Pressure sample adapter

To facilitate wide compatibility with hydrostatic test systems the sample adapter can be available in different thread forms. The most popular likely to be M25x2.0 and M18x1.5.

Model Type	Neck & Stem (A, X) ISO 15245-1	Sample Port (1) ISO 1179-1	Diam. Y (mm)	Diam. W (mm)	Height H (mm)	Working pressure (bar)	Test pressure (bar)
M18	M18 x 1.5	G 1/4 BSP	≈ 30	5 ± 0.2	≈ 85	450	675
M25	M25 x 2.0	G 1/4 BSP	≈ 37	5 ± 0.2	≈ 90	450	675
Notes: 1. Machined from solid Brass or STST 2. Minimum wall thickness 6mm 3. Overall length as short as practicable 4. Add spanner flats if cut from round bar							

Table 1: Basic dimensions and specifications

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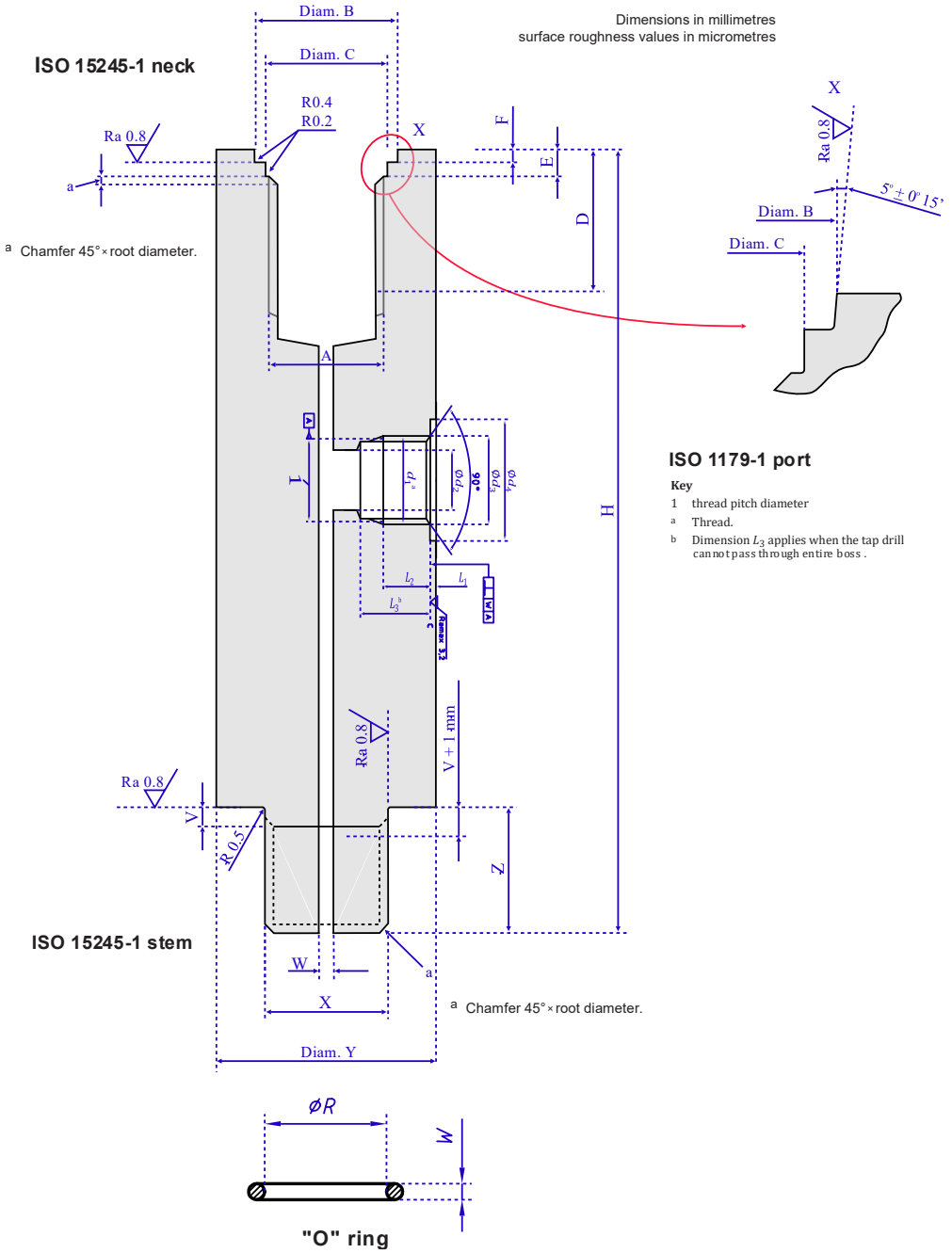

Figure 2: Sample adapter detail drawing

Design references:

- ISO 15245-1:2001+A1:2013
  - Table 1, Valve stem dimensions
  - Table 2, Cylinder neck and thread dimensions
  - Table 3, "O"ring dimensions
- ISO 724:2023
  - Table 1, Basic dimensions
- ISO 1179-1:2013
  - Table 1, Dimensions for ISO1179-1 ports

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2.2 Accuracy and calibration

The Watchlog pressure sensor is specified for ±0.5% full scale accuracy. However, unless the Watchlog has been separately calibrated by a UKAS / ILAC laboratory the point of truth for pressure remains the centre's master gauge.

The centre's master gauge shall be equal to or better than required by EN 837 and must have greater than 0.1% accuracy with scale size and graduations commensurate with the overarching accuracy requirements.

The working gauge total errors of indication, at a reference temperature of 20°C shall not exceed +/- 1% of span (Class 1).

Corrections per the master / working gauge comparison procedure shall be applied to the PAD.

2.3 Design limits and testing

*ISO 18119 para 14.2.2.*1 stipulates that test equipment shall be designed to withstand a working pressure of at least 1.5 times the maximum test pressure of any cylinder that is tested. For 300 Bar cylinders, test pressure is 450 bar and therefore design withstand should be at least 675 bar.

The Watchlog pressure sensor has a pressure range of 700 bar and an overload capacity of 200%FS (1,400 bar) and therefore exceeds the above requirement.

The sampling adapter shall be proof tested to at least 675 bar, holding for 2 minutes, without any adverse observations.

The Watchlog pressure sensor has manufacturer specified protection level of IP65 (protected against low-pressure water jets from any direction), and water attenuates radio energy significantly at Bluetooth frequencies. This may limit the usability of the PAD with jacketed volumetric testing.

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3 Using the PAD

Prior to visiting the centre, the inspector installs the Watchlog Bluetooth Data Collection App on their portable device (iOS or Android only) and connects at least once to the Watchlog pressure sensor.

When required during the inspection the inspector will ask that the PAD is inserted between the hydro test system and the cylinder under test. Once the PAD is installed and wirelessly connected the inspector's mobile device the inspector will monitor the live hydro system pressure.

The inspector will compare the test pressure achieved against the target figures permitted in the standard. The inspector will also request that the test system is run until the pressure control activates and they will evaluate the cut off pressure against the limits in the standard.

3.1 Assessment criteria

The minimum test pressure shall come from the stamp markings on the cylinder or an appropriate design standard (ISO 18119 para 14.1). This is typically 1.5 times the working pressure.

In operation the technician will achieve a test pressure within the range **TPr**, and the pressure control shall operate at or below **PR** as illustrated in table 2.

Parameter	**Abbr.**	**Example 1 (bar)**	**Example 2 (bar)**	**Notes**
Working pressure	WP	232	300	From cylinder stamping
Minimum test pressure	TP	348	450	From cylinder stamping
Test pressure tolerance	tTP	10	10	Least of 3% of TP or 10 bar
Maximum permitted test pressure	mTP	358	460	TP plus mTP
Valid test pressure range	TPr	≥ 348, ≤ 358	≥ 450, ≤ 460	TP to TP plus ttP
Pressure control tolerance	tPR	11	11	tTP plus 10%
Pressure control maximum	PR	359	461	TP plus tPR

Note 1: The master gauge is the point of truth. The example figures shown will be subject to any corrections derived from the master gauge comparison.

This table is derived from ISO 18119 as follows:

- Para 14.2.3.3 the applied pressure shall not be less than the test pressure and shall not exceed the test pressure by 3 % or 10 bar, whichever is lower.
- Para 14.2.2.5 the pressure control device shall ensure that no cylinder is subjected to a pressure in excess of its test pressure by more than the tolerances given in 14.2.3.3 plus 10 %.
- Para 14.2.4 if the applied pressure exceeds the test pressure by more than 3 % or 10 bar, whichever is lower, the cylinder shall be rendered unserviceable.

Table 2: Example test and control pressures

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3.2 Watchlog Bluetooth data collection app

The Watchlog Bluetooth app offers numerical and graphical data views from the Watchlog Bluetooth sensor plus logging data over time and sharing directly from the mobile device.

The app can be found at www.hydrotechnik.co.uk/wlb-app and is available for iOS and Android devices.

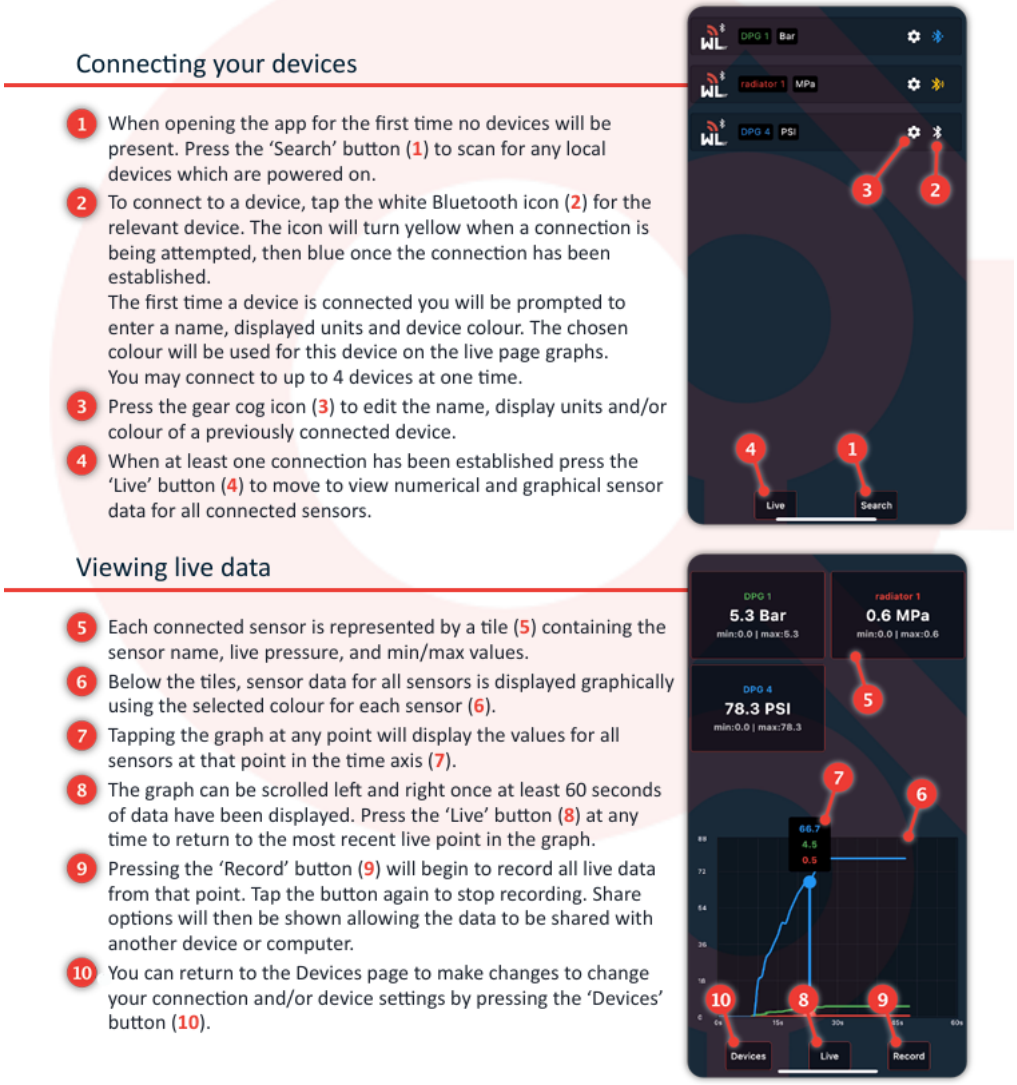

Figure 3: Watchlog app instructions

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4 Test plan

The prototype sample adapter was machined with M25x2.0 male and female thread forms and a G1/4 thread sample port. The test plan serves to evaluate the function and performance of prototype PAD in a working hydrostatic test system. It also includes proof testing of the PAD to ensure it is safe to use at working pressure during future audits.

4.1 Sample adapter thread check

Aim: Determine the PAD prototype threads meet design specification.

Method: Use UKAS calibrated thread gauges to check the PAD thread forms.

Expected result: The PAD passes go and no-go thread gauge checks of both the male and female cylinder connections.

4.2 Start Watchlog app

Aim: Determine the ease of running the Watchlog app and connecting to the pressure sensor.

Method: Open the Watchlog app and wirelessly connect to the pressure sensor.

Expected result: The app opens and a stable data connection is established.

4.3 PAD Installation

Aim: Determine the ease of installation of the PAD prototype.

Method: Install the PAD into the hydro test system between the test system and the cylinder under test. Record any issues, tips or opportunities.

Expected result: PAD is straightforward to install into an existing hydro test system using standard techniques, without any special tools.

4.4 Modified system performance

Aim: Identify the impact (if any) on the performance of the hydro test system following fitting the PAD.

Method: With the PAD installed exercise the hydro test system to the routine test pressure. Observe for any impact on the test system (e.g. leaks, slowed pump rates etc).

Expected result: A working hydro test system with a pump time comparable to operation without the PAD.

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4.5 Master gauge comparison

Aim: Confirm the accuracy of the PAD digital gauge, and that the hydro test system can be exercised across its full design working pressure range without interference from the PAD.

Method: Exercise the system to perform a gauge comparison, recording the master and PAD digital gauge readings.

Expected result: The PAD digital reading tracks the master gauge with accuracy per manufacturer of 0.5 % full scale (±3.5 Bar).

4.6 Hydro test runs

Aim: Confirm that hydro testing can be performed satisfactorily with the PAD installed in the system.

Method: Perform a sequence of hydro test runs through a range of typical target cylinder test pressures. Perform a normal hydro test procedure. Observe for any adverse conditions.

Expected result: Hydro test can be performed normally by the operator, without any impact or interference from the PAD.

4.7 Proof test

Aim: Ensure the PAD is safe to use to working pressure.

Method: With suitable shielding and other safety protocols in place, pressurise the PAD to 1.5 times the desired working pressure. Hold for 2 minutes.

Expected result: The PAD sustains the proof test pressure without any damage, leaks or other adverse indications.

4.8 Immersion test

Aim: Determine if the PAD can be immersed during volumetric testing.

Method: Place the PAD under 30cm water and hold for 5 minutes. Check if wireless connection still functions and pressure sensor remains undamaged.

Expected result: The PAD functions adequately without damage.

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5 Results

The evaluation testing was performed at Poole Diving (7Z) utilising their existing hydro test equipment which is already certified under the IDEST scheme.

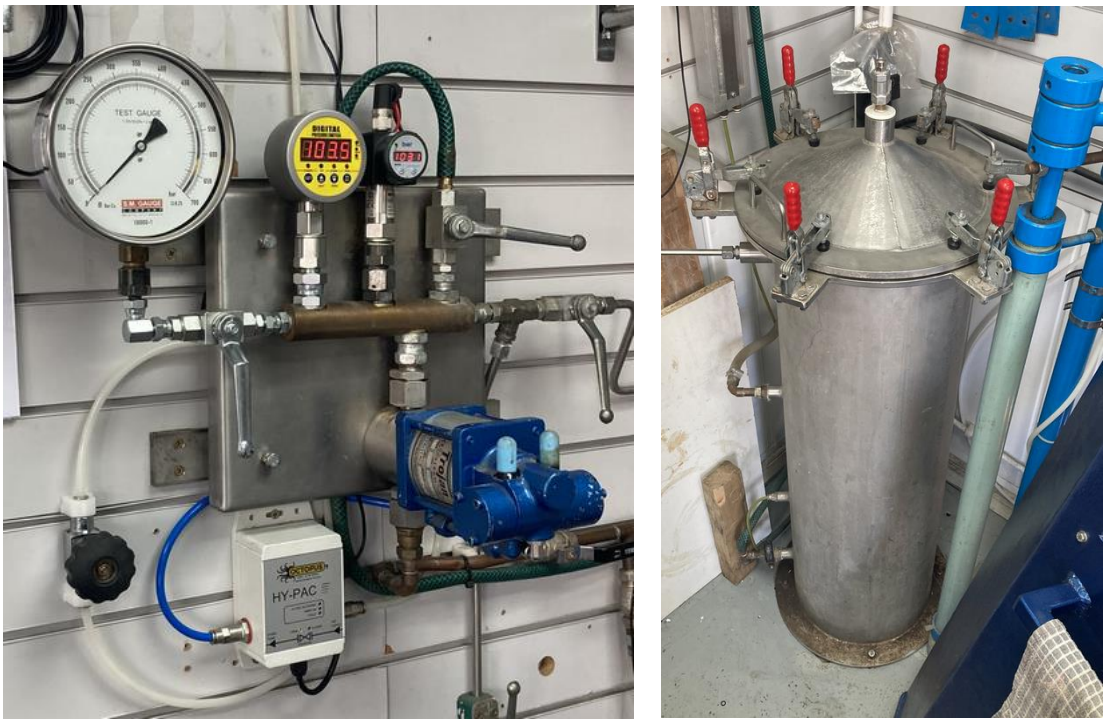

Figure 4: 7Z Hydro test system

The hydro test system has a 150mm SM Gauge master gauge, Octopus HY-PAC digital working gauge, and IDEST reference design digital pressure control.

Poole Diving IDEST certified technicians carried out installation of the PAD and operated the test equipment throughout the evaluation.

A 12 litre, 300 bar rated Faber steel cylinder was used as the target vessel. The cylinder was placed in a steel hydro tank to protect the operators and observers. The cylinder being deliberately taken outside its maximum pressure tolerance was scrapped after the testing.

Testing was undertaken in accordance with the prepared test plan and results recorded as follows:

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5.1 Sample adapter thread check

Go and No-Go plug and ring gauges were used to check the pressure sample adapter male and female cylinder threads, results as follows:

Sampler Port	Gauge	Result
M25 Male	M25x2.0 ring go	Pass
	M25x2.0 ring nogo	Pass
M25 Female	M25x2.0 plug go	Pass
	M25x2.0 plug nogo	Pass

Table 3: Thread check results

5.2 Start Watchlog app

The Watchlog app was started on the inspectors iPhone. Once the app loaded the search function was used to look for the pressure sensor. The sensor was found and the live data display was opened. Live data continued to be gathered even when switching focus away from the Watchlog app to take photographs.

The wireless connection was stable with no dropouts during the entire test session, even with the PAD operating from within a sealed (dry) metal volumetric jacket. All test criteria were achieved.

5.3 PAD Installation

Once the test cylinder was filled with water the PAD was screwed in by hand and tightened with a workshop spanner. The hydro test system connection was then screwed into the top of the PAD and tightened with a workshop spanner. The process was swift and simple.

Observation: Making the pressure sample adapter slightly longer to increase clearance between the pressure sensor housing and the cylinder under test would be beneficial.

5.4 Modified system performance

Installing the PAD had no observable impact on the performance of the hydro test system. Lengthening of the connection between hydro test system and the cylinder under test did not impair placing the cylinder into a jacket or the operation of the hoist system. The system remained leak free and in full conformance with the existing centre certification.

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5.5 Master gauge comparison

Poole Diving have a 6-inch S.M. Gauge 0-700 bar (±2.5% FSD) master gauge which has an annual UKAS 17025 calibration. This master gauge was used as the point of truth for pressure.

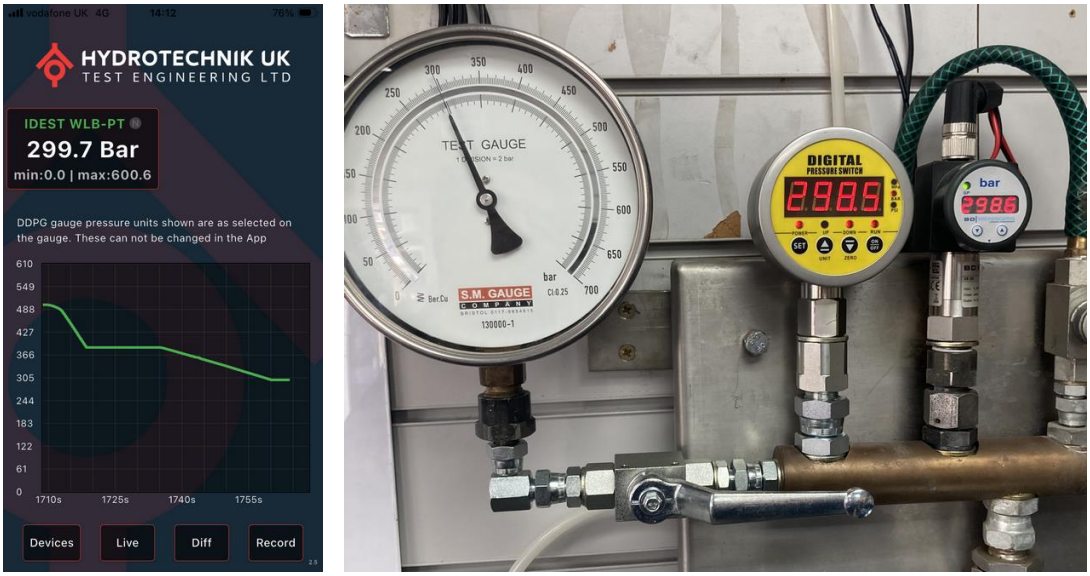

Figure 5: Example gauge comparison (falling)

A gauge comparison was undertaken in both rising and falling directions:

Rising readings (bar)					Falling readings (bar)				
Master	**Octopus**	**IDEST**	**PAD**	**Delta**	**Master**	**Octopus**	**IDEST**	**PAD**	**Delta**
100	101.3	101.0	102.7	2.7	499	499.0	500.2	500.6	1.6
200	201.0	201.3	202.5	2.5	384	384.8	385.6	386.4	2.4
250	251.3	251.5	252.7	2.7	298	298.5	298.6	299.7	1.7
346	346.4	347.0	347.6	1.6	198	197.3	198.2	199.3	1.3
400	400.2	401.0	401.5	1.5	146	147.0	147.2	148.8	2.8
500	500.5	501.2	501.9	1.9	98	98.3	98.3	99.9	1.9
550	551.4	552.0	552.5	2.5	42	42.8	42.5	44.3	2.3
600	600.0	600.0	600.4	0.4	0	0.0	0.0	0.0	0.0
Note 1: The master gauge has a parallax mirror and smallest marked divisions of 2 bar. Note 2: The Watchlog manufacturer claims accuracy of 0.5% FS which equates to ±3.5 Bar.									

Table 3: Master working gauge comparisons

Even with a high-quality large scale, parallax mirror master gauge with small scale divisions it was difficult to assess the master pressure when faced with three digital gauges with close readings.

Taking the master gauge as the point of truth, there was close alignment by all digital gauges, and it was agreed that the gauge comparison showed no need to apply any corrections to other gauges during the further trials.

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5.6 Hydro test runs

Several hydro test runs were undertaken. There was excellent correlation between all the gauges on the test system. The PAD pressure display was responsive with minimal observed lag between the app pressure display and the other gauges.

Tests included both operator-controlled test pressure values (via a manual needle valve) and electronic pressure control stops of the pump (via a solenoid). In all cases the PAD performed flawlessly giving an accurate reading of the pressure achieved.

5.7 Proof test

Due to the Octopus Digital HY-PAC having a maximum operating pressure setting and pressure display value of 600 bar the proof test pressure was constrained to this value.

With the PAD and cylinder under test shielded from the operators within a (dry) sealed volumetric test jacket the system was pressurised in stages to 600 bar. Once the proof test pressure was achieved the system was held at pressure for 2 minutes. The system held pressure during the test period. Pressure was then released in a controlled manner.

The PAD was examined for any damage or deformation, and none was found.

The wireless signal remained stable despite the PAD being within a metal container. Although it is noted that the jacket is not grounded.

As only 600 bar was achieved during the proof test, based upon 1.5 times pressure the maximum ‘tested’ working pressure is 400 bar. However, the ‘design’ rating exceeds 450 bar, and comparison with similar pressure ‘fittings’ suggests no concerns in this regard.

5.8 Immersion test

Due to time constraints on the day, it was not possible to fill the water jacket and perform a wet test with the PAD.

Subsequently the PAD was placed in 30cm of water. The wireless connection could still be established and live data viewed. After 5 minutes there was no evidence of water ingress into the PAD, and it remained fully functional.

Use of the PAD during jacket method volumetric testing may therefore be achievable. Further field trials in this regard are required.

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5.9 Test plan results summary

Testing was undertaken in accordance with the prepared test plan with results summarised as follows:

Ref.	Title	Results	P/F
4.1	Sample adapter thread check	Threads pass go and no-go checks	P
4.2	Start Watchlog app	Watchlog app connected after a brief pause and pressure data was displayed	P
4.3	PAD Installation	The PAD was easily installed using a workshop spanner	P
4.4	Modified system performance	There was no observable impact on system performance from installing the PAD	P
4.5	Master gauge comparison	Gauge comparison on rising and falling showed no necessary correction needed	P
4.6	Hydro test runs	The PAD operated consistently with excellent agreement between all pressure gauges	P
4.7	Proof test	The PAD sustained the proof test pressure without any adverse observations	P
4.8	Immersion test	Immersion to 30cm for 5 minutes no water ingress of other issues observed	P

Table 5: Results summary

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6 Conclusions and recommendations

6.1 Conclusion

The study found that the Pressure Audit Device (PAD) prototype design is safe and useful in allowing inspectors to independently monitor hydrostatic test pressures achieved during cylinder testing.

The PAD can be installed and removed quickly with minimal effort or impact to the hydro test system.

This independent live view on the pressure reading, with ease of digital display allows the inspector to readily assess the performance of the centre's hydro test system against the accuracy requirements of the standard. This can include assessment of the performance and accuracy of the pressure control device when operated.

In this trial the PAD had very close alignment with the master gauge. The need for a UKAS / ILAC calibration of the PAD pressure sensor is mitigated by retaining the centres master gauge as the ultimate point of truth for pressure.

Use of the PAD will significantly improve IDESTs knowledge of real-world hydrostatic test systems performance against the tight parameters and tolerances for target test and control pressures imposed by ISO 18119.

6.2 Recommendations

A test of the PAD in a routine jacket volumetric test would be helpful to confirm the immersion and wireless signal test observations, and that it can be used for monitoring such tests.

IDEST should consider a wider roll out of PAD amongst the inspectors, and the collection of field data to drive compliance and improvement of test systems.

The following improvements were identified for the sample adapter:

- It should be slightly longer (~15mm) to give additional clearance between the pressure sensor housing and the cylinder under test.
- The land area around the G1/4 threaded sample port should be increased to better accommodate the rubber seal of the pressure sensor (in this instance a Dowty washer was used to improve the seal robustness).
- The sample adapter should be permanently marked with a unique serial number, thread details, working pressure and test pressure.

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7 Appendix

7.1 Photographic results record

The test results were recorded mostly by taking screenshots from the Watchlog app and photographs of the test equipment instrumentation. The following is a photo record in order taken.

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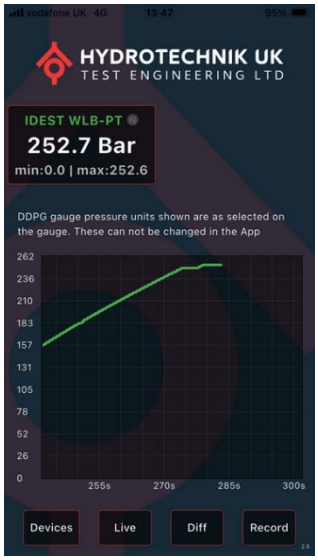

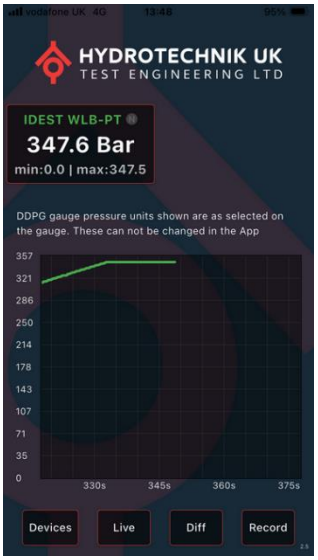

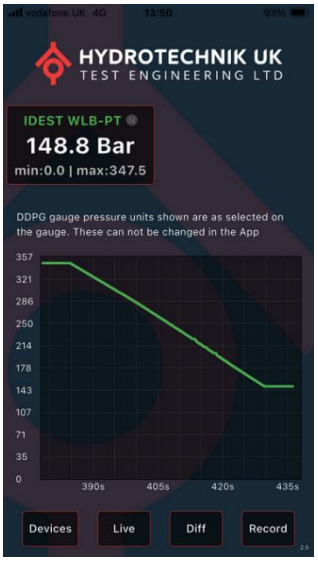

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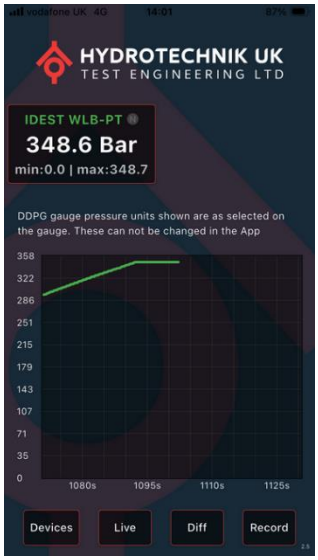

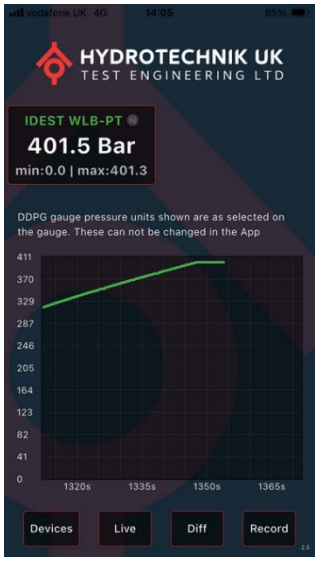

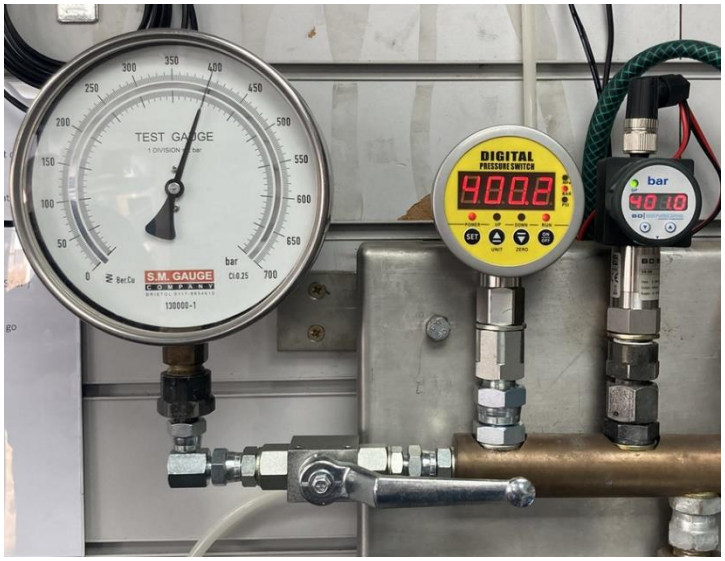

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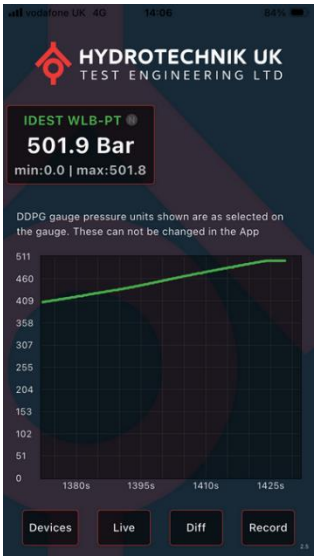

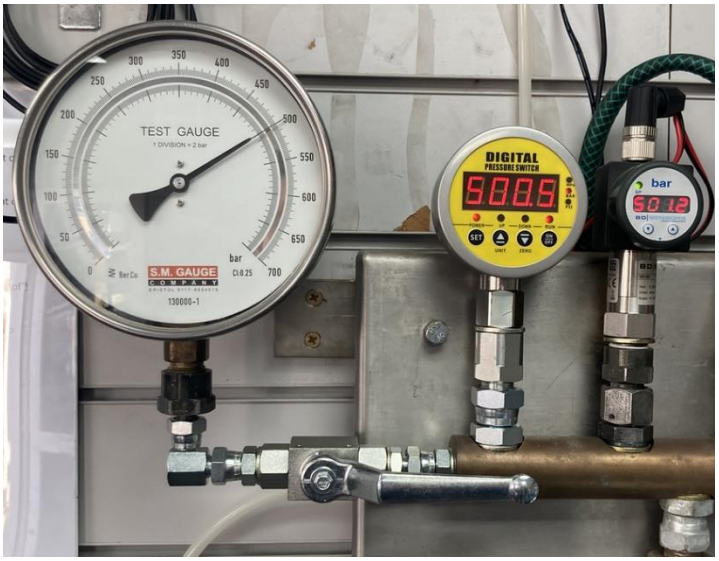

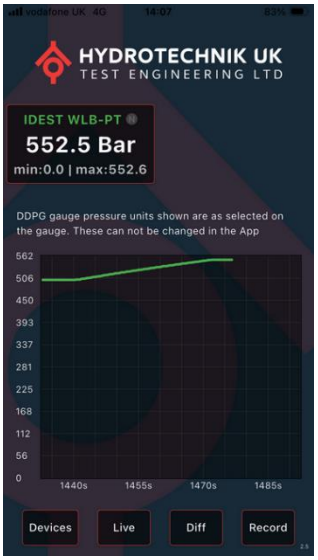

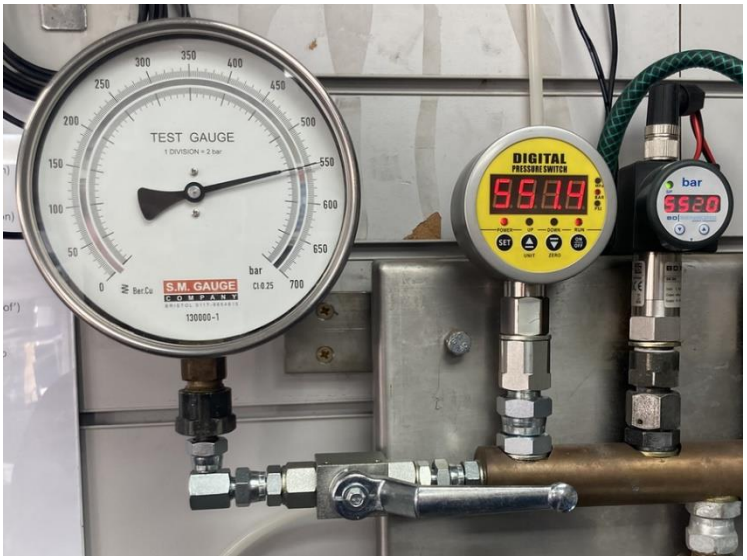

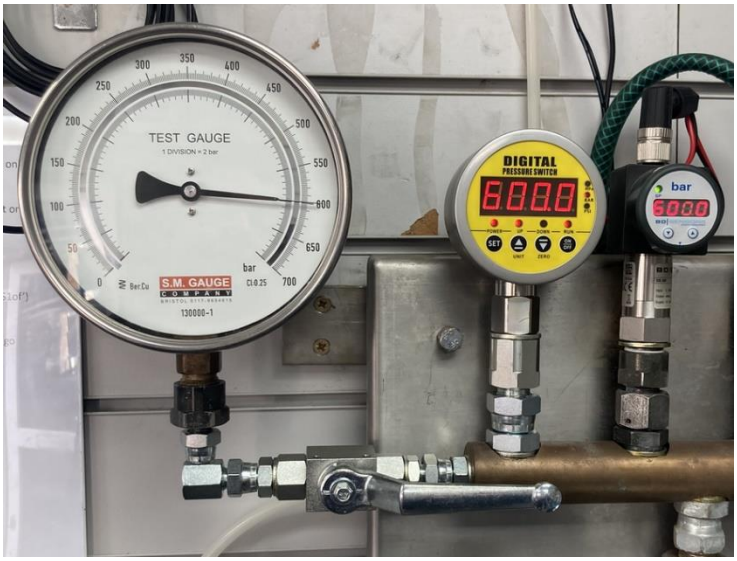

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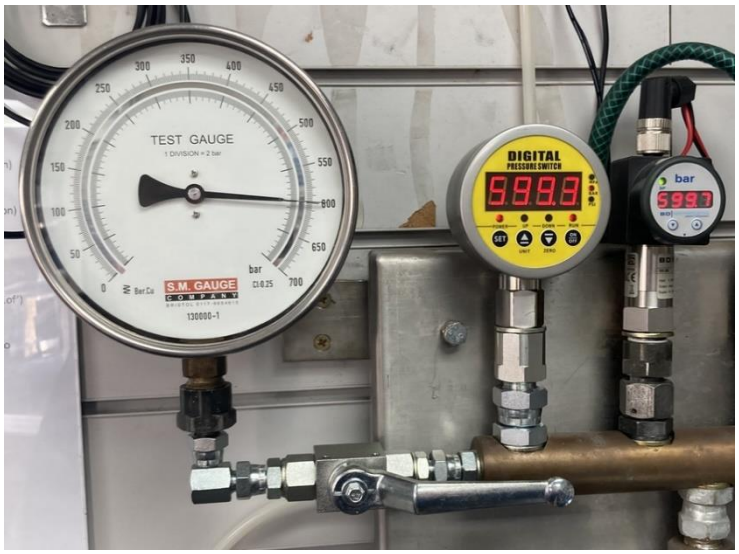
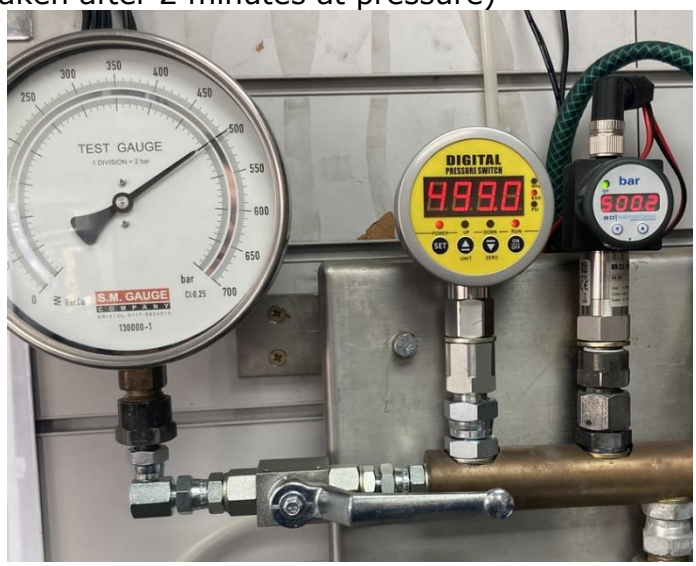
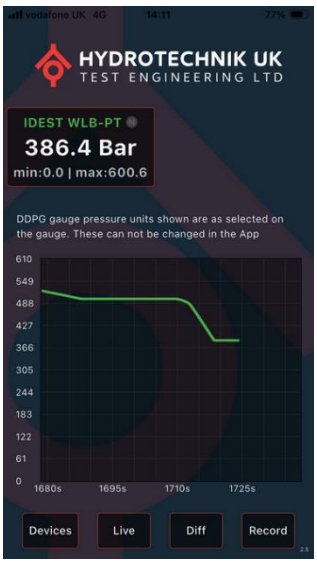
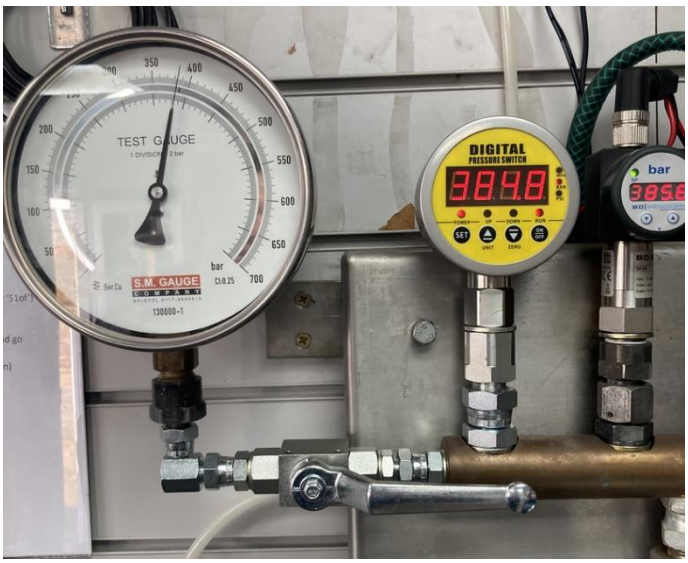
PRESSURE AUDIT DEVICE – PERFORMANCE AND PROOF TEST



(Above taken after 2 minutes at pressure)







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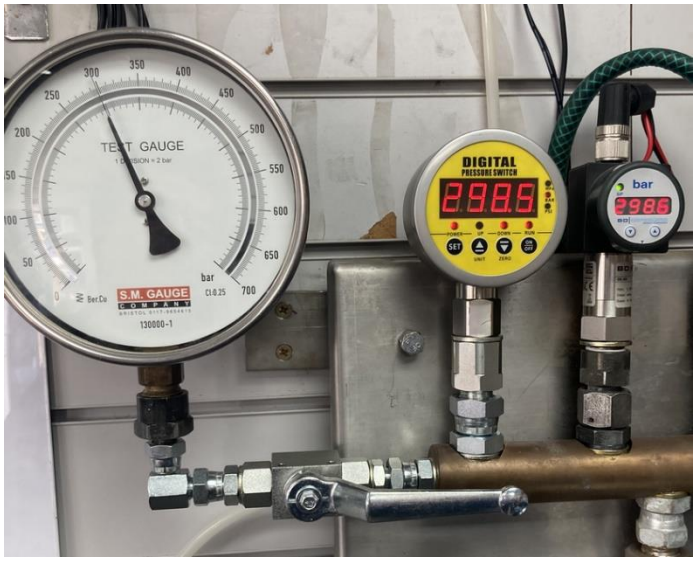
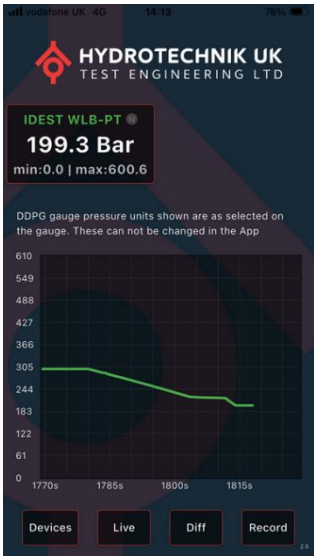
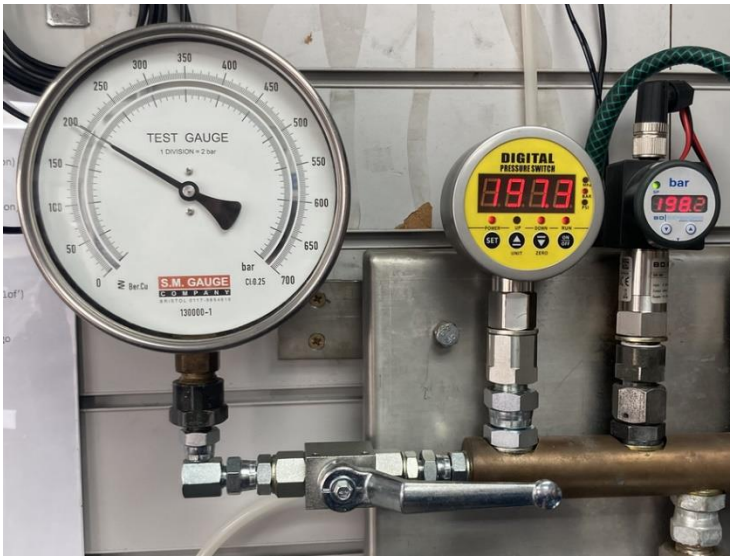
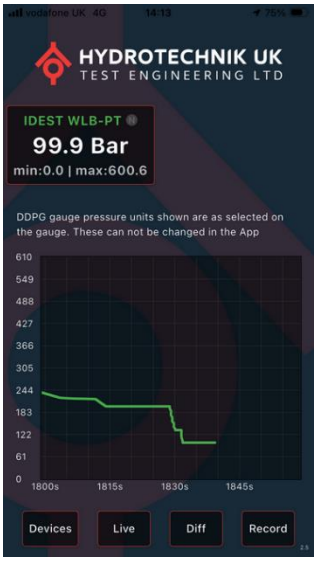
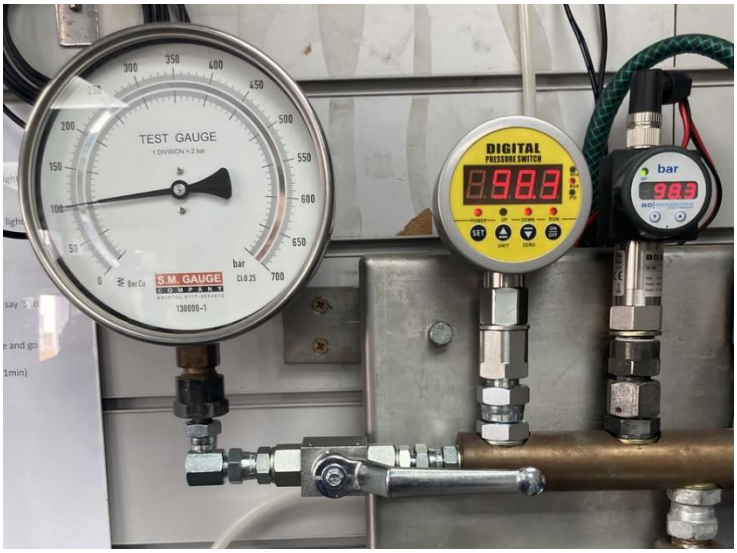
PRESSURE AUDIT DEVICE – PERFORMANCE AND PROOF TEST











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7.2 References from the ISO 18119:2018+A2:2024 Standard

The following clauses in the ISO 18119 standard are referred to extensively within this document:

14.1 The test pressure shall be in accordance with the stamp markings on the cylinder. When applicable and when the test pressure is not marked on the cylinder, the test pressure shall be derived from the appropriate design standard.

14.2.2.1 All rigid pipework, flexible tubing, valves, fittings and components forming the pressure system of the test equipment shall be designed to withstand a working pressure of at least 1,5 times the maximum test pressure of any cylinder that is tested.

14.2.2.2 Pressure gauges (also known as pressure indicating devices) shall be at least to an Industrial Class 1 (±1 % deviation from the end value) with a scale appropriate to the test pressure (e.g. EN 837-1 or EN 837-3).

14.2.2.5 A control device shall be fitted to the test equipment to ensure that no cylinder is subjected to a pressure in excess of its test pressure by more than the tolerances given in 14.2.3.3. The pressure relief device's tolerance shall not exceed the upper tolerance shown in 14.2.3.3 plus 10 %.

14.2.3.3 The pressure indicated on the pressure gauge shall not be less than the test pressure and shall not exceed the test pressure by 3 % or 10 bar, whichever is lower

14.2.4 If the applied pressure exceeds the test pressure by more than 3 % or 10 bar, whichever is lower, the cylinder shall be set aside for further evaluation or rendered unserviceable in accordance with Clause 18

D.2 A suitable system control device shall be used to ensure that no cylinder is subjected to a pressure in excess of its test pressure, +3 % or 10 bar, whichever is lower.

7.3 Acknowledgements

The IDEST project team was led by Nick Clark with team members Nick Clark, Dave Crockford and Alistair Reynolds. The PAD prototype was assembled, evaluated and this report compiled on behalf of the team by Nick Clark.

The assistance of Poole Diving (7Z) with sourcing, evaluation and testing of the PAD prototype is much appreciated.

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