IDEST Worldwide Limited
Company Number 16357221

0248

DIGITAL WORKING GAUGE AND PRESSURE CONTROL DEVICE - REFERENCE DESIGN / CASE STUDY

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

1 Introduction

The adoption of ISO 18119 for gas cylinder Periodic inspection and testing (PIAT) brought with it the requirement for a 'control device' to 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".*

In line with the adoption of the ISO 18119 standard, IDEST made the provision of an effective pressure control device a mandatory requirement for all IDEST test centres, and certification is withheld unless a pressure control device is present.

UKAS recently emphasised the need for additional rigour during inspections in relation to the working gauge - working gauges shall be to at least 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).

It follows on that the pressure control device must be of similar accuracy. Indeed, the standard says … *the pressure relief device's tolerance shall not exceed [the test pressure tolerance], plus 10 %.*

Following UKAS direction, IDEST inspectors have noted examples of working gauges in use that have scale size and graduations that might not be judged appropriate to the test pressure. For example, working gauges less than 100mm diameter, no anti-parallax, with 10 bar or larger scale increments, and coarse alarm setting pointers for electrical contacts. Even when mounted in ideal aspect to the operator the ability to judge accurately pressures and contact settings within a span that may be less than 10 bar is limited.

The upshot of these observations is that IDEST anticipates a likely push towards affirming accuracy and resolution in the working gauge and pressure control operation during future certification activities, and we foresee challenges achieving the requirements with common observed analogue gauges.

As a result, IDEST have undertaken this practical evaluation of a digital working gauge that also supports the pressure control function.

It is important to note that this is a reference design to explore what might be practical. It illustrates one of many possible solutions and should not be seen as promoting any particular product or approach above others. However, we hope the discussion and learnings will be helpful to those looking for a solution.

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1.1 Aim of the reference design

IDEST anticipates an upcoming requirement for test centres to be able to demonstrate during triennial certification the following:

1. They can read the test pressure to at least ±1% accuracy.
2. They 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).

Centres that cannot demonstrate compliance with the above may need to modify their equipment or face losing their certification.

The aim of the reference design is to illustrate a realistic, achievable approach to fulfilling these requirements.

1.2 Pressure control device methods

There are several approaches to provision of a control device, and the majority observed by IDEST inspectors in the field fall into one of the following three categories, as outlined in IDEST Torque newsletter Volume 19, Issue No 3 August 2019…

- Method 1: Use of a fixed-pressure relief valve installed downstream of the pump and working gauge. E.g. for testing cylinders with WP 232 bar at TP 348 bar utilise a relief valve set to 358 Bar. For centres testing cylinders with different working pressures several fixed-pressure relief valves will be required.

- Method 2: Use a working gauge fitted with switch contacts that operate a solenoid to cut-off of the air drive supply to the hydro pump. The contact operating point is set above the test pressure and below the 3% / 10 bar limits.

- Method 3: Use an adjustable low-pressure regulator to control the input air pressure. This method uses the fact that the output water pressure is proportional to the input air pressure. E.g. with a 100:1 pump ratio regulating the input pressure of the pump to 3.5 bar will cause it to stall at 350 bar.

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1.3 Choice of method for the reference design

Whilst all three methods listed above are potentially valid approaches to pressure control; Method 1 is becoming less attractive due to the range of fixed pressure relief valves need to match the broad spectrum of modern cylinder test pressures, and the accuracy of such devices; Method 3 typically lacks the accuracy needed to comply with the standard and is frequently observed to impair the speed of operation of the hydro test pump; For this reason the reference design adopts Method 2, shutoff of the hydro pump drive via electromechanical means.

Whilst there are many sources of high-quality analogue gauges that could easily meet the accuracy and visibility criteria few offer electrical contacts. IDEST therefore chose to explore a digital system to meet the minimum accuracy requirements and support a pressure control function.

1.4 Other options

While IDEST is not an equipment supplier we felt that only through buying, constructing and evaluating a working reference design could we identify the costs and challenges that our test centres will face if a requirement for greater accuracy of the working gauge reading, and pressure control setting is applied in the future.

It is important to note that the reference design illustrates one possible solution to achieving the requirements of the ISO 18119 standard regarding working gauge test pressure reading and pressure control function. Many other solutions exist, and all stand to be judged on their individual merits during the centre certification process.

1.5 Goals of the reference design

The goals for the reference design are:

- Meets the pressure reading accuracy requirements (< ±1% fsd)
- Provides an effective pressure control function
- Adjustable to accommodate a wide range of test and control pressures
- Automatic reset following trigger
- Retrofittable with existing field test systems
- Minimum 600 bar working pressure
- Fail-safe in the event of power loss
- Off the shelf CE marked components
- Minimal assembly or construction
- Compliant with the Pressure Equipment Directive: 2014/68/EU
- Sourceable from established regional suppliers
- Affordable

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2 The reference design

The reference design consists of the following:

- Universal input AC/DC power cube
- Digital gauge with alarm output
- Pressure snubber to protect the pressure gauge
- Solenoid valve
- Flyback diode (to protect the digital gauge)
- Cables and wiring
- Push-fit 8mm air connectors

Figure 1: System components

At the heart of the system is an electronic pressure switch which has a freely configurable transistor output. The pressure switch is mounted in the 'wet' high pressure side of the hydro pump in place of the existing working gauge. Installation of a snubber is desirable to extend the life of the pressure switch transducer.

The pressure switch has a digital pressure display over the range 0-600 Bar with accuracy according to IEC 60770 of 0.35 % FSO. The switch is powered by 24V DC from a universal AC input wall cube. The PNP transistor output of the switch is wired to a solenoid valve.

The solenoid valve is inserted into the 'dry' air supply to the hydro pump and is of normally closed type (hence the system is fail-safe in the event of power loss which cuts the air supply to the pump).

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2.1 Electrical schematic

Here is the basic wiring diagram of the reference design. Connections in the system are as follows:

DC power from the universal input AC wall cube is wired into the smart pressure switch supply terminals. The contact output from the pressure switch is wired to the solenoid. The flyback protection diode is wired across the solenoid. Appropriate polarity is observed for each connection.

24 volts DC was selected for electrical safety in a potentially wet environment and for optimising performance of the solenoid.

By using connectors with screw or push fit terminals, and preformed moulded leads only wire strippers and a small electrical screwdriver were required to assemble the cables.

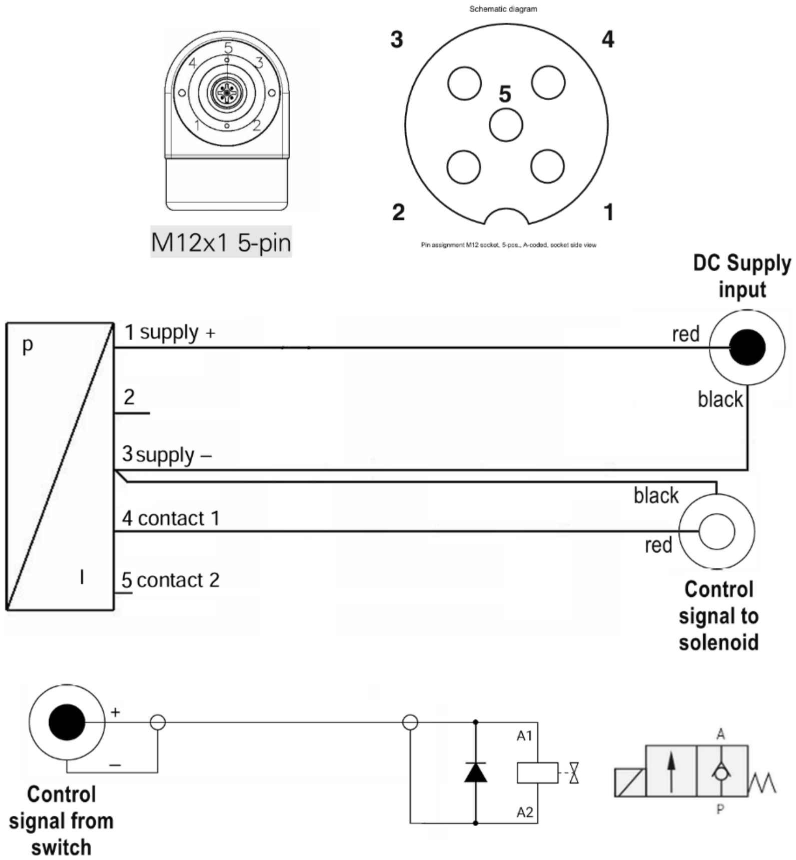

Figure 2: Wiring diagram

Note 1: The flyback diode installed across the solenoid coil to protect the transistor output of the electronic pressure switch.

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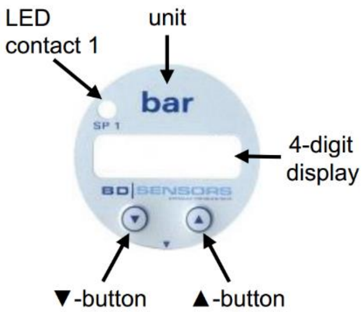
2.2 Theory of operation



In operation, following power up, the solenoid is energised allowing air to flow to the hydro pump. The contact status LED 'SP' will be illuminated.

The operator operates the test system in the normal way using their existing controls. The test pressure can be read from the electronic pressure switch display, allowing the operator to manually stop at the desired test pressure.

In the event of the operator failing to stop the pump in a timely manner, and the test pressure reaching the preset over pressure action value, the electronic pressure switch will de-energise the solenoid isolating the air feed to the hydro pump and stopping further pressure buildup. The status LED 'SP' will be off.

The system is reset by the operator lowering the system pressure to below the recovery value, at which time the solenoid will re-energise, and the air feed to the pump will be restored.

2.3 The switch function

The solenoid chosen is of a normally closed type to facilitate a safe condition in the event of power failure. Therefore, the switch output needs to be active (energised) for normal manual operation of the cylinder test system.

The switch output (S1) has freely configurable switch-on and switch-off points, 'S1on' and 'S1oF' respectively. For the reference design application these are used in 'inverted hysteresis mode'. S1oF is set to the desired control pressure and S1on is set to the recovery pressure (i.e. the pressure the system must be manually reduced to in order to re-enable the hydro pump).

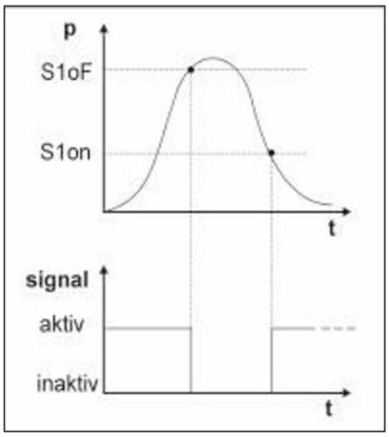


Figure 3: Inverted hysteresis mode

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Note 1: On activation the solenoid valve cuts off the air supply to the hydro pump, and the green LED indicator goes out. However, it does not vent the air feed to the pump which can lead to a small overshoot above the set pressure as the residual air pressure is used up. The control pressure switch point must be set sufficiently below the maximum allowed over pressure to accommodate this. The guideline adopted based on practical observations during evaluation of the reference design was to set S1oF to target test pressure plus 3% or 10 bar, whichever is lower, minus 2 bar.

Note 2: A recovery pressure setting of S1on to 200 Bar was used throughout evaluation as this seems a pragmatic value.

2.4 Configuring the control pressure (S1oF)

The electronic pressure switch must be used as an over pressure control device, and not as the primary control for the test pressure. The operator must remain in control of the test pressure at all times.

The pressure control activation pressure value shall therefore be set in advance according to the target test pressure plus an allowance to give margin for the operator to achieve the correct target pressure, but the setting must not allow the cylinder to be exposed above the maximum defined in the standard.

The electronic pressure switch has two user buttons, up and down, which function as follows:

Button functions	
▲	• move forward in the menu system (beginning with menu 1) • increase the displayed value note: increase the counting speed by keeping the button pushed for more than 5 second
▼	• move backwards in the menu system (beginning with the last menu) • decrease the displayed value note: increase the counting speed: keep the button pushed for more than 5 second
▼ ▲	confirm the menu items and set values by pushing both buttons simultaneously

Figure 4: Button functions

The control activation pressure is set by adjusting the S1oF value as follows:

1. Open the menu by pressing the up button.
2. Scroll through the menu options using the up (or down button) until the S1oF (Menu 8) is reached.
3. Press both up and down buttons simultaneously to access the set value.
4. Press up or down button to increase or decrease the setting value to the required new value (holding the button will increment faster).
5. Once the display reads the desired set point value press both up and down simultaneously to apply the value.
6. Press the up or down buttons to cycle through the menus back to the live display mode (or wait for the unit to timeout).

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2.5 Choosing the pressure control set point

There are several constraints that apply to choice of pressure control set point.

The principal constraints come from ISO 18119, per 14.1 the minimum test pressure shall come from the stamp markings on the cylinder or an appropriate design standard. This is typically 1.5 times the working pressure. From *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. From *14.2.2.5* the pressure control 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 %. From *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.

Additional constraints come from the pressure control system itself, for example the granularity of the setpoint, the speed of operation, any over-run after trigger etc. These practical considerations will result in the pressure control set point needing to be reduced sufficiently below the permitted maximum to ensure the maximum is never exceeded. The necessary reductions can be derived experimentally through observations of the pressure control system in use to arrive at a pragmatic pressure control set point value as illustrated in this table.

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
Maximum system overshoot allowance	mOS	<2	<2	By observation
Pragmatic PR set point	pPR	356	458	mTP minus mOS
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. Note 2: PR exceeds maximum per 14.2.4 so pPR is calculated based upon mTP minus observed overshoot (and not PR minus observed overshoot).				

Table 1: Example calculation of the pressure control set point

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3 Electronic pressure switch menus and settings

3.1 Menu flow chart

The menu is accessed by pressing the up (or down) button. For full details of each menu function refer to the manufacturers operating manual.

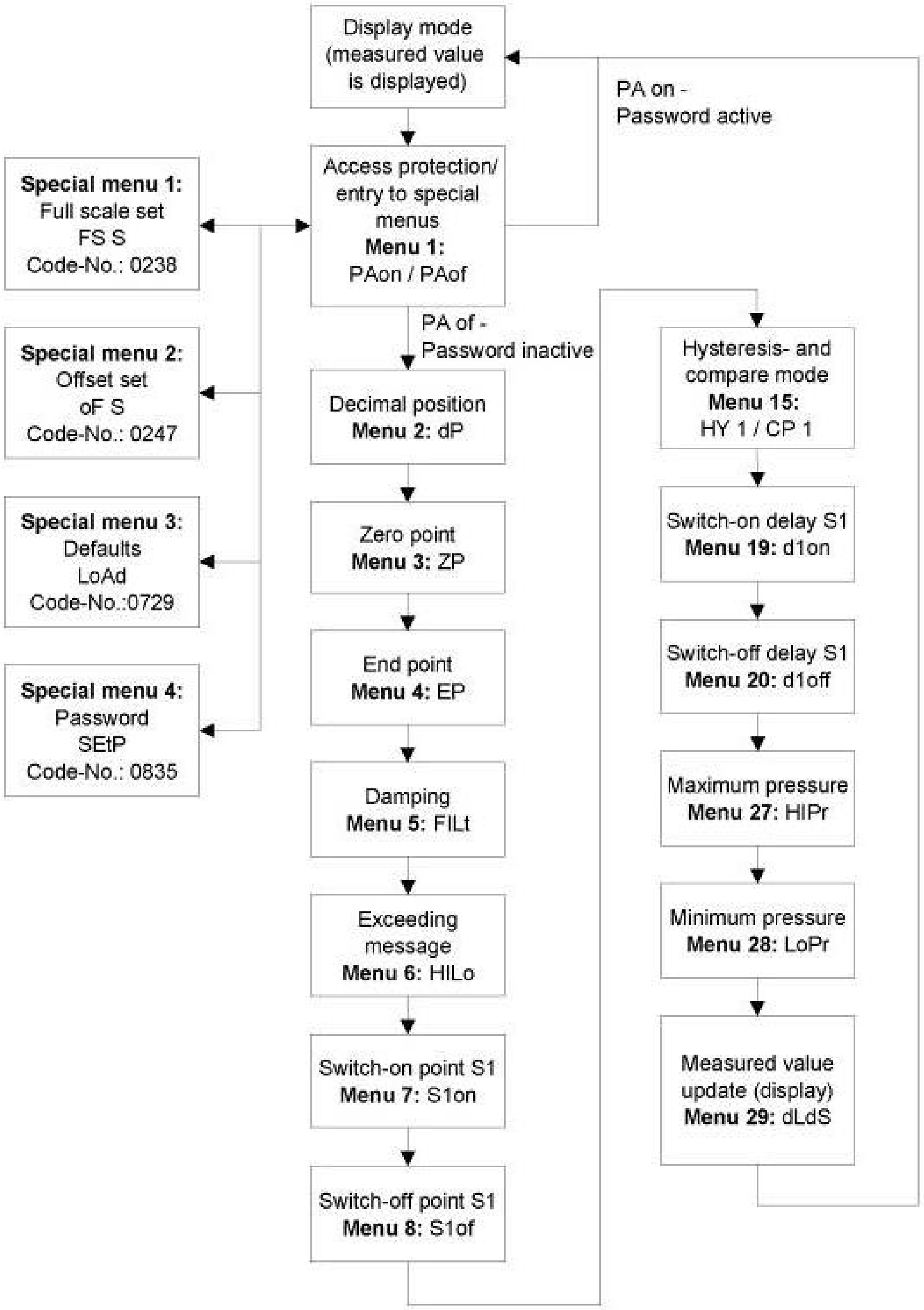

Figure 5: Menu flow chart

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3.2 Menu list and initial settings

The following table shows the initial settings of the electronic pressure switch.

Display	Menu	Initial setting
PRoF	1 – access protection	Off
dP	2 – set decimal point position	- - -.-
ZP	3 – set zero point	0.0
EP	4 – set end point	600.0
F ILt	5 – set damping	1.2 (changed to 0.1)
H ILo	6 – exceeding message	OFF
S 1on	7 – set switch-on point	200.0
S 1oF	8 – set switch-off point	356.0
HY 1	15 – select hysteresis mode	HYon
d 1on	19 – set switch-on delay	0.0
d 1oF	20 – set switch off delay	0.0
H IPr	27 – maximum pressure	(history display value only)
LoPr	28 – minimum pressure	(history display value only)
dLdS	29 – measured value update	0.0

Note 1: S1on is the setting for the pressure control activation threshold. This value must be set in advance according to the according to the target test pressure of the cylinder under test (refer to the section on choosing a value for further guidance).

Note 2: S1oF is the setting for the recovery pressure to which the system must be reduced in order to reactivate following trigger of pressure control. This value should be set sufficiently below the target test pressure to prevent cycling. A value of 200 bar was chosen empirically and worked well during evaluation.

Note 3: During evaluation, the value for FILt was changed from the factory default of 1.2 to the lowest available value 0.1. This made a marginal reduction in overshoot without adversely impacting display stability.

Table 2: Menu list

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4 Test plan

The test plan serves to evaluate the function and performance of the pressure control device (PCD) reference design in real world condition.

4.1 Baseline existing system performance

Aim: Obtain a baseline of the performance of the trial hydro test system prior to modification, to allow for later evaluation of the impact of the PCD on the test system (if any).

Method: Prior to installing the PCD exercise the hydro test system using a sample configuration to the routine test pressure. Record time to achieve the test pressure and retain the same sample arrangement to allow this test to be repeated after the PCD has been fitted.

Expected result: A working hydro test system and a baseline figure for pump time.

4.2 PCD Installation

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

Method: Install the PCD solenoid in the air supply to the hydro pump. Install the PCD smart pressure gauge into the wet side of the hydro test system. Connect the solenoid cable to the smart pressure gauge. Connect the power supply to the smart pressure gauge. Plug the power supply into a mains outlet. Power the system. Record any issues, tips or opportunities.

Expected result: PCD is relatively straightforward to integrate into an existing hydro test system using appropriate fittings, adapters and seals.

4.3 Modified system performance

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

Method: With the PCD solenoid enabled (direct power, or action threshold above hydro system full working pressure). Exercise the hydro test system to the routine test pressure using the sample configuration as before. Record time to achieve the test pressure.

Expected result: A working hydro test system with a pump time comparable to the unmodified unit.

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4.4 Master gauge comparison

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

Method: Set the over pressure control action threshold to the maximum pressure of the hydro test system. Exercise the system to perform a gauge comparison, recording the master and PCD digital gauge readings. Record the results on the standard IDEST gauge comparison chart.

Expected result: The PCD digital gauge accurately tracks the master gauge with accuracy per manufacturer "according to IEC 61298-2 standard of 0.35 % FSO" (±2.1 Bar).

4.5 PCD action

Aim: Determine if the shut-off is capable within the requirements of the standard - minimum of 3% or 10 Bar over target test pressure, and the system is disabled until drained to an appropriate recovery pressure. Assess any need for future adjustments to the action pressure setting (e.g. compensation for accuracy of the PCD digital gauge, pressure over-run etc).

Method: Perform a sequence of pressure runs with the PCD action threshold set at various points within the system working pressure range. Allow the pump to run until the PCD stops the system. Record the target shutoff pressure and actual stop pressure. Drain the pressure down and record the pressure where the pump restarts. In the final run switch off the power to the PCD and ensure the pump stops.

Expected result: Hydro pump is shut down within the requirements of the standard (minimum of 3% or 10 Bar over target test pressure). Achievable action pressure adjustments are calculated for future use. Following trigger, the pump remains disabled until the system pressure falls below the recovery pressure setting. In the event of power failure, the pump is disabled.

4.6 Hydro test runs

Aim: Confirm that hydro testing can be performed satisfactorily with the PCD enabled in the system.

Method: Perform a sequence of hydro test runs through a range of typical target cylinder test pressures. In each case set the PCD action threshold to the over-pressure value less any adjustments derived from previous testing. Perform a normal hydro test procedure. Observe for any adverse conditions.

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

4.7 Human interface

Aim: Determine if the display and menu system of the PCD is satisfactory for use in real world conditions.

Method: Review with the test system operator how they found changing the action threshold of the PCD, its display clarity and other opinions regarding the suitability of the PCD.

Expected result: The PCD menu requires quite a few key presses to change settings. The procedure is onerous but not difficult. Batching cylinders of the same test pressure will likely be recommended as a means of reducing need for adjusting the action threshold of the PCD.

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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.

Poole Diving IDEST certified technicians carried out all commissioning of the evaluation systems and operated the test equipment throughout the evaluation.

Also in attendance was Scott Waddell, director of Octopus Test Systems. Poole Diving use the Octopus Hydrostatic Pressure Automatic Cut-off (HY-PAC) device, and Scott requested to attend and bring a sample digital upgrade for retrofit to existing HY-PAC systems for evaluation side by side with the case study system. IDEST agreed to this request believing it would provide additional insight into digital working gauges and be in the best interests of IDEST members who operate HY-PAC analogue gauge systems.

A 7 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:

5.1 Baseline existing system performance

To de-risk ahead of the day set aside for testing the centre preinstalled the evaluation components to their hydro test system. This meant that it was not possible to baseline the actual performance of the original unaltered system. However, the operator was questioned regarding any perceived changes to the test times or other aspects of the system, and he confirmed no apparent change.

5.2 PCD Installation

The existing Octopus HY-PAC analogue contact working gauge was removed and replaced by the reference design electronic pressure switch. A spare manifold port was utilised to connect the sample Octopus digital working gauge. The HY-PAC solenoid and case study solenoids were configured in parallel (care was taken in later testing to ensure that each part of the system was evaluated without influence from the other, isolating or removing as necessary).

The installation was straightforward, albeit requiring the acquisition of a few high-pressure fittings to allow the new digital gauges to be attached to the wet side of the system.

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A leak test was performed, and a couple of leaks were identified and resolved.

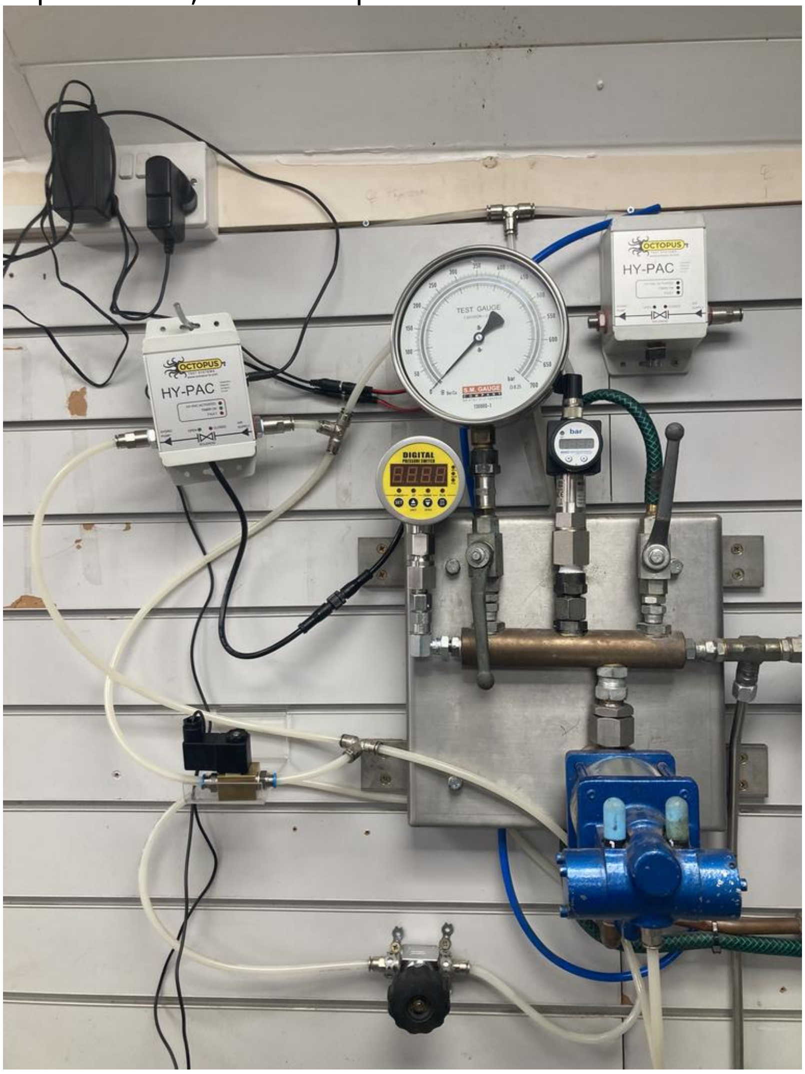

Image 1: The test setup
(Left, Octopus gauge. Right, PCD pressure switch. Lower left, PCD solenoid)

5.3 Modified system performance

Per previous comment, as the test system was commissioned ahead of the test day it was not possible to establish a formal baseline of the unmodified system. However, the technician felt that there was no observable impact from the modifications.

The system was exercised to the maximum permissible working pressure of 600 bar and held for several minutes. No leaks or other issues were observed.

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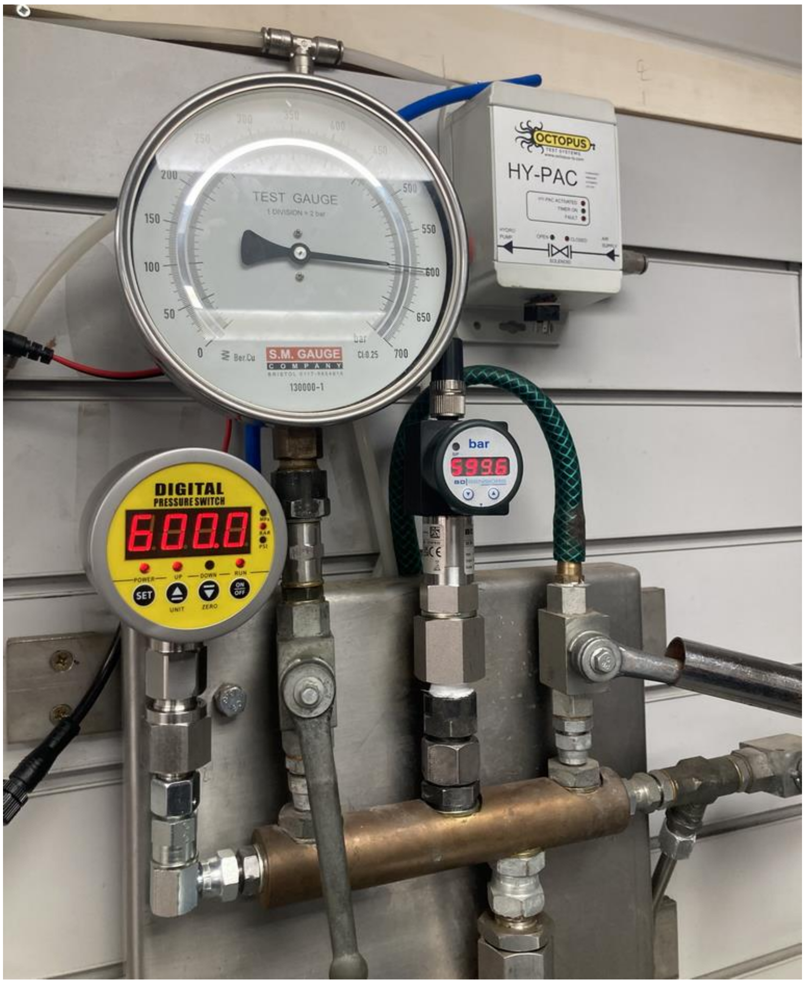

Image 2: Testing to 600 bar

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5.4 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. A gauge comparison was undertaken at roughly 50 bar steps in both rising and falling directions.

Rising readings (bar)					Falling readings (bar)				
Master	**Octopus**	**Delta**	**IDEST**	**Delta**	**Master**	**Octopus**	**Delta**	**IDEST**	**Delta**
50	48.9	-1.2	47.4	-2.7	551	553.4	2.4	553.0	2.0
100	97.7	-2.3	97.0	-3.0	500	500.2	0.2	500.4	0.4
151	150.4	-0.6	150.0	-1.0	450	450.7	0.7	450.7	0.7
199	198.5	-0.5	198.1	-0.9	400	401.2	1.2	401.0	1.0
250	250.4	0.4	249.5	-0.5	347	346.6	-0.4	346.2	-0.8
300	299.2	-0.8	298.8	-1.2	301	302.2	1.2	301.2	0.2
351	351.7	0.7	351.8	0.8	231	232.3	1.3	231.7	0.7
401	402.0	1.0	401.7	0.7	185	184.2	-0.8	184.0	-1.0
450	450.7	0.7	450.6	0.6	152	151.9	-0.1	151.2	-0.8
500	501.0	1.0	500.8	0.8	90	90.1	0.1	89.9	-0.1
550	549.8	-0.2	549.8	-0.2	50	48.1	-1.9	46.6	-3.4
600	E--H	-	600.4	0.4	11	11.3	-	9.4	-1.6

Note 1: The master gauge has a parallax mirror and smallest marked divisions of 2 bar.

Note 2: The IDEST PCD manufacturer claims accuracy "according to IEC 61298-2 standard of 0.35% FSO" which equates to ±2.1 Bar. At pressures below 100 bar small potential deviation may have been observed (red highlight) but this region is far enough away from the test pressures and was discounted.

Note 3: The Octopus digital gauge has a measuring range up 600 Bar and is believed to have a specification of 0.5% FSO (±3 Bar) accuracy.

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 two digital gauges with close readings.

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

It was noted at ambient pressure there was some 'fluttering' of the PCD display, but this largely settled on pressure readings above 10 Bar.

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5.5 PCD action

The test system was exercised to various pressure control set points across the likely target measuring range. The actual pressure in the system after cut-off was recorded.

Set point (bar)	Actual (bar)
360	362.6
360	361.9
460	461.4

Table 4: Set point vs. actual

As expected, there was a slight overrun with both the IDEST PCD and Octopus digital gauges exhibiting similar figures. This suggests that overrun is likely due to residual pressure in the air line causing the pump to briefly continue to cycle. The test system had excess of large bore 8mm pipe, arguably a worst case.

The initial overrun of the IDEST PCD was less than 3 bar. Reconfiguring the electronic pressure switch to reduce the 'filtering' parameter reduced the overrun to consistently less than 2 bar, and this figure was therefore chosen to use for de-rating future pressure control set points to ensure the cylinder under test is not exposed to pressure above the absolute maximum permitted.

It was also noted that the snubber also caused a slight lag on the PCD reading. But it was not necessary to remove it.

Following trigger of the pressure control device the pump remained disabled until the operator manually reduced the system pressure to below the recovery set point, 200 bar in this evaluation.

A power failure was simulated and confirmed that the pump was disabled.

5.6 Hydro test runs

A significant number of hydro test runs were performed at various target test pressures. In each case the PCD set point was pre-configured in relation to the target test pressure per the calculation method detailed in this report titled "choosing the pressure control set point".

In all cases the operator manually stopped the pump achieving a test pressure above the target value, below the target limit value, and without activating the pressure control device. This demonstrated capability and compliance against the requirements of the standard.

Additional scenarios were performed whereby the operator was 'distracted' at critical points causing the system to overrun the target test pressure. In each case the PCD operated correctly to stop the pump below the permitted

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maximum. The PCD was considered an accurate and valuable addition to the test system

Whilst it was not found necessary to 'throttle' the drive to the pump in order to achieve the target result, it is worthy of note that the Poole Diving hydro test system uses a needle valve to control the air supply to the pump and therefore exhibits a high degree of control.

5.7 Human interface

Both Octopus and IDEST PCD use 4-digit red LED indicators to display pressure. Both digital gauges were easily readable in the workshop environment.

During testing the PCD value for over pressure set point needed to be changed at various times. On both Octopus and IDEST PCD this required accessing the relevant menu function, adjusting the set value up or down, end exiting the menu.

As expected, this task, while not overly difficult, was somewhat onerous and time consuming. For this reason, centres will likely want to batch cylinders into similar test pressure groups to reduce the number of set point changes and streamline testing. A digital device with option for quick select preset pressure values would be a superior option.

5.8 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	Baseline existing system performance	System performs normally, no leaks etc	P
4.2	PCD Installation	The PCD was straightforward to install with appropriate fittings and adapters	P
4.3	Modified system performance	No apparent impact to the performance of the test system	P
4.4	Master gauge comparison	Gauge comparison on rising and falling showed no necessary correction needed	P
4.5	PCD action	PCD operated consistently with less than 2 bar overrun above set point	P
4.6	Hydro test runs	Operator controlled the system achieving TP without triggering the PCD	P
4.7	Human interface	Operator could successfully adjust the PCD set point	P

Table 5: Results summary

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6 Conclusions and recommendations

6.1 Conclusion

The case study and reference design establishes that electronic pressure switches with digital displays are excellent replacements for analogue working gauges. They offer the advantage of clear readability, and unambiguous operation within the tight parameters and tolerances for target test pressures imposed by ISO 18119.

The use of electronic pressure switches also facilitates an effective pressure control capability that again is demonstrably within the tight parameters and tolerances imposed by the standard.

Such close control is not likely to be achievable with the analogue over pressure control devices frequently observed in the field.

The two digital systems evaluated in this report both performed well, and to very similar performance levels, which suggests a broad range of modern digital devices may be suitable for this application.

It is encouraging that an equipment manufacturer is already working on a digital upgrade path that may benefit established centres that have already invested in their electronic pressure control equipment.

6.2 Recommendations

Centres should be made aware that whilst the requirements of the standard have not changed, there is increasing suspicion that test pressures, and pressure control specifications might not be achieved consistently by current analogue working gauges.

They should review their existing systems and give consideration to proof of compliance if challenged, and to possible upgrades to ease that burden of proof.

The use of 1/4 turn controls on the air supply to hydro pumps should be reviewed as needle valves provide superior control, which may be helpful when accurate pressure control is in operation.

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7 Appendix

7.1 A human is not a device

A common push back point against fitting a discrete over pressure control device is the feeling that it is unnecessary in a human operated test environment, especially where the hydro pump is controlled by a double handed dead man lockout etc.

The standard is explicit in its terminology regarding a 'device'. And device is commonly defined as "*a piece of equipment or a mechanism designed to serve a special purpose or perform a special function*".

Test equipment with solely human operated control of test pressure, does not contain a discrete "device" with specific function relevant to over pressure control. A human is not a "device" and cannot be relied upon to operate in an automated "device" like fashion, and therefore a manual system fails to fulfil the written criteria of the Standard and must be disregarded by IDEST.

7.2 Calibration and comparisons

Although digital gauges give the illusion of accuracy, the point of truth in the test system is always the master gauge, be it analogue or digital.

As the reference design electronic pressure switch is a replacement for the working gauge it is not subject to annual ISO 17025 calibration in the same way as the master gauge. It must, however, be checked for accuracy against the calibrated master gauge at regular intervals, typically at least once a month.

Any minor discrepancy noted between the master gauge and working gauge should be applied in the normal way by offsetting the target reading expected on the working gauge by the deviation.

Any significant deviation between the master gauge and working gauge must be investigated and remedial action taken.

7.3 Design limits

*14.2.2.*1 stipulates 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. For 300 Bar cylinders, test pressure is 450 bar and therefore design withstand should be at least 675 bar.

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The electronic pressure switch has a nominal pressure gauge range of 600 bar, an overpressure rating of 1,000 bar, and a burst pressure rating of 1,250 bar and therefore exceeds the above requirement.

7.4 Semi-automated test systems

The Octopus HY-PAC and IDEST PCD were trialled in combination. The HY-PAC was set marginally above the target cylinder test pressure, and the IDEST PCD was pre-configured in relation to the target test pressure per the calculation method detailed in this report titled "choosing the pressure control set point".

The operator manually started the test by opening the needle valve to let air to the pump. The HY-PAC successfully stopped the pump at the desired test pressure. The HY-PAC timer started and after 30 seconds an audible alert was given. The operator then released the pressure back to ambient.

The scenario was repeated, but after the HY-PAC stopped the pump at test pressure it was 'defeated' and the pressure allowed to rise again until the PCD activated and stopped it just below the maximum tolerance.

This scenario showed both systems could work well together to provide electronic control of test pressure, and a fully independent PCD. The operator remains a key participant, supervising, starting the pump, taking readings / evaluating the cylinder under test etc but it illustrates the opportunity for semi-automation of pressurisation.

7.5 Fully automated test systems

The standard does not preclude the option for a fully automated 'one button' hydro pressure test but the prospect raises a number of safety and supervision concerns that would need to be addressed. The cost and complexity of such a system sits outside the scope of a reference design aimed at achieving the minimum requirements for compliance with the standard.

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7.6 Parts list and pricing

Item	Vendor	Vendor P/N (and weblink)	Qty	Total
Digital Pressure Transmitter, 0-600 Bar, 1 contact, G ½"	Stork Solutions	DS200 780 6003 0 1 3 N01 200 1 000	1	£291.98
Snubber 10,000 psi, G ½" , CFH@1-PSI 3.0 (Water)	Omega	PS-2E-MG	1	£33.78
Solenoid Valve, G1/4, NBR, 4.5 Watts, 24V DC, 0-16 Bar, 2/2 way Normally Closed	Solenoid World	PU220022AR-24DC	1	£27.89
2.1mm Red Black Cable Plug to Bare Ends, 300mm	CPC Farnell	PW04971	1	£1.25
2.1mm Red Black Cable Socket to Bare Ends, 300mm -	CPC Farnell	PW04972	1	£1.43
Power Supply, 24V, 2.7A, 65W, 2.1mm Plug	CPC Farnell	PW05168	1	£13.78
DC Socket to Bare Ends Power, 2.1mm Socket, 1.5m	CPC Farnell	PW03407	1	£1.21
Phoenix M12 Plug, Female, 5 Contacts, Right angle	RS Components	154-8107	1	£12.97
Vishay 50V 1A, Rectifier Diode, 2-Pin DO-204AL 1N4001-E3/54	RS Components	628-8931 (NB: MOQ 10pcs)	2	£0.15
Festo QS Series Straight Threaded Adaptor, G 1/4 Male to Push In 8 mm	RS Components	121-6173 (NB: MOQ 10pcs)	2	£6.02
				£390.46

Notes:
1. Prices correct September 2025
2. Prices exclude VAT and P&P

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7.7 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.

7.8 Acknowledgements

The IDEST project team was led by Mike Collins with team members Nick Clark, Dave Crockford and Neil Minto.

The reference design prototype was assembled, evaluated and this report compiled on behalf of the team by Nick Clark.

The assistance of Poole Diving (7Z) with evaluation and testing of the reference design prototype is much appreciated.

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