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The Electronic Deadweight Tester — Updating the Conventional Deadweight Tester

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The Electronic Deadweight Tester — A Modern Replacement for the Conventional Deadweight Tester

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This article describes how a conventional deadweight tester is typically used to calibrate hydraulic pressure gauges, presenting some of the disadvantages of this approach. It explains why an electronic deadweight tester can be a more effective, modern alternative.

Introduction to High Pressure Calibration

Figure 1. High pressure instruments such as the analog gauge pictured here are often calibrated using hydraulic test media.

A common pressure calibration application is the calibration of high pressure instruments, typically analog gauges (Figure 1). The definition of "high pressure" varies with context, but typically it refers to instruments with a full scale range over 7 MPa (1,000 psi). Because of the inherent danger in using a gas (very compressible, stores a lot of energy) and the expense/difficulty of generating high pressure with it, high pressure calibrations are typically performed using a liquid as the test medium. This type of calibration is referred to as hydraulic. The two most common hydraulic media are oil and a water/alcohol mixture.

To calibrate an analog gauge, the calibration laboratory must have hardware to generate, control, and measure hydraulic pressure. The deadweight tester conveniently provides all three of these functions in one integrated instrument. (Figure 2).

A manual levered pump on the deadweight tester generates pressure by compressing the fluid in the reservoir. A small adjustable screw allows the operator to adjust the pressure incrementally. The deadweight tester includes a piston-cylinder assembly (Figure 3) configured so the piston can travel up and down within a column. The piston is coupled to a carrier mechanism on which manually loaded masses apply downward force. The operator applies enough pressure in the system to "float the piston" inside the column. The applied pressure is proportional to how much mass is loaded. The gauge to be calibrated is mounted onto a port on the deadweight tester, placing the gauge in parallel with the piston and exposing it to the same pressure. When the system is "ready," the operator makes the measurement by comparing the pressure defined by the deadweight tester to the pressure measured by the gauge.

Figure 2. A conventional deadweight tester generates, controls, and measures hydraulic pressure.

How a Deadweight Tester "Measures" Pressure

A deadweight tester does not actually measure pressure. Rather, it allows the operator to know or calculate the pressure when the system is in a specific state. This state, known as flotation, is achieved when there is enough force from the hydraulic pressure medium to support the piston in a floating state. The resulting pressure is proportional to the force applied by the mass load. The mass produces a force because it is accelerated by gravity — a phenomenon that varies with, and is resident to, geographical location.

When the piston is floating, the pressure (P) is derived by calculating the force (F) derived from the mass, equal to the sum of the piston mass and operator loaded mass platters, divided by the area (A) of the piston: $P = F/A$. Because the pressure is proportional to the force, the operator measures higher pressure by loading additional mass and then re-establishing the floating equilibrium.

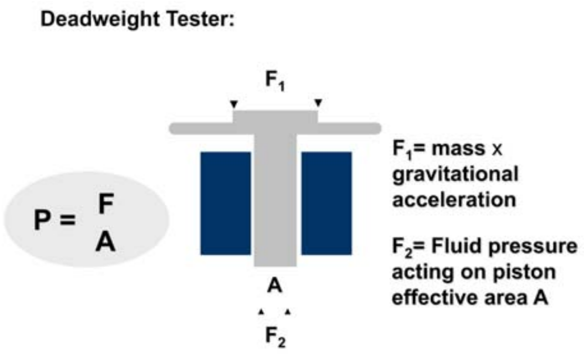

Figure 3. A conventional deadweight tester operates by balancing the gravitational force from loaded masses against the upward force of pressure acting on a floating piston. When the piston floats, the forces F1 and F2 are equal, and pressure is defined at the bottom of the piston by P=F/A.

Calibrating an Analog Gauge Using a Deadweight Tester

When calibrating an analog gauge (or any other type of pressure instrument) using a deadweight tester, the operator connects the gauge in parallel with the piston and then applies the same pressure to both simultaneously. The operator sets each test pressure as instructed by the calibration procedure. At each point, the operator records the analog gauge reading and the calculated pressure from the deadweight tester. After recording the test data at each of the test points, the operator determines which, if any, readings are out of the specified tolerance. If the gauge requires adjustment, the operator follows registered procedures to bring the gauge back into tolerance over its span. The operator then typically runs a second test sequence to confirm that the adjustments were done correctly and that the gauge leaves the calibration lab within its acceptable tolerance. This repetitious process amplifies the time and, therefore, the cost required for calibrations when this inherently slow and cumbersome method is used.

At each point in the test sequence, the operator compares the pressure on the gauge to that defined by the deadweight tester. Normally the test sequence is a number of equally spaced test points over the span of the gauge. A typical test sequence may be from 20 to 100 percent of test span with test points every 20 percent. For a 70 MPa (10,000 psi) test gauge, the first test point in this example is 14 MPa (2,000 psi). Normally the operator will load masses whose total force will result in a pressure of 14 MPa (2,000 psi) when the piston floats.

However, the analog gauge's indicator needle usually will not be on the nominal point when the deadweight tester's pressure is at the nominal value. In order to record a value for the analog gauge, the operator has to interpolate, or visually estimate, the value between two lines. Since each operator may interpolate slightly differently, it is preferable to calibrate an analog gauge by adjusting the test pressure at each point until the indicator needle is directly over the nominal pressure value. To do this using a deadweight tester, the operator must iteratively load very small masses (those corresponding to very small pressure changes) and refloat the piston at each increment until the needle is at the nominal value. The operator repeats this process at each test point throughout the range.

Disadvantages of Using a Deadweight Tester

Although the deadweight tester is considered to be a primary standard, and for that reason is perceived to be a desirable solution for hydraulic calibrations, there are several inherent disadvantages to using it.

- Iteratively loading small incremental masses until the gauge reads the nominal test value is time consuming and very inefficient.
- The minimum pressure increment is limited by the minimum mass value in the mass set. If the test gauge is of high resolution, it may not be possible to position its needle directly on a nominal test point.
- Because the deadweight tester does not measure or display pressure, it is very easy to inadvertently record test data at an incorrect test point due to the incorrect mass being loaded.
- The alternative to setting nominal pressures on the gauge under test by loading incremental masses is to interpolate the gauge's reading, creating an opportunity for errors.
- Achieving low uncertainties with a traditional deadweight tester requires measurement of the piston temperature and calculation of its effect on the measurement. This process is inconvenient and results in a calculated pressure value that is not equal to the nominal pressure to which the masses are adjusted.
- A deadweight tester system is not optimal for on-site or in-situ calibrations. The tester and its accompanying masses are heavy and difficult to carry to the site of the gauge to be calibrated.
- For the same reason, it is inconvenient and expensive to ship the deadweight tester and masses to a calibration laboratory for annual recertification.
- Matching the piston area to each mass platter in the mass set allows each mass to be conveniently equivalent to a whole number nominal pressure value for a given pressure unit. By configuring the mass set properly, the manufacturer can provide the customer with a set that can be loaded in a straightforward manner when the gauge is of that pressure unit. However, gauge faces are applied in a variety of different pressure units, which vary by industry, application, test system manufacturer, and so forth. To use the same deadweight tester to calibrate gauges with various pressure units, the operator either

needs multiple mass sets or a conversion sheet that allow him to know the pressure by multiplying the original unit pressure by the conversion factor.

- Since the force on the system is calculated as the total mass times the acceleration due to gravity, the operator must know the gravity value at the location of use. If the deadweight tester is used in on-site applications, the user must learn the gravity at the various locations in order to make valid measurements. If the mass set is adjusted to nominal pressure values, it will no longer produce nominal values in an on-site location with a different gravity value.
- Since the deadweight tester is inherently a mechanical device, there is no convenient way to automate the data acquisition. Once a test point is defined, the operator must write the data on a data sheet or manually enter it into a customized computer application.

A Better Solution: The Electronic Deadweight Tester (E-DWT)

Despite its drawbacks, the traditional deadweight tester has been the stalwart high pressure, hydraulic calibration tool for many years. With its low uncertainty (accuracy) and comprehensive packaging, it provides all three required calibration functions (generation, control and measurement) in a single instrument. Until now, these features have been important enough to overcome its disadvantages, and the deadweight tester has remained the preferred solution for hydraulic gauge calibrations.

Recently, manufacturers have introduced transducer-based high pressure hydraulic monitors that provide measurement performance sufficient for use as a reference calibration standard. A calibration lab could, in theory, acquire one of these monitors and either purchase a generation/control accessory or connect it to the generation/control portion of a deadweight tester. While feasible, such a solution requires the integration of two separate components and is not appealing enough to replace the conventional deadweight tester.

More recently, a new paradigm has been established with the introduction of the electronic deadweight tester, or E-DWT (Figure 4). E-DWT-H is a single piece solution for calibrating high pressure hydraulic pressure gauges and an electronic replacement for the deadweight tester. It includes numerous features that counter the shortcomings of a traditional deadweight tester and make it ideal for calibrating hydraulic test instruments.

The E-DWT-H housing includes a reservoir for test fluid, a priming pump to force the hydraulic fluid through the test system and to purge unwanted air from the system, a variable volume screw press to generate and set the initial approximate test pressure, and a fine adjustment valve, which provides the operator the means to set the pressure to the "exact" nominal pressure as read by the test gauge.

Figure 4. The E-DWT-H Electronic Deadweight Tester from Fluke Corporation, DH Instruments Division, is a single piece solution for calibrating high pressure hydraulic gauges. The H indicates hydraulic platform.

- Higher pressure ranges are possible, up to 200 MPa (30,000 psi). The maximum pressures of traditional deadweight testers are typically 70 or 100 MPa (10,000 or 15,000 psi). E-DWT-H can therefore add capability that the calibration laboratory did not previously have.
- A low torque, variable volume screw press easily generates the maximum test pressure within a single complete piston stroke.
- User selectable pressure units make changing pressure units quick and easy; this feature provides the versatility to calibrate gauges that measure in any pressure unit.
- A fine pressure adjust valve enables the operator to easily set the test pressure precisely at the gauge's nominal value. Once the nominal test pressure is stable, the operator simply reads the digital reference pressure from the E-DWT-H pressure display. This eliminates the time-consuming iterative process of adding more mass to define different test pressures until the nominal gauge pressure is established.
- The reference uncertainty of the pressure transducer is ±0.02% of reading from 100% down to 10% of the reference transducer's range. With a k=2 coverage factor, this specification is valid for an entire year. E-DWT-H can house a second pressure transducer to extend the percent of reading uncertainty to an even lower pressure. With a second transducer, whose range is 10% of the high range transducer, E-DWT-H offers uncertainty of ±0.02% of reading from 100% down to 1% of the maximum range. The pressure transducer ranges are user selectable. For example, if the user chose a 200 M (30,000 psi) and 20 M (3,000 psi) pressure transducer, this configuration offers one year uncertainty of ± 0.02% of reading from 200 MPa (30,000 psi) down to 2 MPa (300 psi) in a single instrument!
- E-DWT-H always displays the actual reference pressure. The operator no longer needs to worry about incorrect mass loads and subsequent tainted pressure comparisons.
- E-DWT-H reference pressure transducers are not influenced by gravity; therefore, the operator does not

need to know his location's local gravity to use it. E-DWT-H functions identically in the user's calibration lab or at his customer's location when used as an on-site calibration tool.

- E-DWT-H is lightweight (35 pounds, or 15 kilograms) and its metal enclosure is fabricated with recessed areas that function as convenient handles for lifting and carrying. This makes it ideal for on-site applications.
- E-DWT-H is powered by standard line voltage. A rechargeable battery pack accessory allows it to be used for field applications where a power source is not available.

Figure 5. E-DWT-H's fine adjustment valve enables the operator to set pressure to the exact nominal value on the gauge under test.

Unique Benefits of the Electronic Nature of E-DWT-H

In addition to the features of E-DWT-H that overcome the limitations of the traditional deadweight tester, its electronic nature offers advanced features that the operator can exploit to further improve the efficiency and results of the test.

- An objective ready light tells the operator when to record the reference pressure. The indication is based on the stability of the measured pressure and can be set to a value determined by the lab manager. With this feature, all users will very likely obtain repeatable results.
- An AutoTest function enables the operator to define the test sequence and have E-DWT-H guide him point-by-point through the test. At each test point, E-DWT-H records the reference pressure and compares it to the nominal gauge pressure. It then compares the difference to the acceptable tolerance for the gauge under test and determines whether the measurement is within tolerance or not. This feature also helps ensure that test results are consistent among users. The results can be downloaded and viewed with a PC using a remote interface via E-DWT-H's RS-232 communications port.
- A more advanced alternative for recording and evaluating the data is to run the test via PC-based calibration software. Using E-DWT-H's RS-232 communication port, the user can run the test sequence from the PC software and record the test data and other relevant parameters electronically. With this data stored in a test file, the calibration software can then generate customized calibration reports. DH Instruments offers COMPASS® for Pressure calibration software to perform this function.

Summary

The traditional deadweight tester has been the most common instrument used to calibrate high pressure, hydraulic, analog gauges. This trend continued despite significant drawbacks because it offers low uncertainty and a single component for generation, control and measurement of the pressure. Now a new solution is available called the electronic deadweight tester, which offers not only the attractive features of the traditional deadweight tester, but also functions that eliminate deadweight tester drawbacks and add significant utility.

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For product information on the E-DWT visit www.dhinstruments.com