A Comparison of Deadweight Testers and Digital Pressure Calibrators

The deadweight tester has long been the standard for pressure calibration. However, advancements in technology have led to the development of digital pressure standards worthy of consideration in lieu of a deadweight tester. Understanding how to contrast the two technologies is key to selecting the appropriate solution.

From left to right:
Type T deadweight tester, GaugecalHP pressure comparator, and XP2i digital pressure gauge.

Accuracy

Deadweight testers are systems that physically generate a known pressure. They may also be used as gauges to accurately measure system pressure. These devices do not require a display, as the combination of the masses is used to determine the output pressure. They operate under the simple formula that pressure is equal to force applied over a known area. The deadweight tester output is typically very accurate, even at its lower ranges. Industrial deadweights are available with accuracies to ±0.015% of reading.

By contrast, digital pressure standards must be combined with a pressure source to generate a known pressure. Without the capability of producing pressure, the digital standards are technically gauges. However, in the market, they may be called calibrators to distinguish them from the lower classes of digital indicators. These digital devices are typically available in accuracies as a function of their full scale, such as ±0.050% of full scale (FS). However, advancements in technology have led to some instruments specified as a function of the reading, like deadweight testers. Accuracies are available as low as ±0.025% of reading.

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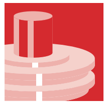
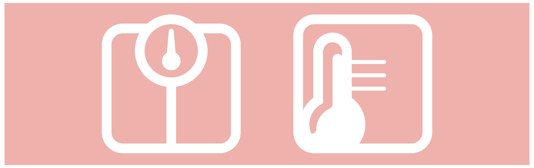
Deadweight Testers and Digital Pressure Calibrators

Site Corrections



When comparing accuracy or uncertainty, an important factor to consider is site corrections. Because deadweight testers are physical standards, they are subject to effects that digital standards are not. One major effect is gravity. The force of gravity on the masses of a deadweight tester varies based on distance from the Equator and elevation. For example, a deadweight using the same exact mass will generate a different pressure at Houston, TX than it does at Denver, CO. The effect is substantial enough that it can alter the output to a value that is outside of the tolerance of the tester. The user has two options to correct for this. They can either have the unit calibrated to their local gravity, or to International Mean Gravity (980.665 gals) and then calculate a correction factor for the work site. Digital standards are not affected by gravity, so such correction is not necessary.

A second site factor to consider is temperature. While the temperature effect on a deadweight tester is not considerable, the additional error should be calculated and accounted for. Many digital gauges and calibrators are subject to temperature effects, which may be significant. The manufacturer's specifications should offer this information, allowing users to calculate a total error for their local conditions. Higher quality digital standards include temperature compensation so that there is no effect on the accuracy of the device.



Gravity may affect the accuracy of a deadweight tester, while digital gauges and calibrators may be affected by temperature.

Other Considerations

Digital devices will typically have other functions that are very beneficial in completing certain tasks. These may include the ability to measure mA in a loop, source and measure the loop, and read temperature. Firmware functions may include special modes for relief/safety valve testing, peak measurement recording, scaling, error calculations, or data logging. In addition to the onboard functions, manufacturers may include software with these devices to allow for automated recording of test results, generation of calibration records, or review and analysis of data. Deadweight testers do not offer such additional functions so additional equipment may be necessary to complete these tasks.

Additionally, digital pressure gauges will typically offer the capability to easily change engineering units (for example, psi, bar, kPa, "H2O). This is particularly useful in workshop or lab settings where various devices using different engineering units may be tested. Because deadweight testers utilize specific masses to produce an output, those masses are dedicated to a specific engineering units and other mass sets are required to produce useable values of other engineering units.

Unlike deadweight testers, digital pressure gauges offer the capability to change engineering units.

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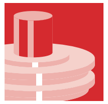
Primary vs. Secondary Standards



Deadweight testers are primary standards. This is because they are based solely upon physical parameters and the pressure measurement is not translated into an electronic or analog signal. Since they are a physical standard, they can be made to cover wide pressure ranges using different masses and effective area components. Conversely, these units are bulkier and much heavier than most digital standards. They are often more difficult to set up and require more training to become an efficient user than would be the case for a digital pressure calibration system. However, because of the stable, regulated output, technicians can become proficient in the use of these testers and can complete a calibration in a very reasonable time.

Digital pressure gauges are secondary standards, because the pressure is translated into an electronic signal using a transducer. They may also be considered as transfer standards, as they are used on site and then checked against a primary standard on a regular basis. Unlike deadweight testers, digital standards have limited ranges due to the sensors used in their construction. Multiple units may be necessary to cover large pressure ranges. Even if multiple units are needed, the overall size and weight of the digital system will typically be less than that of a deadweight tester. Because they do not generate a pressure, some consideration needs to be given to the portability of the pressure source.

If the pressure source is a handpump or jack pump, care must be taken to ensure a stable pressure is applied to the instrument under test and to the reference standard. Additionally, training is required such that the technician understands system indications such as a temperature change, adiabatic effects, and entrained air are identifiable and understood.

Cost of Ownership

One final consideration when evaluating the deadweight testers versus digital gauges is the overall cost of ownership and long term monetary benefit. Deadweight testers typically cost more to purchase than a digital pressure system. In addition to the initial purchase cost, the calibration cost for a deadweight tester is typically more than a digital standard. However, in general, deadweight testers will last longer than digital devices, and their higher accuracy may result in smaller errors throughout a system. These reduced errors may result in a higher monetary benefit.

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Conclusion

When considering a change from one technology to the other, all factors should be considered, including a proper support and training program for the technicians and understanding the complete accuracy/uncertainty specifications for the units. A digital to deadweight change would increase stability and accuracy, and cover a wider pressure range. However, corrections for gravity and temperature must be applied. A deadweight to digital change would increase portability, reduce purchasing and operating costs, add the ability to read directly in multiple pressure units, remove requirement to adjust for gravity, may be fully temperature compensated, and will include useful functions and features. However, they are not as accurate, may not last as long, and are not primary standards.

Deadweight Primary Standard	Digital Pressure Standards with Comparator (pump) or Systems Secondary or Transfer Standard
● Higher accuracy (0.015%).	○ Lower accuracy (0.025% - 0.1%).
● Much higher accuracy at lower pressures below 9 psi / 250 "H_2O.	○ Much lower accuracy at lower pressures below 9 psi / 250 "H_2O.
● One unit covers a wide pressure range.	○ Requires multiple units or unit with multiple sensors to cover a wide range.
● Much better pressure stability, "regulated output."	○ Less pressure stability due to adiabatic affects.
○ Must apply corrections to achieve high accuracy.	● No corrections required if fully temperature compensated.
○ Accuracy affected by ambient temperature, not specified below 0° C.	● Accuracy not affected by ambient temperature, wider temperature range, -20° C.
○ Slower to setup and more complex to operate.	● Faster to setup and easier to use.
○ Heavier.	● Lighter, more portable.
○ More expensive to purchase and own.	● Less expensive to purchase and own.
● No power required.	○ Requires power.
○ No software.	● Software available to speed up calibration process and generate certifcates.
○ One pressure unit.	● Read directly in many pressure units.
○ Cumbersome to set small or specific pressure values.	● Easy to set small or specific pressure values.
● Longer lifetime.	○ Shorter lifetime.
○ Pressure only, may need other equipment for task.	● Pressure, mA, V, task specific features like PSV, switch, logging.