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The Effective Use of Deadweight Tester
Class # 4050

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INTRODUCTION

One of the most difficult problems facing the instrument engineer is the accurate calibration of pressure or differential pressure measuring instruments. The deadweight tester or gauge is the economic answer to many of these problems.

This paper describes methods to select deadweight testers and gauges. Also included are procedures for using pneumatic and hydraulic deadweight testers.

PRECISION PRESSURE STANDARDS

Primary pressure standards are generally more accurate than secondary pressure standards. A primary pressure standard must revert to fundamental units of mass and length. These fundamental units can be determined with a high degree of precision. The two primary pressure standards are the deadweight tester and the U-tube manometer. Accuracy on primary standards is generally measured as a percent of the reading.

Other precision pressure gauges, sensors, and transducers, etc. are classified by the National Institute of Standards and Technology (NIST) as secondary comparison standards. Secondary standard accuracy is usually measured as percent of the full-scale reading.

Electronic pressure testers may be used for instrument calibration in place of deadweight testers because they may be cheaper and offer more portability. However, deadweight testers still provide advantages that must be considered. With respect to operating convenience, deadweight testers do not require a power source and can generate a stable and precise output pressure to be applied to the test device. Especially, if high pressure is required. With electronic pressure calibrators, an alternate source is generally needed for a stable test pressure. In general, deadweight testers are more precise devices providing very low uncertainties based on percent of reading rather than full scale. Also, deadweight testers are generally less susceptible to environmental temperature effects on performance accuracy. Therefore, a close examination on the economic benefits of this improved accuracy can easily justify any added cost of a deadweight tester versus an electronic pressure calibrator.

DEADWEIGHT TESTERS

The base formula for deadweight testers is P = F/A. Where F equals the force or amount of weight, A equals the area over which the force is applied and P equals the resulting pressure. Two general types of deadweight testers exist. First, a closely fit piston and cylinder with weights applied to the piston. Second, a precision ceramic ball within a tapered nozzle, with weights applied to the ball.

SELECTION OF A DEADWEIGHT TESTER

Many different types of deadweight testers are available. In order for a user to select the correct tester, several aspects of the task to be performed should be considered.

The first item that should be considered is the required accuracy of the tester. Accuracy of most instruments is expressed as "percent of full scale". A 1000 PSI instrument with accuracy of 1% full scale can therefore have an allowable error of +/- 10 PSI at any point from 0 to 1000 PSI. Deadweight tester accuracy is generally expressed as "percent of indicated reading. A 1000 PSI tester with an accuracy of 0.1% indicated reading will have an allowable error of +/- .01 PSI, at 10 PSI, +/- 0.1 PSI at 100 PSI and +/- 1 PSI at 1000 PSI.

Another important consideration is the test fluid. Since the test fluid will enter the pressure sensing element of the instrument being tested, the test fluid must be compatible with the process fluid to which the instrument will be attached. Otherwise, all instruments must be cleaned after testing, an expensive operation. The most common test fluid is instrument grade oil. Where usable, oil provides an outstanding combination of corrosion resistance with lubrication of the close fitting piston and cylinder.

Distilled water provides an excellent test fluid that is inert to most process fluids. Clean dry air or nitrogen gas; however, eliminates the problem altogether. The user must be particularly careful that the tester selected is designed for operation with the intended test fluid.

The third consideration is the pressure range. A survey should be made of the pressure range of all instruments to be tested. The tester should produce pressures in excess of the highest instrument to be tested.

Deadweight testers are available with accuracy ranging from +/- .015% to +/- 0.1% of indicated reading. This range of accuracy can be appropriately matched with the various types of process instrumentation (and their respective performance) which are to be calibrated. Ideally, a calibration device should be 4x as accurate as the test device. However, the improved performance in process instrumentation has resulted in a 2:1 ratio as being minimally acceptable.

Piston and cylinder testers are most responsive within the upper 90% of the operating range. If a broad range of pressures are to be tested, the user should consider dual range testers which contain piston and cylinders of more than one size. A second consideration is two types of testers, pneumatic at low pressures and oil or water at higher pressures.

A final consideration should be the task to be performed. If most of the instruments to be tested are fixed in place, such as recorders, the portability of the tester is important. If many instruments are to be tested, dual column testers that change test range quickly are helpful. If many technicians will use the tester, the tester should be rugged and relatively independent of operator technique. High performance tasks, such as testing of instruments at manufacture, require custom designed testers.

USE OF DEADWEIGHT TESTERS

It is most important that the operator consider several items prior to the use of any deadweight tester.

1. The operator should read the instruction manual thoroughly and become familiar with the equipment prior to any usage.
2. The testers should not be operated at pressures in excess of their factory ratings.
3. The pressure rating of the tubing and fittings used to connect the tester to the device being tested must exceed the pressure rating of the deadweight tester.
4. A deadweight tester should not be connected to pressure source such as a well or pressurized tank.
5. All pressure fittings must be tight.
6. The fluid within the deadweight tester must be compatible with the process fluid to which the instrument being tested will be attached. If the test fluid is not compatible with the process fluid, all instruments must be cleaned after test prior to usage.
7. The piston and cylinder should be cleaned prior to use.
8. Before pressure is applied, weights in excess of the maximum pressure should be stacked on the instruments weight carrier.

CLEANING A PISTON AND CYLINDER

Each piston and cylinder should be cleaned prior to use. If the piston and cylinder has been stored outside the tester, it should be recleaned prior to use.

Periodic recleaning of the piston and cylinder is necessary. A lack of sensitivity to small pressure changes is an indication that the piston and cylinder assembly requires recleaning.

Suggested cleaning procedure is as follows:

A. Carefully wipe off any visible dirt or foreign matter from the protruding part of the piston and slowly withdraw the piston from the cylinder. Do not use force, but be sure all dirt is removed so that piston will slip out easily.

B. Boil both the piston and cylinder for at least 15 minutes in distilled water. Cylinder bore should be wiped with a small wood handled wiper such as a "Q Tip" to remove all evidence of dirt. Wipe the piston dry and clean with a lint free wiper such as "Kim Wipe".

C. Rinse piston and cylinder in Freon.

D. Wipe cylinder bore and piston again to remove any dirt.

E. Pick up piston by piston cap and dip it in clean fluid to be used in tester, then carefully insert piston in the cylinder. If any feeling of roughness or what might be grit in the annulus area is suspected, disassemble and repeat cleaning procedure.

F. At the same time, the deadweight column, output post and tubing should be drained and flushed with a solvent such as Freon "TF", then cleaned, dried and refilled using clean fluid.

G. The piston cylinder assembly then can be installed carefully in the mounting column.

REMEMBER - Do not touch piston with fingers or other soiled or contaminating surfaces after cleaning. Extremely minute particles can cause trouble in a closely fitted assembly such as this. It is not possible to over emphasize the value of cleanliness.

PROCEDURES FOR USE OF HYDRAULIC DEADWEIGHT TESTERS

The following procedure is typical of methods used to test pressure instruments using hydraulic deadweight testers. The use is encouraged to modify these procedures to test critical instrument characteristics.

Step by step procedure is as follows:

1. Remove the pressure instrument from service and blowdown.

2. Set up the deadweight tester and level the device.

3. Connect the input of the pressure instrument to the pressure test port on the deadweight tester.

4. Put weight on tester weight carrier equal to 90 to 100% of the range of the instrument being tested.

5. Build up pressure with the tester hand pump until the weights float freely. Rotate weights 10 to 30 RPM. Check to be sure that no leaks are present.

6. If no leaks are present, proceed with calibration. If leaks are apparent, they must be located and repaired before proceeding with calibration.

7. Remove all pressure from the tester hand pump. Vent high and low side of pressure instrument to atmosphere. Adjust the zero output reading of the on instrument.

8. Leave low side of instrument open to atmosphere, open high side of instrument to the deadweight tester.

9. Begin instrument calibration by placing weights on deadweight tester weight carrier equal to 25% of the range of the instrument being tested.

10 Build up pressure with the tester hand pump until the weights float freely. Rotate weight 10 to 30 RPM. Allow instrument to settle for one (1) minute. Tap case of the instrument. Record reading.

11. Place additional weights on deadweight tester to read points at 50%, 75% and 100% of instrument range.

12. Close valve between deadweight tester and the instrument being tested.

13. Remove weights from deadweight tester to read 75% of the range of the instrument being tested.

14. Open valve between deadweight tester and the instrument being tested. Allow deadweight tester weights to settle. Weights must be floating freely and rotating 10 to 30 RPM. Allow tester to stabilize for one (1) minute. Tap case or instrument. Record reading.

15. Repeat step 12 through 14 to read points at 50% and 25% of the instrument range.

16. Remove all pressure from the instrument being tested. Recheck zero on the instrument.

PROCEDURES FOR USE OF HYDRAULIC DEADWEIGHT GAUGES

Deadweight gauges are used to measure pressures contained within an external source with high precision. Deadweight gauges do not contain a pump or any self contained source of pressure.

It is important to emphasize that all tubing, fittings and chambers within the deadweight gauge are rated at pressures higher than any pressure source that may be attached to the gauge. Deadweight testers should not be used as deadweight gauges unless so certified by the manufacturer.

The following procedure is typical of methods used for hydrostatic testing on pipelines and well static pressure testing. Step by step procedure is as follows:

1. Set up deadweight gauge and level the device.

2. Connect the pressure port on the device to be tested to the inlet port of the deadweight gauge. A shut off valve should be placed at the pressure port and at the inlet of the deadweight gauge.

3. A water separator may be connected between the pressure tap and the inlet of the deadweight gauge. Some deadweight gauges contain isolation devices to prevent water from coming into contact with the piston/cylinder.

4. Shut the valve on the deadweight gauge inlet and open the valve on the pressure port. Check for leaks. If no leaks are present, proceed with test.

5. Place weights on the deadweight gauge equal to 100% of the pressure within the line or well to be tested.

6. Open the inlet valve to the deadweight gauge slowly. Rotate the weights 10 to 30 RPM.

7. Observe the direction of float of the piston and cylinder. If the piston and cylinder is falling, weight must be removed. If the piston and cylinder is rising, weight must be added. Weights should be added or deleted until equilibrium within the mid one-third of the piston and cylinder float range is achieved.

8. Sufficient time must be allowed for pressure conditions to stabilize. The higher the pressure the longer the period required for conditions to stabilize.

9. Close the valve on the pressure port on the device being tested. Open the deadweight gauge vent valve to relieve pressure. Close the input valve of the deadweight gauge.

10. Remove the weights on the deadweight gauge. Use the manufacturers data to determine the measured pressure; for example:

Piston & Cylinder Area =	0.0l in^2
Weight of Piston/Cylinder Carrier Assembly =	0.5#
Weights on Carrier:	2 - l0#
	1 - 5#
	3 - 1#
	4 - 0.1#

$P = W/A = 28.9$ lb./0.01 in^2 = 2890 PSI

11. The pressure measured by a piston gauge loaded with a particular set of deadweights is proportional to the local value of gravity. The value of local gravity can differ by more than 0.3% at different locations in the United States. As pressure is defined as "force" per unit area, the mass values must be converted to force values. To accomplish this, the value of gravity must be used. The value of local gravity may be determined by having a gravitational survey made of the local area with a gravimeter or by referring to "Pendulum Gravity Data in the United States", a U.S. Department of Commerce Publication No. 244. Once the local value of gravity is known, the mass values may be converted to force values by the equation:

$F\text{-}\ MG_1/GS$
Where: M = Mass of the Weights_2
G^1 = Local Gravity
(cm/sec^2 or Gals.)
G_S = International Standard Gravity)
= 980.665 Gals.

Under standard conditions the pounds weight is equal to pounds mass.

Continuing the example:

Local Gravity = 979.628 Gals.
Calibrated Gravity of the deadweight testers Weights = 980.665 Gals.

$$P = 2890.\text{PSI} \times \frac{G^1}{G_S}$$

$$= 2890 \times \frac{979.628}{980.665} = 2886.944 \text{ PSI}$$

PROCEDURES FOR USE OF PNEUMATIC DEADWEIGHT TESTERS

The following procedures for calibrating chart recorder type orifice meters using the AMETEK Model PK tester were recommended by Mr. Charles F. Drake, Natural Gas Pipeline Company of America at the AGA Gulf Coast Measurement Short Course, Houston, Texas in l974. The author acknowledges his appreciation for permission to reproduce them in this paper.

"A suggested step-by-step procedure to be used when calibrating a meter with a PK tester follows:

1. Remove meter from service and blow down.

2. Level AMETEK and connect gas supply - 30 - 35 psig to inlet of AMETEK. AMETEK should be located close to meter to eliminate long tubing line on outlet. (Be sure skirt of weight table is not dragging on nozzle body.)

3. Connect AMETEK outlet to high side of meter. Vent low side of meter to atmosphere. Turn on supply gas to AMETEK and open outlet valve. Provide filtered gas, free of liquids.

4. Put weight equal to above 90% to 100% of meter range of AMETEK and allow pen to travel to full stop on chart, (at least one minute.

5. Close outlet of AMETEK and observe reading on chart for about two or more minutes. - IMPORTANT -

6. If no leaks are present, proceed with calibration. If leaks are apparent, they must be located and repaired before proceeding with calibration.

7. With AMETEK outlet valve closed, vent high and low side of meter to atmosphere and adjust zero on chart.

8. Leave low side of meter open to atmosphere - high side of meter connected to AMETEK.

9. Begin meter calibration by placing table and necessary weights on AMETEK to read about 6" on a 50" meter (12" on a 100", etc.). Allow meter and AMETEK to settle in for at least one full minute minimum time before pulling point on chart.

   (Note - use weights which will allow reading to fall on narrow line of calibrating chart).

10. Place additional weights in increments of 10" on table to read points at 16", 26" and 46" on a 50" meter. (32", 52", 72" and 92" on a 200" meter, etc.). Care should be taken when placing weights on table to see that all points are reached with the meter travel in the up direction, in other words, do not overshoot the points. Again, wait a minimum of one full minute before pulling any points.

11. Check down points at 42", 32", 22" and 12" on a 50" meter (84", 64", 44" and 24" on a 100" etc.). Care should be taken to remove weights in the proper manner so that all down points are reached from the downward travel of the meter. This is important, as it will tell if there are binds in the meter.

12. Recheck zero of meter.

SUMMARY

The deadweight tester or deadweight gauge is the most accurate and cost effective piece of equipment to use to measure pressure where a high degree of precision is required. The capability of this equipment is achieved only when correct and safe procedures are employed.