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TECHNIQUES FOR INTER-CALIBRATION OF DEAD WEIGHT PRESSURE TESTERS

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A simple and reliable approach has been made to calibrate and certify Air, Oil or Gas-operated Dead Weight Pressure Tester (DWPT) against a Reference Dead Weight Pressure Tester. Periodic calibration data of dead weight pressure testers of different ranges and make has been collected against a reference DWPT traceable to the National Physical Laboratory, UK and NIST (NBS) USA. Using these techniques, the uncertainties of calibrated DWPTs have been found within their limits of error as specified by the manufacturer. The method has been found suitable for the certification of oil, gas, air-operated Dead Weight Pressure Testers using oil-operated DWPT as reference standard.

Key words.: Dead Weight Pressure Tester, Calibration, Certification.

Introduction

International activities such as trade, aviation and metrology require that the pressure standards of all countries should be in accord. The necessary and logical prerequisite for this is that national reference standards should be in agreements as set by the BIPM (International Bureau of Weights and Measures and the OIML (International Organization of Legal Metrology) [1]. The requirements of traceability of pressure measurement in Pakistan have resulted in the evolution of pressure standard hierarchy presently covering a medium range of pressure 10 kpa to 110 Mpa at the National Physical and Standards Laboratory.

The system of measurement is coherent and worldwide acceptable due to the availability of Internationally Traceable National Reference Dead Weight Pressure Tester. For industrial and scientific work, instruments used for pressure measurement need periodic calibration at all levels using traceable reference standard Dead Weight Pressure Tester [2].

Experimental

Principle of operation of DWPT. The dead weight tester is also named as pressure balance, piston gauge, controlled clearance piston guage, dead weight gauge, dead weight type pressure gauge tester. The pressure is the quotient of a force by an area, due to dead weights the force being at right angle of the area of the piston. For physical realization of this basic definition, the DWPT is an apparatus of measurement based on a piston-cylinder assembly of known areas [3]. The oil-operated DWPT arrangement is shown in Fig.1. The piston is uplifted using air or gas or hydraulic pressure and dead weights are loaded on the carrier to balance the piston. The balance will maintain the lift to a certain distance. In the middle of the total distance the measurement is preferred [4, 5]. The carrier is a circular cocentric metal disc or pan attached with the piston for loading the circular dead weights. The carrier alongwith the piston itself acts as a load. In the floating position carrier establishes the minimum pressure of the DWPT. In our discussion the carrier is denoted with 'C' . The value of pressure against the floated piston with its carrier without any loading of dead weights varies from model to model. The pneumatic DWPT admits air or gas from an external source (compressed gas container or hand held air pump) connected to the piston cylinder assembly instead of hydraulic fluid arrangement shown in Fig. 1. For more accurate measurement the piston loaded with dead weights on the carrier is rotated. During a great part of the time, the piston rotates freely in the cylinder due to ready built torque and thus avoid the friction being able to disturb the upward force, electric motor is also used for this purpose [6,7].

Calibration set-up at NPSL. A dual range oil-operated dead weight pressure tester Model 8260/6 (motorized drive) with pressure range 0.1 to 1100 bar (1.5 to 16000 psi with ± 0.03% accuracy made by Lucas Barnet (England) and

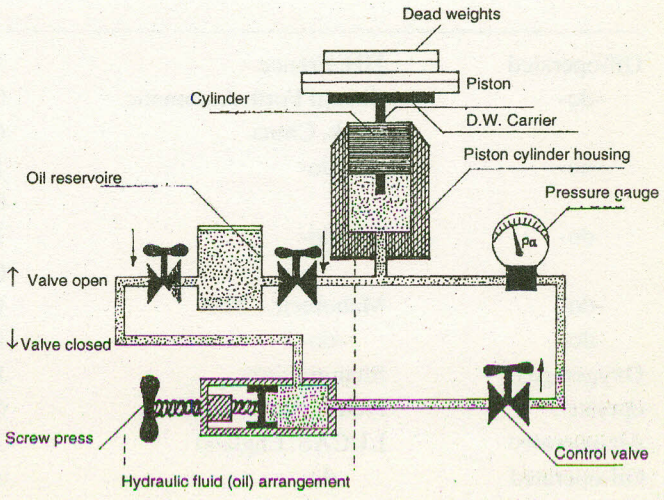

Fig. 1. Oil operated dead weight pressure tester arrangement.

traceable to both the NPL (UK) and NIST (USA) is being used at the NPSL as Reference Standard of Pressure.

Calibration of oil-operated DWPT. The connection for calibration of an oil-operated DWPT against the reference oil-operated DWPT is shown in Fig.2. Both testers are primed independently using recommended specific oil with screw press. Initially, the connection valve is closed and required nominal pressure is generated in the tester under calibration. This pressure may be generated in MKS or conventional units like Pa or Psi, kgf/cm^2 or bar, etc.An estimated equivalent pressure in bar is generated in reference tester. For a moment the connection valve is opened. This will cause pressure from both sides to react and any deviation from balance will be indicated on the differential pressure gauge.

If the gauge shows very large imbalance then connection valve is closed to generate a roughly balanced oil pressure by increasing or decreasing the pressure of reference tester. If the gauge shows a little imbalance but not a null point, then the pressure on standard DWPT may be adjusted using, fractional weights of standard DWPT after opening the valve. At the NPSL, the fractional weights of reference DWPT have been designed to resolve the pressure upto ±0.0001 bar. The stable floatings are indicative of fine pressure balance [7]. The actual value of pressure generated at particular nominal pressure of DWPT under calibration is addition of all pressure indicated on the dead weights, fractional weights and weight of piston with carrier of reference DWPT. If both DWPTs read in bar the difference is reported in bar on the other hand the conversion upto five decimal places is used to find out the equivalent pressure in other conventional units. The densities of hydraulic fluid used for different DWPTs are different as shown in Table 1. The close clearance piston cylinder assemblies requiring slightly low density oil, are found very stable [4]. Before releasing the pressure generated in the system the control valve is closed and the fluid is released into the oil reservoirs using separate relief valves of DWPTs.The specifications of different DWPTs calibrated at the NPSL are given in Table 2.

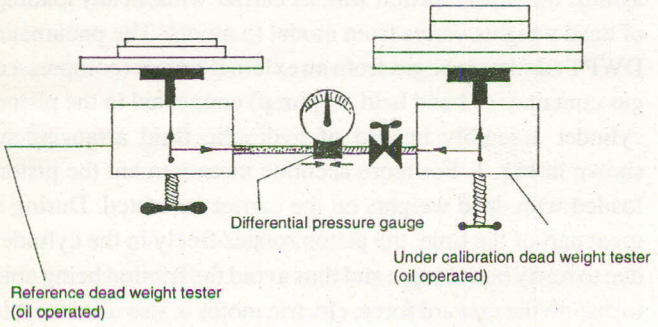

Fig. 2. Arrangement for the comparison of oil operated dead weight pressure tester.

TABLE 1. CALIBRATION OF DWPTs UNDERTAKEN AT THE NPSL.

Year	Reference standard	Dead weight tester		
		Oil-operated	Air-operated	Gas-operated
1988-89	LUCAS 8260/6 (Oil-operated)	3	-	1
1989-90	-do-	4	1	1
1990-91	-do-	3	1	1
1991-92	-do-	5	-	1

TABLE 2. SPECIFICATIONS OF DWPTs CALIBRATED AT THE NPSL.

Type of DWPT	Manufacture	Range	Accuracy (Full range) (%)	Oil type/density g/cm^3 at 20°C
Oil-operated	DH, France	1 bar to 400 bar	±0.08	OM-15/0.8636
-do-	Shangi Forth Automatic work, China	0.4 kgf/cm^2 to 6 kgf/cm^2	±0.05	OM-15/0.8636
-do-	-do-	1 kgf/cm^2 to 60 kgf/cm^2	±0.05	OM-15/0.8636
-do-	-do-	10 kgf/cm^2 to 600 kgf/cm^2	±0.05	OM-15/0.8636
-do-	Mahometr,USSR	40 kpa to 600 kpa	±0.03	ST 50/50/0.8690
-do-	-do-	1 Mpa to 60 Mpa	±0.05	ST 50/50/0.8690
Oxygen gas operated	Shangi Forth Automatic work,China	10 kgf/cm^2 to 600 kgf/cm^2	±0.05	(Alcohol+Glycerin) (5:1) / 0.9060
Air-operated	LUCAS, England	2 psi to 500 psi	±0.03	- -
Oil-operated (Reference DWPT)	-do-	0.1 bar to 1100 bar	±0.03	ST 50/50 /0.8690

Calibration of air-operated and gas-operated DWPT. The connection of air-operated DWPT are shown in Fig. 3. The pressure of air or gas is applied to the reference DWPT through one of its out-let or test station via a control valve of in-let of air or gas-operated DWPT. The air pressure is generated by a hand held pressure test pump connected to the in-let of the air-operated DWPT. For gas-operated DWPT external pressure of gas is used.

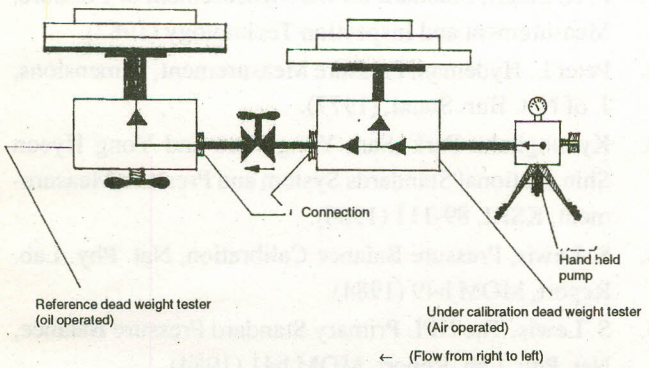

Fig. 3 Arrangement for the comparison of air gas-operated dead weight pressure tester.

The external pressure is applied and both DWPTs up-lift their piston. For a particular reading, testers are balanced by loading dead weights on the respective DWPT. Pressure is calculated on the reference DWPT using same method as of oil-operated DWPT. Before releasing air pressure the control valve is closed. The pressure from the reference DWPT (oil-operated) is released through its oil pressure relief valve whereas the pressure of DWPT under calibration is released using the relief valve mounted on the tester. This avoids any transfer of oil to the piston cylinder assembly of the air or gas-operated DWPT.

Results and Discussion

During last four years, 21 dead weigtht testers have been calibrated using above techniques. Number of calibrations undertaken at the NPSL are shown in Table 1.

Some typical calibration data of two oil operated and one oxygen gas-operated DWPT is tabulated in Table 3.

Figure 4 shows some calibration data collected during four periodic calibrations each at an interval of one year. For the simplicity, only four pressure calibration points of four YU-series DWPTs are plotted. Two extremities of the accuracy in pressure measurement of reference DWPT are drawn with thick lines at ±0.03%. The broken lines indicate ±0.05% error limits as specified by the manufacturer of YU-series China made DWPTs. The calibration data of oil-operated DWPTs at pressure of 5 kgf/cm², 10 kgf/cm² and 30 kgf/cm² are indicated by small circles, triangles and squares (O,▲,■)

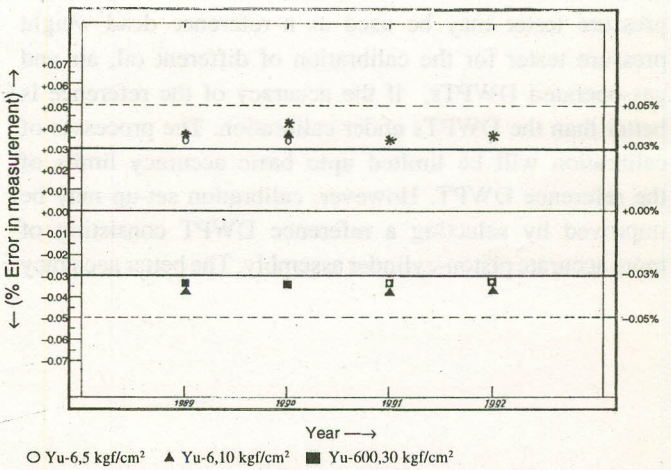

Fig. 4. Comparison of calibration data of YU-series DWPTs.

TABLE 3. CALIBRATION DATA.

DWPT under calibration		Reference DWPT		
Nominal loading of dead weights		Loading of dead	Pressure	Equivalent
Pressure DWPT(Model)	Nominal pressure (kgf/cm²)	Weights for Balancing (bar)	(bar)	pressure (kfg/cm²)
6kgf/cm² (YU-6)	C+0.1+0.1+0.1+0.1+0.1+0.1+ 0.5+0.5+0.5+0.5+0.5+0.5+ 0.5+0.5+0.5+0.5	C_1+5+0.5+0.2+0.04 0.04+0.003+0.0009	5.8840	6.00000
60kgf/cm² (YU-60)	C+5+5+5+5+5+5+5+5+5+5+5+ 1+1+1+1	C_2+2+0.2+0.2+0.04+ 0.002+0.0003	58.848	60.00820
100kgf/cm² (YU-600 O_2)	C+50+10+10+10+10	C_2+2+2+0.2+0.02+ 0.003+0.0002	98.06	99.99335

C = Carrier of China made DWPT = 0.4 kgf/cm² for YU-6, 1 kgf/cm² for YU-60 and 10 kgf/cm² for YU-600 Oxygen-gas-operated. C_1 = Carrier of lower range of reference DWPT = 0.1 bar. C_2 = Carrier of higher range of reference DWPT = 10 bar for C_2 multiplication factor is 20.

respectively whereas the calibration data at pressure of 60 kgf/cm^2 of oxygen-gas-operated DWPT has been indicated using small asterics (*). All the calibration data falls within the limits or error of YU-series and outside the accuracy limits of reference DWPT. There are some pressure points balanced exactly with reference pressure. Such points have the same accuracy as that of the reference standard.

Any other pressure points which may have even better accuracy will be limited to the basic accuracy of the reference standard. Note that there is not a single pressure point with equal or greater error than the extreme limits of ±0.05% for YU-series DWPTs. The calibration data of oxygen-gas-operated and air-operated DWPTs falls within the limits of accuracy of DWPTs under calibration.

Conclusion

The calibration data of 21 DWPTs of different types and makes confirms that an oil-operated certified dead weight pressure tester may be used as a reference dead weight pressure tester for the calibration of different oil, air and gas-operated DWPTs, if the accuracy of the reference is better than the DWPTs under calibration. The processes of calibration will be limited upto basic accuracy limits of the reference DWPT. However, calibration set-up may be improved by selecting a reference DWPT consisting of more accurate piston-cylinder assembly. The better accu racy of reference will result in calibration and certification of extra number of DWPTs. The above calibration schemes may be adopted for the certification of DWPTs used for commercial industrial and scientific purposes. These calibration schemes are recommended for maintaining the National Measurement System as well as International Traceability.

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