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Studies on the stabilities of various types of industrial pressure measuring devices

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Present paper describes studies carried out on an industrial dead weight tester (pressure range, up to 330 MPa; calibration; 3 times; period, 6 years), one pressure dial gauge (pressure range, up to 70 MPa; calibration, 3 times; period, 3 years), and one digital pressure calibrator (pressure range, up to 200 MPa; calibration, 4 times; period, 6 years). A small change was observed in the short-term stability but the change was prominent in case of long-term stability in all the instruments. Stability of dead weight tester and pressure dial gauge was well within their claimed manufacturer uncertainties while it was found to be beyond claimed uncertainty in case of digital pressure calibrator.

Keywords: Calibration, Hydraulic pressure device, Pressure measurement
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Introduction

Role of pressure measurements is well established in industries such as nuclear, thermal and gas based power plants, manufacturing of fertilizers, pesticides, chemicals, petro-chemicals, pharmaceuticals and drugs, forging of hot and cold steels, synthesis of super hard materials like diamond, optimization of domestic appliances like pressure cooker and filling of cooking gas cylinders, and assessment of health like blood pressure monitors, ventilation, filtration and process control[1-5]. Operational integrity of any measuring instrument is determined by evaluating measurement error through calibration, which is always carried out by comparing measurements made by measuring equipment against a standard, whose uncertainty is known and is traceable to the national standards. As per ISO stipulations, whenever such instruments are used for precise and accurate pressure measurements, it is obligatory for measuring authority to indicate the quality of results judged by uncertainty, calibration factor, accuracy, long-term stability (reproducibility) and short-term stability (repeatability) of measuring instruments. The paper presents results of an industrial dead weight tester (10-330 MPa), one Bourdon type mechanical pressure dial gauge (0-70 MPa) and one industrial strain gauge type digital pressure calibrator (0-200 MPa).

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Experimental Setup and Calibration Procedures

All the industrial hydraulic pressure devices were calibrated against the national secondary hydraulic pressure standards. Before starting calibration, pressure standard and test gauge are pressurized to full-scale pressure of the test gauge and then pressure is released slowly to zero. This process is repeated at least three times to ensure that there is no leak in the system. This process also allows compressibility of transmitting fluid, packing of valves, pump plunger and O-ring seals to reach an optimum level. Establishment of proper reference or datum plane is also very important and hence it has been precisely obtained. Usually, the datum level is mentioned in the operational manual or marked on the instrument. Whenever such information was not available, the datum plane was obtained from top of the bottom of the piston for dead weight testers and from the center point of the elastic sensor in case of pressure dial gauges and transducers.

Before starting calibration, the full-scale pressure of the test gauge was divided into 10-equally spaced pressure points. Sufficient time (15-20 min) was given between two successive observations to allow the system to reach thermally equilibrium state. After reaching full-scale pressure in increasing order, the observations were repeated at least after 20 min in decreasing order; the observations thus taken make one pressure cycle. The observations were repeated at least for three pressure cycles. Pressure measured by the pressure standard is then computed using computer software[3].

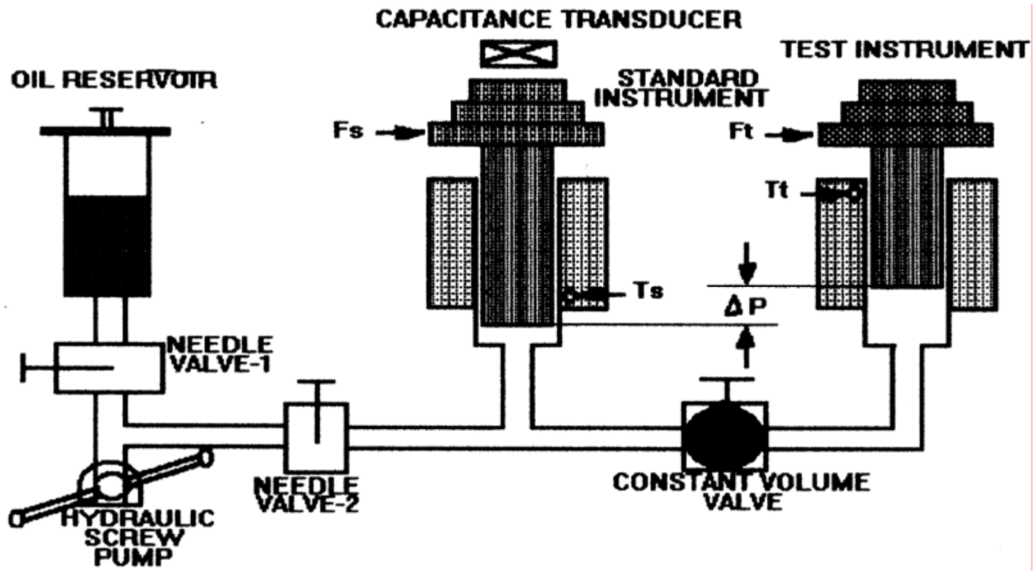

Fig. 1—Experimental setup for the calibration of dead weight testers

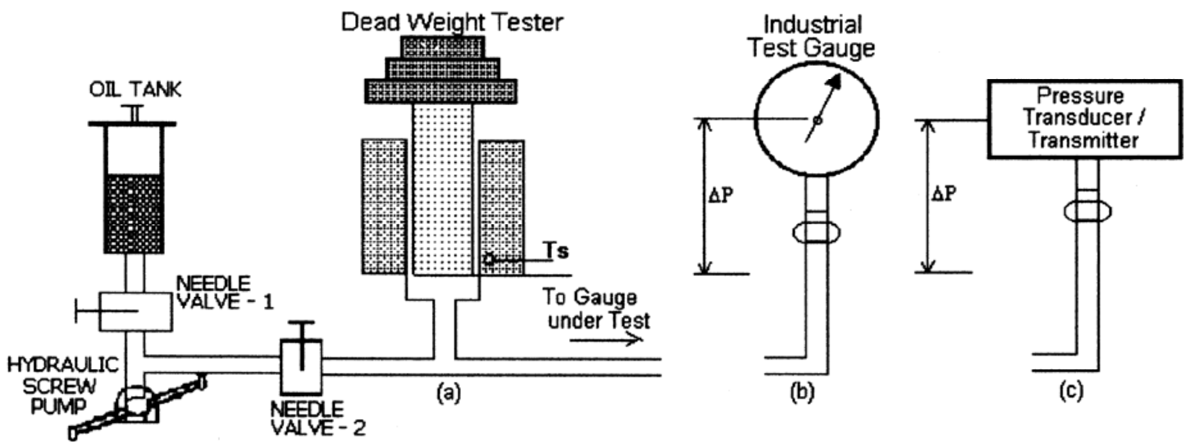

Fig. 2—Experimental setup for the calibration of pressure dial gauges (a+b) and for transducers/transmitters (a+c)

For calibration of dead weight testers, internationally accepted method of cross floating of pressure balances is used (Fig. 1). In this method[4,5], the mass placed on the top of standard is balanced as per mass placed on the test pressure balance as per desired pressure point. Balancing operation is identical with that employed on an equal arm weighing balance where mass of the one weight is compared to the mass of another weight. During cross floating, all the weights are rotated @ 20-30 rpm to reduce the effect of friction.

For the calibration of pressure dial gauges (Fig. 2), the zero shift of the test gauge is carefully adjusted to zero, if any, using mechanical zero adjustment device / knob. In case, zero adjustment knob is not available, the initial bias in the measurement (zero shift) was recorded and necessary corrections were applied at the appropriate level. After ensuring leak testing and proper selection of datum level, the gauge is then pressurized up to the pressure point to be calibrated so that the needle of the test gauge is fixed at particular pressure by adjusting the required masses on the pressure standard to ensure that the piston of pressure standard floats at reference or equilibrium level. The observations were repeated in a similar way to reach the full-scale pressure. The similar experimental set-up (Fig. 2) and calibration procedure is used for calibration of pressure

Table 1—Details of long-term and short-term stabilities of different type of gauges

Name of the instrument	Year of calibration	Measurement uncertainty of the standard used	Short term stability	Long term stability	Accuracy obtained from long term stability	Manuf. specified accuracy
			% of full scale	C_f	% of full scale	% of full scale
DWT	1998	90×10^{-6}	0.012	0.99502	0.25	0.25
	2000	67×10^{-6}	0.004	0.99592		
	2003	61×10^{-6}	0.001	1.00004		
	Avg.		0.006	0.99753		
PDG	2002	61×10^{-6}	0.035	1.00291	0.17	0.25
	2003	61×10^{-6}	0.042	1.00148		
	2004	40×10^{-6}	0.127	1.00071		
	Avg.		0.068	1.00169		
DPT	1999	89×10^{-6}	0.056	0.99584	0.14	0.20
	2000	73×10^{-6}	0.005	0.99802		
	2003	67×10^{-6}	0.021	0.99985		
	2004	40×10^{-6}	0.028	1.00092		
	Avg.		0.027	0.99865		

transducers/transmitters except that the output of the transducer is recorded as a function of applied pressure instead of fixing the gauge reading as in case of pressure dial gauges. The transducer output is then least square fitted as a function of applied pressure.

Results and Discussion

As National Physical Laboratory (NPLI), New Delhi is the custodian of national standards; it is the charter of NPLI, New Delhi to provide national traceability to user industries through calibration. This way NPLI, which receives regularly some of the pressure measuring instruments and has the calibration data bank for over the years, studied several pressure measuring instruments in the past[6,7]. Some of the instruments have been analyzed in the present study. However, some of the old data is taken from old calibration data bank. Therefore, it is quite obvious that the same operator has not calibrated the same instrument in different years. A total number of 40 instruments have been analyzed. Behaviour of almost all the dead weight testers is similar in spite of their design type (simple or reentrant type). However, in some of the dead weight testers (approx 6-7 %), gauge behaviour is not uniform and need further investigations. Similar trends were observed in pressure dial gauges and pressure transducers/transmitters.

The change in short-term stability or repeatability, which is determined as the maximum standards deviation of repeated observations for all the instruments, is found quite low and well within the manufacturer specifications (Table 1). However, the

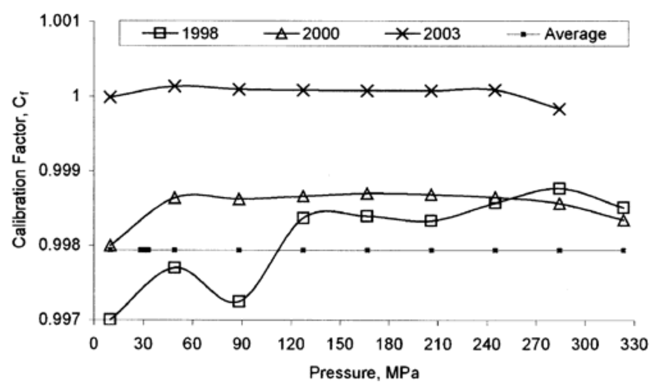

Fig. 3—Long term stability of the calibration factor as a function of time for a dead weight tester

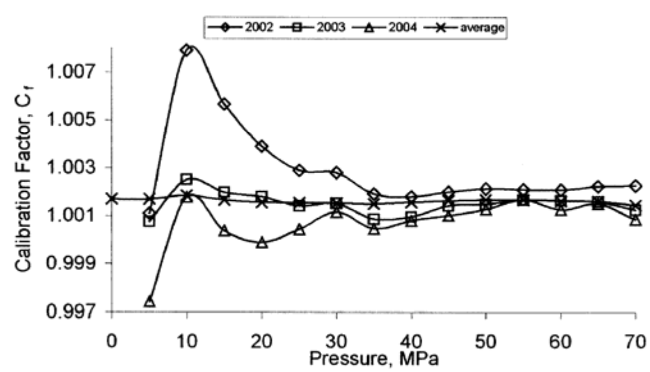

Fig. 4 —Long term stability of the calibration factor as a function of time for a pressure dial gauge

change in long-term stability or reproducibility is quite prominent and can easily be seen from unidirectional drift in the calibration factor as a function of time for all the instruments (Figs 3-5).

Calibration factor (C_f) is the ratio of the gauge

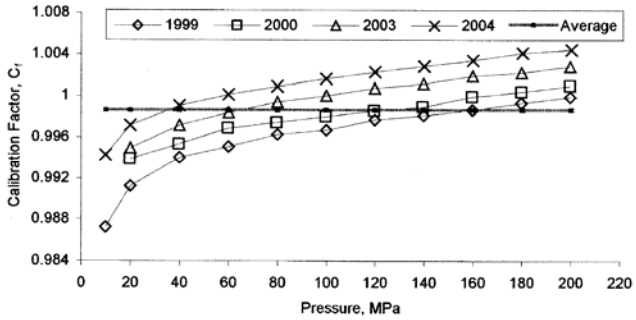

Fig. 5—Long term stability of the calibration factor as a function of time for a digital pressure transducer

reading (pressure measured by the gauge under test) and standard reading (pressure measured by the standard). Therefore, for ideal calibration, C_f, should be unity. The value of C_f is coming closer to unity in successive calibrations in 1998, 2000 and 2003 for an industrial dead weight tester and it is almost unity during 2003 (Fig. 3). This implies that the accuracy of the DWT is continuously improving because of the improved environmental conditions in the calibration room and improved measurement uncertainty of the standard. However, the definite conclusion can only be drawn after at least two future calibrations because the drift in calibration factor is unidirectional. This argument is easily evident (Fig. 4) for an industrial dial gauge, studied up to 70 MPa. C_f, is drifting towards unity here again in two calibrations during 2002 and 2003 but slightly drifting away from unity in the unidirectional mode during calibration of 2004.

Similar behaviour is obtained for the digital pressure transducer studied up to 200 MPa (Fig. 5). The transducer behaviour is identical for the four calibrations during 1999, 2000, 2003 and 2004 and its C_f is drifting towards unity up to 2003 but slightly drifting away from unity during 2004. However, the full-scale accuracy estimated from average C_f is well within the manufacturer specifications for the instruments studied in the present study. The change in long-term stability is comparably higher in lower pressure regions, especially below 15% of full-scale pressure. It is always difficult to answer the calibration intervals of the gauges. However, ISO 17025 clearly stipulates that the next calibration due date should be decided by the user itself[8] because it depends upon the number of usage in a defined period, place of use, environmental conditions, operator's skills and of course the type of instruments. If such information data bank is maintained by the users for particular gauge for over the years, it would help them to decide and increase the calibration interval of their instruments.

Conclusions

Several hydraulic pressure-measuring instruments have been studied for their shot-term and long terms stabilities for the usage and calibrations over the years in the pressure range from atmospheric pressure to 330 MPa. A small change in the short-term stability of all the gauges was observed but this change is very prominent and unidirectional in case of long-term stability.

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