Evaluation of Associated Uncertainties in Calibration of Direct Pressure Indicating Electromechanical Devices

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Abstract: *A wide range of direct pressure measuring electromechanical transducers is now commercially available in the market. In such electromechanical type direct indicating devices, the applied pressure is directly measured by a sensing element with a suitable mechanism into an analog / digital electrical signal in terms of voltage, current or frequency. The generation of such signals is based upon some electromechanical effects viz. inductive, capacitive, resistive, piezoelectric, piezoresistive, reluctive, resonative and optoelectric etc. A wide range of such pressure measuring instruments is now commercially available in the market. The high-pressure technology and new applications demand that the best instrumentation should ensure the lowest measurement uncertainty, particularly in the fluid media. The calculation of the calibration results and associated uncertainties is a complex matter involving many influencing quantities. The present paper describes a novel method for evaluating uncertainty in pressure measurement using electromechanical type direct pressure indicating devices through statistical analysis of errors. The method of evaluation of associated uncertainties is in line with ISO and EA Guidelines on the evaluation and expression of uncertainty in measurement. The results thus obtained are compared with the results obtained by using standard technique described in EA guidelines. Both the methods are quite comparable.*

Keywords: electromechanical transducers, pressure measurement, uncertainties

1. Introduction

The mathematical modeling of the measurement that transforms the set of repeated observations into the measurements results is of critical importance because, in addition to the observations, it generally includes various influencing quantities that are not exactly known. This lack of knowledge contributes significantly to the uncertainty of the measurement results where well-defined mathematical modeling is not well defined or available like in electrometrical pressure transducers. To date there is little uniformity in the ways, which the measurement uncertainties of electrometrical direct pressure indicating transducers, are evaluated and expressed. Some researchers used standard deviation of the repeated observations to estimate standard uncertainty using Type A method. Sometimes, uncertainty contributions of slope and intercept of fitted curve are treated as uncertainty components evaluated through Type B method. The recent document published by European Cooperation for Accreditation is a good attempt to improve the harmonization in the pressure measurement methodology using such pressure transducers [1]. In the present paper, a novel method is proposed for calibration and evaluating uncertainty in pressure measurement using electromechanical type direct indicating devices through statistical analysis of errors. The method proposed is in line with guidelines given in the respective guides, manuals and test books available on the subject [1-4]. The methodology is supported by a practical example prepared as case study.

2. Calibration Method

In the present case study, we have calibrated a hydraulic commercially available digiquartz digital pressure transducer, make Paroscientific INC., USA, in gauge mode using dead weight tester as pressure standard. A typical experimental setup is shown in Fig. 1.

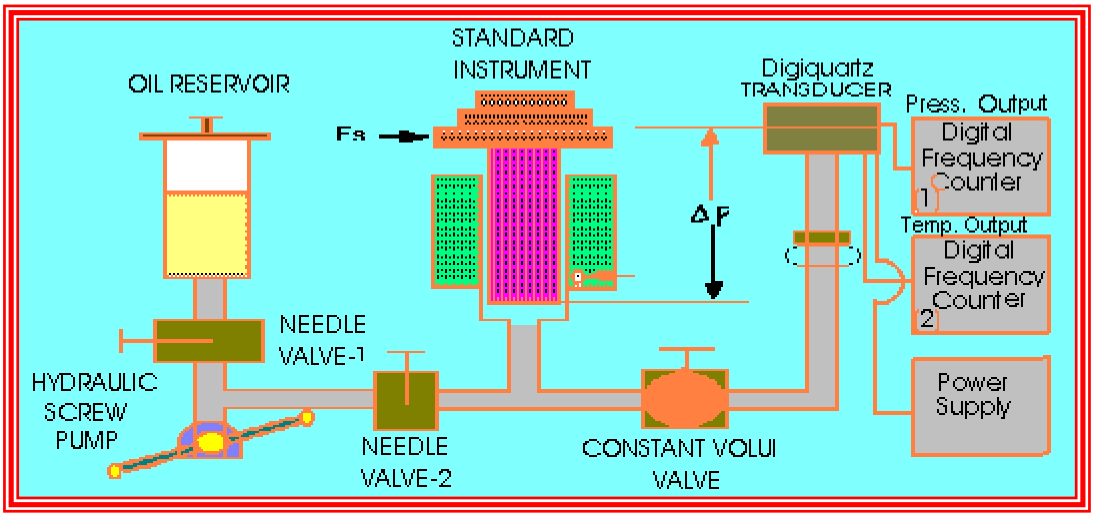

Fig. 1: Experimental setup for calibration of Digital Quartz Pressure Transducer using Dead Weight Tester as Standard Instrument

The sensor of the transducer detects the pressure-induced stress by means of changes in the resonant frequency of the quartz crystal. Two frequency outputs of the transducer, one as pressure output and another as temperature compensated output, are recorded using two separate Digital Frequency Counters, make Hewlett and Packard, USA, respectively. Both the resonators were excited by a regulated DC power supply of 6.0 V. The conversion of two frequency outputs of the transducers into pressure and temperature and other details of the methodology are published elsewhere [5]. The standard instrument used in the present study is a simple type dead weight tester, a national hydraulic pressure standard, designated as NPL500MPA herein thereafter, make Desgranges and Huot, France, capable to measure high hydrostatic pressure up to 500 MPa. The relative uncertainty associated with pressure measurement using this standard is 67 x 10^{-6} x P at a coverage factor k = 2 and its compatibility and traceability is established through CCM sponsored international key comparison and in-house intercomparison exercises [6-8]. The pressure measured by the standard is computed using the computer software developed by the group [9] based on theory of pressure balances [10-12].

The calibration procedure starts with leak testing, zero setting and selection of reference or datum plane. Before starting observations, the whole setup is pressurized to the full-scale pressure of the instrument under calibration, 275 MPa in the present case, for few minutes to check the leakage in the system and then pressure is released slowly to zero. This process is repeated at least three times to ensure that there is no leakage in the system. It also helps to minimize the error due to compressibility of fluid, packing of valves, pump plunger and O-ring seals. As no zero adjustment knob was provided with the transducer, the initial bias in the instrument is recorded and necessary correction is applied at the appropriate level. The reference planes for both the instruments were clearly marked on the instruments.

The full-scale pressure of the transducer was divided into 12 equally spaced pressure points. The NPL500MPA is then pressurized up to the pressure point to be calibrated and brought to the floating position at the datum plane and the corresponding frequency outputs of both the resonators were recorded. Observations were repeated in a similar way to reach the full-scale pressure. Total number of 24 observations, in increasing as well as decreasing orders of pressures, is taken in one pressure cycle to evaluate hysteresis in the pressure cycle. After reaching full-scale pressure in increasing order of pressure, 10 minutes were allowed to pass before repeating the observations in decreasing order of pressure. Sufficient time of at least 15-20 minutes is given between two successive observations to allow the system to reach thermally equilibrium state. Three pressure cycles were employed so that the minimum number of observations at each pressure point is 6 and there are total 72 observations as a whole.

3. Evaluation of Measurement Uncertainty

The major uncertainty contributions to be taken in to consideration for the evaluation of uncertainty associated with electromechanical transducers are uncertainty due to repeatability of the data, uncertainty due to hysteresis, uncertainty of the measuring instruments, uncertainty due to influencing parameters, uncertainty due to resolution of the gauge, uncertainty due to modeling, uncertainty due to reproducibility of the gauge, uncertainty due to drift in the measurement over a period of time, uncertainty due to head correction between the standard and instrument under calibration and uncertainty of the reference standard.

The mathematical model for such a direct pressure indicating device is given by sum / difference model as follows:

$$P_g = P_{c(i)} + \Delta P \qquad [1]$$

where P_g is the output quantity or corrected pressure measured by the device under calibration, $P_{c(i)}$ is the input quantity or modeled indicated pressure, defined by eqn. (7) and ΔP is the pressure indication error or uncorrected errors having no contributions to output quantity i.e. P_g but to the measurement uncertainty. This model is suited to determine the error of indicated pressure gauges.

The pressure indication error is determined using the following equation:

$$\Delta P = \delta\left(P_{c(i)} - P_{t(i)}\right) + \sum_{i}^{n} \delta P_i \qquad [2]$$

or

$$\Delta P = \delta P_0 + \delta P_c + \delta P_{res} + \delta P_{hys} \qquad [3]$$

where ΔP is the error of average indicated pressure, $\delta\left(P_{c(i)} - P_{t(i)}\right)$ is the error due to deviations, δP_0, δP_c *and* δP_{hys} are the uncorrected measurement errors due to offset or zero setting, repeatability of the indicated pressure, resolution of the device under calibration and hysteresis effect. Substituting eq.-(3) into eq. (1), we obtain:

$$P_g = P_{c(i)} + \delta P_0 + \delta P_c + \delta P_{res} + \delta P_{hys} \qquad [4]$$

Now, we will discuss the quantification of all these uncertainty components, one by one.

3.1. Repeatability

First, we take repeatability, which is evaluated by standard deviations of calibration factor and indication pressure. Generally, in the direct pressure indicating devices, the statement of a single value of the calibration factor or transmission coefficient is given. The calibration factor (C_f) of the transducer is defined by:

$$C_{f(i)} = \frac{P_{r(i)}}{P_{t(i)}} \qquad [5]$$

where $P_{r(i)}$ is the i[th] reference pressure applied by the standard and $P_{t(i)}$ is the i[th] indicated pressure of the transducer under test. This implies that the gauge under test would have as may as calibration factors as the number of calibration points. Generally, the application of different calibration factors for different calibration points is not required and the use of a single calibration factor for the total pressure range covered by the transducer is sufficient. The single calibration factor is obtained either by the slope of the line fitted through all measured values or the mean calibration factor $\overline{C_f}$ as follows:

$$\overline{C_f} = \frac{\sum_{i}^{n} C_{f(i)}}{n} \qquad [6]$$

From the mean calibration factor $\overline{C_f}$, the corrected modeled indicated pressure and its standard deviation at each pressure point are computed using the following relationships:

$$\mathrm{p}_{\mathrm{c(i)}} = \overline{\mathrm{C}_{\mathrm{f}}} * \mathrm{p}_{\mathrm{t(i)}} \qquad [7]$$

$$\sigma(\mathrm{p}_{\mathrm{c(i)}}) = \sqrt{\frac{\sum (\mathrm{p}_{\mathrm{c(i)}} - \overline{\mathrm{p}_{\mathrm{c(i)}}})^2}{\mathrm{n}-1}} \qquad [8]$$

The uncertainty associated with corrected modeled indicated pressure is then computed by applying correction factor $\sqrt{\frac{\mathrm{n}-1}{\mathrm{n}-3}}$ = 1.29 for n = 6 measurements with effective degree of freedom 5, as suggested by Kacker and Jones [13], as follows:

$$\mathrm{u}\left(\mathrm{p}_{\mathrm{c(i)}}\right) = \frac{\left(\sqrt{\frac{\mathrm{n}-1}{\mathrm{n}-3}}\right) \cdot \sigma(\mathrm{p}_{\mathrm{c}})}{\sqrt{\mathrm{n}}} \qquad [9]$$

The whole process requires that the limit of permissible error be fixed, which can be done on the basis of calibration results by calculating the error span by the i) uncertainties associated with the mean calibration factor and the ii) uncertainties associated with deviations of reference applied pressure and corrected modeled pressure. The standard deviation of mean calibration factor is computed as follows:

$$\sigma\left(\overline{C_f}\right) = \sqrt{\frac{\sum \left(C_{f(i)} - \overline{C_f}\right)^2}{n-1}} \qquad [10]$$

Since $\sigma\left(\overline{\mathrm{C}_{\mathrm{f}}}\right)$ is the standard deviation determined for n = 72 measurements with an effective degree of freedom 71, $\sigma\left(\overline{\mathrm{C}_{\mathrm{f}}}\right)$ was multiplied by a correction factor $\sqrt{\frac{\mathrm{n}-1}{\mathrm{n}-3}}$ = 1.014. The standard uncertainty associated with mean calibration factor is then computed as follows:

$$\mathrm{u}\left(\overline{\mathrm{C}_{\mathrm{f}}}\right) = \frac{\left(\sqrt{\frac{\mathrm{n}-1}{\mathrm{n}-3}}\right) \cdot \sigma\left(\overline{\mathrm{C}_{\mathrm{f}}}\right)}{\sqrt{\mathrm{n}}} \qquad [11]$$

The calibration factor of zero pressure value is ignored in the computation of uncertainty associated with mean calibration factor because of zero or no applied pressure. Further, the standard deviation of the deviations of reference applied pressure and corrected modeled pressure is given by following equations:

$$\sigma\left(P_{r(i)} - P_{t(i)}\right) = \sqrt{\frac{\sum\left\{\left(P_{r(i)} - P_{t(i)}\right) - \left(\overline{P_{r(i)} - P_{t(i)}}\right)\right\}^2}{n-1}} \quad [12]$$

Further, as reported above, $\sigma\left(p_{r(i)} - p_{t(i)}\right)$ is the standard deviation of the deviations ($p_{r(i)}$-$p_{t(i)}$) values of all the n = 72 observations (Table 1, column 7) with effective degree of freedom 71, the correction factor $\sqrt{\frac{n-1}{n-3}}$ = 1.014 is again applied to $\sigma\left(p_{r(i)} - p_{t(i)}\right)$ and the uncertainty associated with $\sigma\left(p_{r(i)} - p_{t(i)}\right)$ is then computed as follows:

$$u\left(P_{r(i)} - P_{t(i)}\right) = \frac{\left(\sqrt{\frac{n-1}{n-3}}\right) \cdot \sigma\left(P_{r(i)} - P_{t(i)}\right)}{\sqrt{n}} \quad [13]$$

Finally, the standard uncertainty associated with modeled corrected pressure is computed as follows:

$$u\left(\partial p_c\right) = \sqrt{c_1^2 \cdot u^2\left(\overline{C_f}\right) + c_2^2 \cdot u^2\left(p_{t(i)}\right) + u^2\left(p_{r(i)} - p_{t(i)}\right)} \quad [14]$$

where, $c_1 = \frac{\partial P_{c(i)}}{\partial \overline{C}_f}$ and $c_2 = \frac{\partial P_{c(i)}}{\partial P_{t(i)}}$ are the sensitivity coefficients derived from partial derivations of eq. (7) and $u\left(p_{t(i)}\right) = \max u\left(p_{c(i)}\right)$ is the maximum uncertainty evaluated using eq. (9).

3.2. Zero Setting

Generally, zero setting knob is provided with transducer. The zero point is set before each measurement cycle. If such knob is not provided then zero off set value is recorded at the beginning and end of measurement cycle, both in increasing as well as decreasing orders of pressure. Therefore, zero error is calculated using the formula:

$$\delta P_0 = \max\left\{\left|Z_{2,0} - Z_{1,0}\right|, \left|Z_{4,0} - Z_{3,0}\right|, \left|Z_{6,0} - Z_{5,0}\right|, \ldots\ldots \left|Z_{n,0} - Z_{n-1,0}\right|\right\} \quad [15]$$

where, $Z_{1,0}$, $Z_{3,0}$, $Z_{5,0}$, $Z_{n-1,0}$ are the zero pressure values recorded at the beginning of each pressure cycle while $Z_{2,0}$, $Z_{4,0}$, $Z_{6,0}$, $Z_{n,0}$ are the zero values recorded after reaching full scale pressure in each pressure cycle. This implies that the maximum difference of zero offset value recorded at the beginning and reaching full scale pressure of the pressure cycles (three pressure cycles in the present case) is the zero setting error. The uncertainty contribution to the pressure measurement due to zero setting error is estimated as follows assuming rectangular distribution:

$$u(\delta P_0) = \frac{\delta P_0}{\sqrt{3}} \quad [16]$$

3.3. Resolution

The resolution is the smallest measure or digit step of an electromechanical pressure transducer. During pressure release or unloading of device, the indication does not vary by more than one digit step. If ‘r’ is the resolution of the device, the error due to resolution and its associated uncertainty contribution are given by eqs. (17) and (18), respectively, assuming a rectangular distribution.

$$\delta P_{res} = a = \frac{r}{2} \qquad [17]$$

$$u(\delta P_{res}) = \frac{a}{\sqrt{3}} \qquad [18]$$

where, ‘a’ is semi range of the resolution of the device.

3.4. Hysteresis

The difference between corresponding values in increasing and decreasing orders of pressure in a pressure cycle is called hysteresis or reversibility in the measurements. The hysteresis at a particular pressure point, j, is determined by:

$$\delta P_{hys,j} = \frac{1}{n}\{|x_{2,0} - x_{1,0}| + |x_{4,0} - x_{3,0}| + |x_{6,0} - x_{5,0}| + ... + |x_{n,0} - x_{n-1,0}|\} \qquad [19]$$

The maximum value of $\delta P_{hys,j}$ is then selected to estimate the uncertainty contribution as follows:

$$\delta P_{hys} = \max\{|\delta P_{hys,j}|\} \qquad [20]$$

$$u(\delta P_{hys}) = \frac{\delta P_{hys}}{\sqrt{3}} \qquad [21]$$

3.5. Combined Standard Uncertainty

Finally, the combined standard uncertainty associated with pressure measurement is then computed using the following relationship:

$$U(P_g) = \sqrt{c_1^2 \cdot u^2(P_{std}) + c_2^2 \cdot u^2(\delta P_0) + c_3^2 \cdot u^2(\delta P_c) + c_4^2 \cdot u^2(\delta P_{res}) + c_5^2 \cdot u^2(\delta P_{hys})} \qquad [22]$$

where, c_1, c_2, c_3 and c_4 are the sensitivity coefficients of the different error components described in eq. (4), which are determined by their partial derivatives.

The practical example thus prepared as case study is shown in Tab. 1. and uncertainty budget is presented in Tab. 2.

Measured Pressure by the Standard	Indicated Pressure by the Gauge under Test	Calibration Factor $C_f = P_r / P_t$	Modeled Indicated Pressure $p_c = C_f{*}p_t$	Standard Deviation of P_c	Deviation $P_r - P_c$	Standard Deviation of $P_r - P_c$	Hysteresis
P_r (bar)	P_t (bar)		P_c (bar)	$\sigma_{Pc(i)}$ (bar)	(bar)	(bar)	δP_{hys} (bar)
0	0.0001	0	0.0001	5.16541E-05	-0.000100028	0.344856295	-0.0001
0	0.0002	0	0.0002		-0.000200056		
0	0.0002	0	0.0002		-0.000200056		
0	0.0002	0	0.0002		-0.000200056		
0	0.0001	0	0.0001		-0.000100028		
0	0.0002	0	0.0002		-0.000200056		
249.584	249.5531	1.000124	249.6224	0.286778846	-0.038376659		0.478333
249.5815	249.3266	1.001022	249.3958		0.185686218		
249.5799	249.8761	0.998815	249.9455		-0.365566325		
249.5765	249.1856	1.001569	249.2548		0.32172536		
249.5783	249.6863	0.999567	249.7556		-0.177313636		
249.5804	249.1683	1.001654	249.2375		0.342930163		
499.1335	499.0409	1.000186	499.1794	0.214266361	-0.04593519		0.293
499.1295	498.7501	1.000761	498.8886		0.240945537		
499.1263	499.0555	1.000142	499.194		-0.067739243		
499.1189	498.5866	1.001068	498.725		0.393890925		
499.1234	498.6979	1.000853	498.8363		0.287060027		
499.1263	498.5786	1.001099	498.717		0.409293145		
748.6688	748.5387	1.000174	748.7465	0.196191251	-0.077696498		0.2485
748.6626	748.226	1.000584	748.4337		0.228890309		
748.6587	748.4241	1.000313	748.6319		0.026835315		
748.6471	748.0743	1.000766	748.282		0.365132421		
748.6539	748.1432	1.000683	748.3509		0.303013294		
748.6577	748.0602	1.000799	748.2679		0.389836335		
998.1932	998.0627	1.000131	998.3398	0.182617475	-0.146565079		0.2419
998.1855	997.7288	1.000458	998.0058		0.179727613		
998.1805	997.867	1.000314	998.144		0.036489248		
998.1656	997.6316	1.000535	997.9085		0.257054596		
998.1744	997.708	1.000467	997.985		0.189433387		
998.1788	997.5516	1.000629	997.8285		0.350276804		
1247.709	1247.59	1.000095	1247.936	0.170526651	-0.227334575		0.230667
1247.699	1247.259	1.000353	1247.605		0.093757311		
1247.693	1247.343	1.000281	1247.689		0.003733993		
1247.699	1247.259	1.000353	1247.605		0.093757311		
1247.693	1247.343	1.000281	1247.689		0.003733993		
1247.691	1247.066	1.000501	1247.412		0.278810889		

Tab. 1: Uncertainty Analysis of a Direct Pressure Indicating Device: a Case Study

Tab. 1 continued: Uncertainty Analysis of a Direct Pressure Indicating Device: a Case Study

1497.213	1497.163	1.000033	1497.579	0.181982818	-0.365616759		0.137
1497.203	1496.852	1.000234	1497.268		-0.064530424		
1497.195	1496.96	1.000157	1497.376		-0.180560405		
1497.176	1496.944	1.000155	1497.36		-0.183555964		
1497.188	1496.734	1.000303	1497.149		0.038502333		
1497.193	1496.65	1.000363	1497.065		0.127525652		
1746.706	1746.692	1.000008	1747.177	0.182770637	-0.470886727		0.103
1746.697	1746.436	1.000149	1746.921		-0.223815661		
1746.688	1746.548	1.00008	1747.033		-0.344846752		
1746.666	1746.56	1.000061	1747.045		-0.378850084		
1746.679	1746.277	1.00023	1746.762		-0.082771522		
1746.684	1746.212	1.00027	1746.697		-0.012753478		
1996.189	1996.226	0.999981	1996.78	0.188150858	-0.591158084		0.071667
1996.178	1996.043	1.000068	1996.597		-0.419107283		
1996.165	1996.173	0.999996	1996.727		-0.562143371		
1996.143	1996.164	0.999989	1996.718		-0.575140873		
1996.158	1995.818	1.00017	1996.372		-0.214044822		
1996.162	1995.795	1.000184	1996.349		-0.187038437		
2245.656	2245.735	0.999965	2246.358	0.20719095	-0.702422501		0.056
2245.65	2245.607	1.000019	2246.23		-0.580386967		
2245.631	2245.78	0.999934	2246.403		-0.772434993		
2245.61	2245.733	0.999945	2246.356		-0.746421945		
2245.627	2245.325	1.000135	2245.948		-0.321308683		
2245.63	2245.332	1.000133	2245.955		-0.325310627		
2495.11	2494.772	1.000135	2495.465	0.321927449	-0.354555889		-0.22433
2495.103	2495.215	0.999955	2495.908		-0.804678867		
2495.083	2495.247	0.999934	2495.94		-0.85668775		
2495.073	2495.279	0.999917	2495.972		-0.898696633		
2495.078	2494.534	1.000218	2495.226		-0.148489819		
2495.082	2494.732	1.00014	2495.425		-0.342544785		
2744.555	2743.57	1.000359	2744.332	0.345893038	0.22337707		-0.15
2744.554	2744.554	1	2745.316		-0.761896091		
2744.529	2744.182	1.000126	2744.944		-0.414792823		
2744.52	2744.012	1.000185	2744.774		-0.25374563		
2744.525	2744.416	1.00004	2745.178		-0.652857782		
2744.528	2744.052	1.000173	2744.814		-0.285756734		

Zero Setting Error δP_0 (bar)	Mean Calibration Factor $\overline{C_f}$	Resolution (bar)	Standard Deviation of Calibration Factor $\sigma_{C_f} =$	$\max\left\{\left\|\sigma_{P_c}\right\|\right\}$ (bar)	max $u(p_{c(i)}) = 0.1822$ Hysteresis $\delta P_{hys} = \max\left\{\left\|\delta P_{hys,j}\right\|\right\}$(bar) =0.478333	
-0.0001	1.000278	0.0001	0.000419	0.345893038	$c_1 = P_t = 2750$	$c_2 = \overline{C_f}$
$u(\delta P_0)$ = 5.7E-05	$u(\delta P_{res})$ = 2.9E-05	$u(\overline{C_f})$ = 4.25E-04		$u(P_{c(i)} - P_{t(i)}) = 0.04121$		$u(\delta P_{hyst})$= 0.2762
$u(\delta p_c) = 0.1940$						

SOURCE OF UNCERTAINTY	TYPE	PROBABILITY DISTRIBUTION	VALUE OF SENSITIVITY COEFFICIENT	PARAMETRIC UNCERTAINTY	CORRELATION	DIVISOR	STANDARD UNCERTAINTY	DEGREE OF FREEDOM (υ_f)
u(δP_0) bar	B	Rectangular	1	0.0001	NC	√3	5.7E-05	∞
Resolution u(r) bar	B	Rectangular	1	5.00E-05	NC	√3	2.9E-05	∞
Hysteresis u(δP_{hys}) bar	B	Rectangular	1	0.4784	NC	√3	0.2762	5
u(δp_c) bar	A	Normal	1	0.14501	NC	1	0.1940	26
u(P_r) = u(P_{std}) bar	B	Normal	1	0.18425		1	0.18425	∞
U(P_g) bar	$U(P_g) = \sqrt{c_1^2 \cdot u^2(P_r) + c_2^2 \cdot u^2(\delta P_0) + c_3^2 \cdot u^2(\delta P_c) + c_4^2 \cdot u^2(\delta P_{res}) + c_5^2 \cdot u^2(\delta P_{hys})}$ =						0.3845	19
The expanded uncertainty associated with measured pressure is 0.83 bar at a coverage factor k = 2.14.								

Tab. 2: Uncertainty budget at maximum pressure of 2750 bar

4. Comparison of Results

The results thus analyzed using the proposed technique are also compared with the results obtained using the technique described in EA Guidelines, and are shown in Table –3. It is clear from Table – 3 that the uncertainty evaluated through proposed technique is quite comparable and well within the uncertainty limits.

Description	Present Technique	As per EA Guidelines	Manufacturer's Specifications
Standard Uncertainty estimated at a maximum pressure of 2750 bar	0.4169 bar at a coverage factor k = 1.	0.3845 bar at a coverage factor k = 1.	0.025 % of full scale pressure i.e. 0.68759 bar
Expanded Uncertainty	0.9088 bar at a coverage factor k = 2.18 and degree of freedom ν = 12.	0.83 bar at a coverage factor k = 2.14 and degree of freedom ν = 19.	-
% of full scale	0.015	0.014	0.025

Tab. 3: Comparison of evaluated results

5. Conclusions

The calibration of direct pressure indicating electromechanical transducers with associated uncertainties is a subject of considerable interests and complex matter among researchers and metrologists. In the present paper, an attempt has been made to describe the fundamental necessary for the calibration and evaluation of associated uncertainties for such transducers involving many influencing quantities. The uncertainty associated with a set of calibration results is computed using a new approach and results are presented with a practical example prepared as case study. The standard uncertainty estimated with calibration results at maximum pressure of 2750 bar using proposed approach as $\pm$ 0.4169 bar is quite comparable with the results obtained as $\pm$ 0.3891 bar, using EA Guidelines and also well within the manufacturer's specifications of $\pm$ 0.025 % of full scale pressure i.e. 0.6875 bar. It is evident from the analysis that the present approach may be adopted for the evaluation of measurement results. The method used is in line with ISO and EA Guidelines on the evaluation and expression of uncertainty in the measurements. The method described herein is applicable only for the direct pressure indicating devices. For the indirect pressure indicating devices where output is recorded in terms of voltage, current, frequency or capacitance etc., the method of polynomial curve fitting is used which is again a subject of considerable interest. The method of least square fitting is not included in the present paper due to obvious reasons and would be published separately.

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