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CALIBRATION OF ABSOLUTE PRESSURE TRANSMITTERS BY USE OF THE DIRECT COMPARISON METHOD ACCORDING TO DIN 28418

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ABSTRACT

Calibration experiments carried out in 62 absolute capacitance pressure transmitters using the direct comparison method showed that 53 of them met the purchase specification requirements and 9 presented some kind of failure: 6 due to inaccuracy, 2 to the inability to make the zero adjustment and 1 due to the lack of output signal.

Typical values of accuracy, resolution, and dead zone for the accepted transmitters were: 0.2%, 0.02% and 0.04% of full scale (F.S) respectively.

1. INTRODUCTION

Modern chemical process industries rely on accurate measurement of one or more of the following classical process variables: flow, liquid level, pressure and temperature.

As pressure measurements is the key factory of major process control loops, a great number of skilled devices has been developed to measure pressure throughout the entire pressure spectrum.

Among instruments with so many different work principles, capacitance pressure transmitters have been widely adopted in chemical process where pressure must be strictly controlled in an aggressive media [1].

This choice is motived by the instrument's robustness, high accuracy as well as independence of the gas being measured [2].

Even so, a calibration practice is important to check new instruments as they are received as well as essential to keep them operating properly overtime [3].

The frequency of recalibration depends on the kind of application, the user's experience and the company's metrology rules. In spite of that, the most accepted recalibrated interval is one year.

Among other possible calibration methods, the direct comparison was chosen due to its ability to provide fast and reliable calibration services to different kinds of vacuum gauges in the range of 1000 down to 10^{-5} mbar [4, 5, 6].

2. EXPERIMENTAL SECTION

2.1 CALIBRATION SYSTEM

The calibration system CS 1000 supplied by Leybold-Heraeus (Köhn, Germany) is a mobile framed, vibration damped unit containing basically a test chamber, pumping system and appropriate pressure reference standards.

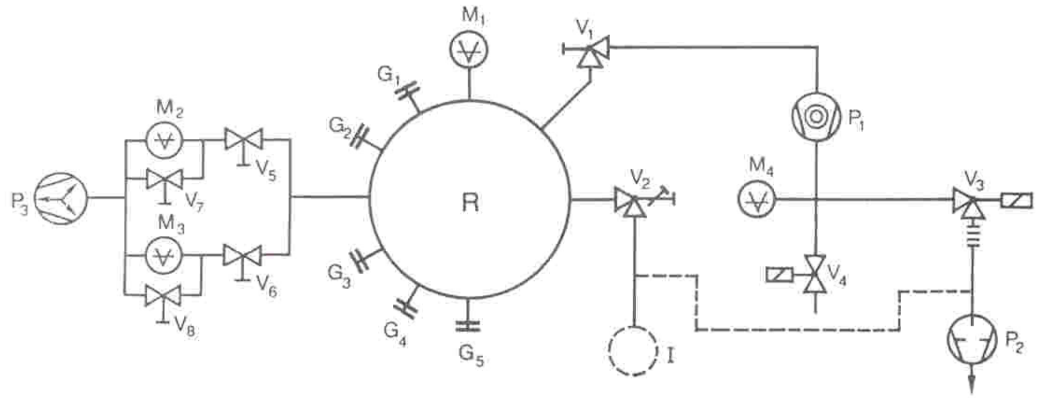
The stainless steel test chamber was constructed under the requirements of DIN Standard Specification 3567. Four test ports are available for the test gauges and into an additional central port a residual gas analyzer (RGA) was definitely installed in order to permit leak detection and mass spectra acquisition.

The pumping system comprising a turbomolecular pump and a rotatory vane vacuum pump is responsible for evacuating the test chamber. Special high vacuum valves are conveniently distributed in the system making possible the calibrating gas inlet and outlet.

The reference standards used are the VISCOVAC VM 210-Leybold-Heraeus for the range of 1.0×10^{-5} to 1.0×10^{-2} mbar and two MKS 690A Capacitance Manometer - MKS Instruments (Andover, MA, U.S.A.) for 1.0×10^{-3} to 1000 mbar. The first one is to be used from 1.0×10^{-2} to 10 mbar and the other from 10 to 1000 mbar. This reference standards are regarded as suitable to be used as transfer standards due to its low resolution and long term stability [7]. Both standards are periodically calibrated at the MKS Instruments and are traceable to the National Institute of Standards and Technology (NIST, Gaithersburg, U.S.A.).

The International System (S.I.) unit for pressure is the Pascal (Pa), defined as Newton per square Meter ($N.m^{-2}$). However, the most used units are bar, mbar and Torr. The unit adopted in this article is the mbar which equals 100 Pa.

Figure 1 presents a schematic diagram of the calibration system.



Erläuterungen zur Abb. 1

G1 bis G5 Anschlußflansche
M1 VISCOVAC VM 210
M2 Membran-Vakuummeter MKS BARATRON
M3 Membran-Vakuummeter MKS BARATRON
M4 THERMOTRON-Vakuummeter
P1 Turbo-Molekularpumpe
P2 Vorpumpe
P3 Ionen-Zerstäuberpumpe IZ
R Prüfkammer
V1 Hochvakuumventil
V2 Dosierventil
V3 Vorvakuumventil
V4 Flutventil
V5 und V7 zugeordnet zu M2
V6 und V8 zugeordnet zu M3

Key to Fig. 1

G1 to G5 Connection flanges
M1 VISCOVAC VM 210
M2 MKS BARATRON diaphragm vacuum gauge
M3 MKS BARATRON diaphragm vacuum gauge
M4 THERMOTRON vacuum gauge
P1 Turbomolecular pump
P2 Backing pump
P3 IZ sputter-ion pump
R Test chamber
V1 High-vacuum valve
V2 Variable-leak valve
V3 Forevacuum valve
V4 Venting valve
V5 and V7 assigned to M2
V6 and V8 assigned to M3

Abb. 1 Schematischer Aufbau des Kalibriersystems CS 1000
Fig. 1 Schematic diagram of CS 1000 Calibration System

Figure 1 - Calibration System Diagram

2.2 PRESSURE TRANSMITTER

A lot of 62 oil filled microprocessed absolute capacitance transmitters manufactured by SMAR - Equipamentos Industriais S. A. (Sertãozinho, SP) to be installed in a new chemical facility was submitted to several acceptance tests to check its conformity to the purchase specification requirements.

Despite of the great amount of experimental data collected this text will only report results related to the determination of accuracy, resolution and dead zone.

It is not a waste of time to remember the definitions of accuracy, uncertainty, resolution and dead zone: Accuracy is normally stated as the uncertainty in transmitter measurements. Uncertainty is defined as the sum of the errors due to non-linearity, hysteresis and non-repeatability. Resolution is defined as the smallest change in pressure that causes a change in the transmitter output . Dead zone is that range where an input signal change is not followed by any output signal change [8].

Table 1- Pressure Transmitter Purchase Specification Requirements

Pressure Range (mbar)	0.1 to 50.0
Accuracy (%F.S.)	≤ 0.5
Resolution (% F.S.)	< 0.1
Ambient Temperature (^{o}C)	-20 to 70
Gas Temperature (^{o}C)	-20 to 100
Temperature Effects (% F.S./^{o}C)	
on Zero	≤ 0.015
on Span	≤ 0.025
Maximum Pressure (bar)	100
Helium Leak Rate (mbar.l/s)	1.0×10^{-9}
Input Power (VDC)	12 to 45
Output Signal (mA)	4 to 20

2.3 CALIBRATION PROCEDURE

The specific calibration procedure was developed from the DIN Standard Specification 28418.

The initial requirement is that the residual gas pressure should be lower than the initial calibration pressure by a factor of 50. This means that if the initial calibration pressure is 0.1 mbar, the residual gas pressure must be at least 2.0×10^{-3} mbar.

To meet this requirement the calibration system has undergone a bake-out session of 12 hours at 350ºC. The same amount of time was needed to let the system cool down to the ambient temperature leaving a clean environment inside the test chamber.

The whole calibration sequence was carried out according to the transfer standards pressure ranges. Three independent measurements were taken at each point with a 2 minute interval between them, so as to have an indication of the calibration system stability. It was taken 3 points per decade.

3. EXPERIMENTAL RESULTS

All the 62 units were submitted to a Helium Leak Rate Test giving results bellow 1.0×10^{-9} mbar.l/s as required by the specification.

Six out of the 62 absolute capacitance transmitters showed accuracy values higher than the required specification presented at Table 1. Two did not even permitted an initial zero adjustment due to diaphragm malfunction and one had electronic problems. The remaining 53 transmitters were fully approved.

The accepted transmitters had similar performances to that presented as an example at Table 2.

In this table, the standard pressure values monitored by the MKS Capacitance Manometer are presented in the column "Std. P.", the pressure values indicated by the transmitter under calibration are in the column "Meas. P." and the differences between them, expressed as transmitter's full scale (F.S.) percentage, are indicated in the column "Bias".

Observe that the three identical measurements made at each point are a clear demonstration of the calibration system stability.

Although absolute zero pressure is not achievable, capacitance manometers are in practice zeroed at pressures below their resolution. In this way, the initial values of Table 2 (0.00 mbar) were taken at the pressure of 1.0×10^{-3} mbar, where both instruments were zeroed.

Table 2 - Calibration Data Sheet

Std P. (mbar)	Meas P. (mbar)	Bias (% F.S.)
0,00	0,00	0,00
0,00	0,00	0,00
0,00	0,00	0,00
1,00	0,97	0,06
1,00	0,97	0,06
1,00	0,97	0,06
5,02	5,00	0,04
5,02	5,00	0,04
5,02	5,00	0,04
10,0	9,98	0,04
10,0	9,98	0,04
10,0	9,98	0,04
20,0	19,9	0,20
20,0	19,9	0,20
20,0	19,9	0,20
30,0	30,0	0,00
30,0	30,0	0,00
30,0	30,0	0,00
41,0	41,0	0,00
41,0	41,0	0,00
41,0	41,0	0,00
50,0	49,9	0,20
50,0	49,9	0,20
50,0	49,9	0,20

The higher bias verified in Table 2 are of 0.20% of full scale which represents the instrument accuracy.

To determine the transmitter under test resolution, the MKS Baratron Capacitance Manoter gain was increased from 1.0 to 0.01 so as to provide 2 more decimals in the standard pressure indication. This has enabled us the identification of even smaller changes in the transmitter's pressure values as can seen in Table 3.

Table 3 - Small Measurements Pressure

Std. P. (mbar)	Meas. P. (mbar)
0,0000	0,00
0,0100	0,02
0,0201	0,03
0,0301	0,03
0,0400	0,04
0,0500	0,05
0,0600	0,06
0,0700	0,07
0,0801	0,08
0,0901	0,09
0,1001	0,10

As can be seen in Table 3, the transmitter is only able to detect changes of 0.01 mbar which represents a resolution value of 0.02% of its full scale (F.S.).

It is interesting to observe that the transmitter is not able to detect any pressure change below 0.02 mbar. This is the transmitter's dead zone, which is typically 0.04% of full scale.

4. CONCLUSION

The calibration task was successfully carried out permitting the identification of 53 transmitters (85.4% of the lot) which complied to the technical specification and were ready to be installed in the new chemical plant.

The calibration system and procedure adopted was regarded as suitable to this kind of job because provided fast and reliable calibration services to the company's quality control programme.

The accuracy, resolution and dead zone results were very similar to those commonly reported in technical literature[9], a clear indication of the instrument's high quality.

Above all, the experiment demonstrated the laboratory ability to perform fast and reliable pressure calibration under the most stringent specifications.

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