ESTABLISHMENT THE TRACEABILITY OF NIS PISTON-CYLINDERS FOR THE 200 MPa RANGE OF HYDRAULIC PRESSURE

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Pressure balances are excellent standards for measuring pressure with acceptable uncertainty and they are widely used at the primary pressure laboratories in the world. This study aims to establish the traceability of NIS piston cylinder assemblies for the 200 MPa hydraulic pressure range by calibrating them with the smallest uncertainty. All assemblies will be traceable to a transfer standard calibrated at BNM-LNE-France using di-ethylhexyl-sebacate as the pressure medium.

The consistency of all calibration data available will be investigated in order to draw conclusions regarding the realization of traceability in the 200 MPa range of hydraulic pressure by the cross float method. New values of the effective areas and the pressure distortion coefficients as will as the associated expanded uncertainties of NIS piston cylinder assemblies will be derived from the results of this study.

The present study also establishes a link to the latest trilateral intercomparison in the pressure range 40-200 MPa between NIST-USA, AIST- Japan and NIS-Egypt.

Key words: Pressure balances, Uncertainty, Calibration, Traceability and Cross floating

1. Introduction

In establishing traceability in fluid pressure at elevated ranges, there is a significant challenge compared to many other measurands in the International System of Units (SI) [1]. Pressure (Pa) is intensive (1) and has no sources of defined reference points by intrinsic standards. When examining traceability in quantities (or measurands) such as length (m), mass (kg), current (A), amount of substance (mol) and mass flow (kg/s), these measurands have the advantage that larger amounts can be obtained by the addition of known smaller amounts. For example, to calibrate a 2 kg/s mass flow device, an option is to use two 1 kg/s standards in parallel. If a 10 kg mass needs to be determined, two 5 kg masses may be used. To measure a 1 meter device, two 0.5 meter standards in series can be used. However it is not possible to use two 200 kPa standards to calibrate one 400 kPa test instrument.

From this aspect temperature (K) can be put in the same category as pressure. Yet temperature has the support of the International Temperature Scale of 1990 (ITS90) with intrinsic reference points well dispersed over a very wide range. Research has taken place to this end, and is currently being pursued at NIS, but at this point pressure has no intrinsic reference points to support traceability. It is completely dependent upon derived standards, specifically the manometer and the piston gauge. Though the manometer has performed well in support of lower pressures, a practical limitation of the height of the liquid column keeps it from being a useful instrument for traceability in ranges higher than about 350 kPa. For a pressure laboratory with daily applications reaching 500 MPa the manometer can only support the first 0.07 % of the range.
The answer to the traceability problem described above for many years has been the piston gauge. The piston gauge defines pressures when a piston is floating by the simplified equation:

$$pressure = \frac{m \cdot g}{A_{(t,p)}}$$

Where:
m is true mass loaded on the piston-cylinder assembly
g is the acceleration of gravity at the location of the piston gauge
A(t, p) is the effective area of the piston-cylinder assembly at temperature (t) and pressure (p)

The effective area of high range pistons can be obtained by cross-floating experimental measurements.
When the equilibrium in the cross-floating is reached placing appropriate trim weights on the assemblies, the pressure is equal on both balances. We have done three measurement cycles of cross-floating each one consist of ten points over the whole range up and down with monitoring all environmental conditions .the cross-floating between the air and oil medium were run through DH pressure separator of max. pressure 800 bar

$$P_{\text{standard}} = P_{\text{undertest}}$$

$$P_{\text{standard}} = \left(\frac{F}{A} \right)_{undertest}$$

$$A_{undertest} = \frac{F_{unertest}}{P_{\text{standard}}}$$

$$P_{\text{standard}} = \frac{\sum M_C.g.\left(1 - \frac{\rho_a}{\rho_m}\right) + \gamma\, C}{A_0 + (1 + \lambda p) + [1 + (\alpha_C + \alpha_P).(t - 20)]} + (\rho_f.g.\Delta h)$$

Where: p is the pressure;
M_C is the convention mass on the piston;
ρ_m is the density of the weight;
ρ_a is the density of ambient air;
ΣM_C is the sum of the convention masses of the weights applied on the piston and the weight carrier;
g is the local gravity;
A_0 is the effective area at temperature 20 oC and at null pressure; and
α_C is the thermal expansion coefficient of the cylinder
α_P is the thermal expansion coefficient of the piston; and
t is the temperature of the piston cylinder assembly.

2. The Piston-Cylinder Pressure Calibration Chain

<u>Experimental and calibration chain :</u>

This work divide into two parts :

1- The pressure Traceability transfer using three cross-floating calibration chain as described in fig (1) :

i) Calibration of 50 MPa piston cylinder assembly with respect to the 20 MPa piston cylinder assembly which is traceable to BNM-LNE , the calibration result of effective cross section area at null pressure of piston 50 MPa was used in the second cross-floating as a standard.

ii) calibration of 100 MPa piston cylinder assembly with respect to the 50 MPa piston cylinder assembly the calibration result of effective cross section area at null pressure of piston 100 MPa was used in the third cross-floating as a standard.
iii) calibration of 200 MPa piston cylinder assembly with respect to the 100 MPa piston cylinder assembly.

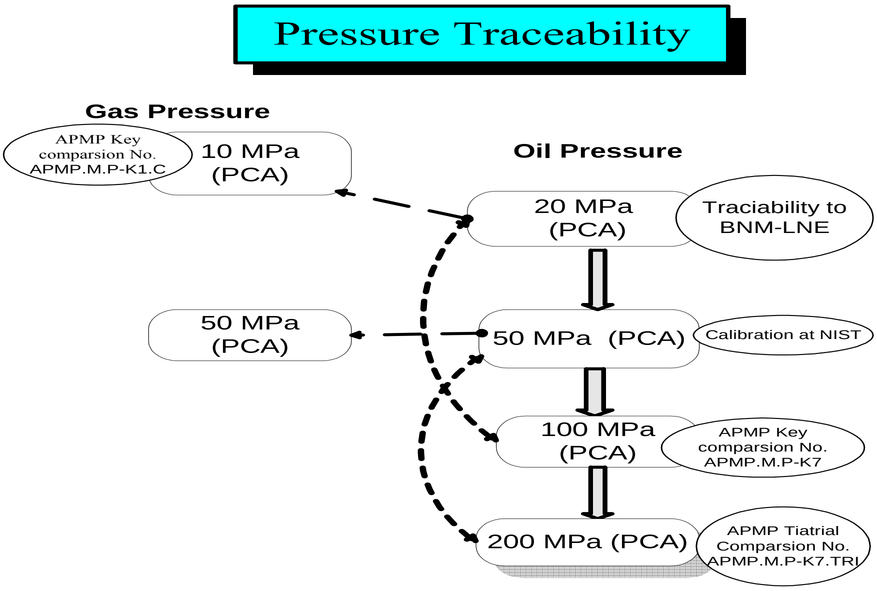

Fig.(1) Pressure traceability and validity

2-The results validation or check using four cross-floating calibration chain between the pistons which were take part in an international comparisons:

i) Calibration of 10 MPa gas piston cylinder assembly shared in APMP Key comparison No.APMP.M.P-K1.C traceable to the 20 MPa oil piston cylinder assembly which is traceable to BNM-LNE.
ii) Calibration of 100 MPa oil piston cylinder assembly shared in APMP Key comparison No.APMP.M.P-K7 traceable to the 20 MPa oil piston cylinder assembly which is traceable to BNM-LNE.
iii) Calibration of 200 MPa oil piston cylinder assembly shared in APMP Trilateral Comparison No. APMP.M.P-K7.TRI traceable to the 50 MPa oil piston cylinder assembly that is calibrated at NIST.
iv) Calibration of 50 MPa gas piston cylinder assembly with respect to the 50 MPa oil piston cylinder assembly which is Calibrated at NIST.

Results

1- The results of The pressure Traceability :-

Calibration No.	Standard PCA	Under test PCA	Effective area at null pressure(A_0) (mm^2)	**U**(A_0)	Pressure distortion coefficient (λ) (MPa^{-1})	**U**(λ) (MPa^{-1})
i	20 MPa	50 MPa	19.61072	$\pm 2.1\times10^{-5}\times A$	9.6×10^{-7}	$\pm 6.7\times10^{-8}$
ii	50 MPa	100 MPa	9.804572	$\pm 2.2\times10^{-5}\times A$	1.03×10^{-6}	$\pm 0.7\times10^{-7}$
Iii	100 MPa	200 MPa	4.902311	$\pm 2.5\times10^{-5}\times A$	8.0×10^{-7}	$\pm 4.3\times10^{-8}$

2- The results of The pressure validation :-

Calibration No.	Standard PCA	Under test PCA	Effective area at null pressure(A_0) (mm^2)	**U**(A_0)	Pressure distortion coefficient (λ) (MPa^{-1})	**U**(λ) (MPa^{-1})
i	20 MPa Oil	10 MPa Gas	98.05070	$\pm 18.1\times 10^{-6}\times A$	Do not calculated	Do not calculated
ii	20 MPa	100 MPa	9.804565	$\pm 2.8\times10^{-5}\times A$	1.03×10^{-6}	$\pm 2.33\times10^{-7}$
iii	50 MPa	200 MPa	4.902319	$\pm 2.9\times10^{-5}\times A$	8.0×10^{-7}	$\pm 4.3\times10^{-8}$
iv	50 MPa Oil	50MPa Gas	19.61201	$\pm 3.2\times10^{-5}\times A$	4.2×10^{-7}	$\pm 1.72\times10^{-7}$

Conclusions:

It could be demonstrated that oil-operated 200 MPa piston cylinder assembly could be calibrated traced to a 20 MPa piston cylinder assembly through three steps with total uncertainty of less that 25 ppm.
Validation of this calibration chain was guaranteed through a set of validation cross-floating experiments using different piston cylinder assembles those used as a standard in different international comparisons.
A future work is planed to study the traceability traced to 1 MPa gas piston cylinder assembly that will be measured dimensionally.

7. References

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