Rapport BIPM-90/10

INTERNATIONAL COMPARISON

IN THE PRESSURE RANGE

20 - 100 MPa

(forth phase)

organized by the High Pressure Working Group
of the Comité Consultatif pour la Masse et les grandeurs apparentées

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J.C. LEGRAS[1], G.F. MOLINAR[2], K. SCHMALHOFER[3], J.K.N. SHARMA[4],

M. THRANE[5], D.B. WALKER[6]

ABSTRACT

An international intercomparison in the pressure range 20-100 MPa has been organized under the auspices of the Bureau International des Poids et Mesures. Given here is a brief outline of the results of the later of four phases in which the national standards laboratories of FRANCE, SOUTH AFRICA, HUNGARY, DENMARK and INDIA participated.

The results of the three former phases have been published as <u>B.I.P.M. reports</u> (B.I.P.M.-84/2, B.I.P.M.-86/1 and B.I.P.M.-86/3 respectively). The all results have been published in METROLOGIA 25, 21-28 (1988).

1. Laboratoire National d'Essais (L.N.E.), PARIS - FRANCE
2. Istituto di Metrologia "G. Colonnetti" (I.M.G.C.), TURIN - ITALY
3. National Office of Measures (O.M.H.), BUDAPEST - HUNGARY
4. National Physical Laboratory (N.P.Li), NEW DELHI - INDIA
5. The Jutland Technological Institute (J.T.I.), AARHUS - DENMARK
6. Council for Scientific and Industrial Research (C.S.I.R.), PRETORIA - SOUTH AFRICA

INTRODUCTION

The high pressure Working Group of the Comité Consultatif pour la Masse et les grandeurs apparentées (C.C.M.) of the Bureau International des Poids et Mesures (B.I.P.M.) has organized an international comparison in the pressure range 20-100 MPa. Initially foreseen with 13 countries, the comparison work was divided into three phases. As new countries have asked to participate to it, a forth phase has been organized. This note briefly outlines the results of this later phase.

For the measurement of pressure in the range above atmospheric, the primary standard in general use is the pressure balance (or piston gauge), where the pressure is derived from the application of a known gravitational force balanced against an upward force generated by the action of the system pressure on a known area. This area is provided by a carefull matched piston-cylinder assembly, and is termed the effective area of the assembly. The determination of the effective area, especially its dependence upon pressure due to the elastic distortion of the piston and cylinder, forms the major source of uncertainty in establishing high pressure standards.

Dissemination of pressure measurements in this pressure range is also achieved using pressure balances. The natural choice for a transfer standard for this intercomparaison was therefore a pressure balance, the measured parameter being the effective area of its piston-cylinder assembly.

The participants of the forth phase of the comparison, which was carried out over a period of about three years, were as follows (the acronyms were above defined) :

JANUARY 1986	: L.N.E. 5
FEBRUARY 1987	: C.S.I.R.
MAY-JULY 1987	: O.M.H.
FEBRUARY 1988	: J.T.I.
JUNE - SEPTEMBER 1988	: N.P.Li
SEPTEMBER 1989	: L.N.E. 6

with LABORATOIRE NATIONAL D'ESSAIS acting as the Pilot Laboratory.

All the standards used by the participating laboratories were pressure balances. The two major differences between these standards are the design of the piston-cylinder assemblies and the materials chosen for their construction. Brief details of each Laboratory's standard are given in Table 1, which also shows the diversity in the methods of determination of the pressure distortion coefficients of the piston-cylinder assemblies.

OUTLINE OF PROCEDURES

The transfer standards is a DESGRANGES et HUOT pressure balance, type 5300 S, which has been put at the disposal of the Working Group by the manufacturers. It has a range of 2 - 100 MPa and a set of stainless steel weights with a total mass of 50 kg. The cylinder is made of tungsten carbide, and the piston is of high-speed steel.

During the forth phase, due to an unusual leakage, the variable volume of the transfer standard has been changed twice. These modifications did not have any influence on the uncertainty of the comparison.

At the beginning of the forth phase, the cylinder of the transfer standard was changed with the cylinder usually kept in reserve at L.N.E. The transfer standard was returned to L.N.E. after the comparison at O.M.H. The situation was analysed and the transfer standard was again equipped with the usual unit. The additionnal components of the uncertainty due to the change during the intercomparison at C.S.I.R. and O.M.H. have been estimated to be 10×10^{-6} (relative value) for the effective area and 0.1×10^{-6} MPa^{-1} for the pressure distortion coefficient. These components will be taken into account in the evaluation of the uncertainties of the comparison in the two laboratories.

Each laboratory determined the effective area of the piston-cylinder assembly, $\underline{A_p}$, at a series of applied pressures, using samples of the same oil as the pressure medium.

The measurements were made in five pressure cycles by direct comparison (crossfloating) between the laboratory's standard and the transfer standard. Each cycle consisted of 17 measurements at 9 pressures, between 20 and 100 MPa at intervals of 10 MPa.

In general, the dependence of effective area on applied pressure can be expressed in the form

$$\underline{A}_{\underline{p}} = \underline{A}_{o} (1 + \lambda \underline{p})$$

where λ is termed the pressure distortion coefficient.

The results from each participating laboratory have been analysed by the Pilot Laboratory. As a test of the linearity assumption, the deviations of the observed values of $\underline{A}_{\underline{p}}$ from the appropriate least squares best fit straight line are shown in Fig. 1 as a function of applied pressure, where the appropriate least squares best fit straight line obtained for each of the Laboratories have all been superimposed in order to provide a basis for comparison.

As the intercomparison is being carried out on a blind basis, the actual measured values of effective area obtained by the participants are not given here. Therefore, to facilitate comparison of the results of the participants, reference values of $\underline{A}_{oREF}$ and λ_{REF} have been adopted which define the effective area, $\underline{A}_{\underline{p}}$, of the transfer standard. As the values of $\underline{A}_{o}$ and λ as measured by the Pilot Laboratory have not significantly changed with time, the reference values used are the values issued from the calculation presented in the paper relating to the three first phases [METROLOGIA 25, 21-28 (1988)]. These values are the mean of the values determined by all the laboratories, weighed by the reverse of the squares of the claimed uncertainties.

SUMMARY OF RESULTS

The results of the forth phase show agreement between the five laboratories within 140×10^{-6} for the measurement of the effective area, $\underline{A}_{o}$, at zero pressure (see Table 2). These differences are inside the limits of the combined uncertainties obtained from the estimated uncertainties for four laboratories (see Table 1). All uncertainties are evaluated on the basis of three times the standard deviations.

The results also show agreement for the pressure distortion coefficient, within the combined uncertainties for three laboratories.

The values of $\underline{A_p}$ for all the laboratories are plotted as a function of pressure in Fig. 2. The interlaboratory differences of $\underline{A_p}$ are within 140×10^{-6}.

As indicated in Table 2, the measured values of $\underline{A_0}$ show a stabilization between LNE 5 and LNE 6. These values are very near of the values indicated as LNE 3 and LNE 4 for the third phase. This confirmes that the changes in area measured during the two first phases have disappeared after about three years. The same behaviour has been observed in the back-up piston and cylinder not circulated to the participants.

Since the same references for $\underline{A_0}$ and λ have been used in analysing the results, they can be directly compared with the results published in METROLOGIA for the three first phases.

Acknolegments

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TABLE 1 – Details of the Laboratories standards

LABORATORY Parameter	LNE (F) Pilot lab.	CSIR (SA)	OMH (H)	JTI (DK)	NPLi (I)	
					NPL – 140	NPL – 100
Range (MPa)	5-200	2.5-100	5-100	0.4-100	0.24-140	0.2-100
Material of piston and cylinder	tungsten carbide	tungsten carbide	steel	tungsten carbide	cemented tungsten carbide	tungsten carbide
Effective area at zero applied pressure and at ref.temperature ($\underline{A}_o$ (mm^2)	50.2732	4.90266	4.993	4.90253	16.802 44	9.80487
Uncertainty of $\underline{A}_o$ $\Delta\ \underline{A}_o/\underline{A}_o$ (parts in 10^6)	27	60	94	42	73	74
Type of assembly	controled clearance	free distortion	free distortion	free distortion	reentrant	free distortion
Pressure distortion coefficient λ (MPa^{-1})	$-$ 0.02 x 10^{-6}	1.4 x 10^{-6}	2.9 x 10^{-6}	0.95 x 10^{-6}	2.76 x 10^{-6}	0.3 x 10^{-6}
Method of determination of λ	flow leak + variation of jacket pressure	experimental	calculated	experimental	experimental	experimental
Uncertainty on λ (parts in 10^6/MPa)	0.1	0.5	3	0.3	0.1	0.1
Temperature coefficient 2α (°C^{-1})	0.84 x 10^{-5}	0.9 x 10^{-5}	2.3 x 10^{-5}	0.9 x 10^{-5}	0.91 x 10^{-5}	0.9 x 10^{-5}

TABLE 2 - Variation in measured values of $\underline{A}_0$ and λ with respect to the reference values defined during the three first phases

LABORATORY	DATE	$\underline{A}_0$		λ	
		Measured value - "reference" value (parts in 10^6)	Uncertainty of measurement (parts in 10^6)	Measured value - "reference" value (parts in 10^6/MPa)	Uncertainty of measurement (parts in 10^6/MPa)
LNE 5	01.86	+ 4.9	± 31	- 0.11	± 0.11
CSIR	02.87	- 71.0	± 66	+ 0.76	± 0.51
OMH	05.87	+ 65.9	± 98	- 0.71	± 3.1
JTI	02.88	- 1.8	± 49	+ 0.06	± 0.31
NPL 140 100	08.88	- 51.5	± 74	- 0.47	± 0.15
LNE 6	09.89	+ 5.3	± 31	- 0.13	± 0.11

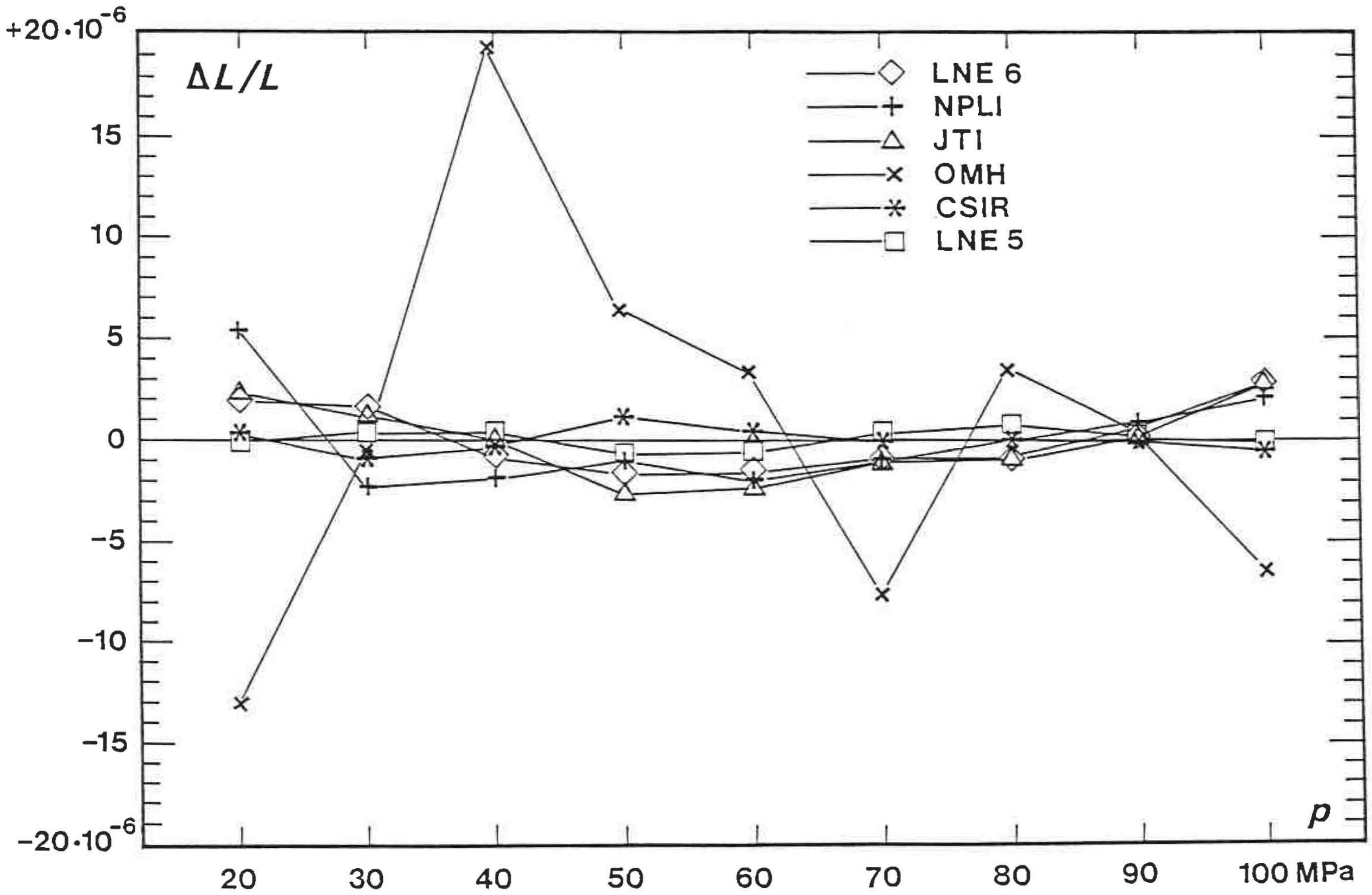

Fig. 1.- Deviations in the measured effective area, A_p, from linear functions of applied pressure, fitted to the data from each laboratory.

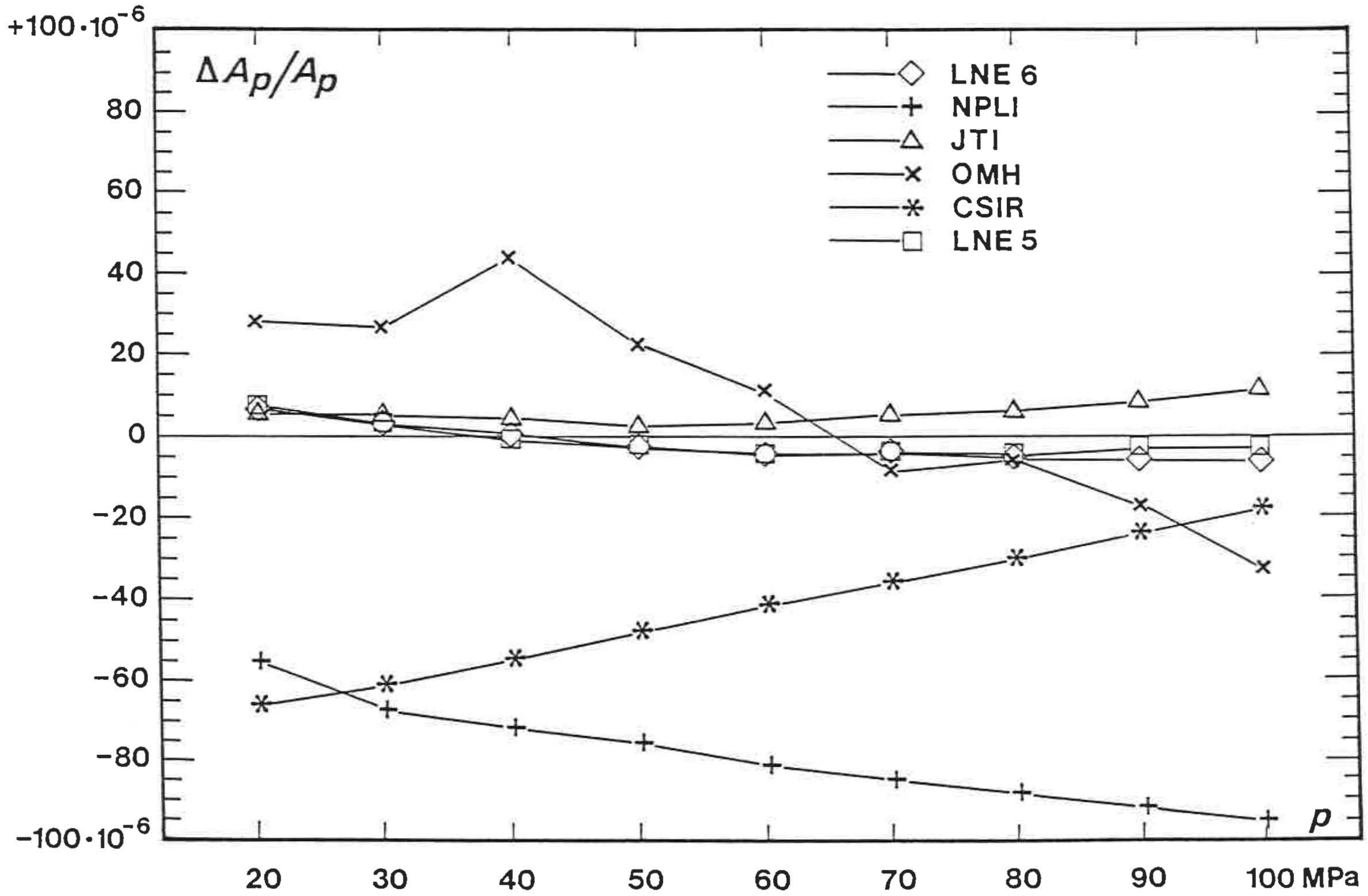

Fig. 2.- Difference between the values of the effective area, A_p, as measured by each laboratory and the reference values, as a function of the pressure. The difference ΔA_p is expressed as relative value.