Rapport BIPM-86/3

INTERNATIONAL COMPARISON

IN THE PRESSURE RANGE

20-100 MPa

(third phase)

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

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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 third of three phases in which the national standards laboratories of France, Japan, China, German Democratic Republic and U.R.S.S. participated.

The results of the first phase has been published as a note in Journal of Physics E, 18, 1985, p. 361.

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INTRODUCTION

The high pressure Working Group of the Comité Consultatif pour la Masse et les grandeurs apparentées (CCM) of the Bureau International des Poids et Mesures (BIPM), has organized an international comparison in the pressure range 20 - 100 MPa. As 13 countries are participating in the intercomparison, it has been necessary to divide the work into three phases. This note briefly outlines the results of the third phase ; a detailed report of the full intercomparison will be shortly published in due course.
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 intercomparison was therefore a pressure balance, the measured parameter being the effective area of its piston-cylinder assembly.
The participants of the third phase of the comparison, which was carried out over a period of about one year, were as follows (the acronyms were above defined) :

April	1984	: LNE 3
August	1984	: NRLM
November	1984	: NIM
February	1985	: ASMW
June	1985	: VNIIFTRI
August	1985	: LNE 4

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 détermination of the pressure distortion coefficients of the piston-cylinder assemblies.

OUTLINE OF PROCEDURES

The transfer standard 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.

Each laboratory determined the effective area of the piston-cylinder assembly, 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

$$A_p = A_o (1 + \lambda p)$$

where is termed the pressure distortion coefficient. The results from each participating laboratory have been analyzed by the Pilot Laboratory. As a test of the linearity assumption, the deviations of the observed values of A_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, $\underline{A}_p$, of the transfer standard. As the values of $\underline{A}_o$ and λ as measured by the Pilot Laboratory slightly changed with time, the reference values used are the same as for first phase (the arithmetic mean of the pilot Laboratory's results at the beginning, LNE A1, and at the end of the first phase, LNE A2).

SUMMARY OF RESULTS

The results of the second phase show agreement between the five laboratories within 120×10^{-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 three 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 all the 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 130×10^{-6}.

As indicated in Table 2, the measured values of $\underline{A}_o$ show a stabilization between LNE 3 and LNE 4. After the increases during the two first phases, this suggests the possibility that the area changes asymptotically with time. Similar but somewhat larger changes have been observed in a back-up piston and cylinder not circulated to the participants.

As synthesis of the comparison, comparative values of the effective area $\underline{A}'_p$ versus pressure for the three phases are shown in Fig.3.

The results presented here have not been corrected for any possible changes in the transfer standard.
A full BIPM report of the intercomparison and a paper in METROLOGIA are to be published shortly.

TABLE 1 -Details of the Laboratories standards

LABORATORY Parameter	LNE (F) Pilot lab.	NRLM (J)	NIM (C)	ASMW (RDA)	VNIIFTRI (USSR) simple piston	VNIIFTRI (USSR) intensifier
Range (MPa)	5-200	2.5-100	10-100	5-100	12,5-100	0,025-100
Material of piston and cylinder	tungsten carbide	tungsten carbide and steel (cylinder)	steel	steel	steel	steel
Effective area at zero applied pressure and at ref.temperature (A_o (mm^2))	50.2732	99.9860	10.00451	20.3325	20 (nominal)	100 + 2000 + 100
Uncertainty of A_o $\Delta A_o/A_o$ (parts in 10^6)	27	18	20	35	20	20
Type of assembly	Controled clearance	Controled clearance	Free distortion	Free distortion	Free distortion	Free distortion
Pressure distortion coefficient λ (MPa^{-1})	-0.02×10^{-6}	$-0,558 \times 10^{-6}$	2.9×10^{-6}	3.96×10^{-6}	2.76×10^{-6}	$2,76 \times 10^{-6}$
Method of determination of λ	Flow leak + variation of jacket pressure	Variation of jacket pressure from null clearance	calculated	calculated	calculated	calculated
Uncertainty on λ (parts in 10^6/MPa)	0.1	0.03	0.15	0.4	0.06	0.06
Temperature coefficient 2α (°C^{-1})	0.84×10^{-5}	1.45×10^{-5}	2.50×10^{-5}	2.2×10^{-5}	2.2×10^{-5}	2.2×10^{-6}

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

LABORATORY	DATE	$\underline{A}$		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 3	04.84	+ 21,9	± 31	- 0,16	± 0,11
NRLM	08.84	- 1,2	± 46	- 0,18	± 0,06
NIM	11.84	+ 25,2	± 29	- 0,26	± 0,18
ASMW	02.85	- 95,8	± 33	- 0,20	± 0,45
VNIIFTRI	06.85	- 100,9	± 43	± 0,21	± 0,06
LNE 4	08.85	+ 21,9	± 30	- 0,09	± 0,10

FIG 1 - Déviations in the measured effective areas, $\underline{A}_{\underline{p}}$, from linear functions of applied pressure, fitted to the data from each laboratory.

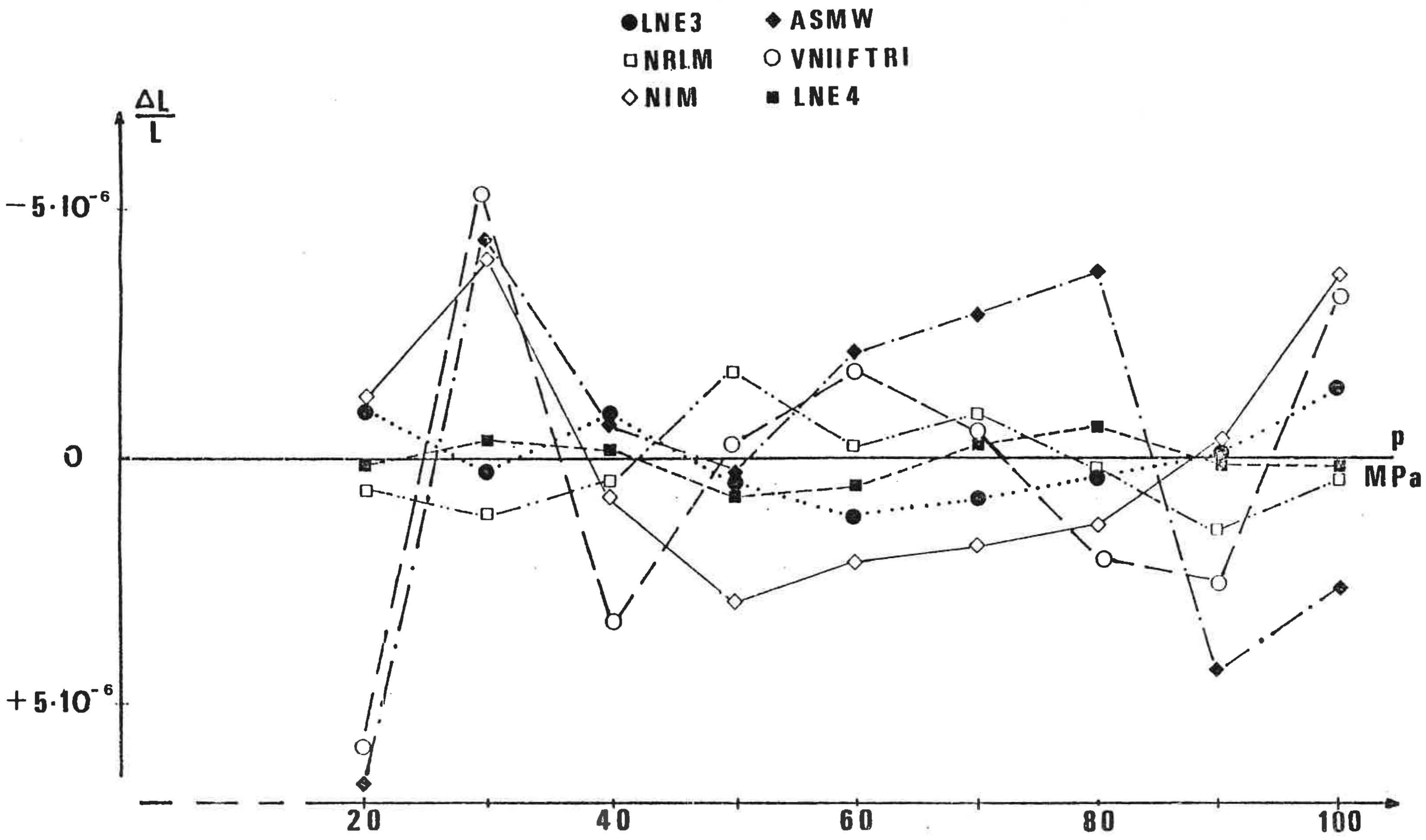

FIG 2 - Différence between the values of the effective area, $\underline{A}_P$, as measured by each laboratory and the values of $\underline{A}_{PREF}$ obtained by the Pilot Laboratory, as a function of applied pressure.

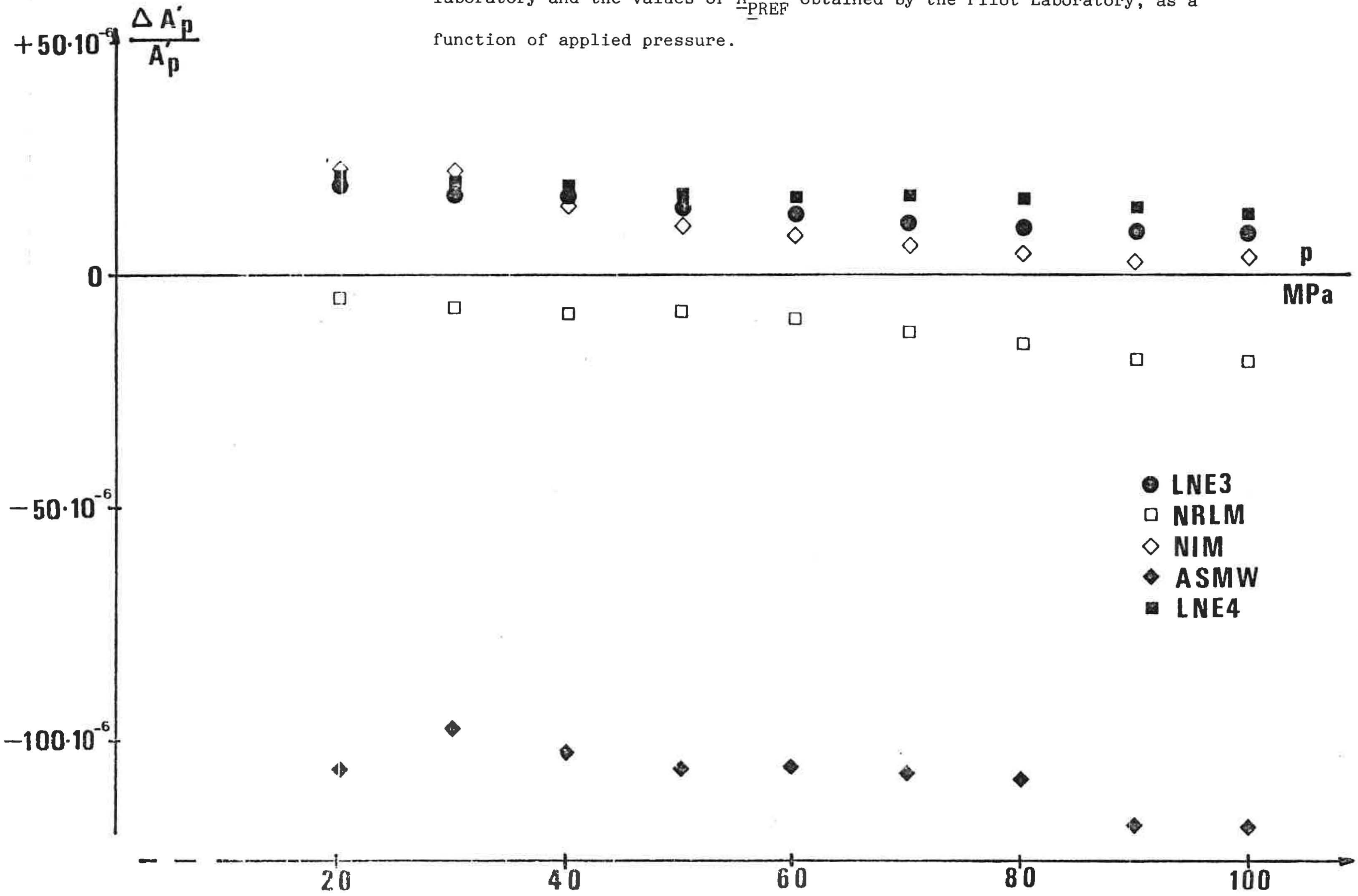

FIG 3 - Différence between the values of the effective area $\underline{A'_P}$ as measured by each laboratory of the 3 phases, and the values of $\underline{A}_{PREF}$ obtained by the Pilot Laboratory, as a function of applied pressure.