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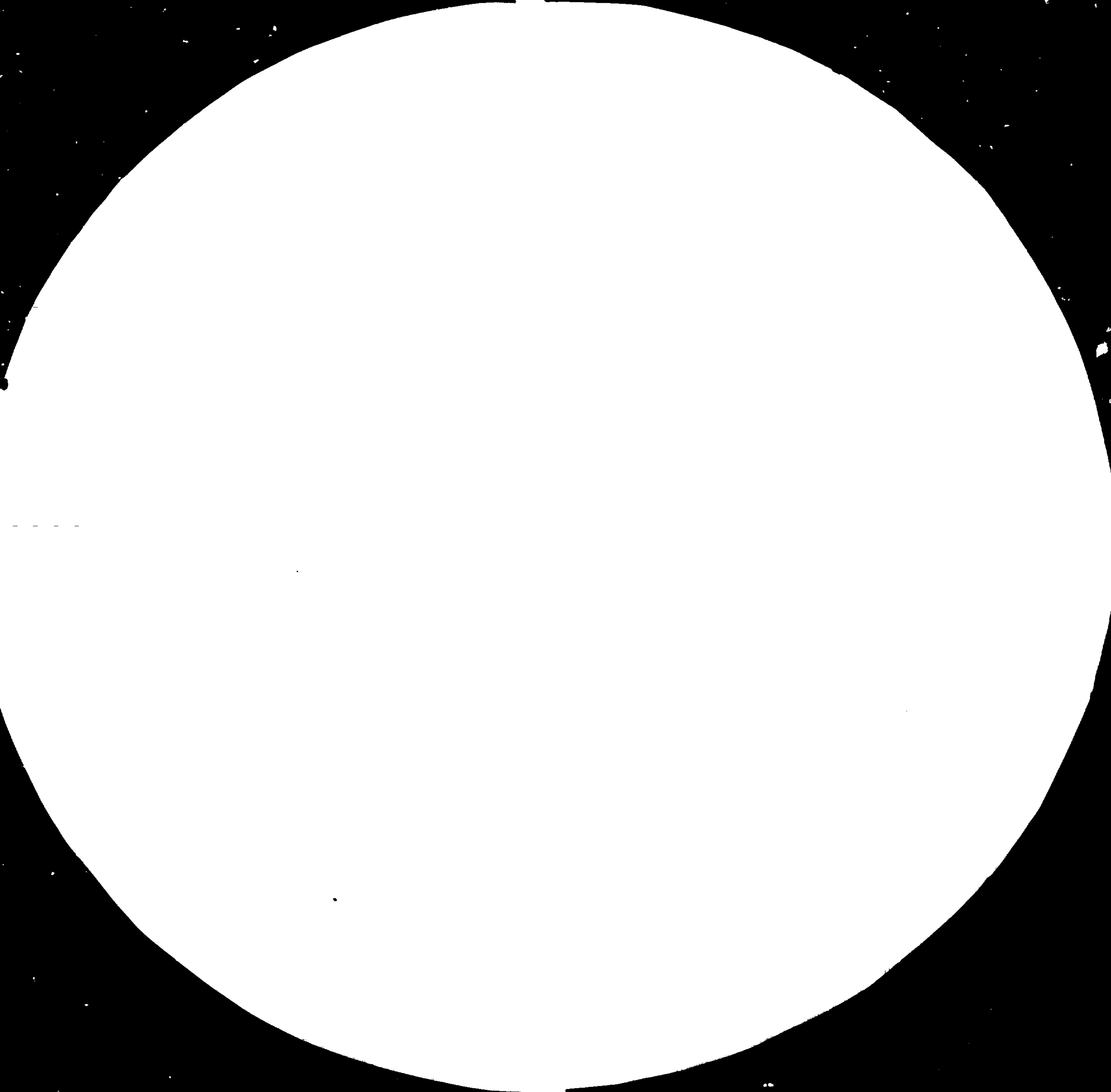

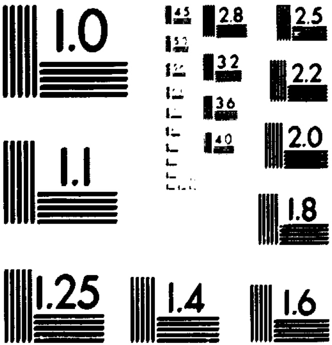

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UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION

India.

PRESSURE STANDARDS.

DP/IND/79/004

REPUBLIC OF INDIA

1985

Final Report *

Prepared for the Republic of India by the
United Nations Industrial Development Organization,
executing agency for the United Nations Development Programmme

G.F. Molinar

Based on the work of Dr. Molinar Min Beciet Gianfranco,
Consultant in the erection and commissioning of laboratory equipment
related to primary and transfer pressure standards
(mission: 29 October - 24 November 1984)

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UNIDO Final Report

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Consultant to : National Physical Laboratory
Pressure and Vacuum Section
New Delhi, INDIA

Subject : Erection and commissioning of laboratory equipment related to primary and transfer pressure standards
(Jop description DP/IND/79/004/11-01/31.3.K)

Period : - Departure Torino 3.30 pm on 27/10/1984
Arrival New Delhi 9.05 am on 28/10/1984

- Departure New Delhi 10.25 am on 25/11/1984
Arrival Torino 10.30 pm on 26/11/1984
(after debriefing in Vienna - UNDP offices)

- Worked at N.P.L. from 29/10/1984 to 24/11/1984 inclusive, except holidays

1. Introduction

Dr. J.KN. Sharma, head of pressure and vacuum standerd at NPL, organized two high pressure laboratories: one for liquid media and another for gas media.

Dr. K.K. Jain is responsable for primary and secondary standards up to 1.4 GPa in liquid media. He put all apparatuces in operation before my coming the metrological characterization of all the piston gages is in progress.
The primary standards available at this laboratory are presently the following:

- Ruska re-entrant piston gages (range 0.06 ÷ 28.0 MPa, range 0.5 ÷280 MPa);
- Harwood controlled clearance piston gages (range 55 ÷ 550 MPa, range 140 ÷ 1400 MPa).

As secondary standards there are 2 Harwood manganin gages that can be used up to 1.4 GPa, and many Heise dial gages up to 700 MPa.

They are equipped with many Ruska components (ΔP cells, tubing, fittings, ...) and also with Nova Swiss pumps of 200 and 700 MPa and other fittings, plus the Harwood components which are very specific for their use at very high pressures.

The laboratory is also equipped with a fall sphere viscometer built in cooperation with the N.B.S. (USA) and installed here in Nov. 1983 when Dr. V. Bean was at NPL.

Dr. A.K. Bandyopadhyay, with Mr. R.K. Kulshrestha, is responsable for primary and secondary standards in gas media up to 4.2 MPa (absolute pressure measurements) and 7.0 MPa (relative pressure measurements).

The primary standards are all in operation, but also in this case as in liquid media a complete metrological characterization is in progress but not yet arrived to a conclusion.

In my opinion a complete "internal" characterization will give the possibility of a better uncertainty analysis.

The primary standards available at this laboratory are presently the following:

- Absolute pressure measurements
  Ruska (0.014 ÷ 0.14 MPa)
  Ruska (0.42 ÷ 4.2 MPa)
- Relative pressure measurements
  Ruska (0.014 ÷ 4.2 MPa)
  same as above
  Harwood controlled clearance
  (atm P ÷ 7 MPa)

The evaluated uncertainty ranges from ± 100 ppm to ± 150 ppm.
This laboratory, apart from some dial gage, is not equipped with any pressure transducer with electrical output.

The laboratory space is generally adequate to the purposes of the work, and also the division in 2 laboratories (gas and liquid) is appropriate.

It must be improved the cleaning of these laboratories, particularly for what concerns gas piston gages to be used in relative and absolute mode.

The local conditions of the 2 laboratories are satisfactory for temperature changes and stability; care must be used in order to provide each laboratory of better equipment for relative humidity and atmospheric pressure measurements.

Care must also be used to direct the air flow coming from the cooling systems, or from the big fans installed in the ceilings, very far from the piston gages in order not to give them any unmeasurable buoyancy during their operations.

My first impression is very positive particularly for the care that indian scientists take in the work, which also reveals a very deep theoretical preparation in their background. However it is still necessary to conclude quickly with the available apparatuces the metrological characterization of the primary standards, as well as to begin quickly a calibration service activity, which is presently at an initial stage, in favour of indian industries and users.

Dr. J.K.N. Sharma and all his staff of the pressure and vacuum section were very active in making my stay pleasant and profitable.

2. Description of the work done

2.1. Discussion and analysis of the available data in order to characterize metrologically the Harwood controlled clearance piston gage of 500 MPa capacity.

This system, completely operative was used for the calibration of 2 transfer standards, one strain gage pressure transducer of 700 MPa capacity and one manganin pressure transducer of 1.0 GPa capacity (see points 2.2

and 2.3).

2.2. Calibration analysis of the data and comparison with IMGC results of a strain gage pressure tranducer (Q.U.B. SN 300) for relative pressure in liquid (UNIVIS J13) media from 58 to 457 MPa.

After 10 initial pressure cycles, 3 complete calibration cycles have been performed.

The reproducibility, in the range of overlapping pressure between the calibration at NPL (58 to 457 MPa) and the one at IMGC (148 ÷ 700 MPa), was typically of $\pm$ 5×10^{-4}.

With the available data of the piston gage, the difference between NPL and IMGC calibrations is below 1×10^{-5} in the overlapping range.

In order to increasethe confidence of the data I gave NPL scientists the following suggestions:

- to make a metrological determination of all the masses of the piston gage and of the effective area of the piston;
- to make an analysis of errors due to different parameters related to pressure and to combine them for obtaining an evaluated uncertainty.

Detailed discussion have been made in order to select the proper fitting to be used with the available experimental data.

2.3. Calibration, analysis of the data and comparison with IMGC results of a manganin gage pressure transducer (IMGC, IN-2) for relative pressure in liquid media (UNIVIS J13) from 58 to 457 MPa.

1 calibration cycle have been performed. The manganin transducer was set at a temperature of 31 $\pm$ 0.1°C similar to the one used at IMGC for calibration.

Reading of electrical resistance of manganin is performed with a A7-ASL bridge (manual mode) equipped with a standard resistor of 25 ohm.

We were not able to perform tests with the A7-ASL bridge in automatic mode because of mulfunctions in its logical circuits. It was not possible to repair the bridge:

I recommend this bridge being sent to ASL (U.K.) for proper repair.

Results of the calibration of the manganin gage are:

- reproducibility of resistance measurements was well below $\pm$ 6 ppm;
- from 170 to 500 MPa the agreement between NPL and IMGC calibration is inside $\pm$ 4×10^{-4}, at low pressures the agreement is lower than 1×10^{-3} due to parabolic behaviour of $K = \delta/P = f(P)$ typical of manganin and to the reduced sensitivity of manganin gages.

It was not possible to perform more pressure cycles with this gage because on 22/11/84 the piston of the 500 MPa system was broken.

I strongly recommend that a new piston-cylinder unit must be replaced with a very high priority.

The results of the work done at NPL (points 2.1, 2.2 and 2.3) will be published in a joint internal report in preparation.

2.4. Different consultings about high pressure measurements, particularly about the following subjects:

a) Experimental determination of the coefficient "d" in controlled clearance piston gages and analysis of fall rates measurements;
b) Measurements associated with piston gages mostly for temperature (with PRT), fall rates (with LVDT or non-contact transducers) and frequency of

rotation of the pistons;

c) Resolution improvement of the output signals of the 2 fixed manganin gages installed on Harwood apparatus;
d) Computer programming for best fittings of experimental data in calibration of transducers or for cross floating operations between piston gages;
e) Selection of high pressure fluid and associated measurements of viscosity, density and surface tension;
f) Examination of equipments and several discussions about gas pressure measurements particularly for the characterization of controlled clearance piston gage up to 7 MPa with different fluid (argon, nitrogen, helium).
g) Discussion and preparation of a work program in the field of gas pressure measurements for the fellowship of Mr. R.K. Kulshrestha at IMGC for a period of 6 months.

3. General notes

I have found a very good qualification of the scientists working in high pressure metrology at NPL both on a theoretical and experimental point of view.

Originally their studies were not metrology oriented so at the beginning they had no detailed experience in metrology.

The situation is quickly improving, but it is necessary to promote opportunities for NPL scientists to go abroad in other national laboratories for jointly working on high pressure metrology projects.

In my opinion it is necessary to understand that NPL scientists are working in conditions which are different from other countries: services at NPL (mechanical shop and electronic service) are very traditional and the quality of the final product sometimes is not satisfactory.

This makes scientists reluctant to design new complex apparatuces where mechanical parts of very high accuracy are needed.

They are also suffering for the difficulties of finding easily spare parts (fittings, tubes, adapters, fluids, ...) which are to be used every day by high pressure metrologist.

Another difficulty, related to unavailable spare parts, is due to the fact that in high pressure metrology there are frequently needs of adapters to shift between metric, english and U.S. threads. If these adapters are not easily available there will be a waste of time waiting for their construction.

I found scientists at NPL not always aware of recent papers and books in high pressure metrology.

This is not a technical problem of having a better library; this is the results of a isolation suffered by NPL scientists in respect to other countries.

Today if one does not go frequently to international conferences or seminars of the sector after a while he will find very difficult to have an up to date information of his own field.

Therefore, it will be beneficial to all high pressure metrologists, to indian industries and to scientific institutions if NPL scientists could attend on regular basis meetings, conferences, seminars oraganized yearly in the field of high pressure science and technology.

4. Recommendations

UNIDO high pressure project has already given good results, with the present apparatuces NPL scientists have realized the high pressure scale which is now available for practical users (calibration, services, ...) and also as a support to other R & D institutions in India.

First objective now for NPL must be the adjustment of the available primary standards for high pressure metrology with an "internal" evaluation of all the parameters affecting the accuracy of pressure measurements.

Second objective must be related to increase the experience of NPL scientists in the calibration of the different pressure transducers as well as for the complete calibration (by cross floating techniques) of piston gages.

This will lead to a "calibration service" of great importance for indian industries and other different indian scientific institutions requiring high accuracy in pressure measurements.

In order to achieve these objectives I specifically recommend:

4.1. A new piston-cylinder of 500 MPa capacity for Harwood system must be replaced with very high priority.

4.2. NPL high pressure laboratories need to obtain better instruments to perform high accuracy measurements of temperature (platinum resistance thermometer), fall rates and rotational frequency of pistons with the available piston gages.

4.3. In order to work extensively on the calibration of pressure transducers NPL needs some high accurate pressure transducers (strain gage, manganin, ...), and also stabilized power supplies and digital voltmeter for high resolution measurements.

4.4. In order to work extensively on the calibration of piston gages by cross-floating techniques NPL needs piston gages to be used in liquid and gas media as transfer standards, that is, as the better link between their primary standards and the instrumentation to be calibrated.

4.5. NPL needs to improve its capabilities of pressure measurements with primary standards (piston gages) in the range 28 ÷ 100 MPa in liquid, a range of great importance for the many industrial (chemical, aeronautical, ...) applications (accuracy requirement of $\pm$ 100 ppm).

4.6. NPL is not performing presently differential pressure measurements at high line pressure in gas. Such area for a line pressure up to 20 MPa and with Δ P's from 25 kPa and over and accuracy between $\pm$ 55 ppm to $\pm$ 100 ppm could be covered with double piston gages commercially available.

4.7. Statistical treatement of data fittings of calibration equations, calculation of various effects with a primary pressure standard are normal task in a well equipped calibration service.
NPL high pressure laboratories will strongly benefit from a small computer (HP86, HP series 200 or similars) for data handling and data acquisition during experiments.

4.8. Particularly in the case of complex apparatuces coming from foreign industries a service - contract requiring the test at NPL of the equipment and training "in loco" of NPL employees will be very useful.

4.9. There should be an exchange between NPL scientists and others of national metrology laboratories.
Fellowships given to NPL scientists for research in high pressure metrology will be very useful at this stage, and they must continue also for a few years.
Mr. R.K. Kulshrestha's fellowship for 6 months at IMGC (Torino - Italy) for training and research on gas pressure measurements is of high interest to IMGC high pressure group.
I recommend the period 1 Sept. 85 ÷ 28 Feb. 86.
This period, due to other work appointment of IMGC scientists, is the best possible.
I ask UNIDO to favour this period.

4.10. NPL scientists working in high pressure should be favoured in order to attend on a regular basis international conferences (AIRAPT, EHPRG), meetings (Gordon conferences) and seminars at an international level as well as the conferences at the national level (Instr. Society of India, ...).

4.11. NPL scientists must take part in international intercomprisons organized by BIPM working group on high pressure, and they must be favoured and supported in order to carry bilateral intercomparisons with other national metrology laboratories.

4.12. NPL scientists need, in relation to their objectives of work to carry research on some problems of high pressure metrology particularly oriented on refinement of primary standards, new measurement techniques with secondary standards, fixed points, ...

In conclusion, I am in favour of a short extension (few years) of UNIDO programs for high pressures in India, particularly for fellowships to allow indian scientists of NPL to be in other national laboratories for common research work in the field of high pressure metrology.