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INTERCOMPARISON OF MEASUREMENT TECHNIQUES ON SMALL MASSES

EUROMET PROJECT A88/143

SP REPORT 1989:44
Weights & Measures
Borås 1989

ABSTRACT.

INTERCOMPARISON OF MEASUREMENT TECHNIQUES ON SMALL MASSES
EUROMET PROJECT A88/143

The report gives an account of weighings at the 10g and 50g levels performed at Statens Provningsanstalt (SP), SE, of two masses from the National Physical Laboratory (NPL), Teddington, GB, during week 17, April 24 - 29, 1989. The weighings form part of a EUROMET project, A88/143, which is an intercomparison of measurment techniques on small masses between the NPL, as a pilot laboratory, and four European mass laboratories (Instituto di Metrologia <<G Colonetti>>, Turin, IT; Laboratoire Nationale d'Essais, Paris, F; Physikalisch-Technische Bundesanstalt, Braunschweig, D; and SP, SE).

KEYWORDS: SUBMULTIPLE, KILOGRAM, SWEDEN, MASS, STANDARD, TRACEABILITY, INTERCOMPARISON

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0. INTRODUCTION

During 1983 - 5, twelve mass measurement laboratories in Western Europe, including Statens Provningsanstalt (SP), Borås, participated in a BCR-sponsored mass intercomparison of four weights, 10g, 50g, 20kg and 50kg, which were circulated amongst the laboratories, starting and finishing at the pilot laboratory, Laboratoire Nationale d'Essais, Paris, F. The intercomparison results, especially for the two lighter masses, showed large discrepancies amongst the laboratories /1,2/.

The present EUROMET project, A88/143, is aimed at following up the BCR results, in a smaller mass intercomparison described below:

0.1 Definition and organisation

Two stainless steel masses, weighing nominally 10g and 50g, from the National Physical Laboratory (NPL), Teddington, GB, were taken in turn to each of the four laboratories participating in the project:

. Instituto di Metrologia <<G Colonetti>> (IMGC), Turin, IT;
. Laboratoire Nationale d'Essais (LNE), Paris, F;
. Physikalisch-Technische Bundesanstalt (PTB), Braunschweig, D; and
. Statens Provningsanstalt (SP), Borås, SE.

It was intended that each laboratory should take two of its own masses for 10g and 50g to the NPL for a reciprocal mass intercomparison, within a short time of each mass comparison. One would then be able to compare measurement results, methods and traceability.

The present report gives an account of weighings at the 10g and 50g levels performed at Statens Provningsanstalt (SP), SE, of the two masses from the National Physical Laboratory (NPL), Teddington, GB, during week 17, April 24 - 29, 1989.

0.2 Masses

The two weights from the NPL weighed at SP had nominal masses of 10g and 50g, and belonged to the weight set 'NPL47'. The densities of the two weights were, respectively, 7840 kg/m^3 (assumed) and 7849 kg/m^3 (measured).

1 WEIGHING EQUIPMENT

1.1 Balance and standards

The balance used in the mass comparison was a Sartorius C50 mass comparator, with a single pan, capacity 50 g, scale division 1µg, reproducibility 6 µg (manufacturer's specifications).

Two mass standards belonging to SP were employed at each calibration of the NPL weights:

. from weight set 'AII3', cylinders in one piece without knob, made of guilded brass, 10g and 50g;

. from weight set 'PTB', in one piece with knob, made of non-magnetic stainless steel by Gragerts Våg- och Viktservice, Kungsholmsgatan 26, 112 27 Stockholm, 10g and 50g. The 'PTB' weights participated in the reciprocal weighings at the NPL during week 15, April 10 - 14, 1989.

The density of each weight had been previously determined by hydrostatic weighing:

SP weight density (kg/m^3)			
PTB 10g	$7861._8(68)$	AII3 10g	8536.1
PTB 50g	$7863.0_9(130)$	AII3 50g	8463.7

1.2 Traceability of standards

Each of the SP mass standards had been most recently calibrated in March 1989, through a subdivision procedure starting with the Swedish national kilogram prototype in Pt-Ir, K 40. A full description of these calibrations is given in /3/. The national prototype was most recently calibrated at the International Bureau of Weights and Measures (BIPM), Sèvres, F, in 1984 /4,5/.

Weight	Mass value	reference
PTB 10g	10g + 375(3)µg	1989-03 /3/
AII3 10g	10g - 882(3)µg	1989-03 /3/
PTB 50g	50g + 810(10)µg	1989-03 /3/
AII3 50g	50g - 1377(10)µg	1989-03 /3/

1.3 Air density

The means used for the determination of air density for air buoyancy compensation during the weighings are listed in the table below. Since masses of largely similar densities were compared, the effects of air buoyancy were not pronounced.

All weighing were performed in the primary comparison room at SP.

Table. Instruments for the measurement of atmospheric parameters used in the calculation of air density according to B.I.P.M. recommendations /6/. Copies of instrument calibration certificates are reproduced in appendices at the end of this report.

Parameter	Laboratory	Instrument
Temperature	20 °C $\Delta T = \pm 0.05$ °C	digital instrument Pt 100 sensor 1B uncertainty ± 0.005 °C calibrated 1989-04-24 certificate 01-G89046 (SP, SE)
Pressure	No control	Bourdon tube pressure gauge, uncertainty ± 5 Pa calibrated 1988-10-27 certificate 03-1935 (FFA, SE)
Humidity	50 % $\Delta H = \pm 5$ % RH	Dew-point mirror hygrometer uncertainty ± 1.5% RH calibrated 1986-09-30 certificate 08142A/B5 /2/021 (NPL, GB)
Carbon-dioxide	$x_{CO2} = 0.0004$	experience-based

2 COMPARISON PROCEDURE

2.1 Triangular weighing comparison

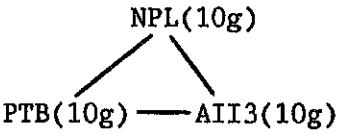
For each mass level, three weighing comparisons amongst the weights N, A and B, were performed, where N denotes 'AII3' and A and B denote, respectively 'NPL47' and 'PTB'. Each weight was thus compared with each of the other two weights.

Trend elimination was achieved through performing weighing cycles for the comparison of two weights 'A' and 'B', where the weighing sequence $A_1:B_1:B_2:A_2$ was followed. The weight difference for each cycle was then calculated using a computer program, ABBA.FOR, in FORTRAN 77, and run on SP's VAX computer. An example of this program for the pair of weights 'PTB' 10g and 'NPL(47)' 10g is reproduced in Appendix D.

Wednesday 26 April 1989

(a) Weighing on Sartorius C50
with A:B:B:A method, 15 weighing cycles, manual

10g :



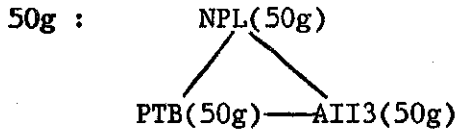
RESULTS:

Weights compared	diff (µg)	s.d. (µg)	Air density kg/m³	Mass difference (µg)
NPL - PTB	- 355.2	(4.1)	1.1548	- 351.1
PTB - AII3	+ 1137.0	(3.6)	1.1563	+ 1253.2
AII3 - NPL	- 781.4	(6.6)	1.1565	- 901.7
				Σ = + 0.4 µg

's.d.' is the standard deviation of each weighing series (with further discussion of uncertainties in section 3).

Tuesday 25 April

(a) **Weighing on Sartorius C50**
with A:B:B:A method, 15 weighing cycles, manual



RESULTS:

Weights compared	diff (µg)	s.d. (µg)	Air density kg/m³	Mass difference (µg)
NPL - PTB	- 495.35	(4.0)	1.1604	- 482.11
PTB - AII3	+ 1657.0	(6.6)	1.1579	+ 2179.51
AII3 - NPL	- 1160.83	(5.8)	1.1581	- 1696.64
				Σ = + 0.8 µg

2.2 Calibration of balance

Prior to the above weighings, the balance was checked by weighing the 'AII3' 50g weight alternately with and without a sensitivity weight, from weight set 'AII10' of nominal mass 2 mg, about 7 pairs of readings.

The weight 'AII10' 2 mg had a mass of 2.0064(10) mg, and density 2700 kg/m³, according to the most recent calibration (1988-01-26, certificate 01-B88102 SP, SE).

RESULTS:

Weights compared	diff (µg)	s.d. (µg)	Air density kg/m³	Mass difference (µg)
AII3 + AII10 50g 2 mg - AII3 50g	2005.4	(0.65)	1.160	2006.3

3 UNCERTAINTIES OF MEASUREMENT

3.1 Type A uncertainties

Each weighing series error was estimated from the observed standard deviation of the series: these values are given in the above tables of results in the column marked 's.d.', and in parentheses after each mean weighing deflection value, d_i. Since each series consisted of 15 weighing cycles, A:B:B:A, one obtained N, = 30, weighing differences per series, and the standard deviation, $s(d_i)$, of the mean deflection over each weighing series was calculated on the assumption of a normal (Gaussian) distribution, i.e.

$$s(d_i) = \sqrt{\frac{1}{N(N-1)} \sum_k (d_k - d_i)^2} \qquad (3.1)$$

where $1 \leq k \leq N$.

The long-term performance of the balance was known, so that an estimate of the between-times weighing error was available /3/. This estimate was not used in the present weighings, however, since the performance of the balance was temporarily worse during the present comparison.

3.2 Type B uncertainties

3.2.1 Calibration uncertainties in sensitivity weight

The variance associated with the uncertainty in weighing the sensitivity weight used for balance calibration (section 2.2) is given by /7/:

$$\sigma^2(s) = \frac{v(\delta)}{n} \cdot \frac{MS(d)}{\delta^2} \qquad (3.2)$$

where $v(\delta)$ is the variance in the mass, δ, of the sensitivity weight; and MS(d) is the mean-square sum of the n deflections, d_i:

$$MS(d) = \frac{1}{n} \cdot \sum_i d_i^2 \qquad (3.3)$$

$v(\delta)$ is taken from the quoted calibration uncertainty ($\pm$ 1µg) and by dividing by 3, as given in the calibration certificate.

3.2.2 Calibration uncertainties in reference weights

The uncertainty with which the mass of the reference weight from the set 'AII3' is determined /3/ enters as a non-statistical uncertainty, $\sigma(c_r)$, in the present calibrations. In order to combine this uncertainty with the other contributions to the error budget discussed above, the uncertainty quoted in /3/ is first divided by the factor 3 stated in the original calibration.

3.3 Combined measurement uncertainty

The combined measurement uncertainty in the determination of each mass is calculated by performing a root-sum-squares (r.s.s) summation of the calculated and estimated standard deviations from the various uncertainty contributions considered in sections 3.1 and 3.2. The table below summarises the numerical values:

Weight	$s(d_i)$	$\sigma(s)$	$\sigma(c_r)/3$	r.s.s.
		(µg)		
10g	1.2	0.08	1.0	1.6
50g	1.2	0.14	3.3	3.5

3.4 Overall measurement uncertainty

The overall measurement uncertainty in the determination of the mass of each weight in the subdivision is calculated by multiplying the combined uncertainty by a factor 3.

4 MEASUREMENT RESULTS

4.1 Present comparison

Weight	density (kg/m³)	Mass value	reference
NPL(47) 10g	7840	10g + 20(5)µg	AII3 10g
PTB 10g	$7861._8(68)$	10g + 371(5)µg	AII3 10g
AII3 10g	8536.1	10g - 882(3)µg	1989-03

Weight	density (kg/m³)	Mass value	reference
NPL(47) 50g	7849	50g + 320(11)µg	AII3 50g
PTB 50g	$7863.0_9(130)$	50g + 802(11)µg	AII3 50g
AII3 50g	8463.7	50g - 1377(10)µg	1989-03

4.2 Comparison with earlier calibrations

Calibration reference	PTB/9/ 1980	BCR/NPL 1983**	MV3* 1986	MV3 1988	MV3 1989	/3/ 198903
PTB 10g	--	--	372(4)	383(4)	378(5)	375(3)
PTB 50g	786(20)	800(33)	779(15)	822(15)	810(12)	810(10)

* 'MV3' is a weight set similar to 'PTB'

** "BCR/NPL" are values derived by taking the values quoted /2,8/ for the mass of the 50g BCR circulating weight /1/ as an intermediary between the NPL and SP standards.

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1. A Gosset and M Priel 1986 "Mass intercomparison. E.C.C. BCR Convention no. 1328/I/069/82/7. B.C.R. - F(30)" LNE Report LNE/DMI/13203-12.

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7. G D Chapman 1987 "Calibration of kilogram submultiples", National Research Council Canada, Physics Division, Ottawa, ANMS-002, NRCC 25819

8. S Lewis 1987 (March 3) Letter to Gosset and Priel, LNE on BCR results.

9. K-H Ach 1980 Calibration certificate 1980-06-12, Gesch.-Nr. 1.31-16608/80, Physikalisch-Technische Bundesanstalt, Braunschweig, Federal Republic of Germany

STATENS
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Fysikalisk mätteknik
RMP 01 Temperatur
Box 857
501 15 BORÅS

Tel 033-165000
Telex 36252 testing s

KALIBRERINGSBEVIS

utfärdat av riksmätplats

CALIBRATION CERTIFICATE issued by a National Laboratory

Nummer (*Number*)	Sida (Sidantal: *Page tot*)
01-G89046	1 (2)

Ort (*Location*)	Kalibreringsdatum (*Date of calibration*)
Borås	1989-04-24

Ansvarig för mätplatsen (*Laboratory head*)

Jan Ivarsson

Ansvarig för mätningen (*Calibration performed by*)

Lars-Erik Josefson

Riksmätplats utses av regeringen enligt lag om riksmätplatser m m (SFS 1974:897) och kungörelse om riksmätplatser m m (SFS 1974:899, ändrad och omtryckt som 1983:639). Se även bevisets baksida.

National laboratories are appointed by the Swedish Government under the terms of the Act relating to National Laboratories inter alia (SFS 1974:897) and the Order relating to National Laboratories inter alia (SFS 1974: 899, revised and re-issued as Order No. 1983:639). See also other side.

Uppdrag nr: 88F40062

Uppdragsgivare: SP, MVm, Borås

Provföremål: 1 st digital temperaturmätare av fabrikat Systemteknik AB,typ S1228, serienummer 6629 med selektorlåda typ S1203, serienummer 6561 och tillhörande givare Pt100 ohm märkta 1 och 2.

Uppdrag: Kalibrering.

Metod: Jämförelse i vätskebad med en av SP-s resistanstermometernormaler.

Resultat:

Givare	Kanal	Korrektion vid 20 °C °C	Onoggrannhet °C
1	A	-0,006	±0,005
2	A	-0,005	"
1	B	-0,002	"
2	B	±0,000	"

Verklig temperatur = instrumentets visning + korrektion.

Kalibreringsförutsättningar: Omgivningstemperatur 23 ±1 °C
Temperaturskala IPTS-68
Uppvärmningstid >12 h

Spårbarhet: Riksmätplatsen för temperatur realiserar IPTS-68 från -182,962 °C till 1064,43 °C.

PMP 01

Vid kalibreringen använd utrustning

Termometernormaler

Resistanstermometer L&N 8163-Q, s/n 1741828		.....
Resistanstermometer L&N 8163-Q, s/n 1865685		.....X.....
Resistanstermometer L&N 8930-Q, s/n 1143		.....
Termoelement typ platina-10%rodium / platina	s/n	.....
Pyrometer IKE LP2, s/n 7901		.....

Fixpunktceller

Trippelpunktcell Argon INM, s/n 17		.....
Tenncell NPL		.....
Zinkcell NPL		.....
Trippelpunktcell vatten Spembly	s/n	.....
Metallfixpunkter för termoelement		.....

Bandlampor

General Electric 10/G, s/n C657	.....
General Electric 10/V, s/n C658	.....

Bad och ugnar för jämförelsekalibrering

Isbad	.....
Spritbad Heto SA-121, s/n 7703132	.....
Vattenbad Heto KB 21, s/n 7903186, 7905224, 7909520	.....X.....
Oljebad Heto KB11, s/n 7903, 7906, 8011	.....
Saltbad Heto KB 41, S/n 8104	.....
Rörugn Heraeus TPKe, s/n 72811115/7	.....
Rörugn Sola Basic Lindberg 54459, s/n 777827	.....
Rörugn Johnson-Matthey TK2, s/n 3991	.....

Resistans och spänningsmätdon

DC-resistansmätbrygga Guildline 9970, s/n 36940	.....X.....
AC-resistansmätbrygga ASL A7, s/n 330-1/095	.....
DMV Datron 1051, s/n 03598	.....
DVM Keithley 181, s/n 65763	.....
DMM Solartron 7081, s/n 000365	.....

Resistans och spänningsnormaler

Guildline 9330, 10 ohm, s/n 37110	.....X.....
Guildline 9330, 100 ohm, s/n 36383	.....
Tinsley 5685 A, 25 ohm, s/n 236044	.....
Tinsley 5685 A, 100 ohm, s/n 237850	.....
Likspänningsnormal Fluke 731 B, s/n 935008	.....

SVENSK MATERIALTORGANISATION
RMP 01

FFA FLYGTEKNISKA FÖRSÖKSANSTALTEN

RIKSMÄTPLATSEN FÖR TRYCK

BOX 11021
161 11 BROMMA
TELEFON 08-759 10 00

KALIBRERINGSBEVIS

utfärdat av riksmätplats

CALIBRATION CERTIFICATE issued by a National Laboratory

Nummer (*Number*)	Sida (Sidantal) *Page (of)*
03-1935	1 (3)

Ort (*Location*)	Kalibreringsdatum (*Date of calibration*)
Stockholm	1988-10-27

Ansvarig för mätplatsen (*Laboratory head*)

L. Rydström

Lennart Rydström

Ansvarig för mätningen (*Calibration performed by*)

M. Lönnstedt

Magnus Lönnstedt

Riksmätplats utses av regeringen enligt lag om riksmätplatser m m (SFS 1974:897) och kungörelse om riksmätplatser m m (SFS 1974:899, ändrad och omtryckt som 1983:639). Se även bevisets baksida.

National laboratories are appointed by the Swedish Government under the terms of the Act relating to National Laboratories inter alia (SFS 1974:897) and the Order relating to National Laboratories inter alia (SFS 1974: 899, revised and re-issued as Order No. 1983:639). See also other side.

BESTÄLLARE:Statens Provningsanstalt
REFERENS:Håkan Skoogh
POSTADRESS:Box 857;501 15 Borås

FFA UPPDRAGSNUMMER:TU-970

OBJEKT:Tryckindikator TEXAS mod.145-01 s/n 3299 med bourdonrör s/n 3935

KALIBRERINGEN,VILKEN ÄR SPARBAR TILL BIPM,ÄR UTFÖRD VID EN RUMS-TEMPERATUR AV 20.29 °C,EN JORDGRAVITATION AV 9.8182840 m/s² SAMT ETT OMGIVANDE ATMOSFÄRSTRYCK AV 99.42 kPa.

OMRÄKNING FRAN DEN PRIMÄRA ENHETEN PASCAL UTFÖRD ENLIGT SI-SYSTEMETS REKOMMENDATIONER (SS 016211).

OBJEKTETS BOURDONRÖRSTEMPERATUR: 50.7 °C

KALIBRERINGEN UTFÖRD AV: Magnus Lönnstedt

KAL. PKT. NR.	PRIMÄRNORMALENS ALSTRADE TRYCK (ABSOLUTTRYCK)			OBJEKT AVLÄST VÄRDE
	PASCAL	PSI	OSÄKERHET ppm	enheter
1	94922	13.7674	36	85830
2	96648	14.0177	36	87410
3	98374	14.2680	36	88982
4	100100	14.5182	36	90560
5	101826	14.7686	36	92127
6	103551	15.0189	36	93702

KALIBRERINGSBEVIS
fortsättningsblad

Nummer	Sida (Sidantal)
03-1935	2(3)

KAL. PKT. NR.	PRIMÄRNORMALENS ALSTRADE TRYCK (ABSOLUTTRYCK)			OBJEKT AVLÄST VÄRDE enheter
	PASCAL	PSI	OSÄKERHET ppm	
7	105277	15.2692	36	95277
8	107003	15.5195	36	96853
9	108729	15.7698	36	98434
10	101825	14.7685	36	92128
11	94921	13.7672	36	85829
12	101825	14.7685	36	92127
13	108729	15.7698	36	98433
14	101825	14.7685	36	92128
15	94921	13.7672	36	85828
16	101825	14.7685	36	92127
17	108729	15.7698	36	98433
18	101825	14.7685	36	92128
19	94921	13.7672	36	85829
20	101825	14.7684	36	92128
21	108728	15.7697	36	98434
22	101824	14.7684	36	92129
23	94921	13.7671	36	85829
24	101824	14.7684	36	92128
25	108728	15.7697	36	98434
26	101824	14.7684	36	92129
27	94921	13.7671	36	85829
28	101824	14.7684	36	92129
29	108728	15.7697	36	98434
30	101824	14.7684	36	92129
31	94920	13.7671	36	85829

MR

KALIBRERINGSBEVIS
fortsättningsblad

Nummer	Sida (Sidantal)
03-1935	3 (3)

BERÄKNING AV POLYNOM ENLIGT MINSTA KVADRATMETODEN

POLYNOMET BERÄKNAT PA KALIBRERINGSPUNKTERNA 1-9 I KALIBRERING 03-1935

OMVANDLING TILL STORHETEN PASCAL

Polynom av 3 :e graden:

β_0 = 44359.1328334672940000

β_1 = -0.3312808694341961

β_2 = 0.0000155885173830

β_3 = -0.0000000000566837

KONTROLL AV POLYNOMETS ANSLUTNING I DE INMATADE PUNKTERNA:

X =	85830.000	Y =	94922.004	AVVIKELSE:	-0.379
X =	87410.000	Y =	96649.484	AVVIKELSE:	1.286
X =	88982.000	Y =	98371.808	AVVIKELSE:	-2.347
X =	90560.000	Y =	100102.976	AVVIKELSE:	3.403
X =	92127.000	Y =	101823.009	AVVIKELSE:	-2.675
X =	93702.000	Y =	103551.436	AVVIKELSE:	-0.021
X =	95277.000	Y =	105278.149	AVVIKELSE:	0.974
X =	96853.000	Y =	107002.912	AVVIKELSE:	-0.072
X =	98434.000	Y =	108728.745	AVVIKELSE:	-0.169

KVADRATSUMMA: 27.026255

MAX. AVVIKELSE I
% AV FULLT UTSLAG: 0.003130

RMP 03 ML

NATIONAL PHYSICAL LABORATORY

Teddington, Middlesex, England.

Certificate of Calibration

OPTICAL DEW-POINT HYGROMETER

FOR: Swedish National Testing Institute
Box 857
S-501 15 Boras
Sweden
For the attention of L R Pendrill

DESCRIPTION: EG&G Model 660

IDENTIFICATION: Serial Nos 0000736 (hygrometer)
903 (sensor)

MEASUREMENTS

The hygrometer was equipped with a digital panel meter to display the measured dew-point temperature.
As requested, the analogue output of the displayed temperature was monitored directly. A customer-supplied voltage versus temperature relationship, -5 to +10 V representing -50 °C to +100 °C dew-point, was used to provide the indicated dew-point temperatures that appear in the table of results below.

REFERENCE: 08142A/B5/2/021

DATE: 30 September 1986 SIGNED: K L Bird for Director

CHECKED: WtM.

The NPL Standard Humidity Generator is based on the recirculation principle. Air of known dew-point, at a pressure of 105.0 kPa, was supplied to the test hygrometer inlet via a short length of PTFE tubing and a 0.3 m length of 4.5 mm internal diameter stainless steel tubing and vented to atmosphere, through a rotameter with a needle valve assembly for flow control. The air flow rate through the test hygrometer was set to 0.5 l/min.

The "generated dew-point" is determined from measurements made by platinum resistance thermometers. Traceability of measurement is provided by calibration of these thermometers to IPTS-68 through NPL Temperature Standards.

The test hygrometer, plus any ancillary equipment provided for the calibration, was used in accordance with the instructions supplied by the customer.

Before use, the hygrometer mirror was cleaned successively with isopropyl alcohol, deionised water and then again with isopropyl alchohol, using cotton buds. On each occasion the mirror enclosure was dried in a stream of clean dry air.

At each of the calibration temperatures requested, the measurement procedure was as follows:

a) air was recirculated through the pipework

b) the temperature of the thermostatically controlled NPL Generator bath containing the relevant primed saturator was set

c) the NPL Generator system was allowed to come to equilibrium

d) the hygrometer mirror was cleared of condensate which was then allowed to reform

e) the signal output from the test hygrometer was monitored for between 1 and 2 hours, until the instrument was seen to have stabilised

f) a set of ten readings was then taken over a period of 15 minutes. During this period the bath temperature did not differ by more than 0.08 °C from the air temperature at the saturator exit (the "generated dew-point temperature")

Throughout the calibration, the NPL Generator's performance was monitored by a second optical dew-point hygrometer.

RESULTS

The results of the calibration are given in the table that follows. Each value of the generated dew-point temperature is quoted with its overall uncertainty. The test hygrometer results quote the mean and associated standard deviation of ten readings for that instrument. The figures in the final column show the correction to be applied to the dew-point obtained from the test instrument.

GENERATED DEW-POINT		TEST HYGROMETER READING		
TEMP	UNCERTAINTY	INDICATED DEW-POINT	STANDARD DEVIATION	CORRECTION REQUIRED
°C	°C	°C	°C	°C
19.04	±0.10	18.7	0.04	+0.3
15.11	±0.10	14.9	0.06	+0.2
10.07	±0.10	9.9	0.05	+0.2
1.01	±0.10	0.8	0.07	+0.2
-5.57*	±0.15	-5.6	0.08	0.0

*the dew-point temperature calculated from a measured frost-point of -4.93 °C; there was ice in the saturator and dew on the hygrometer mirror

a) throughout the calibrations the measurement head of the test hygrometer was kept at a temperature of approximately +20 °C

b) pressure gradients within the NPL Generator system are equivalent to a correction of less than 0.02 °C in the dew-point

UNCERTAINTIES

The uncertainty figures quoted in the above table represent a combination of the observed variability in measurements and estimated uncertainties arising from temperature gradients within the NPL Generator bath, temperature conditioning of air entering the saturator and the calibration of thermometers and other ancilliary equipment. They represent an uncertainty of measurement at the 95 % confidence level.

```
c ABBA.FOR                                                    APPENDIX D
c Namn:      Beräkning av A:B:B:A vägningar
c Beskrivning: Calculates
c Författare: 890315 Leslie Pendrill
c Ändrat:    890426
c*************************************************************************

      Program ABBA

      Dimension x(100),y(100),z(100),t(100)
      Real p1,m1,p2,m2,m3

c *************************************************************************
c Assign input data file
      OPEN (Unit=10, File='10P-10N.grl', Status='Old')
c
c Number of data
      N=30

c INPUT facts in weighings

c Nominal mass of weights in g

      Sleft= 10
      Sright=10

c Density of weights in kg/m³

      dleft=7861.8
      dright=7840

c Volume difference of weights in cm³

      V= (Sleft/dleft - Sright/dright)*1E6

c Input air parameter values
      write(6,*) 'Input texas, temp, dew'
      read(5,*) texas,temp,dew
c Calibration Systemteknik S-1228 s/n 6629 Pt 100 Givare 1 ingång B
c FEf RMP 01 1989-04-24
      temp = temp - 0.002

c Dew point correction EG&G 660
c NPL 08142A/B5/2/021,1986-09-30
      dew = dew + 0.2

c CO concentration
c   2
      coc=.0004

c READ DATAFILE

      Read(10,*)
      Read(10,*)
      Read(10,*)

      DO 5 i=1,N
      Read(10,*)
   5  Continue

      Read(10,*)

      DO 10 i=1,N
       Read(10,*) x(i)
```

```
 10     continue

        Read(10,*)

        DO 15 i=1,N
         Read(10,*) y(i)
 15     continue


c*************************************************************************

c Calculations

c Namn:          Statistical evaluation of measurement results
c Beskrivning: Calculation of mean and standard deviation of
c              data from input data file (of .grl format).

c*************************************************************************
c
c Mean
c
        p1=0
        Do 16 j=1,N
         p1=p1+x(j)-y(j)
 16     continue
        m1=p1/N

c Standard deviation
c
        d1=0
        DO 17 k=1,N
         d1=d1+((x(k)-y(k))-m1)**2
 17     continue
        s1=(d1/(N-1))**(0.5)
        s1=s1/(N**0.5)


        CALL densi(texas,temp,dew,coc,dens)

c Air buoyancy
        buoy = V*dens


c RESULTS
        write(6,*) 'Air density=',dens,'kg/m³'
        write(6,*) 'Mean weight diff=',m1,'µg'
        write(6,*) 'Air compensated=',m1 + buoy,'µg'
        write(6,*) 'St.dev(mean)=',s1,'µg'



        stop
        end



        SUBROUTINE densi(texas,temp,dew,coc,dens)
c*************************************************************************
c
c Beskrivning: Beräkning av luftens tryck och densitet
c Författare: Leslie Pendrill 870421
c Ändrat: 890203
c
```

```
c*****************************************************************
      Implicit Double Precision (A-H,O-Z)

      DOUBLE PRECISION m,p,T,dewT,dew,psv,psv1,mm1,mm2,mm3,f,f1,Xv
     1 ,y1,y2,y3,Z,texas,temp,coc,dens,A,B,C,FF

c*****************************************************************
c Calculation of air pressure in Pa from Texas instrument
c calibration : 1988-10-27, FFA 03-1935

      press=44359.132833467294 - .3312808694341961*texas
     1  + .0000155885173830*(texas**2) - 5.66837*1.D-11*(texas**3)
      write(6,*)'Pressure(Pa)=',press
c Conversion to torr
      torr=press*.00750062
      vac=vac*(100)*.00750062
c Absolute temperatures
      dewT=dew + 273.15
      tempT=temp + 273.15
c Water vapour
      A=1.2811805*1.D-5
      B=-1.9509874*1.D-2
      C=34.04926034D0
      D=-6.353611*1.D3
c Enhancement factors
      f=1.00062 + press*(3.14*(1.D-8)) +
     1 (dew**2)*(5.6*(1.D-8))
      f1=1.00062 + press*(3.14*(1.D-8)) +
     1 (temp**2)*(5.6*(1.D-8))
c Saturated vapour pressures in Pa
      psv=DEXP(A*(dewT**2) + B*dewT + C + D/dewT)
      psv1=DEXP(A*(tempT**2) + B*tempT + C + D/tempT)

c Xv
      Xv=f*psv/press

c air mass in g.mol-1
      mm1=21.878746 + 6.700229 + .366323 + .000367 + .00017
c water vapour mass in g.mol-1
      mm2=18.015
c humidity
      humid=Xv*press/(f1*psv1)

c CO  mass in g.mol-1
c   2
      mm3=44.01

c compressibility of air
      y1=1.62419*(1.D-6) - (2.8969*(1.D-8))*temp
     1 + (1.088*(1.D-10))*(temp**2)
      y2=Xv*(5.757*(1.D-6) - (2.589*(1.D-8))*temp)
      y3=(Xv**2)*(1.9297*(1.D-4) - (2.285*(1.D-6))*temp)
      Z= 1- press/tempT*(y1+y2+y3) + ((press/tempT)**2)
     1    *(1.73*(1.D-11) - (Xv**2)*1.034*(1.D-8))

c AIR DENSITY in kg.m-3

      dens=press/(Z*tempT)*(1-.378*Xv)*(3.48353
     1 + 1.44*(coc-.0004))*(1.D-3)

      return
      end
```

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Telex 36252 testing s

KALIBRERINGSBEVIS

utfärdat av riksmätplats

CALIBRATION CERTIFICATE issued by a National Laboratory

Nummer (Number)	Sida (Sidantal) (Page (of))
01-B88102	1 (1)

Ort (Location)	Kalibreringsdatum (Date of calibration)
Borås	1988-01-26

Ansvarig för mätplatsen (*Laboratory head*)

Håkan Källgren

Ansvarig för mätningen (*Calibration performed by*)

Sven Ivarsson

Riksmätplats utses av regeringen enligt lag om riksmätplatser m m (SFS 1974:897) och kungörelse om riksmätplatser m m (SFS 1974:899; ändrad och omtryckt som 1983:639). Se även bevisets baksida.

National Laboratories are appointed by the Swedish Government under the terms of the Act relating to National Laboratories inter alia (SFS 1974:897) and the Order relating to National Laboratories inter alia (SFS 1974: 899, revised and re-issued as Order No. 1983:639). See also other side.

Uppdragsgivare SP, MVm.

SPs uppdragsnr 87V10083.

Mätobjekt Bladviktssats AII1O.

Uppdrag Kalibrering.

Mätmiljö Omgivningstemperatur +20 °C.

Mätmetod Vikternas massa bestämdes genom jämförelse med Statens provningsanstalts (enheten för mått och vikt) viktnormaler PTB och AII5.

Vägningarna utfördes med laboratoriets vågar med Max = 3 g.

Spårbarhet Mätresultaten är genom regelbunden kalibrering av mätplatsens viktnormaler, spårbara till världsnormalen vid BIPM (Bureau International des Poids et Mesures) i Paris.

Resultat

Nominell massa, mg	Massa, mg	Total mätosäkerhet mg (±)	Densitet kg/m³
500	499,9703	0,0015	21400
200	199,9817	0,0010	21400
100	99,9772	0,0010	21400
50	49,9745	0,0010	18100
20	19,9969	0,0010	18100
10	10,0047	0,0010	18100
5	5,0194	0,0010	2700
2	2,0064	0,0010	2700
1	1,0014	0,0010	2700

Mätosäkerhet Mätosäkerheten erhålles genom sammanläggning av mätosäkerhetskomponenter enligt reglerna för kombination av varianser. Den angivna totala mätosäkerheten är sedan beräknad genom multiplikation med talfaktor 3.

5379M/af

FMP 01