VARIATION IN MASS VALUES OF INDIAN PROTOTYPE KILOGRAM

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Abstract: The National Physical Laboratory, India (NPLI) is the custodian of National Prototype of the Kilogram (NPK) No. 57, which was provided by the BIPM in 1958 after its first calibration in 1955. The NPK has been recalibrated in 1985, 1992 & 2002 so far at the BIPM.

The change in mass values are estimated 218 μg from 1955 to 1985 (7.3 μg/year), 36 μg from 1985 to 1992 (5.1 μg/year) and 24 μg from 1992 to 2002 (2.4 μg/year) between after cleaning and washing of previous calibration to before cleaning and washing of next calibration. Now, the recalibration period of NPK is maximum 10 years.

The rate of change may, in aggregate with respect to the IPK, due to loss of mass from wear during use, increase in mass from and irreversible surface contamination and possibly, additional processes that are not yet understood.

In this paper, the BIPM method, NPL, UK formula and NMIJ, Japan formula are used to evaluate the change in mass values of NPK No. 57.

Keywords: Stability of NPK, BIPM method, NPL, UK formula and NMIJ, Japan formula.

1. INTRODUCTION

Since the kilogram is an artifact, to verify the stability of national prototypes the 3rd periodic verification of NPKs was anticipated by Resolution 1 of the 18th General Conference on Weights and Measures (CGPM) in 1987 [1]. It began in the autumn of 1988 and was finished in the autumn of 1992 [2].

Also monitoring the stability of the IPK was adopted as Resolutions 5 of the 20th CGPM in 1995 [3] because of the results of the 3rd periodic verification of NPKs, which showed drifts of the national prototypes, official copies and working copies with respect to the IPK held by the BIPM and the fundamental impossibility of drawing definite conclusions from these results about the long-term stability of the IPK and its copies.

Since, we have only one NPK, we are not able to compare it against any standard. Therefore, in this study, the changes in mass values were determined from calibration certificates of NPK no. 57 [4] to [7] issued by the BIPM and stability has been calculated using BIPM method, the NPL, UK formula and the NMIJ, Japan formula [8] from these data.

2. DESCRIPTIONS OF NPK No. 57

Fig. 1. NPK No. 57

The NPK is a cylinder, its height is equal to its diameter (39 mm) and its edges are slightly rounded off. It was made by M/s Johnson Mattley & Co. Ltd., London in 1954 and it was adjusted by the BIPM. The number "57" can be seen on account of light frosting on the lateral surface of the kilogram.

Material : The NPK No. 57 was fabricated using following materials [9] :

Platinum (Pt)	:	90.09 %
Iridium (Ir)	:	9.91 %
Ruthenium (Ru)	:	0.000 2 %
Gold (Au)	:	0.002 %

Palladium (Pd)	:	0.002 %
Silver (Ag)	:	Traces
Copper (Cu)	:	Traces.

Volume : The density of the NPK No. 57 was determined at BIPM in May 1954, before finally adjusting it, by hydrostatic weighing using Rueprecht balance No. 6.

The volume of the adjusted kilogram was calculated from density.

The coefficient of cubical thermal expansion was also determined at BIPM on Platinum-Iridium.

Mass **:**

1955 : The NPK No. 57 was determined by the BIPM using all possible combinations with the prototype kilograms No. 9, 25 and 31 belong to BIPM, No. 56 belongs to South Africa. These comparisons were carried out from April to June 1955 using Rueprecht balance No. 1.

1985 : This was again determined by the BIPM using all possible combinations with the prototype kilograms No. 9, 31 and 42' belong to BIPM, No. 18 belongs to Great Britain and No. 45 belongs to Argentina. These comparisons were carried out in April 1985 using NBS-2 balance.

1992 : Thirty-four NPKs including No. 57 were sent to BIPM for the 3rd periodic verification of NPKs. Ten prototypes of each of the four groups were formed to compare with two official copies. Latter, all the NPKs as well as the other official copies and the working standards of the BIPM were compared directly to the IPK at the beginning and at the end of the 3rd periodic verification. For these comparisons NBS-2 balance was used.

Note : All the data of density, volume, cubical thermal expansion and mass are given in Table 1

2002 : The NPK No. 57 was last determined at the BIPM using all possible combinations with the prototype kilograms No. 42', 63 and 83 belong to BIPM. These comparisons were carried out during 17th to 21st December 2002 using HK 1000 MC balance.

2012 : The NPK No. 57 has been sent to the BIPM for recalibration.

3. DETERMINATION OF STABILITY OF NPK

BIPM method : The BIPM method is based on BIPM certificates. According to the certificates of 1993 and 2003, the mass of platinum-iridium prototypes increases due to surface contamination. Immediately after cleaning and washing, the mean coefficient describing this phenomenon is approximately +0.037 µg per day and this coefficient is considered valid for maximum of three months.

Long term stability of NPK No. 57 is determined separately using mass values from certificates issued by the BIPM and given in Table 1.

NPL, UK formula : The NPL, UK formula is expressed as follows :

$$\Delta m = 0.356\ 097 \cdot t^{0.511\ 678} \qquad (1)$$

Where the Δm is the change in mass and t is the lapsed days since cleaning and washing.

NMIJ formula : The NMIJ formula is expressed as follows :

$$\Delta m = a + b \cdot t \qquad (2)$$

Where the Δm is the change in mass, a is 0.010 mg as a rapid increment mass immediately after cleaning and washing, b is the slope of 0.001 mg/y and t is the lapsed year since cleaning and washing.

Table 1. National Prototype Kilogram No. 57
(Date are taken from BIPM certificates)

Descriptions	Year of calibration			
	1955	**1985**	**1992**	**2002**
Certificate No.	19	50	33	11
Date of issue	03.09.1958	26.11.1985	19.05.1993	12.03.2003
Density at 0 °C (g/cm^3)	21.549 64			
Volume at 0 °C (cm^3)	46.404 5			

Descriptions			Year of calibration			
			1955	**1985**	**1992**	**2002**
coefficient of cubical thermal expansion, α (°C^{-1})			$(25.863 + 0.005\ 62 \cdot \theta) \times 10^{-6}$		$(25.869 + 0.005\ 65 \cdot t_{90}) \times 10^{-6}$	
Mass value before cleaning and washing (in µg in excess of 1 kg)			---	162	14	− 12
After cleaning and washing	Date of calibration		April to June 1955	October 1985	12.02.1992	13.12.2002
	Mass value (in µg in excess of 1 kg)		− 54	− 22	− 36	− 44
	Standard uncertainty [k=1] (µg)		Not reported	± 8	± 2.3	± 5
Change after cleaning and washing (µg)			---	- 184	- 50	- 32
Calibration frequency			---	30 years 4 months	6 years 3 months	10 years 10 months
Change in mass values (µg)	BIPM method	Total	---	216	36	24
		Per year	---	7.12	5.76	2.22
	NPL, UK formula	Total	---	41.77	18.62	24.66
		Per year		1.38	2.98	2.28
	NMIJ formula	Total	---	40.33	16.25	20.83
		Per year		1.33	2.60	1.92

4. STABILITY OF NPK No. 57

We have described the stability of the NPK No. 57 using the following figures :

Fig.2 : Change in mass values before and after cleaning and washing are reducing with time.

Fig.3 & Fig.4 : Trend of mass values before and after cleaning and washing respectively.

Fig.4 : Stability of the NPK No. 57 according to BIPM method, NPL, UK formula and NMIJ, Japan formula (change in mass value per year).
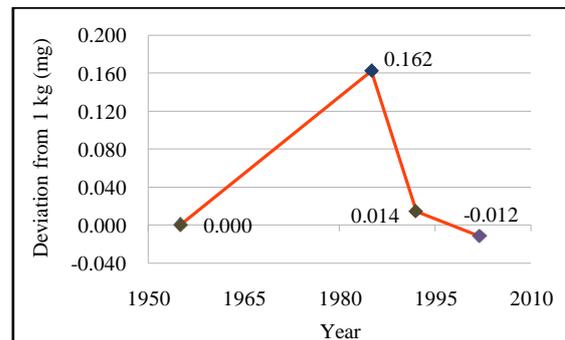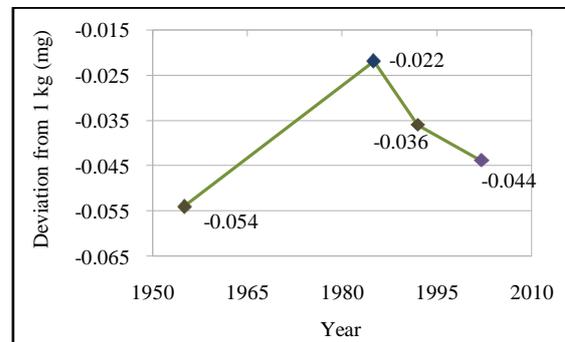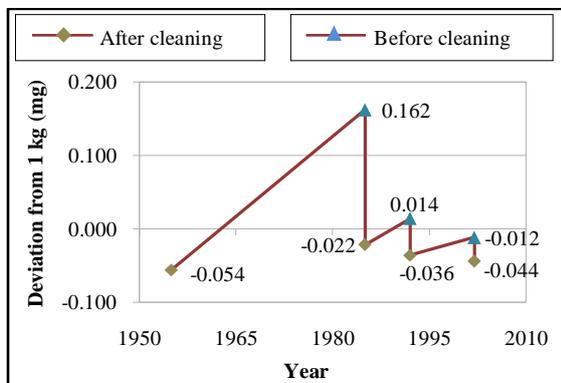

Fig.2. Mass values before cleaning

Fig. 2. Change of mass values before and after cleaning and washing at BIPM
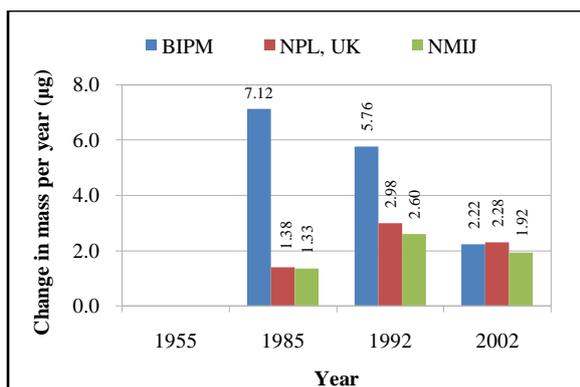

Fig. 3. Mass values after cleaning

Fig.4. Stability of the NPK No. 57

5. CONCLUSION

From Fig.1 & Fig.4, we may conclude that change rate of mass values of NPK No. 57 is reducing over the year. However, after getting data in 2012, it will be very much clear.

6. ACKNOWLEDGEMENT

7. REFERENCES

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