Bilateral Mass Comparison between INMS/NRC (Canada) and LACOMET (Costa Rica), SIM.7.36

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Background

- Project: Canada Costa Rica - 2004
  - **Improved Metrology Infrastructure for Costa Rica**
    - As a part of a Free Trade Agreement between Costa Rica and Canada
    - A way to optimize conditions for a better trade

- Main objective
  - Increase the metrological capacity of the “Laboratorio Costarricense de Metrología” (LACOMET) for:
    - Maintain and disseminate the SI units
    - Provide technical support for Costa Rican Accreditation Entity (ECA) and reinforcing national accreditation program for secondary laboratories
    - To diminish technical barriers for trade and competitiveness

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Background

- Main activities of the project were covered by INMS/NRC from Canada and LACOMET from Costa Rica:
  - Training
  - Traceability
  - Implementation of knowledge
  - Verification of implementation

- Internship training at INMS/NRC 2005
  - Mass expert from LACOMET
- Implementation
  - Study of calibration methods undeveloped in the country
    - Subdivision methods - Orthogonal Design
    - Traceability of the Costa Rican national standards toward to the national reference unit mass, the kilogram

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Background

- Activities to verify the implementation of the project outputs:
  - Visits to LACOMET
    - Technical advisors for mass measurements
    - Peer evaluators for Mass CMCs submission to BIPM
  - Bilateral comparison process between the INMS/NRC and LACOMET
- Process of bilateral comparison for mass measurements between INMS / NRC and LACOMET 2005 – 2006
  - Based on Subdivision Method – Orthogonal Design (200 g – 2 mg)
  - Direct comparison method – RTTR (1 kg)

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Weights used for the comparison

Nominal Value (g)	Id	Density (kg/m^3)	u (Density) (kg/m^3)
1000	CLASkg	7 902	75
200	200CLAS	7 678	138
20	20D4	7 850	20
2	2D4	7 850	20
0,2	0,2D4	7 850	20

- Magnetic properties measured by the INMS / NRC
- Reported in accordance with the requirements of OIML R111-1 2004 to E1 weights

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Dates for Measurements

Nominal Value (g)	Id	NRC/INMS 2005	LACOMET 2006	NRC/INMS 2006
1000	CLASkg	2005-11-03	2006-03-14	2006-05-23
200	200CLAS	2005-11-11	2006-03-14	2006-05-24
20	20D4	2005-11-07	2006-03-14	2006-06-02
2	2D4	2005-11-07	2006-03-14	2006-06-02
0,2	0,2D4	2005-11-04	2006-03-14	2006-06-05

- Measurements to check the stability of the weights was made by NRC in 2006-05
  - Results were satisfactory

Methodology for the measurements

- Comparison process
  - Weights (200 g to 200 mg)
  - Subdivision method for an orthogonal array (orthogonal design)[1] [2]

- The equation that represents the process is:

$$X \cdot C = Y \qquad (1)$$

Where:

X distribution matrix of the combinations

C vector of unknowns

Y vector of differences

[1] Recommendation R 111-1:2004. OIML, page 63, Annex C, sec. C.3.2, Table C.2

[2] Chapman, G. D., *Orthogonal Designs for Calibrating Kilogram Submultiples, NRCC 25819, 2004*.

Methodology of the measurements

- The solution to this system is achieved with the implementation of least squares

- The solution of the equation (1) is given by:

$$[[X^T \cdot X]^{-1} \cdot X^T] \cdot \{Y\} = C \qquad (2)$$

Where:

X^T transpose of X matrix

$[X^T \cdot X]^{-1}$ inverse of the product of the matrix X^T by the matrix X

$\{Y\}$ vector of differences minus the correction of the standard, with buoyancy correction

$[[X^T \cdot X]^{-1} \cdot X^T]$ least squares estimator

$X^T \cdot X$ is diagonal, this is why it is an "orthogonal" design

Methodology of the measurements

- Results of the comparison process for 1 kg weight was obtained using a direct comparison method (RTTR), with the use of a sensitivity weight "m_{sw}" [3]

$$\Delta m = \left(\frac{T - R + (R + m_{sw}) - (T + m_{sw})}{2} \right) \left(\frac{m_{sw}}{((T + m_{sw}) - T)} \right) \qquad (3)$$

[3] Recommendation R 111-1:2004. OIML, page 63, Annex C, section C.4.1

- Sensitivity weight (m_{sw})
  - Compensates the effect of balance drift

Reference Value (RV)

- The reference values (RV) were calculated as weighted means between NRC/INMS y LACOMET, given by:

$$RV = \frac{\frac{M_{NRC}}{u^2_{NRC}} + \frac{M_{LACOMET}}{u^2_{LACOMET}}}{\frac{1}{u^2_{NRC}} + \frac{1}{u^2_{LACOMET}}} \qquad (4)$$

$$u^2_{RV} = \frac{1}{\frac{1}{u^2_{NRC}} + \frac{1}{u^2_{LACOMET}}} \qquad (5)$$

$$weight = \frac{1}{u_i^2}$$

Reference Value (RV)

- Expanded Uncertainty (U_{RV}) of the reference values (RV):

$$U_{RV} = 2u_{RV} \tag{6}$$

- NRC/INMS values
  - Simple means from the two sets of measurements

$$M_{NRC} = \frac{M_{NRC-2005} + M_{NRC-2006}}{2} \tag{7}$$

  - Uncertainties
    - Means of the respective uncertainties

$$u_{NRC} = \frac{u_{NRC-2005} + u_{NRC-2006}}{2} \tag{8}$$

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Results (NRC/INMS)

Nominal Value (g)	Id	NRC 2005		NRC 2006	
		Correction (mg)	Uncertainty u (mg), k=1	Correction (mg)	Uncertainty u (mg), k=1
1000	CLASkg	2,071	0,025	2,073	0,031
200	200CLAS	0,112	0,010	0,102	0,012
20	20D4	0,002 4	0,003 4	0,003 9	0,003 4
2	2D4	0,027 2	0,002 5	0,028 2	0,002 5
0,2	0,2D4	-0,001 01	0,000 65	-0,001 56	0,000 65

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Results (LACOMET)

Nominal Value (g)	Id	NRC means		LACOMET 2006	
		Correction (mg)	Uncertainty u (mg), k=1	Correction (mg)	Uncertainty u (mg), k=1
1000	CLASkg	2,072	0,028	2,20	0,20
200	200CLAS	0,107	0,012	0,02	0,16
20	20D4	0,003 2	0,003 4	-0,001	0,010
2	2D4	0,027 7	0,002 5	0,030 3	0,008 6
0,2	0,2D4	-0,001 28	0,000 65	0,000 42	0,000 94

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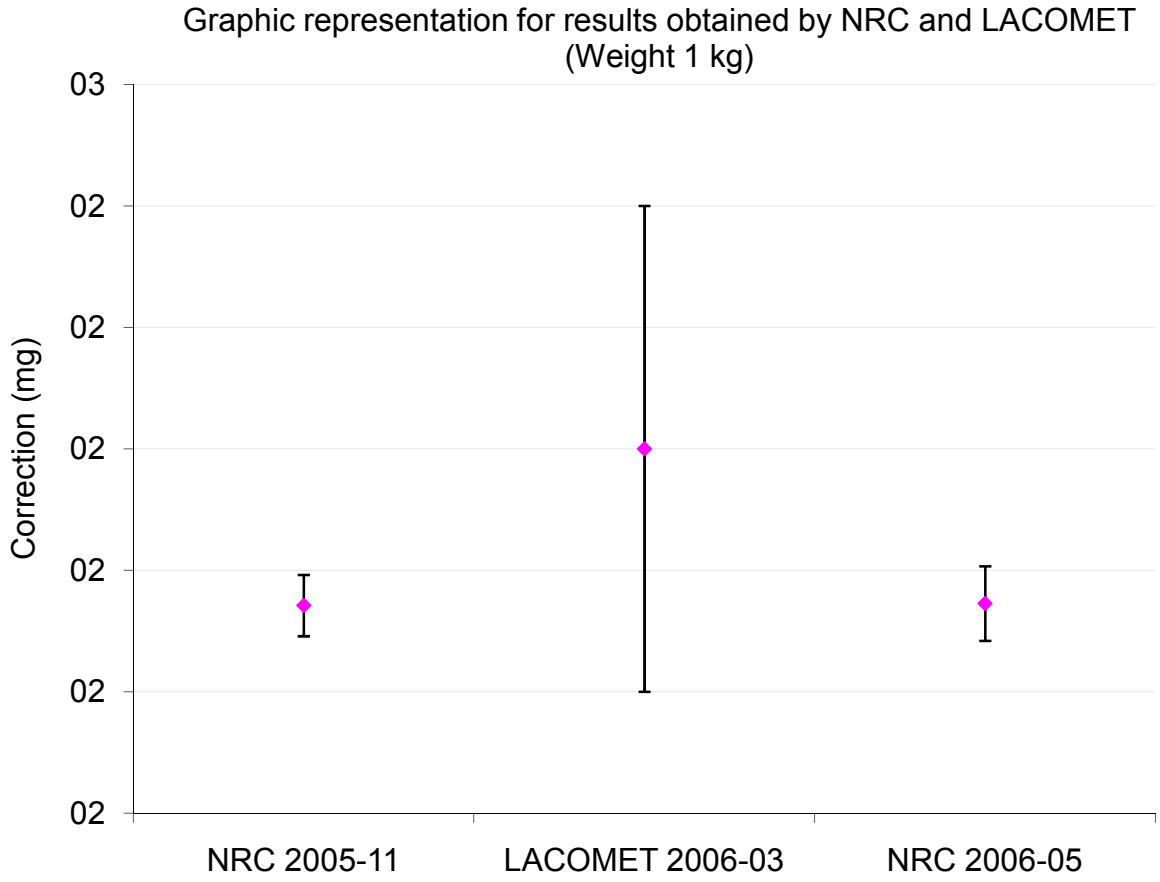
Reference Value (RV)

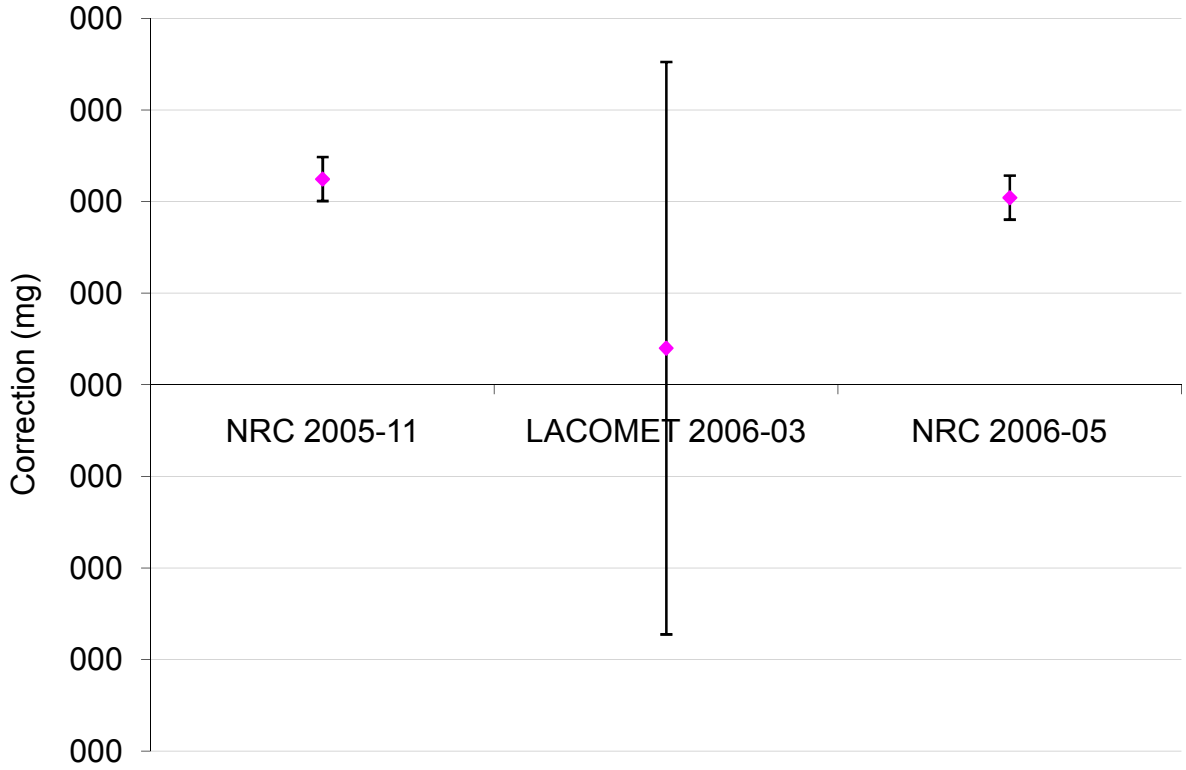
Nominal Value (g)	Id	Value Reference (RV) (mg)	Uncertainty U (mg), k=2
1000	CLASkg	2,074	0,055
200	200CLAS	0,107	0,024
20	20D4	0,002 7	0,006 4
2	2D4	0,027 9	0,004 8
0,2	0,2D4	-0,000 7	0,001 1

Bilateral Mass Comparison between INMS/NRC (Canada) and LACOMET (Costa Rica), SIM.7.36



Bilateral Mass Comparison between INMS/NRC (Canada) and LACOMET (Costa Rica), SIM.7.36

Graphic representation for results obtained by NRC and LACOMET
(Weight 200 g)



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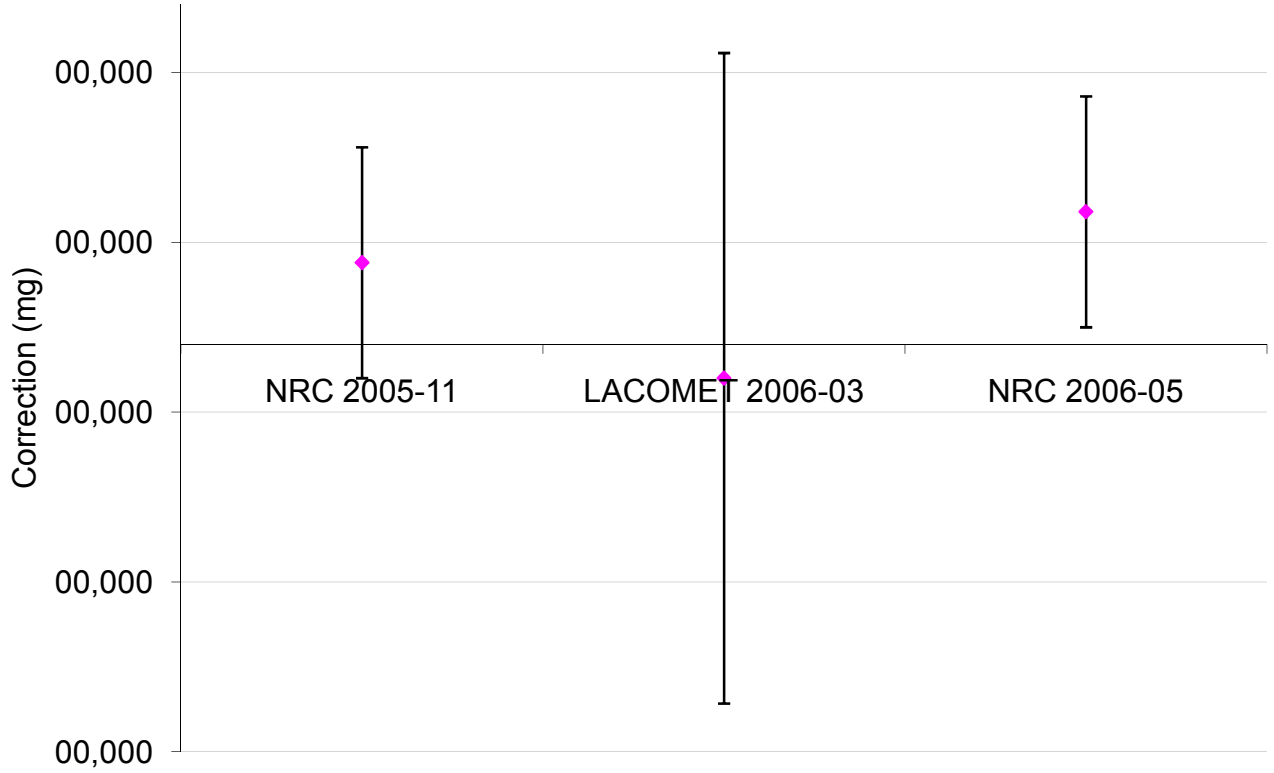
Graphic representation for results obtained by NRC and LACOMET
(Weight 20 g)



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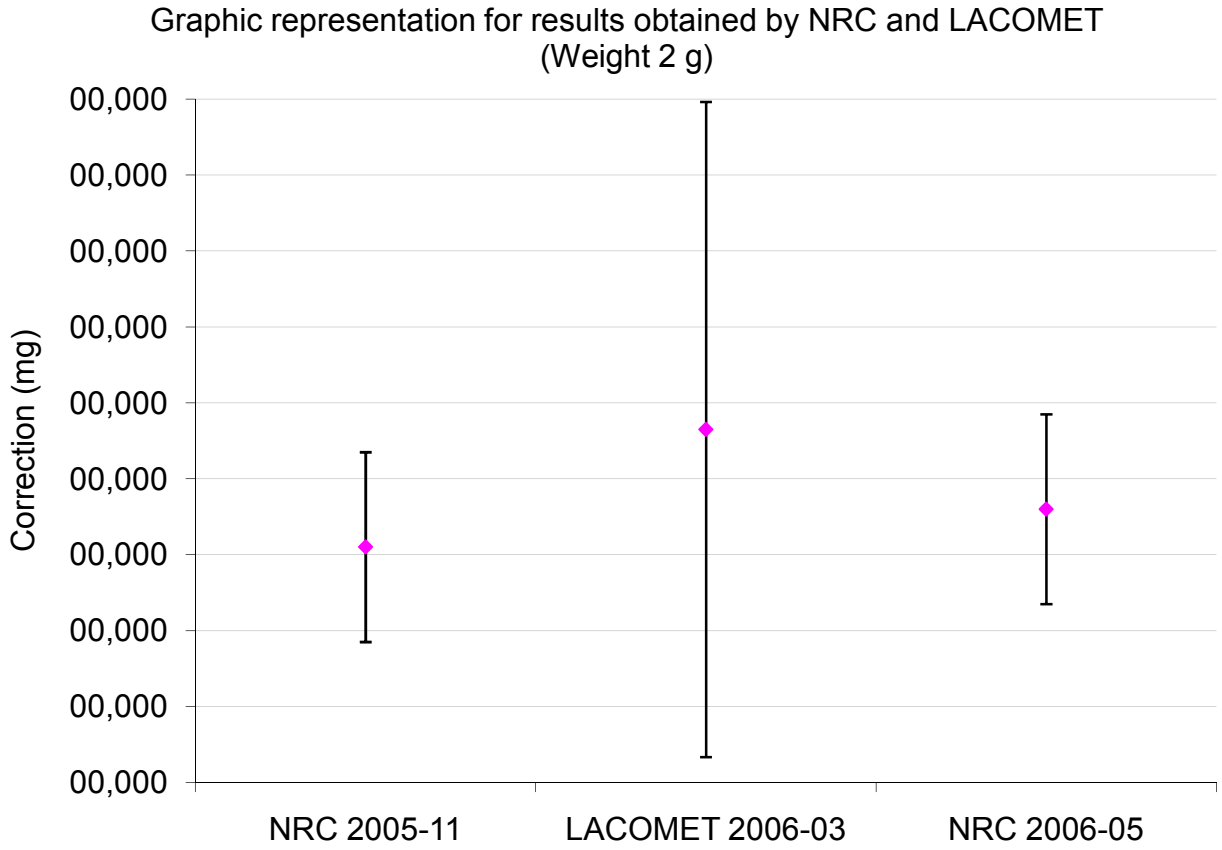

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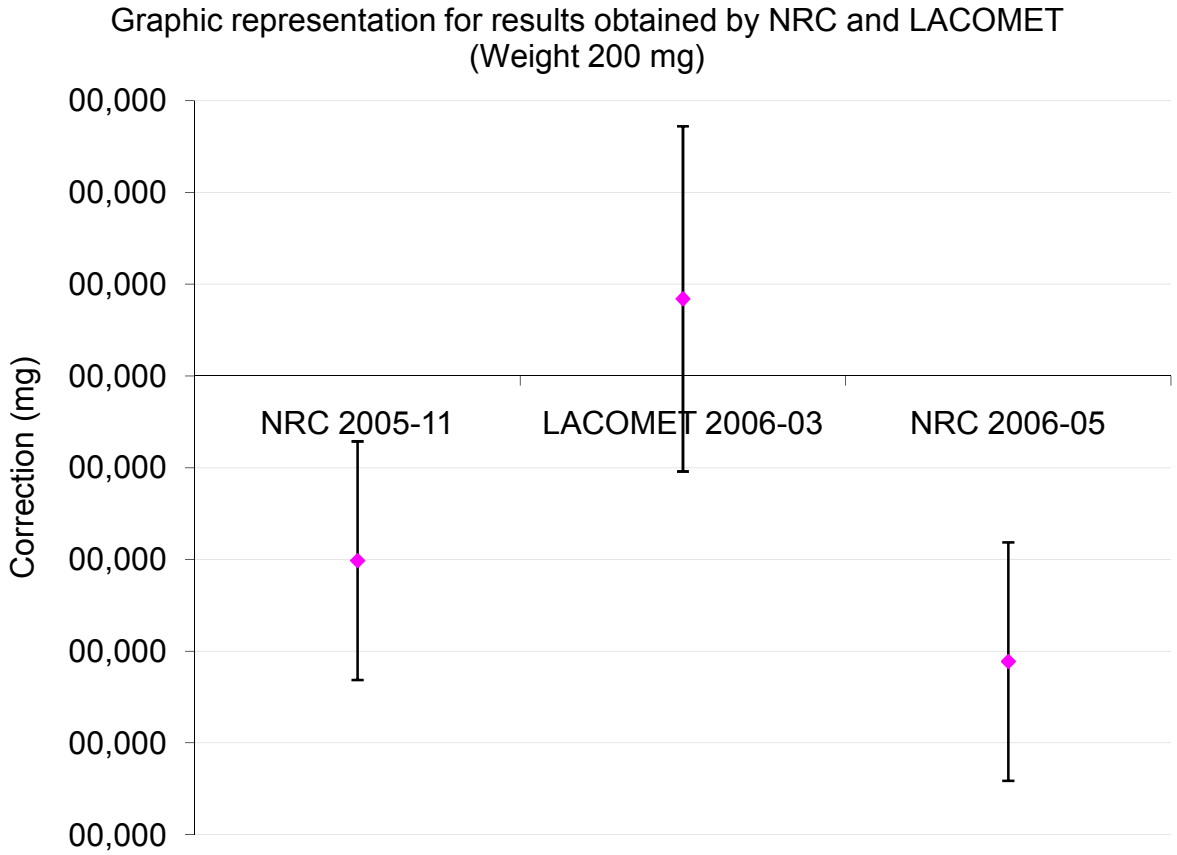

Degrees of Equivalence (DoE)

- The degrees of equivalence were expressed with two components:
  - The difference between the reported corrections of both laboratories against the Reference Value (RV)

$$DoE = M_{NRC} - RV \tag{9}$$

$$DoE = M_{LACOMET} - RV \tag{10}$$

  - The Expanded Uncertainty of this differences for each participant

$$u^2_{DoE}\{M_{NRC} - RV\} = u^2_{NRC} - u^2_{RV} \tag{11}$$

$$u^2_{DoE}\{M_{LACOMET} - RV\} = u^2_{LACOMET} - u^2_{RV} \tag{12}$$

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Degrees of Equivalence (DoE)

Nominal Value (g)	Id	NRC - RV		LACOMET - RV		LACOMET - NRC	
		DoE (mg)	Uncert. U (mg), k=2	DoE (mg)	Uncert. U (mg), k=2	DoE (mg)	Uncert. U (mg), k=2
1000	CLASkg	-0,002 5	0,007 8	0,13	0,40	0,13	0,40
200	200CLAS	0,000 5	0,001 8	-0,09	0,31	-0,09	0,31
20	20D4	0,000 5	0,002 3	-0,004	0,018	-0,004	0,020
2	2D4	-0,000 2	0,001 4	0,002	0,017	0,003	0,016
0,2	0,2D4	-0,000 55	0,000 74	0,001 2	0,001 5	0,001 7	0,002 3

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Results (Correction)

Nominal Value (g)	Id	NRC means		LACOMET 2006	
		Correction (mg)	Uncertainty u (mg), k=1	Correction (mg)	Uncertainty u (mg), k=1
1000	CLASkg	2,072	0,028	2,20	0,20
200	200CLAS	0,107	0,012	0,02	0,16
20	20D4	0,003 2	0,003 4	-0,001	0,010
2	2D4	0,027 7	0,002 5	0,030 3	0,008 6
0,2	0,2D4	-0,001 28	0,000 65	-0,000 42	0,000 94

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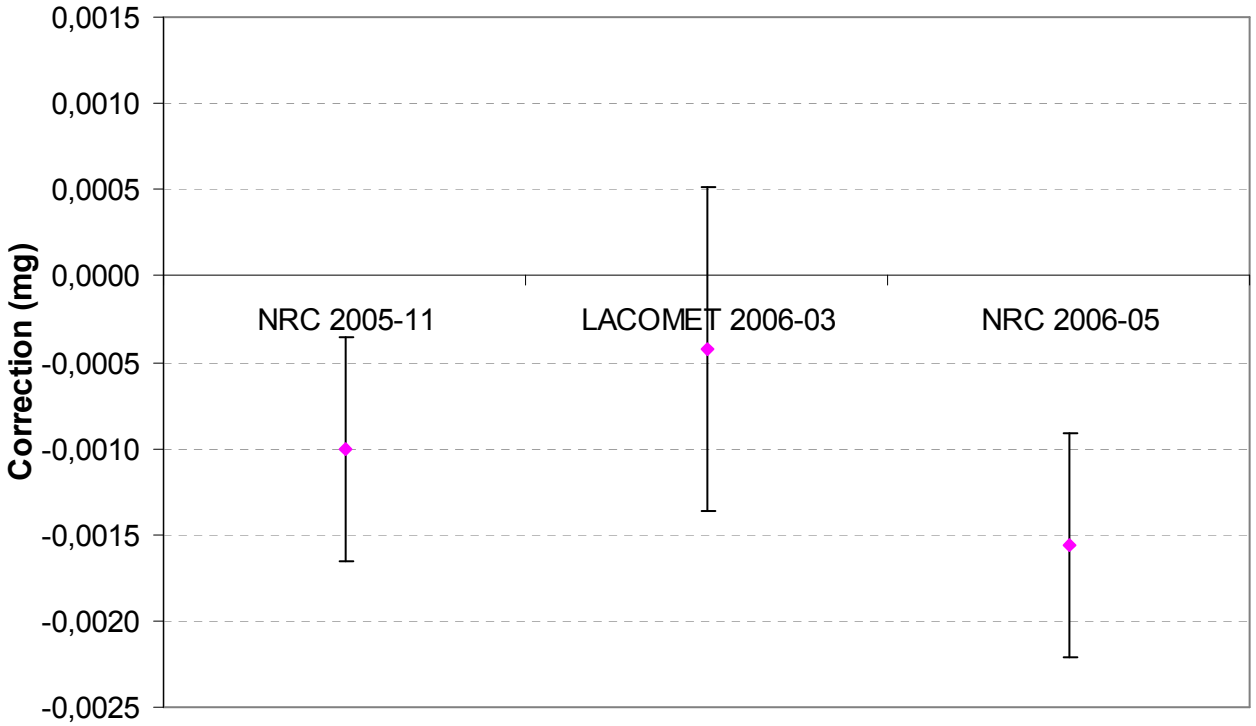
Graphic representation for results obtain by NRC and LACOMET (Weight 200 mg)



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Normalize Error

Nominal Value (g)	Id	NRC means		LACOMET 2006		
		Correction (mg)	**Uncertainty u (mg), k=1**	**Correction (mg)**	**Uncertainty u (mg), k=1**	**Normalize Error**
1000	CLASkg	2,072	0,028	2,20	0,20	**0,63**
200	200CLAS	0,107	0,012	0,02	0,16	**0,54**
20	20D4	0,003 2	0,003 4	-0,001	0,010	**0,40**
2	2D4	0,027 7	0,002 5	0,030 3	0,008 6	**0,29**
0,2	0,2D4	-0,001 28	0,000 65	-0,000 42	0,000 94	**0,75**

$$NE = \frac{\left| M_{NRC} - M_{LACOMET} \right|}{\sqrt{u^2_{NRC} - u^2_{LACOMET}}} \qquad (13)$$

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Degrees of Equivalence (DoE)

Nominal Value (g)	Id	NRC - RV		LACOMET - RV		LACOMET - NRC	
		DoE (mg)	Uncert. U (mg) k=2	DoE (mg)	Uncert. U (mg) k=2	DoE (mg)	Uncert. U (mg) k=2
1000	CLASkg	-0,002 5	0,007 8	0,13	0,40	0,13	0,40
200	200CLAS	0,000 5	0,001 8	-0,09	0,31	-0,09	0,31
20	20D4	0,000 5	0,002 2	-0,004	0,019	-0,004	0,020
2	2D4	-0,000 2	0,001 4	0,002	0,017	0,003	0,016
0,2	0,2D4	-0,000 55	0,000 74	0,000 6	0,001 5	0,000 86	0,002 3

Conclusion

- Absolute values of the Degrees of Equivalence (DoE) are smaller than their respective expanded uncertainties
- Comparison results were successful for each weight and each laboratory
- The LACOMET calibration methods was validated with this comparison
- Part of LACOMET Mass CMCs will be supported with those results
- The implementation process of the project "**Improved Metrology Infrastructure for Costa Rica**" conclude and was successful

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