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EURAMET Project n°1161

**Intercomparison on water/heat meter
calibration at 50°C, 6 - 25 L/h**

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1. Scope

This comparison is similar to the comparison E877 organized by SP from 2006 to 2009. As the meter used for that comparison were still existing and available, LNE-CETIAT, CMI and SP decided to start a similar comparison because LNE-CETIAT and CMI were not involved in the first project.

2. Participating laboratories

This inter-comparison started in 2010 under the Euramet project number 1161 with 3 participating laboratories (LNE-CETIAT, CMI and SP). LNE-CETIAT was selected to be the pilot laboratory. The application form for this comparison is shown in appendix 1.

As the meters were the property of SP, intermediate measurements to analyze possible drift of the meter were done by SP in Sweden. The final schedule of the project is shown in the following table:

Laboratory	Country	Date of calibration
SP	Sweden	25/10/2010
CMI	Czech Republic	19/01/2011
SP	Sweden	13/02/2011
LNE-CETIAT*	France	08/09/2011
SP	Sweden	21/09/2011

*Pilot laboratory

3. Used material and protocol

3.1. Used material

Two meter (see following figures) borrowed from SP were used for the comparison: one Coriolis meter and one mag meter. The identical meter were used for the comparison E887 (see report on the Euramet webpage). The package included heat insulation and thermostatic heat exchanger around the meter as for the previous comparison.

The two meters used in this inter-comparison were never zero-adjusted.



Fig. 1 Danfoss Mass 2100 - Coriolis mass flow meter; Pipe size Ø 1,5 mm

Fig. 2 Endress and Hauser - Magnetic induction volume flow meter; Pipe size Ø 2 mm

3.2. Measurement protocol

No specific procedure was given for connecting and realizing the calibration of the meters.

The only important points were the following:

- Calibration might be performed at each laboratory with its usual procedure,
- The calibrations should be performed as close as possible to the following flow values: 6, 12, 25 l/h and with water at a temperature as close as possible to 50°C,
- A minimum of two repeated runs might be performed at each flow rate,
- Three pulse signals were to be calibrated (the volume flow signal from the mag meter and both mass and volume flow signals from the Coriolis meter),
- The results might contain at least the obtained mean values for: temperature, pressure, flow rate, result of the measurement (error on the pulse outputs) and associated expanded uncertainties.

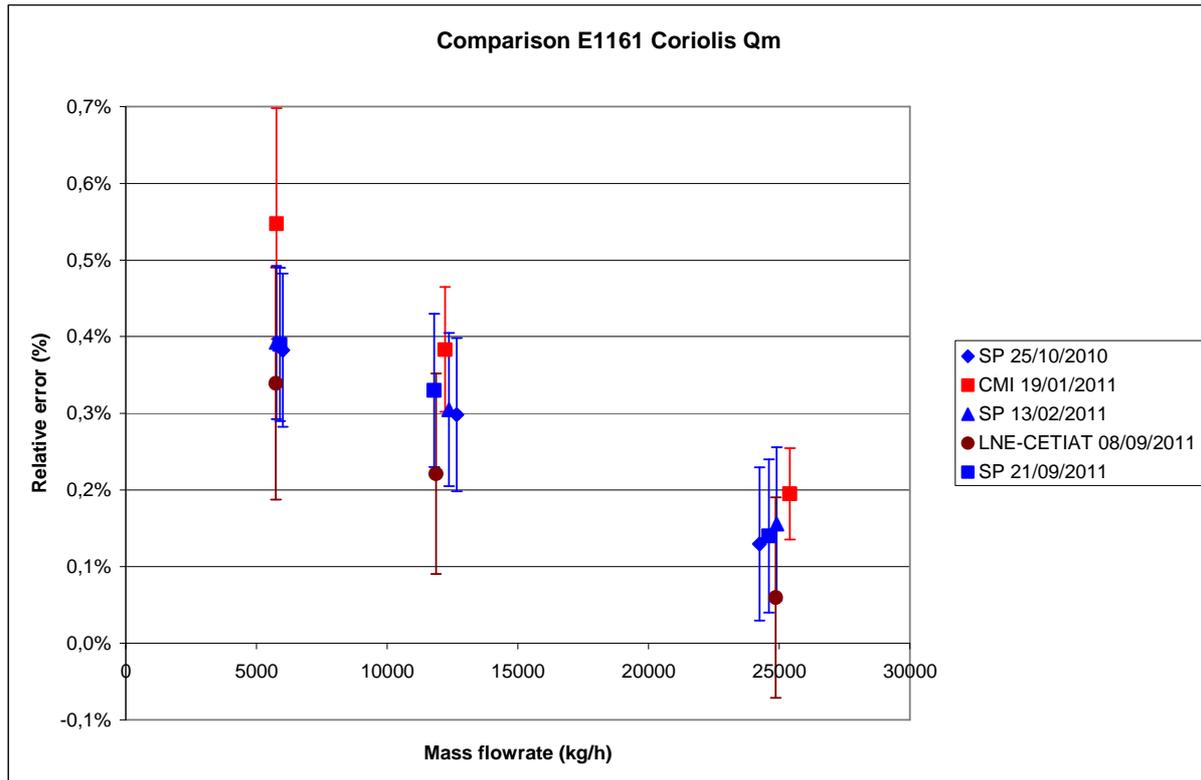
4. Analysis

4.1. Raw data

The following tables and figures summarize the results obtained by each laboratory during the comparison.

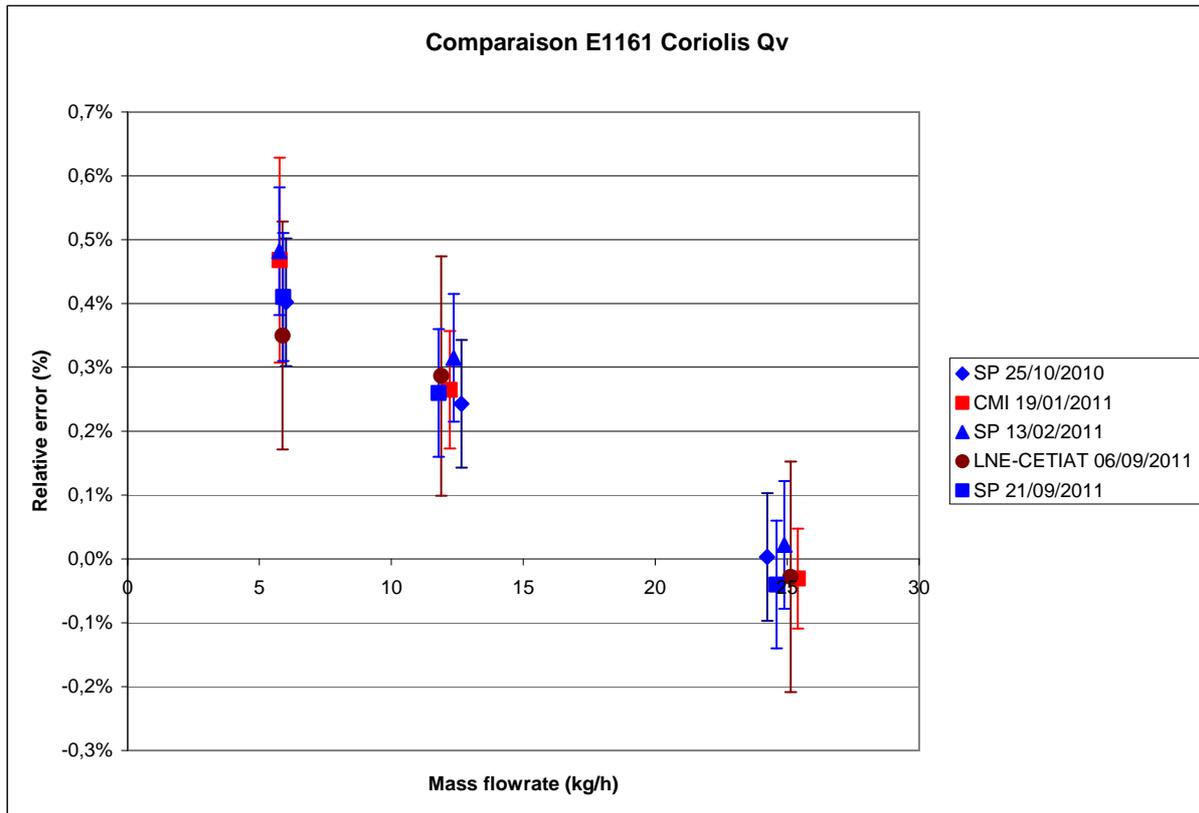
4.1.1. Coriolis mass flow signal at 50°C

SP	25/10/2010					
Mean liquid temperature (°C)	Mean liquid pressure (bar)	Mean reference flow rate (l.h ⁻¹)	Theoretical pulse mass (kg)	Mean measured pulse mass (kg)	Mean relative error	Relative expended uncertainty (±)
48,2	3,12	24240	0,0010	0,0009987	1,3E-03	1,0E-03
48,9	2,94	12660	0,0010	0,0009970	3,0E-03	1,0E-03
48,8	2,94	6000	0,0010	0,0009962	3,8E-03	1,0E-03
CMI	19/01/2011					
Mean liquid temperature (°C)	Mean liquid pressure (bar)	Mean reference flow rate (l.h ⁻¹)	Theoretical pulse mass (kg)	Mean measured pulse mass (kg)	Mean relative error	Relative expended uncertainty (±)
51,7	2,86	5768	0,0010	0,0009945	5,5E-03	1,5E-03
51,9	2,87	12209	0,0010	0,0009962	3,8E-03	8,2E-04
51,5	2,89	25407	0,0010	0,0009981	1,9E-03	6,0E-04
SP	13/02/2011					
Mean liquid temperature (°C)	Mean liquid pressure (bar)	Mean reference flow rate (l.h ⁻¹)	Theoretical pulse mass (kg)	Mean measured pulse mass (kg)	Mean relative error	Relative expended uncertainty (±)
50,9	3,12	24900	0,0010	0,0009984	1,6E-03	1,0E-03
49,8	2,89	12360	0,0010	0,0009970	3,0E-03	1,0E-03
49,7	2,56	5760	0,0010	0,0009961	3,9E-03	1,0E-03
LNE-CETIAT	08/09/2011					
Mean liquid temperature (°C)	Mean liquid pressure (bar)	Mean reference flow rate (l.h ⁻¹)	Theoretical pulse mass (kg)	Mean measured pulse mass (kg)	Mean relative error	Relative expended uncertainty (±)
50,2	0,95	5740	0,0010	0,0009966	3,4E-03	1,5E-03
50,2	0,95	11870	0,0010	0,0009978	2,2E-03	1,3E-03
50,5	1,59	24866	0,0010	0,0009994	6,0E-04	1,3E-03
SP	21/09/2011					
Mean liquid temperature (°C)	Mean liquid pressure (bar)	Mean reference flow rate (l.h ⁻¹)	Theoretical pulse mass (kg)	Mean measured pulse mass (kg)	Mean relative error	Relative expended uncertainty (±)
45,7	2,30	5900	0,0010	0,0009961	3,9E-03	1,0E-03
45,4	2,97	11800	0,0010	0,0009967	3,3E-03	1,0E-03
45,3	3,15	24600	0,0010	0,0009986	1,4E-03	1,0E-03



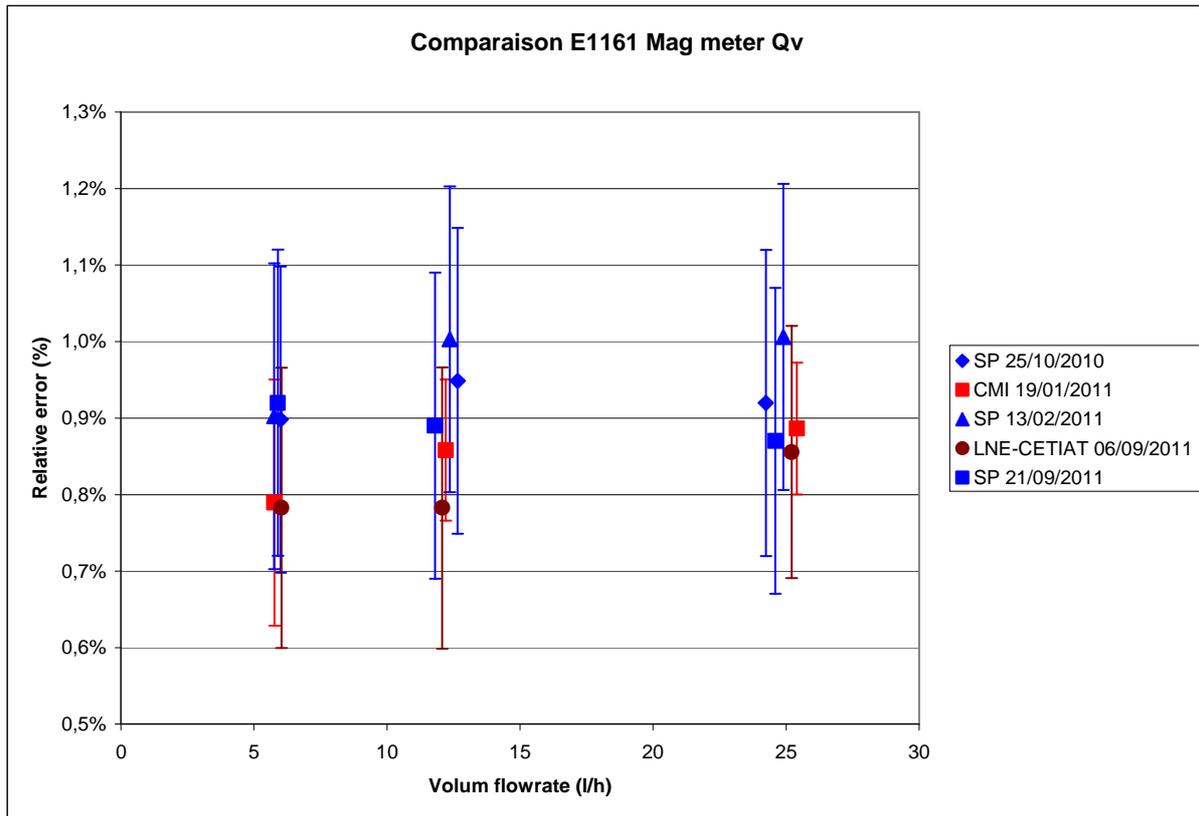
4.1.2. Coriolis volume flow signal at 50°C

SP	25/10/2010					
Mean liquid temperature (°C)	Mean liquid pressure (bar)	Mean reference flow rate (l.h ⁻¹)	Theoretical pulse volum (l)	Mean measured pulse volum (l)	Mean relative error	Relative expended uncertainty (±)
48,2	3,12	24,240	0,0010	0,0010000	3,0E-05	1,0E-03
48,9	2,94	12,660	0,0010	0,0009976	2,4E-03	1,0E-03
48,8	2,94	6,000	0,0010	0,0009960	4,0E-03	1,0E-03
CMI	19/01/2011					
Mean liquid temperature (°C)	Mean liquid pressure (bar)	Mean reference flow rate (l.h ⁻¹)	Theoretical pulse volum (l)	Mean measured pulse volum (l)	Mean relative error	Relative expended uncertainty (±)
51,7	2,86	5,768	0,0010	0,0009953	4,7E-03	1,6E-03
51,9	2,87	12,209	0,0010	0,0009974	2,6E-03	9,2E-04
51,5	2,89	25,407	0,0010	0,0010003	-3,1E-04	7,8E-04
SP	13/02/2011					
Mean liquid temperature (°C)	Mean liquid pressure (bar)	Mean reference flow rate (l.h ⁻¹)	Theoretical pulse volum (l)	Mean measured pulse volum (l)	Mean relative error	Relative expended uncertainty (±)
50,9	3,12	24,900	0,0010	0,0009998	2,2E-04	1,0E-03
49,8	2,89	12,360	0,0010	0,0009969	3,1E-03	1,0E-03
49,7	2,56	5,760	0,0010	0,0009952	4,8E-03	1,0E-03
LNE-CETIAT	06/09/2011					
Mean liquid temperature (°C)	Mean liquid pressure (bar)	Mean reference flow rate (l.h ⁻¹)	Theoretical pulse volum (l)	Mean measured pulse volum (l)	Mean relative error	Relative expended uncertainty (±)
50,1	0,94	5,884	0,0010	0,0009965	3,5E-03	1,8E-03
49,8	0,95	11,890	0,0010	0,0009971	2,9E-03	1,9E-03
50,5	1,59	25,131	0,0010	0,0010003	-2,8E-04	1,8E-03
SP	21/09/2011					
Mean liquid temperature (°C)	Mean liquid pressure (bar)	Mean reference flow rate (l.h ⁻¹)	Theoretical pulse mass (kg)	Mean measured pulse mass (kg)	Mean relative error	Relative expended uncertainty (±)
45,7	2,30	5,900	0,0010	0,0009959	4,1E-03	1,0E-03
45,4	2,97	11,800	0,0010	0,0009974	2,6E-03	1,0E-03
45,3	3,15	24,600	0,0010	0,0010004	-4,0E-04	1,0E-03



4.1.3. Mag meter volume flow signal at 50°C

SP	25/10/2010					
Mean liquid temperature (°C)	Mean liquid pressure (bar)	Mean reference flow rate (l.h ⁻¹)	Theoretical pulse volum (l)	Mean measured pulse volum (l)	Mean relative error	Relative expended uncertainty (±)
48,2	3,12	24,240	0,0010	0,0009908	9,2E-03	2,0E-03
48,9	2,94	12,660	0,0010	0,0009905	9,5E-03	2,0E-03
48,8	2,94	6,000	0,0010	0,0009910	9,0E-03	2,0E-03
CMI	19/01/2011					
Mean liquid temperature (°C)	Mean liquid pressure (bar)	Mean reference flow rate (l.h ⁻¹)	Theoretical pulse volum (l)	Mean measured pulse volum (l)	Mean relative error	Relative expended uncertainty (±)
51,7	2,86	5,768	0,0010	0,0009921	7,9E-03	1,6E-03
51,9	2,87	12,209	0,0010	0,0009914	8,6E-03	9,2E-04
51,5	2,89	25,407	0,0010	0,0009911	8,9E-03	8,6E-04
SP	13/02/2011					
Mean liquid temperature (°C)	Mean liquid pressure (bar)	Mean reference flow rate (l.h ⁻¹)	Theoretical pulse volum (l)	Mean measured pulse volum (l)	Mean relative error	Relative expended uncertainty (±)
50,9	3,12	24,900	0,0010	0,0009899	1,0E-02	2,0E-03
49,8	2,89	12,360	0,0010	0,0009900	1,0E-02	2,0E-03
49,7	2,56	5,760	0,0010	0,0009910	9,0E-03	2,0E-03
LNE-CETIAT	06/09/2011					
Mean liquid temperature (°C)	Mean liquid pressure (bar)	Mean reference flow rate (l.h ⁻¹)	Theoretical pulse volum (l)	Mean measured pulse volum (l)	Mean relative error	Relative expended uncertainty (±)
50,2	0,95	6,029	0,0010	0,0009922	7,8E-03	1,8E-03
50,2	0,95	12,079	0,0010	0,0009922	7,8E-03	1,8E-03
49,3	1,60	25,211	0,0010	0,0009915	8,6E-03	1,6E-03
SP	21/09/2011					
Mean liquid temperature (°C)	Mean liquid pressure (bar)	Mean reference flow rate (l.h ⁻¹)	Theoretical pulse mass (kg)	Mean measured pulse mass (kg)	Mean relative error	Relative expended uncertainty (±)
45,7	2,30	5,900	0,0010	0,0009908	9,2E-03	2,0E-03
45,4	2,97	11,800	0,0010	0,0009911	8,9E-03	2,0E-03
45,3	3,15	24,600	0,0010	0,0009913	8,7E-03	2,0E-03



4.2. Evaluation

To analyze these data, two reference values were calculated (weighted mean and arithmetic mean) and compare to the reference value (weighted mean) obtained during the project E887.

4.2.1. Determination of the reference values

4.2.1.1. Determination of the Comparison Reference Value (CRV) and its associated uncertainty

The weighted mean value of the results was chosen as the Comparison Reference Value (CRV). This CRV and its associated uncertainty were calculated according to Cox *et al.* publication (The evaluation of key comparison data, M G Cox, 2002, Metrologia 39 589).

The reference value y is then calculated as a weighted mean error:

$$y = \frac{\frac{x_1}{u_{x1}^2} + \frac{x_2}{u_{x2}^2} + \dots + \frac{x_n}{u_{xn}^2}}{\frac{1}{u_{x1}^2} + \frac{1}{u_{x2}^2} + \dots + \frac{1}{u_{xn}^2}}$$

Where x_i is the measured quantity provided by the i -th laboratory and $u_{x1}, u_{x2}, \dots, u_{xn}$ are the standard uncertainties for the laboratories $1, \dots, n$ including the uncertainty caused by the stability of the meter.

In our analysis, x_i is equal to the mean error on the measured pulse output of the i -th laboratory. The values of i are $i = 1, \dots, n$, where n is the number of laboratories.

Each individual uncertainty is calculated as follow:

$$u(x_i) = \frac{U(x_i)}{2}$$

Where $U(x_i)$ is the expanded combined uncertainty ($k=2$) determined by the i -th laboratory.

The expanded uncertainty of the CRV is then calculated as follow:

$$U(y) = 2 \times u(y)$$

4.2.1.2. Determination of the arithmetic mean

For this comparison, only three laboratories were involved. Because of this small number of participating laboratories and for some results the CRV could have been too much influenced by one of the participants when its claimed uncertainty was really small.

In addition to the CRV, the arithmetic mean has also been calculated.

When the difference between both results is significant (higher than 5%), it mean that it is difficult to interpret and decide whether the CRV value or the arithmetic mean is the best adapted.

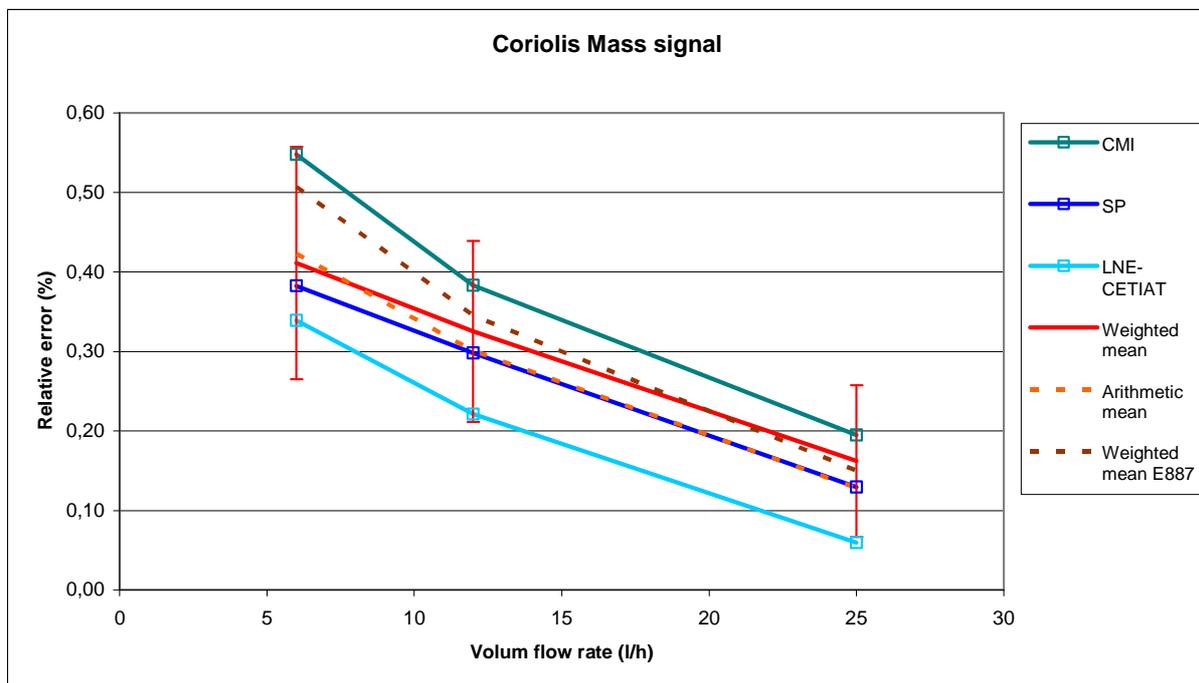
In addition, the CRV obtained during the comparison E887 is also recall as a

4.2.2. Results

The following tables and graphs summarize the references values obtained during the comparison. In addition, the results obtained during the comparison E887 are superimposed on the results of this comparison in appendix.

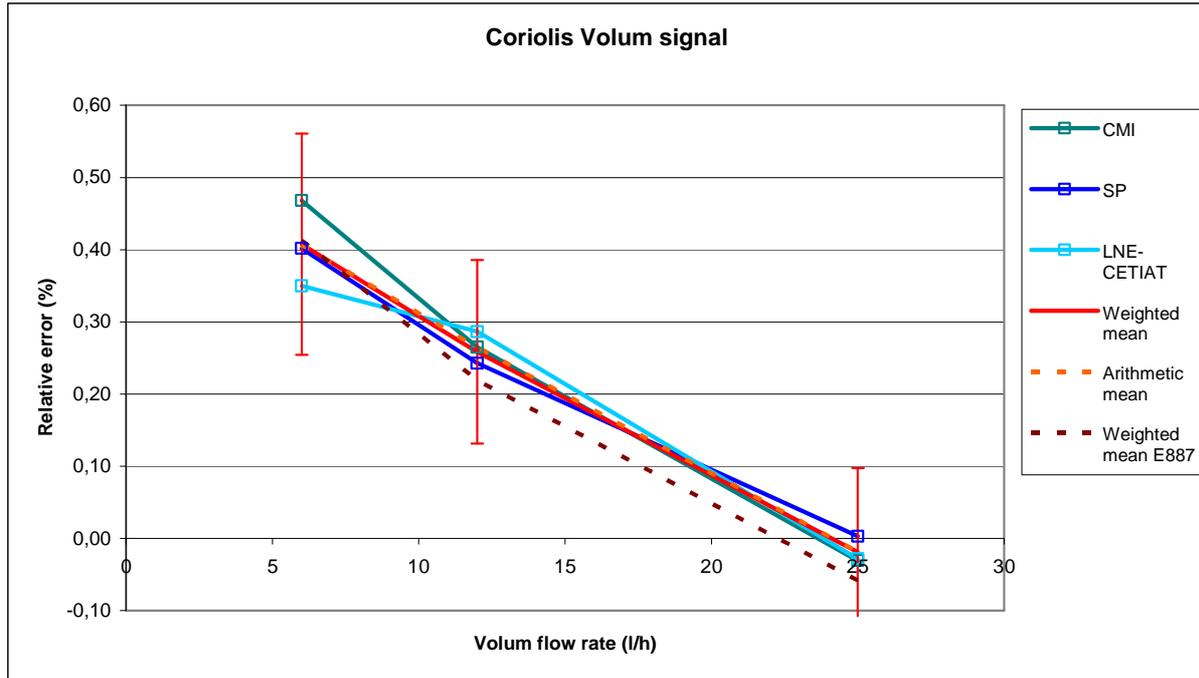
4.2.2.1. Results obtained on the mass flow signal of the Coriolis meter

Flow rate (l/h)	6		12		25	
Laboratory	E (6 l/h)	U(6 l/h)	E(12 l/h)	U(12 l/h)	E(25 l/h)	U(25 l/h)
	%	%	%	%	%	%
CMI	0,55	0,15	0,38	0,08	0,19	0,06
SP	0,38	0,10	0,30	0,10	0,13	0,10
LNE-CETIAT	0,34	0,15	0,22	0,13	0,06	0,13
Weighted mean	0,41	0,15	0,32	0,11	0,16	0,10
Arithmetic mean	0,42		0,30		0,13	
Weighted mean E887	0,51	0,08	0,35	0,06	0,15	0,06



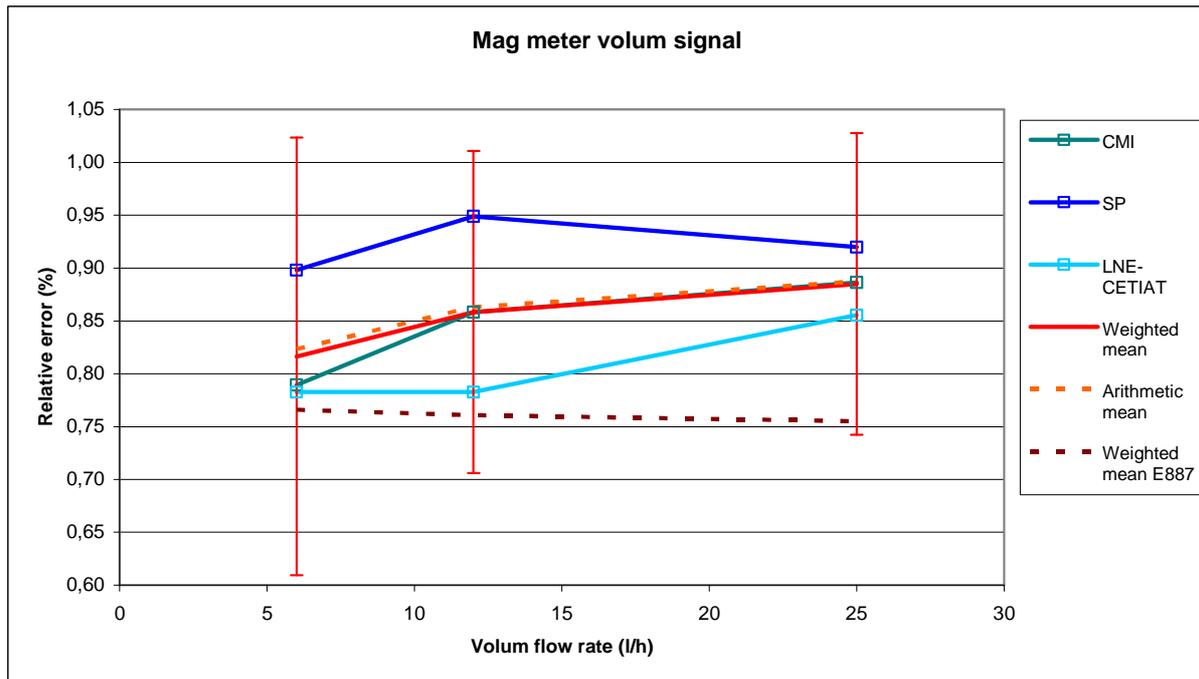
4.2.2.2. Results obtained on the volume flow signal of the Coriolis meter

Flow rate (l/h)	6		12		25	
Laboratory	E (6 l/h)	U(6 l/h)	E(12 l/h)	U(12 l/h)	E(25 l/h)	U(25 l/h)
	%	%	%	%	%	%
CMI	0,47	0,16	0,26	0,09	-0,03	0,08
SP	0,40	0,10	0,24	0,10	0,00	0,10
LNE-CETIAT	0,35	0,18	0,29	0,19	-0,03	0,18
Weighted mean	0,41	0,15	0,26	0,13	-0,02	0,12
Arithmetic mean	0,41		0,26		-0,02	
Weighted mean E887	0,41	0,09	0,22	0,07	-0,06	0,07



4.2.2.3. Results obtained on the volume flow signal of the magnetic meter

Flow rate (l/h)	6		12		25	
Laboratory	E (6 l/h)	U(6 l/h)	E(12 l/h)	U(12 l/h)	E(25 l/h)	U(25 l/h)
	%	%	%	%	%	%
CMI	0,79	0,16	0,86	0,09	0,89	0,09
SP	0,90	0,20	0,95	0,20	0,92	0,20
LNE-CETIAT	0,78	0,18	0,78	0,18	0,86	0,16
Weighted mean	0,82	0,21	0,86	0,15	0,88	0,14
Arithmetic mean	0,82		0,86		0,89	
Weighted mean E887	0,77	0,09	0,76	0,07	0,76	0,06



4.2.3. En values

In order to check the consistency of the results obtained, the degree of equivalence between each laboratory and the reference value is calculated as follow:

$$En(lab_i) = \left| \frac{x_i - y}{\sqrt{U^2(x_i) + U^2(y)}} \right|$$

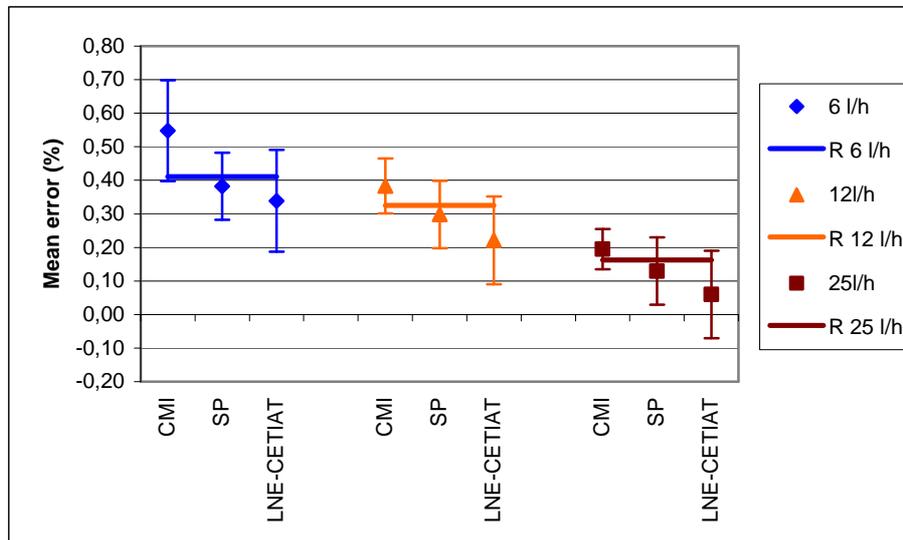
Where x_i correspond to the relative error obtained by the i -th laboratory; y is the CRV; $U(x_i)$ the uncertainty on the result x_i and $U(y)$ the uncertainty on y

When the values are smaller than 1, it means that all results are consistent.

4.2.3.1. En values obtained on the mass flow signal of the Coriolis meter

The following tables and graphs summarized the results obtained for the En values and show the dispersion of the results obtained around the CRV for the mass flow signal of the Coriolis meter.

Flow rate (l/h)	En Values		
	6	12	25
CMI	0,65	0,42	0,29
SP	0,16	0,18	0,23
LNE-CETIAT	0,34	0,60	0,63

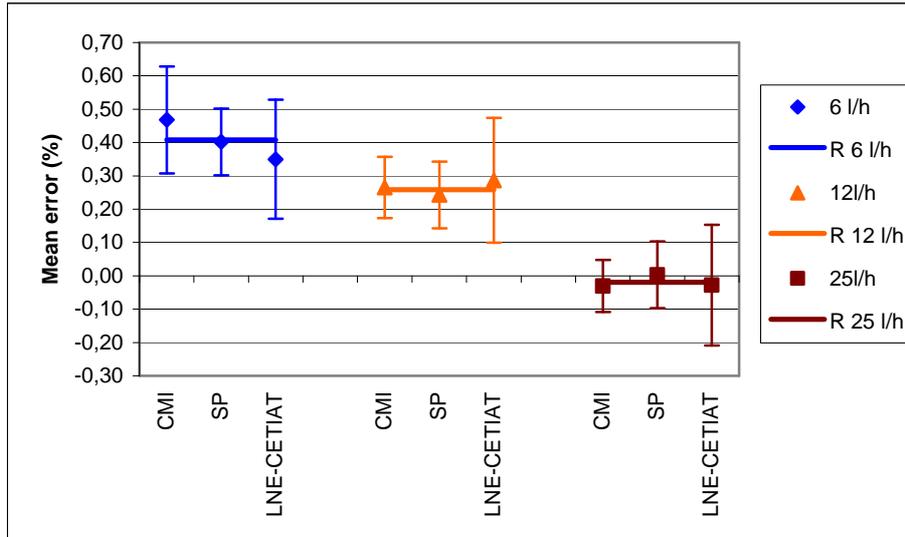


All results are consistent and give support to the claims uncertainties of the participating laboratories.

4.2.3.2. En values obtained on the volume flow signal of the Coriolis meter

The following tables and graphs summarized the results obtained for the En values and show the dispersion of the results obtained around the CRV for the volume flow signal of the Coriolis meter.

Flow rate (l/h)	En Values		
	6	12	25
CMI	0,27	0,04	0,08
SP	0,03	0,10	0,14
LNE-CETIAT	0,24	0,12	0,04

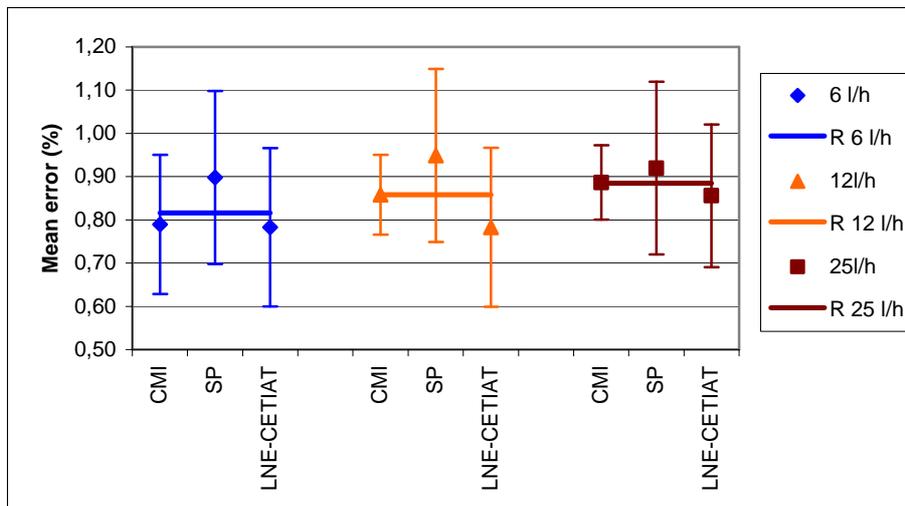


All results are consistent and give support to the claims uncertainties of the participating laboratories.

4.2.3.3. En values obtained on the volume flow signal of the magnetic meter

The following tables and graphs summarized the results obtained for the En values and show the dispersion of the results obtained around the CRV for the volume flow signal of the magnetic meter.

Flow rate (l/h)	En Values		
	6	12	25
CMI	0,10	0,00	0,01
SP	0,28	0,36	0,14
LNE-CETIAT	0,12	0,32	0,13



All results are consistent and give support to the claims uncertainties of the participating laboratories.

5. Conclusion

To conclude, the results obtained during this comparison confirm the comparability of the three laboratories involved. These results are also really consistent with results obtained during the previous comparison (E887).

APPENDIX 1 - Project proposal form

EURAMET Project Form "Proposal"



Status: proposed agreed

1. Ref. No.: <i>(please leave blank)</i>	2. Subject Field: Flow
3. Type of collaboration: Comparison of measurement standards	
3A. In the case of a comparison: Registered as Key comparison (KC) or Supplementary Comparison (SC) in the KCDB: <input checked="" type="checkbox"/> no <input type="checkbox"/> yes If yes: No. of KC/SC:	
4. Participating Partners: 4A EURAMET members or associates (Institute's standard acronym with country code in brackets) as registered on EURAMET website. LNE-CETIAT (FR); SP (SE); CMI(CZ)	
4B Institutes not being EURAMET members or associates (Institute's full name and name the of country in brackets)	
5. Title: Intercomparison on water/heat meter calibration at 50°C, 6 - 25 L/h	
6. Description: This comparison will be realize with two stable flow meters from SP, a coriolis mass flow meter and a magnetic inductive meter. The calibrations would be performed with water at 50 °C and at three flow rates (6, 12 and 25 L/h). This comparison will be realized on the same protocol as the comparison E877	
7. Additional remarks: (e.g. external funding available etc.)	
8. Proposer's name: Christopher DAVID Address: CETIAT, Domaine scientifique de la doua, 25 avenue des arts B.P. 52042, 69603 Villeurbanne Telephone: +33 (0)4 72 44 59 45 Fax: +33 (0)4 72 44 4946 E-mail: christopher.david@cetiat.fr	
9. Date: 26/08/2010	10. Proposed starting date: 06/09/2010
Only for agreed projects:	
11. Date project agreed: Ref.No. of proposal:	12. Starting Date: 13. Expected completion date: Only for permanent agreements: <input type="checkbox"/> On-Going

Notes for completion of the form overleaf

APPENDIX 2 - Comparison of the results obtained during this comparison (E1161) and the previous comparison (E887)

