Date : 12/11/2013

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Project MeDD - Task 1.1. Comparison report

1. Introduction

The comparison was organized within the scope of the task 1.1. of the EMRP project HLT07 MeDD (Metrology for Drug Delivery). The aim of this task was to validate the uncertainty of 4 primary standards (LNE-CETIAT, DTI, IPQ, EJPD) for flow rate ranging from 10 ml/min down to 10µl/min.

The comparison has been performed through the calibration of 2 transfer standards (TS) by each laboratories. Two Coriolis Flowmeter were used as TS. The first flowmeter has been calibrated at 2; 6; 20; 60 and 200 g/h at ambient conditions. The second flowmeter was calibrated at 200 and 600 g/h at ambient temperature. Calibrations were performed using the individual procedures and flow generators of each laboratory.

The comparison has been piloted by LNE-CETIAT (France).

2. Transfer standards (TS)

2.1. Packages and transport for the transfer standards (TS)

The TS has been transported only by road (to avoid possible influence of low pressure around the meter during air transport) in 1 transportation box indentified as follow:

Box n°	Box content	Dimensions of the box (Width*Height*Depth) (mm)	Weight of the box (kg)	Value (Euros)
1	M12P and M13 Flowmeters	524*429*206	15	9024 €

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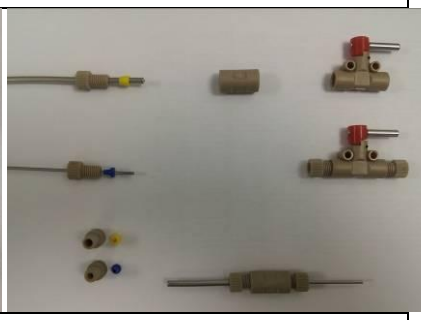
2.1.1. Box contain

The box contained:

- Instructions sheets,
- One Bronkhorst M12P flowmeter (ref: M12P-AGP-11-0-S; S/N: B12200826A),
- One Bronkhorst M13 flowmeter (ref: M13-AAD-33-0; S/N: B8200211A),
- Two Mass Block (useful for flowmeter stability),
- One Bright (converter) to check communication if needed. This converter was not used for the comparison,
- A CD with the useful Software,
- Electrical wire and adaptators, Signal cable, Hydraulic connectors.

		
M12P + 2kg Mass block + valves	M13 + 2kg Mass block + Bright	CD
		
Electrical wire + signal cable	Electrical adaptators	Hydraulic connectors

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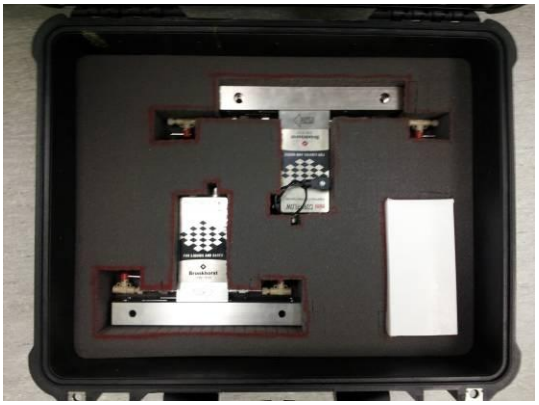
2.1.2. Box arrangement

The following pictures show how the TS and accessories were arranged in the box:




Bottom layer inside the box (flowmeters + electrical connector) before and after adding the protection


Upper layer inside the box (CD room + Bright + signal cable + hydraulic connectors)

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2.2. Participants and time schedule

Step n°	Laboratory (Country)	Contact Person	Date
1-1	LNE-CETIAT (France)	Christopher DAVID christopher.david@cetiat.fr +33 643 960 142	16th August 2012 to 3rd September 2012
1-2	DTI (Denmark)	Claus Melvad cmd@teknologisk.dk +45 7220 2098	7th September 2012 to 2th November 2012
1-3	EJPD (Switzerland)	Hugo Bissig hugo.bissig@metas.ch +41 31 32 34 915	19th November 2012 to 18th December 2012
1-4	IPQ (Portugal)	Elsa Batista ebatista@mail.ipq.pt +351 212 948 167	8th January to 29th January 2013
1-5	LNE-CETIAT (France)	Christopher DAVID christopher.david@cetiat.fr +33 643 960 142	29th January 2013 to 3rd February 2013

3. Organization of the comparison

3.1. Measurement procedure for the M12P and M13

3.1.1. Plugging and connection of the flowmeters (M12P and M13)

For the comparison, the M12P and M13 flowmeters were sent around with 1/8” stainless steal tubing upstream and downstream from the flowmeter. Fast connecting valves (from Upchurch company) were also sent around (see figure below). Theses valves offer the possibility to easily plug 1/8” or 1/16” tubing. The flowmeter was fixed on a mass block to limit the influence of vibrations.

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Figure showing the first TS: M13 with fittings and valves

Plugging of the transfer standard to the calibration bench was realized using the fast connectors sent around with the valves as shown:

1) Install the connectors (Nut + Ferrule) on the tubes (blue ferrule for 1/16", yellow ferrule for 1/8") as follow. The tubes are the one from each partners laboratories.

2) Insert the tube in the valve till a contact (between the end of the tube and the inner part of the valves) is reached.
3) Screw the Nut firmly while ensuring that the end of the tube stay in contact with the inner part of the valve.
4) Test the water tightness.

3.1.2. Data acquisition for the Meters under calibration (TS)

Softwares ("FlowDDE.msi" and "FlowPlot.exe") available on a CD from Bronkhorst, or a latest version obtained on the internet were used to perform the calibrations. The acquisitions were performed using the following parameters:

- No filters on the output and sensor signal (see the following figure)
- 1 acquisition every 100ms

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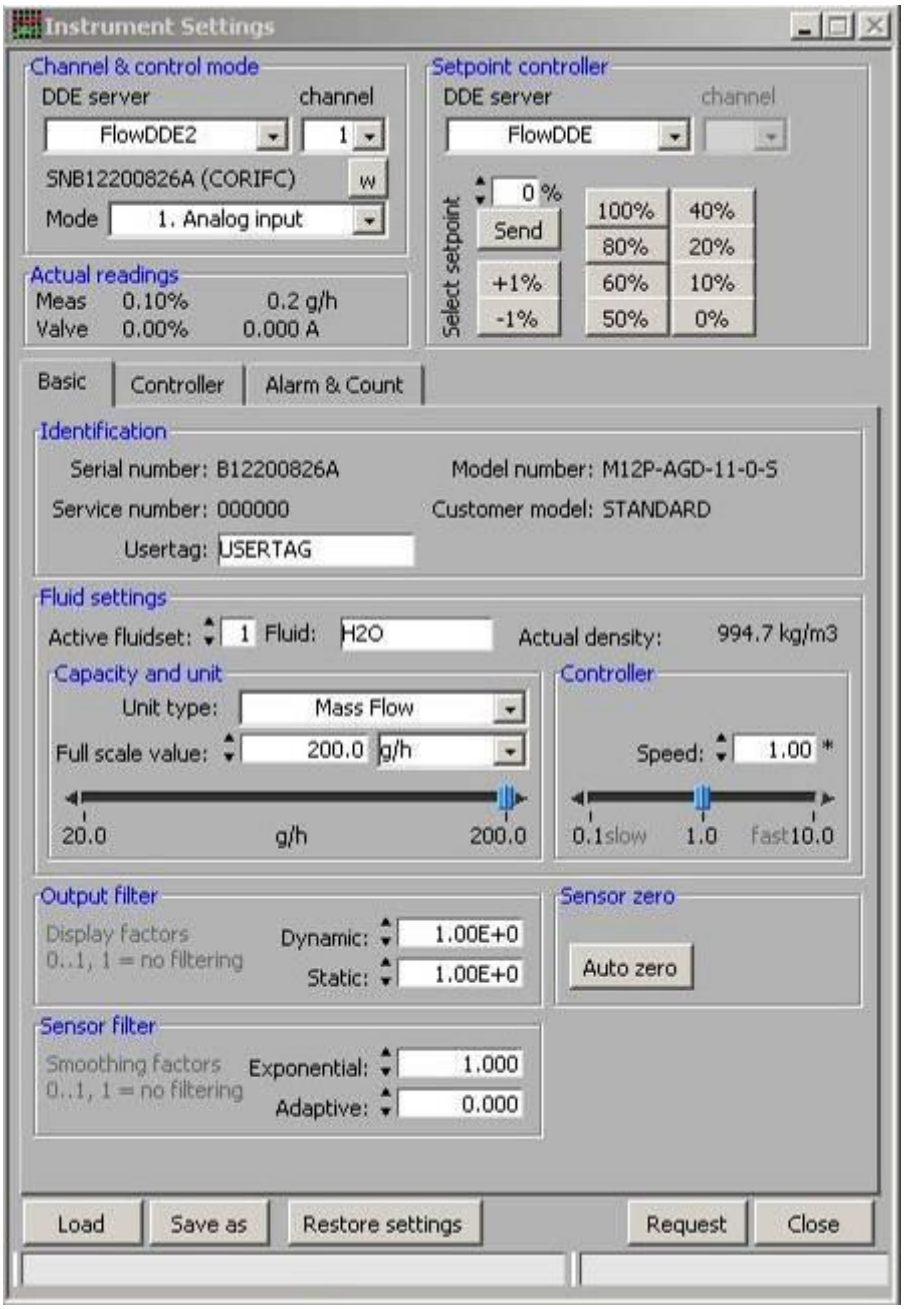
- Full scale corresponding to the TS under test (200g/h for M12P and 2 000g/h for M13)



3.1.3. Protocol for M12P and M13

The calibration procedure was the following (when possible):

- Upstream pressure: 0,5 to 2,5 bar
- Water temperature: 20°C +/- 1°C

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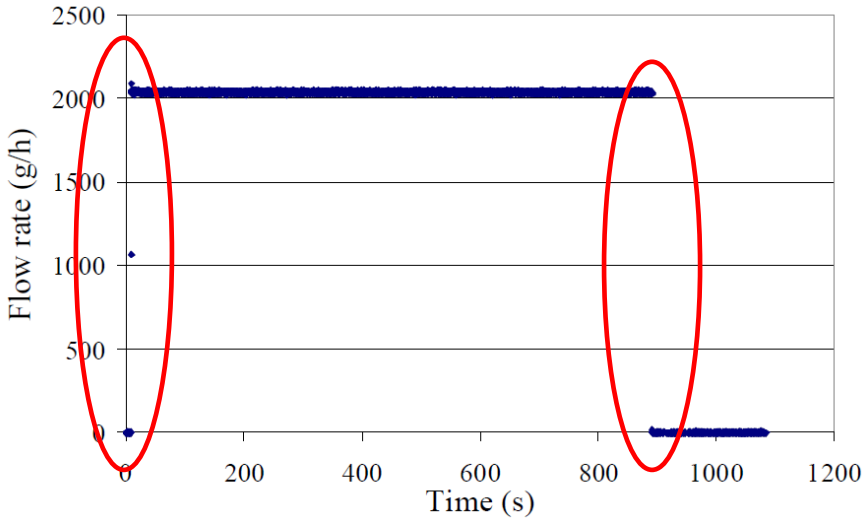
- Water flows : 600 and 200 g/h for the M13 (with a minimum of 3 points for each flow value)
- Water flows : 200; 60; 20; 6 and 2 g/h for the M12P (with a minimum of 3 points for each flow value)

When the flowmeter was connected to the calibration facility and **before starting the calibration**, each partner had to go after the following procedure:

- Start the flowmeter and make **flow the water through the flowmeter for 30 minutes** with all conditions corresponding to the calibration conditions (water and air temperatures, water pressure) and **at the maximum flow** of the flowmeter (200 g/h for M12P and 600 g/h for M13),
- **Check for the full degas** of the water in the circuit. To check the quality of the flushing procedure, participant could open and close a fast valve (less than 1s) in their circuit. If the curve from the meter present a sharp change in flow (less than 1s answer with no oscillation of the flow), participants could expect that degasing procedure was OK (see example below).



- Close the upstream and downstream valves (with the pressure corresponding to the calibration to be performed). **Perform a "zero"** procedure. Open the valves.

The "zero" procedure was repeated only one time for each flowmeter and then calibration points were realized according to partner procedures.
At least 3 independents points were realized for each flow value (2 repetitions).

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4. Results

All results presented in the report are presented anonymously. The results presented for CETIAT are the results obtained at the end of the comparison. The aim of the comparison was to obtain results and to highlight the needs of improvements. Another official comparison will be performed when improvement will be made.

4.1. Raw results

The following tables sum up the results obtained by the different laboratories:

4.1.1. Laboratory n°1

			M12P all	Lab 1				
Point number	Expected flow (g/h)	Water temperature (°C)	Upstream pressure (bar)	Reference flow value (g/h)	Read flow value (g/h)	Uncertainty (g/h)	Error (%)	Uncertainty (%)
1	2	20,5	0,6	2,305	2,271	x	-1,50%	x
2	2	20,5	0,6	2,326	2,289	x	-1,59%	x
3	2	20,3	0,6	2,263	2,225	x	-1,67%	x
4	6	20,3	1,8	5,611	5,534	x	-1,38%	x
5	6	20,3	1,9	5,442	5,399	x	-0,76%	x
6	6	20,2	1,8	5,830	5,785	x	-0,78%	x
7	20	20,3	2,3	19,714	19,553	x	-0,82%	x
8	20	20,3	2,3	19,797	19,642	x	-0,79%	x
9	20	20,3	2,3	19,754	19,629	x	-0,64%	x
10	60	20,4	1,4	64,258	63,069	x	-1,84%	x
11	60	20,4	1,4	65,037	64,186	x	-1,31%	x
12	60	20,4	1,4	64,062	63,157	x	-1,41%	x
13	200	20,3	2,3	196,778	194,931	x	-0,93%	x
14	200	20,3	2,3	198,743	196,884	x	-0,92%	x
15	200	20,3	2,3	198,685	196,082	x	-1,28%	x

			M12P mean	Lab 1			
Expected flow (g/h)	Mean water temperature (°C)	Upstream mean pressure (bar)	Reference flow value (g/h)	Mean read flow value (g/h)	Uncertainty (g/h)	Error (%)	Uncertainty (%)
2	20,4	0,6	2,298	2,262	0,015	-1,59%	0,67%
6	20,2	1,9	5,630	5,573	0,041	-1,00%	0,72%
20	20,3	2,3	19,755	19,608	0,048	-0,75%	0,24%
60	20,4	1,4	64,452	63,471	0,230	-1,52%	0,36%
200	20,3	2,3	198,069	195,966	0,605	-1,05%	0,31%

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			M13 all	Lab 1				
Point number	Expected flow (g/h)	Water temperature (°C)	Upstream pressure (bar)	Reference flow value (g/h)	Read flow value (g/h)	Uncertainty (g/h)	Error (%)	Uncertainty (%)
1	200	20,3	2,3	205,116	204,962	x	-0,08%	x
2	200	20,3	2,2	205,370	204,982	x	-0,19%	x
3	200	20,3	2,7	205,362	204,931	x	-0,21%	x
4	600	20,4	2,8	623,365	621,798	x	-0,25%	x
5	600	20,4	2,8	622,103	620,528	x	-0,25%	x
6	600	20,4	2,8	622,343	620,788	x	-0,25%	x

			M13 mean	Lab 1			
Expected flow (g/h)	Mean water temperature (°C)	Upstream mean pressure (bar)	Reference flow value (g/h)	Mean read flow value (g/h)	Uncertainty (g/h)	Error (%)	Uncertainty (%)
200	20,3	2,2	205,281	204,952	0,455	-0,16%	0,22%
600	20,4	2,8	622,604	621,038	1,290	-0,25%	0,21%

4.1.2. Laboratory n°2

			M12P all	Lab n°2				
Point number	Expected flow (g/h)	Water temperature (°C)	Upstream pressure (bar)	Reference flow value (g/h)	Read flow value (g/h)	Uncertainty (g/h)	Error (%)	Uncertainty (%)
1	2	23,0	0,5	1,994	1,981	0,042	-0,7%	2,1%
2	2	23,0	0,5	1,829	1,814	0,042	-0,8%	2,3%
3	1,5	23,0	0,5	1,502	1,482	0,043	-1,4%	2,8%
4	6	23,0	0,5	6,005	5,993	0,042	-0,19%	0,70%
5	6	23,0	0,5	5,899	5,873	0,042	-0,44%	0,71%
6	6	23,0	0,5	6,258	6,211	0,042	-0,74%	0,66%
7	20	23,0	0,5	19,985	19,951	0,043	-0,17%	0,21%
8	20	23,0	0,5	20,298	20,250	0,042	-0,24%	0,20%
9	20	24,0	0,5	20,231	20,186	0,047	-0,22%	0,23%
10	60	23,0	0,5	59,405	59,301	0,042	-0,175%	0,070%
11	60	23,0	0,5	59,445	59,346	0,043	-0,165%	0,072%
12	60	23,0	0,5	62,761	62,648	0,089	-0,18%	0,14%
13	200	23,0	2,0	199,10	198,78	0,14	-0,165%	0,072%
14	200	23,0	2,0	197,17	196,88	0,13	-0,147%	0,068%
15	200	23,0	2,0	197,40	197,09	0,13	-0,153%	0,064%

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			M12P mean	Lab n°2			
Expected flow (g/h)	Mean water temperature (°C)	Upstream mean pressure (bar)	Reference flow value (g/h)	Mean read flow value (g/h)	Uncertainty (g/h)	Error (%)	Uncertainty (%)
2	23,0	0,5	1,911	1,897	0,042	-0,7%	2,2%
6	23,0	0,5	6,054	6,026	0,042	-0,46%	0,69%
20	23,3	0,5	20,172	20,129	0,044	-0,21%	0,22%
60	23,0	0,5	60,537	60,432	0,058	-0,17%	0,095%
200	23,0	2,0	197,89	197,58	0,14	-0,155%	0,068%

			M13 all	Lab n°2				
Point number	Expected flow (g/h)	Water temperature (°C)	Upstream pressure (bar)	Reference flow value (g/h)	Read flow value (g/h)	Uncertainty (g/h)	Error (%)	Uncertainty (%)
1	200	23,5	0,6	210,304	210,292	0,13	-0,005%	0,063%
2	200	24,1	0,6	200,477	200,532	0,12	0,027%	0,060%
3	200	23,9	0,6	200,436	200,481	0,12	0,022%	0,059%
4	200	23,9	0,6	198,110	198,133	0,13	0,011%	0,064%
5	600	24,0	0,6	588,073	588,123	0,32	0,009%	0,054%
6	600	23,9	0,6	587,335	587,348	0,41	0,002%	0,069%
7	600	24,1	0,6	587,680	587,697	0,43	0,003%	0,073%
8	600	23,5	0,6	588,077	588,105	0,34	0,005%	0,058%

			M13 mean	Lab n°2			
Expected flow (g/h)	Mean water temperature (°C)	Upstream mean pressure (bar)	Reference flow value (g/h)	Mean read flow value (g/h)	Uncertainty (g/h)	Error (%)	Uncertainty (%)
200	23,8	0,6	202,33	202,36	0,12	0,014%	0,062%
600	23,9	0,6	587,79	587,82	0,37	0,005%	0,064%

4.1.3. Laboratory n°3

This laboratory performed measurements with M12P and calibrated it up to 60g/h.

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			M12P all	Lab n°3				
Point number	Expected flow (g/h)	Water temperature (°C)	Upstream pressure (bar)	Reference flow value (g/h)	Read flow value (g/h)	Uncertainty (g/h)	Error (%)	Uncertainty (%)
1	2	22,5	0,0022	2,1197	2,1079	0,0040	-0,56%	0,19%
2	2	22,6	0,0036	2,1283	2,1147	0,0043	-0,64%	0,20%
3	2	22,3	0,0010	2,1193	2,1121	0,0040	-0,34%	0,19%
4	6	22,5	0,0014	6,0358	6,0285	0,0062	-0,12%	0,10%
5	6	22,7	0,0015	5,9893	5,9849	0,0061	-0,07%	0,10%
6	6	22,7	0,0018	5,9274	5,9236	0,0085	-0,06%	0,14%
7	20	23,0	0,0084	18,8952	18,8726	0,019	-0,12%	0,10%
8	20	23,2	0,0034	18,9368	18,8890	0,030	-0,25%	0,16%
9	20	22,8	0,0034	18,9380	18,9052	0,020	-0,17%	0,10%
10	60	22,7	0,0171	61,9214	61,7996	0,071	-0,20%	0,12%
11	60	22,8	0,0185	61,4842	61,3750	0,080	-0,18%	0,13%
12	60	22,8	0,0190	62,1796	62,0786	0,063	-0,16%	0,10%

			M12P mean	Lab n°3			
Expected flow (g/h)	Mean water temperature (°C)	Upstream mean pressure (bar)	Reference flow value (g/h)	Mean read flow value (g/h)	Uncertainty (g/h)	Error (%)	Uncertainty (%)
2	22,5	0,0022	2,1224	2,1116	0,0058	-0,51%	0,27%
6	22,6	0,0015	5,9842	5,9790	0,0071	-0,09%	0,12%
20	23,0	0,0051	18,9233	18,8889	0,0291	-0,18%	0,15%
60	22,8	0,0182	61,8617	61,7511	0,0813	-0,18%	0,13%

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4.1.4. Laboratory n°4

			M12P	Lab n°4				
			all					
Point number	Expected flow (g/h)	Water temperature (°C)	Upstream pressure (bar)	Reference flow value (g/h)	Read flow value (g/h)	Uncertainty (g/h)	Error (%)	Uncertainty (%)
1	200	19,7	1,0	198,90	198,31	x	-0,30%	x
2	200	19,7	1,0	198,65	198,22	x	-0,22%	x
3	200	19,6	1,0	197,74	197,68	x	-0,03%	x
4	60	19,9	1,0	59,81	59,73	x	-0,14%	x
5	60	19,9	1,0	59,83	59,75	x	-0,14%	x
6	60	20,1	1,0	59,85	59,75	x	-0,16%	x
7	20	19,4	1,0	19,91	19,91	x	-0,03%	x
8	20	19,4	1,0	19,93	19,94	x	0,04%	x
9	20	19,4	1,0	19,68	19,67	x	-0,04%	x
10	6	19,7	1,0	6,216	6,207	x	-0,14%	x
11	6	19,6	1,0	6,191	6,195	x	0,07%	x
12	6	19,8	1,0	6,185	6,194	x	0,15%	x
13	2	19,2	1,0	2,104	2,108	x	0,17%	x
14	2	19,2	1,0	2,073	2,082	x	0,45%	x
15	2	19,2	1,0	2,102	2,098	x	-0,21%	x

			M12P	Lab n°4			
			mean				
Expected flow (g/h)	Mean water temperature (°C)	Upstream mean pressure (bar)	Reference flow value (g/h)	Mean read flow value (g/h)	Uncertainty (g/h)	Error (%)	Uncertainty (%)
2	19,7	1,0	198,43	198,07	0,54	0,14%	0,27%
6	20,0	1,0	59,83	59,74	0,16	0,03%	0,27%
20	19,4	1,0	19,84	19,84	0,05	-0,01%	0,28%
60	19,7	1,0	6,197	6,199	0,024	-0,15%	0,39%
200	19,2	1,0	2,093	2,096	0,014	-0,18%	0,69%

			M13	Lab n°4				
			all					
Point number	Expected flow (g/h)	Water temperature (°C)	Upstream pressure (bar)	Reference flow value (g/h)	Read flow value (g/h)	Uncertainty (g/h)	Error (%)	Uncertainty (%)
1	200	19,8	1,0	596,97	593,50	x	-0,58%	x
2	200	19,7	1,0	596,87	593,73	x	-0,53%	x
3	200	19,8	1,0	597,34	593,76	x	-0,60%	x
4	600	19,8	1,0	199,38	198,36	x	-0,51%	x
5	600	19,9	1,0	199,03	198,55	x	-0,24%	x
6	600	19,9	1,0	199,36	198,62	x	-0,37%	x

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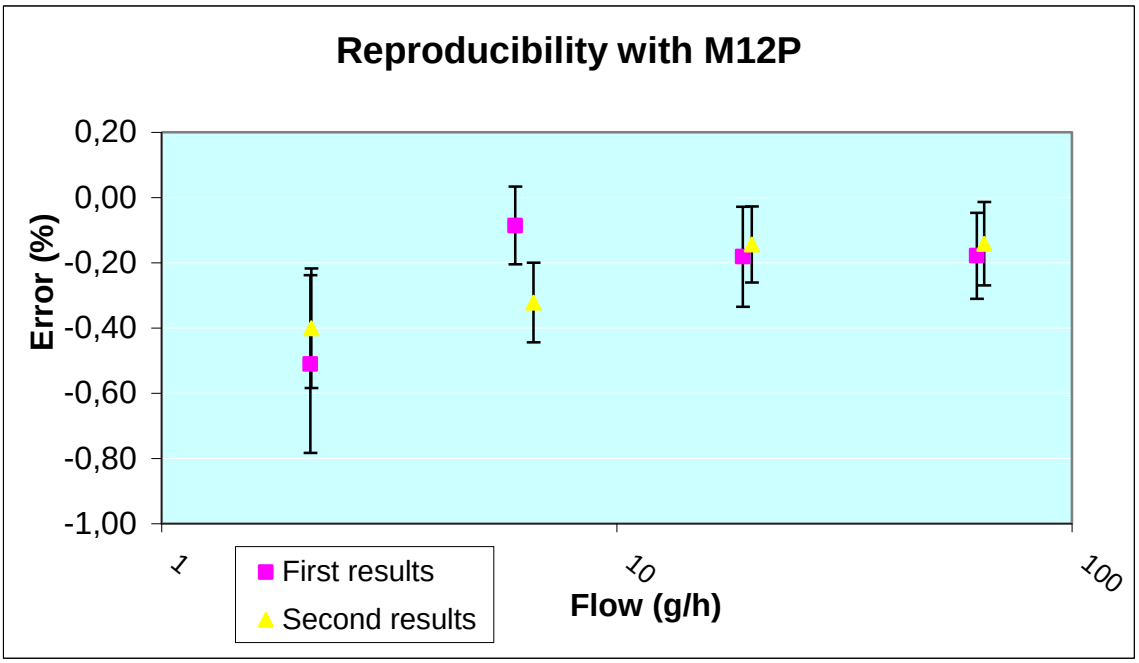
			M13 mean	Lab n°4			
Expected flow (g/h)	Mean water temperature (°C)	Upstream mean pressure (bar)	Reference flow value (g/h)	Mean read flow value (g/h)	Uncertainty (g/h)	Error (%)	Uncertainty (%)
200	19,7	1,0	597,06	593,66	0,87	-0,57%	0,15%
600	19,9	1,0	199,26	198,51	0,54	-0,38%	0,27%

4.1.1. Reproducibility

One of the laboratory performed reproducibility tests with M12P. The following graph shows the results obtained with a 6 month interval between both calibrations.



4.2. Results analysis

Results were analyzed according to two method:

- Comparison of the mean results of each laboratories to the mean value of all laboratories (REF1)

$$En1 = \frac{LAB - REF1}{\sqrt{(U_{95}LAB)^2 + (U_{95}REF1)^2}}$$

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with $REF1 = \frac{1}{n} \times \sum LAB$, n = number of laboratories and $U_{95}REF = \frac{1}{n} \times \sqrt{\sum (U_{95}LAB)^2}$

- Comparison of the mean results of each laboratories to the weighted mean value (REF2), using laboratories uncertainties

$$En2 = \frac{LAB - REF\,2}{\sqrt{(U_{95}LAB)^2 + (U_{95}REF\,2)^2}}$$

with $REF\,2 = \frac{\sum \left(LAB / (U_{95}LAB)^2 \right)}{\sum \left(1 / (U_{95}LAB)^2 \right)}$ and $U_{95}REF = \frac{1}{\sqrt{\sum \frac{1}{(U_{95}LAB)^2}}}$

Both results permit to obtain complementary information.

Assuming that the both meter have a nearly "zero" error when measuring, a leakage between the meter under calibration and the calibration facility would lead to a positive deviation. As we can see on the following graphs, all results presents negative deviations. This could give a better confidence in the results obtained.

4.2.1. Results obtained with M12P

The following tables present the results of the "En" tests obtained using the mean errors of each laboratories. Mean and weighted mean values were calculated as described (§4.2.). In this part no selection of the points (based on an exclusion test) was performed. Most of the laboratories performed the measures 3 time to obtain their mean values.

	M12P	2g/h			
	Error (%)	Uncertainty (%)		En values 1	En values 2
Lab 1.	-1,59%	0,67%		-0,38	-1,86
Lab 2.	-0,73%	2,18%		-0,02	-0,20
Lab 3.	-0,51%	0,27%		0,07	-0,64
Lab 4.	0,14%	0,27%		0,35	1,32
Mean	-0,67%	2,31%			
Weighted mean	-0,30%	0,18%			

	M12P	6g/h			
	Error (%)	Uncertainty (%)		En values 1	En values 2
Lab 1.	-1,00%	0,72%		-0,49	-1,23
Lab 2.	-0,46%	0,69%		-0,06	-0,52
Lab 3.	-0,09%	0,12%		0,28	0,07
Lab 4.	0,03%	0,27%		0,38	0,42
Mean	-0,38%	1,04%			
Weighted mean	-0,10%	0,11%			

	M12P	20g/h			
	Error (%)	Uncertainty (%)		En values 1	En values 2
Lab 1.	-0,75%	0,24%		-0,90	-1,84
Lab 2.	-0,21%	0,22%		0,15	0,24
Lab 3.	-0,18%	0,15%		0,22	0,46
Lab 4.	-0,01%	0,28%		0,53	0,88
Mean	-0,29%	0,45%			
Weighted mean	-0,27%	0,10%			

	M12P	60g/h			
	Error (%)	Uncertainty (%)		En values 1	En values 2
Lab 1.	-1,52%	0,36%		-1,53	-3,52
Lab 2.	-0,17%	0,09%		0,59	0,48
Lab 3.	-0,18%	0,13%		0,57	0,35
Lab 4.	-0,15%	0,39%		0,52	0,21
Mean	-0,50%	0,56%			
Weighted mean	-0,23%	0,07%			

	M12P	200g/h			
	Error (%)	Uncertainty (%)		En values 1	En values 2
Lab 1.	-1,05%	0,31%		-0,72	-2,71
Lab 2.	-0,16%	0,07%		0,40	0,44
Lab 4.	-0,18%	0,69%		0,27	0,02
Mean	-0,46%	0,76%			
Weighted mean	-0,20%	0,07%			

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4.2.2. Results obtained with M13

	M13	200g/h			
	Error (%)	Uncertainty (%)		En values 1	En values 2
Lab 1.	-0,16%	0,22%		0,22	-0,35
Lab 2.	0,01%	0,06%		0,90	1,14
Lab 4.	-0,57%	0,15%		-1,07	-3,14
Mean	-0,24%	0,27%			
Weighted mean	-0,08%	0,05%			

	M13	600g/h			
	Error (%)	Uncertainty (%)		En values 1	En values 2
Lab 1.	-0,25%	0,21%		-0,11	-1,00
Lab 2.	0,00%	0,06%		0,60	0,45
Lab 4.	-0,38%	0,27%		-0,38	-1,24
Mean	-0,21%	0,35%			
Weighted mean	-0,03%	0,06%			

4.2.3. Chi square test

To determine a reference value of this comparison the weighted mean was selected and a selection of the point was performed using the chi square test. To calculate the reference value, the second results obtained at LNE-CETIAT were used to avoid dominance in the calculation. The weighted mean value (1) is determined using the inverses of the squares of the associated standard uncertainties as the weights, according to the recommendations given by the BIPM (Cox M.G., The evaluation of key comparison data, Metrologia, 2002, Vol. 39, 589-595):

$$y = \frac{x_1/u^2(x_1)+\ldots+x_n/u^2(x_n)}{1/u^2(x_1)+\ldots.+1/u^2(x_n)} \quad (1)$$

To calculate the standard deviation u(y) associated with the flow rate y, equation (2) was used:

$$u(y) = \sqrt{\frac{1}{1/u^2(x_1)+\ldots+1/u^2(x_n)}} \quad (2)$$

To identify eventual inconsistent results, a chi-square test has been applied to all n calibration results of each experimental test:

$$\chi^2_{obs} = \frac{(x_1-y)^2}{u^2(x_1)}+\ldots+\frac{(x_n-y)^2}{u^2(x_n)} \quad (3)$$

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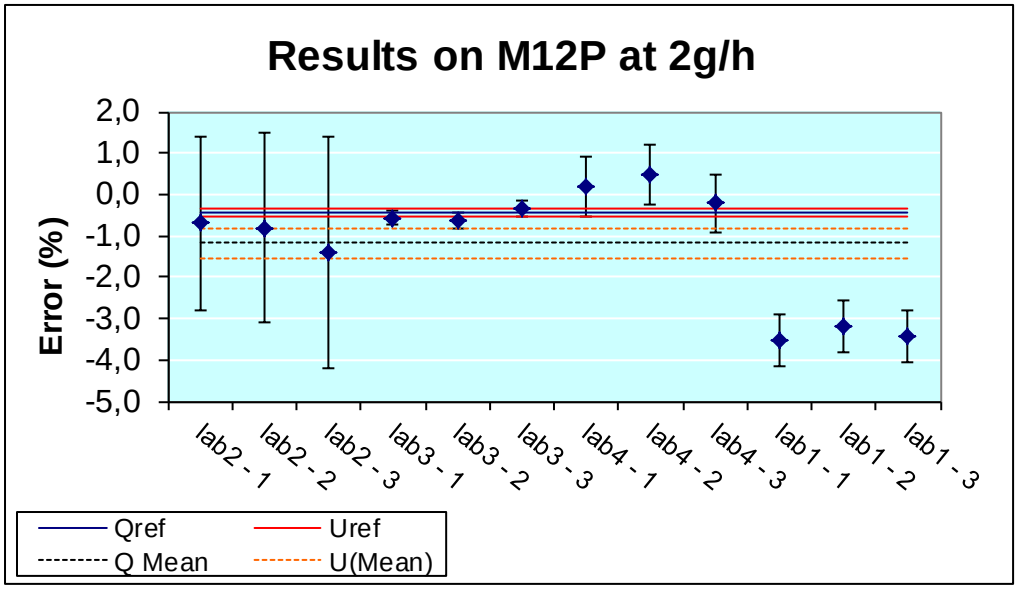
where the corresponding degree of freedom is: ν = n -1
The consistency check is regarded as failed at a significance level α = 5% if:

$$\Pr\left\{\chi^2(\nu) > \chi^2_{obs}\right\} < 0{,}05$$

4.2.4. Graphical view of the results

The following graphs were obtained by analyzing the results with both methods (Mean and weighted mean values). In this part, all single points were analyzed independently.
To calculate the mean value, no points were excluded.
To calculate the "reference values" (coming from the weighted mean method), the results were obtained after excluding points while the chi square test was not successful. This method led to the exclusion of all points from one laboratory (for nearly all cases) because the repeatability at each laboratories was fine. The statistics (number of individual and independents measurements) was too low to be able to clearly identify the outliers. For the results obtained at 600g/h, the obtained weighted mean value has particularly less significance because two laboratories out of three were excluded.



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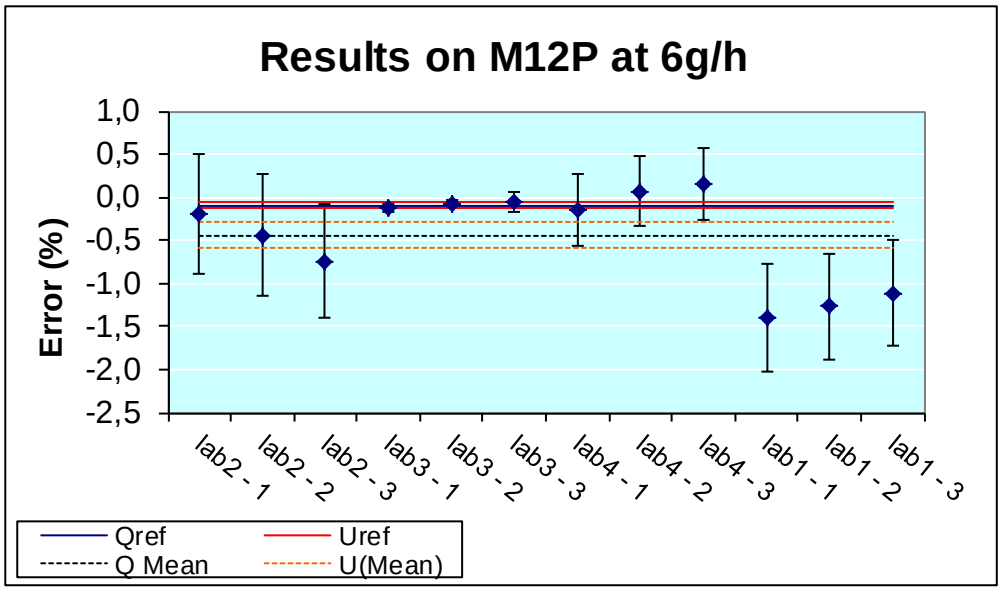

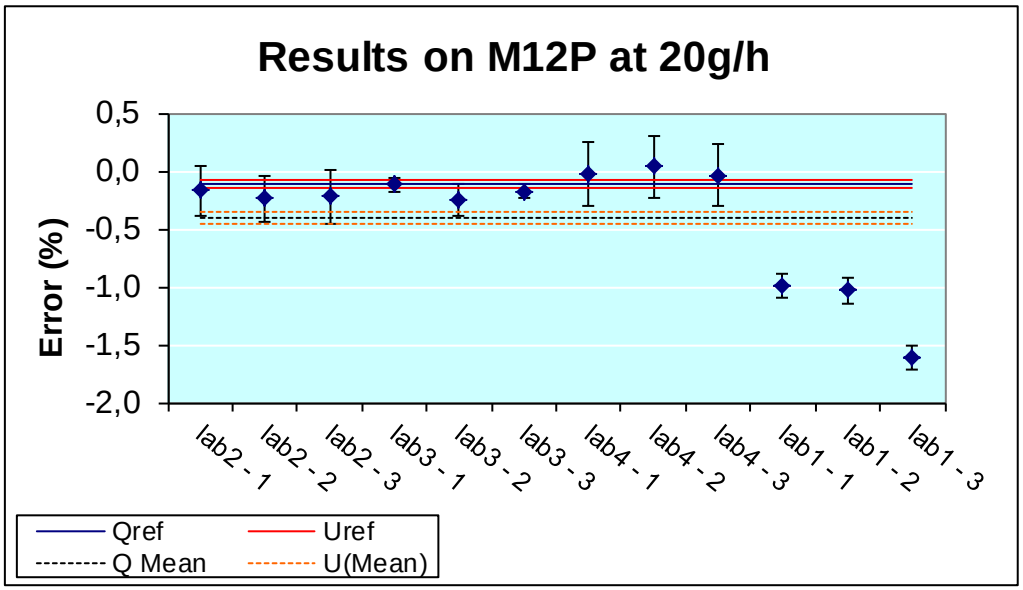

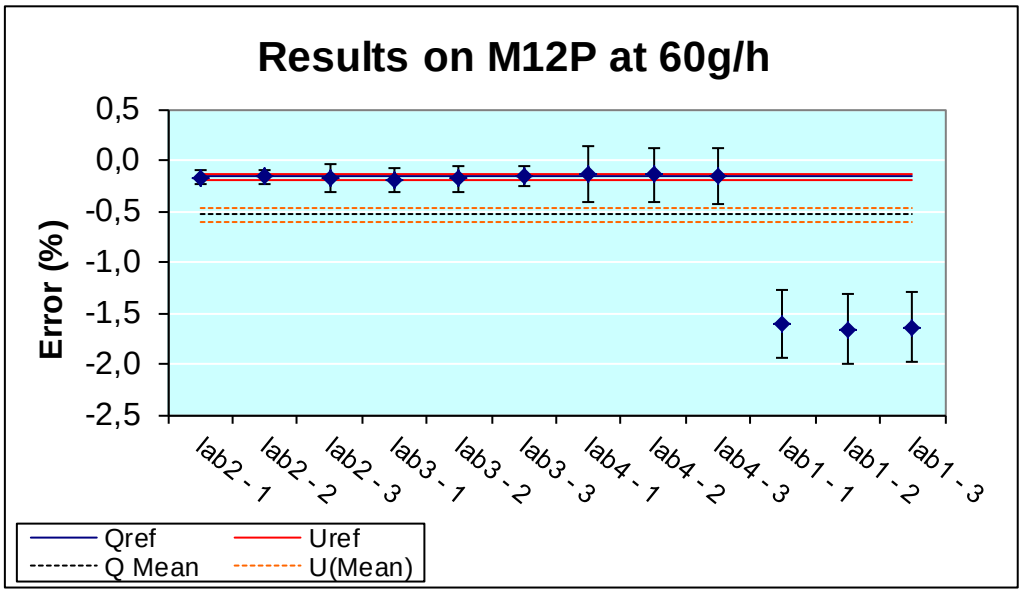

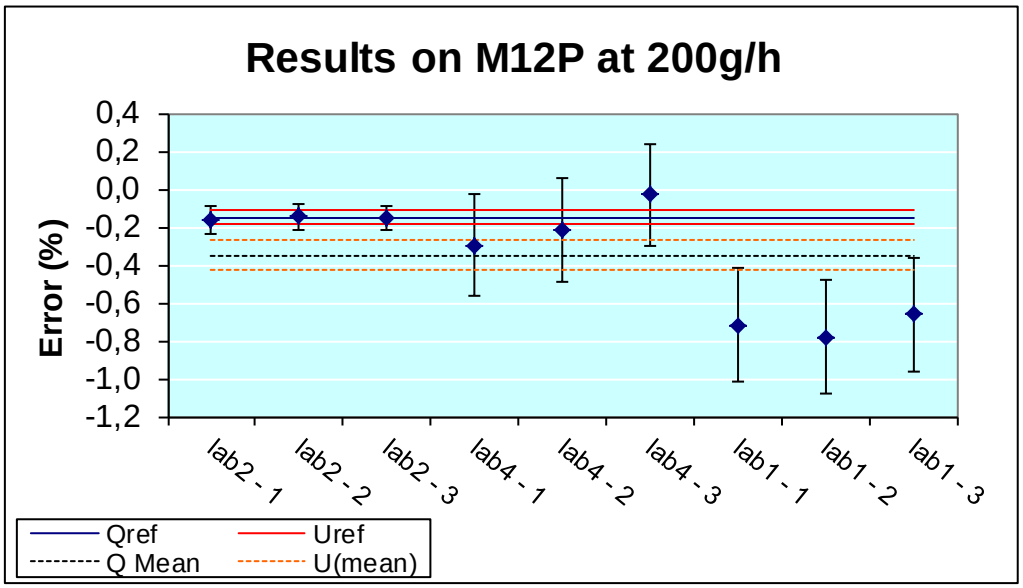

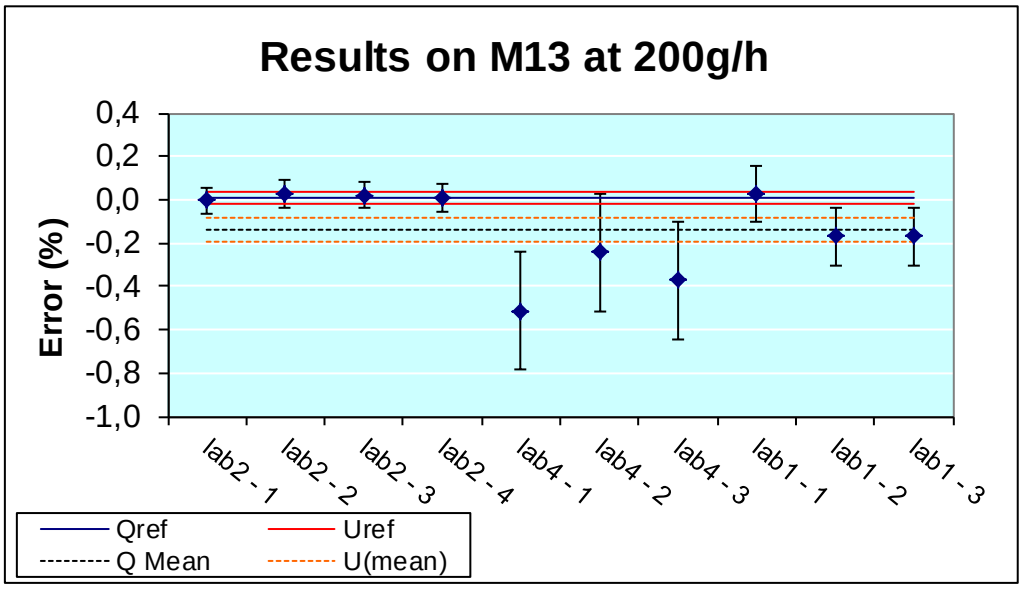

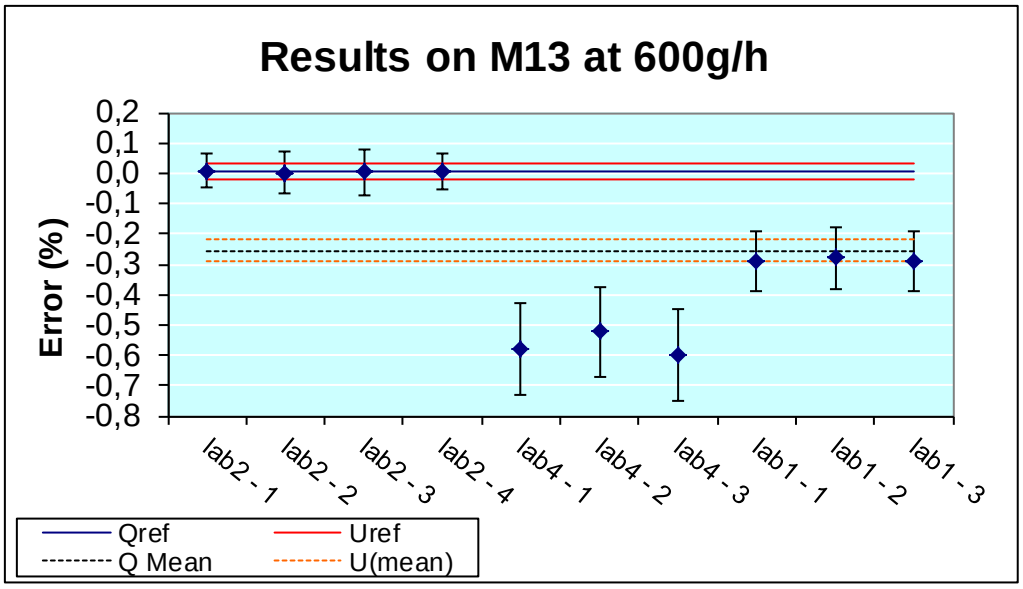

5. Conclusion

This first attempt to compare primary standards for micro flow (2g/h to 600g/h) will help the MeDD group to improve their calibrations facilities and methods. All participants succeeded to realize measurements and to obtain results following the agreed protocol.

As a research project, this comparison also succeeded to set down a lot of new questions regarding:

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- the way comparison can be organized (mainly concerning the way laboratories realize calibrations),
- the way the different laboratories evaluate uncertainties.

With regards to the results, we can state the following conclusions:

- Both flowmeters used for the comparison (M12P and M13) are repeatable enough to perform a comparison,
- Both flowmeters used for the comparison (M12P and M13) seam reproducible enough to perform a comparison,
- The uncertainties claimed by some of the different laboratories are not in agreement with the results obtained (it can be due to the uncertainties evaluation and/or from a poor calibration method),

Other points need new measurements and other comparisons to be clarified:

- Is the flowmeter sensible to specific flow calibration procedures?

  Several parameter could influence the meter and this influence have to be evaluated. The following parameters will be tested: pressure dependence of the meter, influence of the way meters are installed and plug (calibrations procedures), influence of the flow stability on the meter (followings tasks of the MeDD project)
- Can we improve our calibration procedures to improve the reproducibility of the meter?

  The analysis of the flow stability in the different laboratories during calibration could help to know if there is an influence. Connection and pipes used by the different laboratories could influence the results.
- Can we find other flowmeters to perform cross-check calibrations?

Several questions were already identified for the MeDD project (influence of flow stability, influence of connections and pipes). The following tasks of the project will bring new data to improve our standards and the way we will perform new comparisons.

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