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"Gas: Sustaining Future Global Growth"

Analysis of the metrological performance of diaphragm gas meters in a city distribution network

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Summary

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- Summary/Conclusions

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Background

- Nowadays, almost totally **diaphragm gas meters** are installed in the national distribution networks ;
- Very wide market (in Italy about 20 millions domestic gas meters) with **very old meters** in absence of a strict law regarding their legal duration until 2009 (nowadays the legal duration is fixed at 15 years);
- **gradual substitution** of all the old domestic gas meters installed in the distribution networks (AEEG resolution n.155/08);
- Very old gas meters installed (before 1990) were manufactured with **animal diaphragms**;
- Recent meters (after 1990) were manufactured with **synthetic diaphragms**;
- The attention to unaccounted for gas (UAG) is nowadays continuously increasing both at transport and at distribution level and to this aim the knowledge of the **metrological performance** of the meters play a very critical role.

Aims

- Withdrawal of a **representative sample** of the domestic diaphragm gas meters installed in the distribution network of Genoa;

Ref.	Diaphragm	Installation	Number of meters
I batch	Animal	Before 1990	>60
II batch			>60
III batch	Synthetic	After 1990	>60
IV batch			>60

- The following **sampling criteria** have been adopted, when possible:
  - *i) year of construction (up to 1965 and further groups of five years each),*
  - *ii) manufacturer,*
  - *iii) type of gas consumptions (kitchen, water heater, boiler),*
  - *iv) consumptions ranges (<100, 100÷500, >500 m^3/year),*
  - *v) installation (indoor/outdoor).*

  After their removal all the meters have been immediately filled with humidified gas, sealed and stored in a conditioned room before their transportation to the laboratory.

Methods

- **Performance tests** in compliance to the main applicable parts of the international standard **EN 1359:2006**

  i) error of indication;

  ii) pressure absorption;

  iii) external leak tightness;

  iv) resistance to internal pressure;

  v) disassembling and visual check;

  vi) planarity of the moving couplings (grids and valves).

Methods

- **Error of indication** and **pressure absorption** tests:
  - **test ambient** at controlled temperature and humidity [(20±1) °C - (50±10) %UR];
  - tests conducted by means of a 550 L **bell prover test bench** (traceability from a 50 L first line volume standard, calibrated at INRIM, the Italian National Metrology Primary Institute expanded uncertainty of 3,3 mL);
  - typical relative **expanded uncertainty** of the bell prover test bench less than ± 0,3% (less than 1/5 of the maximum permissible errors of the meter in first verification);
  - **test flowrates** Q_{min}, $0{,}2 \cdot Q_{max}$ and Q_{max}, in compliance to the Italian legal metrology law in force before 2007, and a further verification point at $0{,}5 \cdot Q_{max}$.

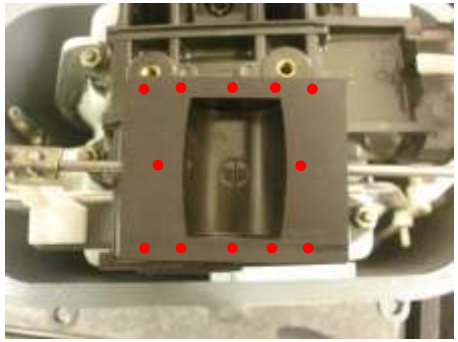
Methods

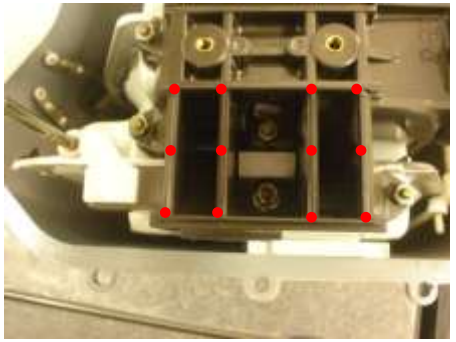
- **External leak tightness**
  the meter under test is pressurized at normal laboratory temperature with air to 1,5 times the declared maximum working pressure.

- **Resistance to internal pressure**
  the external case of the meter under test is pressurized with air to 1,5 times the maximum working pressure.

- **Disassembly and visual check**
  integrity of couplings and of the exit pipe;
  possible leakages from the coupling grid-distributing valve and their wear conditions

- **Planarity of grid and distributing valve**
  maximum height difference between 12 points in the coupling area by means of a calibrated coordinate measuring machine
  A tolerance of 0,020 mm is fixed both for grid and distributing valve, as usually stated by the main diaphragm gas meters manufacturers.





Results

- According to OIML R137-1:2006 [5] par. 2.2.8, a **weighted mean error of indication** (WME) has been calculated as a function of the errors and of the flowrates at which the errors have been measured.
- A ±0,6% maximum permissible error (MPE) in initial verification is permitted for WME. No indication is given for the subsequent verification.

$$WME = \frac{\sum_{i=1}^{n} \frac{Q_i}{Q_{max}} \cdot E_i}{\sum_{i=1}^{n} \frac{Q_i}{Q_{max}}}$$

Table 1 – Maximum Permissible Error (MPE) for domestic gas meters (MID class 1,5) in initial conformity assessment and in subsequent verification*

	Flowrate range	*MPE for the EU MID (class 1,5) in force after 2007*	*MPE for the Italian legal metrology law in force before 2007*
in initial conformity assessment	$Q_{min} < Q < Q_t$	± 3 %	± 3 %
	$Q_t < Q < Q_{max}$	± 1,5 %	± 2 %
*in subsequent verification**	$Q_{min} < Q < Q_t$	± 6 %	-
	$Q_t < Q < Q_{max}$	± 3 %	-

*fixed equal to twice the MID MPE (to be confirmed in a specific italian decree).

Results (by year)

Table 2a – Average errors of indication of the meters grouped by year.

Year		Number of meter tested	Average E%				WME	% of meters presenting at all the test flowrates	
			Q_{min}	0,2 Q_{max}	0,5 Q_{max}	Q_{max}		negative errors	positive errors
Synthetic d.	from 2001 to 2006	33	-2,8%	0,3%	-0,2%	-1,2%	-0,8%	27,3%	9,1%
	from 1996 to 2000	56	-2,6%	0,9%	0,2%	-0,8%	-0,3%	19,6%	8,9%
	from 1991 to 1995	41	-4,0%	0,8%	0,3%	-0,4%	-0,1%	14,6%	9,8%
	synthetic diaph. meters average	130	-3,1%	0,7%	0,1%	-0,8%	-0,4%	20,0%	9,2%
Animal diaphragm	from 1986 to 1990	20	-0,8%	1,8%	1,2%	0,8%	1,1%	5,0%	30,0%
	from 1981 to 1985	21	-4,0%	2,3%	2,5%	1,6%	**1,9%**	9,5%	19,0%
	from 1976 to 1980	17	0,1%	2,2%	2,6%	2,3%	**2,4%**	0,0%	52,9%
	from 1971 to 1975	19	**-6,0%**	-0,6%	1,1%	1,4%	1,1%	5,3%	21,1%
	from 1966 to 1970	21	**-9,1%**	-1,0%	0,6%	0,7%	0,4%	14,3%	4,8%
	up to 1965	19	**-18,8%**	0,3%	0,1%	0,8%	0,3%	15,8%	0,0%
	animal diaphragm meters average	117	-5,3%	0,9%	1,4%	1,3%	**1,2%**	8,5%	20,5%
Overall average**		247	-4,1%	0,8%	0,7%	0,2%	0,4%	14,6%	14,6%
*MPE in subsequent verification**-			*±6,0%*	*±3,0%*	*±3,0%*	*±3,0%*	*±1,2%*	-	-

* equal to twice the MID MPE (to be confirmed in a specific italian decree)
** weighted in function of the number of meters tested

Results (by year)

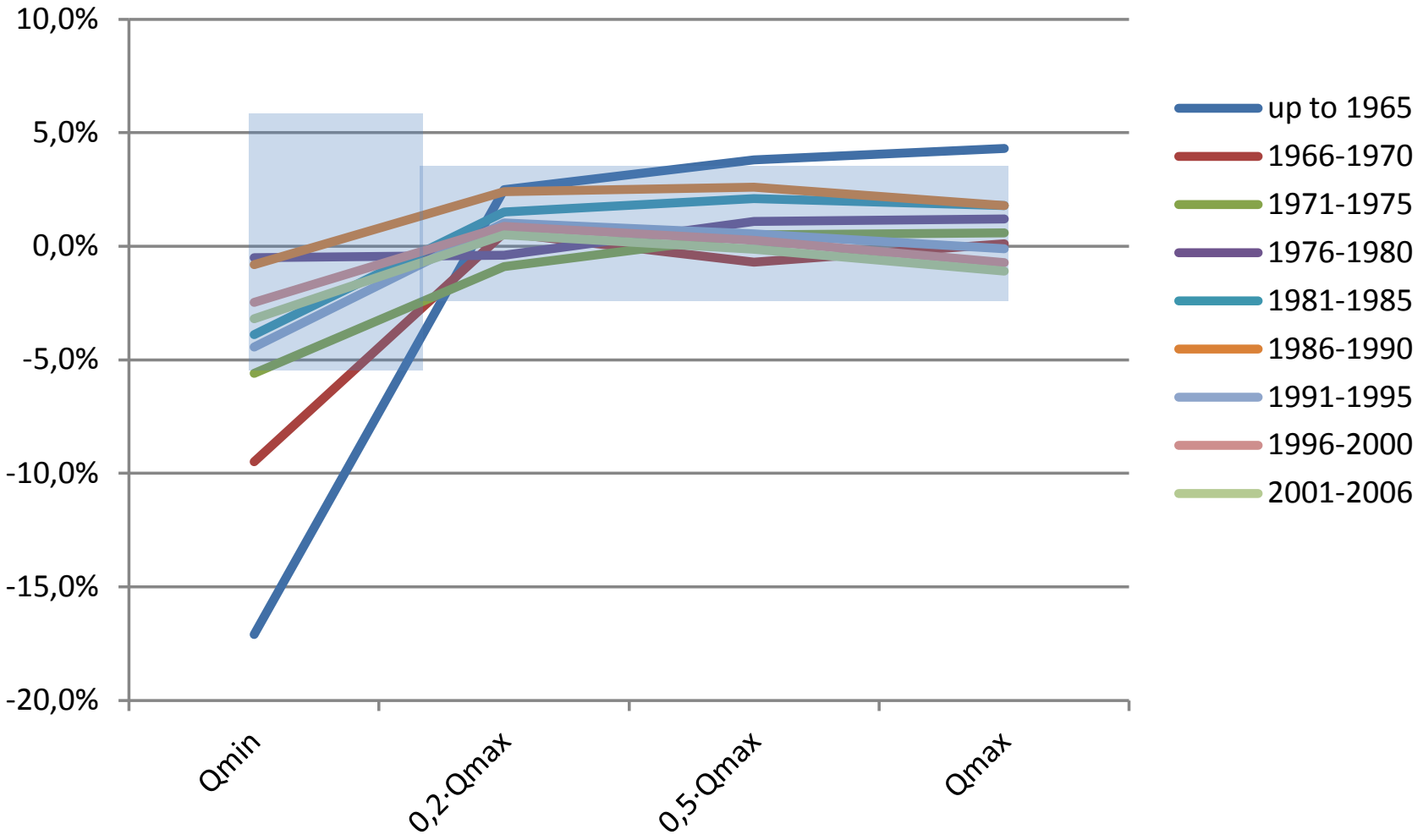
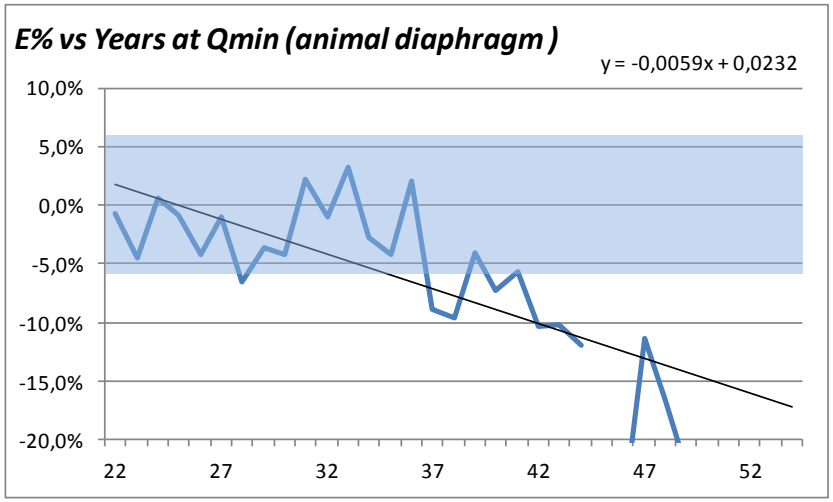
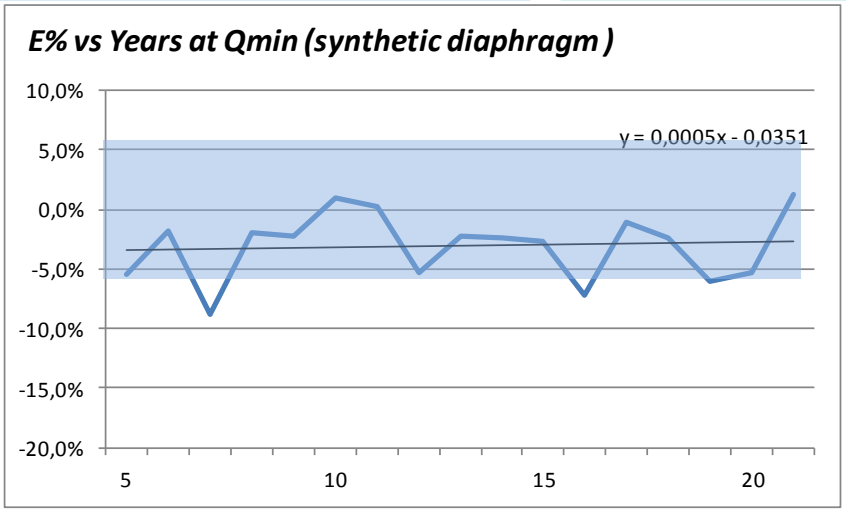
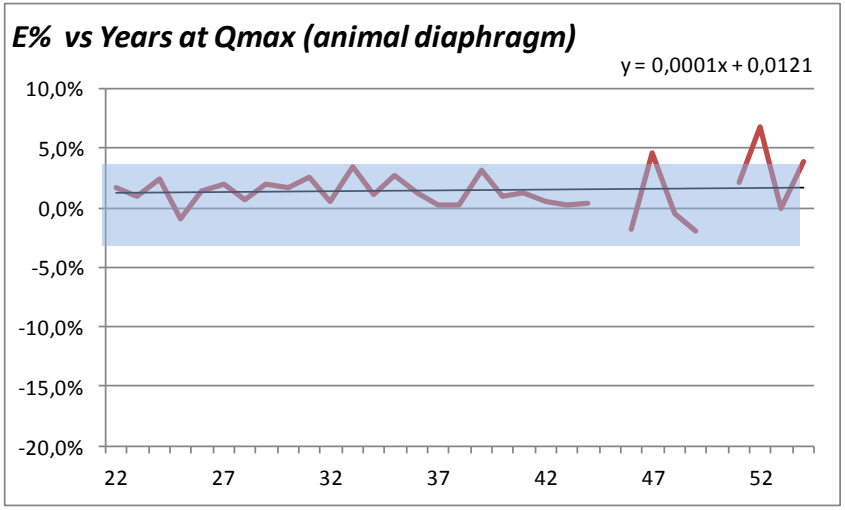


Fig.8 – Average error of indication of the gas meters tested, grouped by year and compared to the conformity area in subsequent verification*

Results (by year)







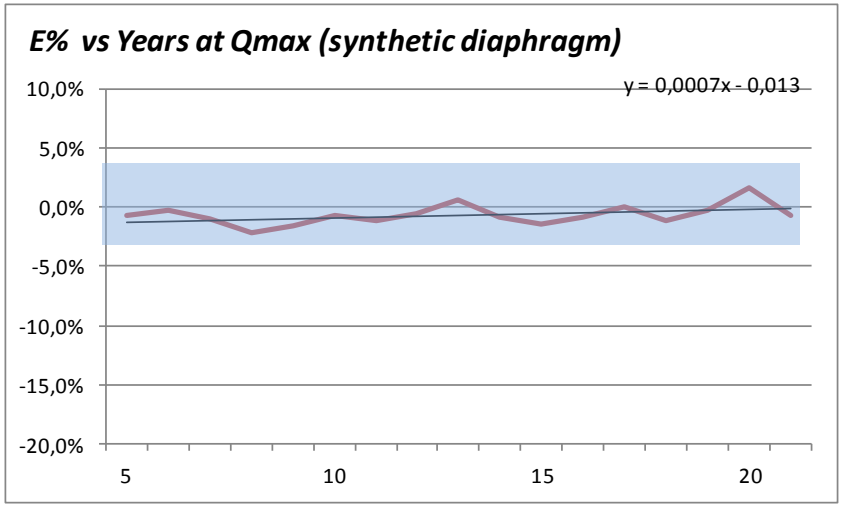


Fig.10 – Trend of the average error of indication at Q_{min} and Q_{max} as a function of the age of the meters

Results (by manufacturer)

Table 2b – Average error of indication of the meters grouped by manufacturer.

Manufacturer		Number of meter tested	Average E%				WME	% of meters presenting at all the test flowrates	
			Q_{min}	0,2 Q_{max}	0,5 Q_{max}	Q_{max}		negative errors	positive errors
synthetic diaphragm	Man.#1	22	-1,2%	1,4%	1,2%	0,9%	1,0%	36%	5%
	Man.#2	66	-4,4%	0,4%	1,5%	1,1%	1,1%	2%	9%
	Man.#3	4	0,2%	1,7%	0,7%	-1,0%	0,2%	25%	0%
	Man.#4	13	**-7,1%**	0,1%	0,1%	-0,3%	-0,2%	15%	31%
	Man.#5	13	**-8,2%**	0,1%	-0,6%	-1,3%	-1,0%	0%	38%
	Man.#6	6	-4,9%	0,4%	-0,5%	0,1%	-0,1%	17%	67%
	Man.#7	5	-5,8%	0,9%	0,9%	1,7%	**1,4%**	0%	0%
animal d.	Man.#1	41	-2,2%	1,7%	2,0%	1,8%	**1,7%**	32%	7%
	Man.#2	49	-1,5%	0,6%	-0,2%	-1,6%	-0,9%	18%	4%
	Man.#3	9	**-6,6%**	3,3%	1,6%	2,6%	**2,4%**	11%	0%
	Man.#4	14	**-21,0%**	-1,8%	-0,7%	-0,7%	-0,9%	0%	36%
*MPE in subsequent verification**			*±6,0%*	*±3,0%*	*±3,0%*	*±3,0%*	*±1,2%*	-	-

* equal to twice the MID MPE (to be confirmed in a specific italian decree).

Results (by manufacturer)

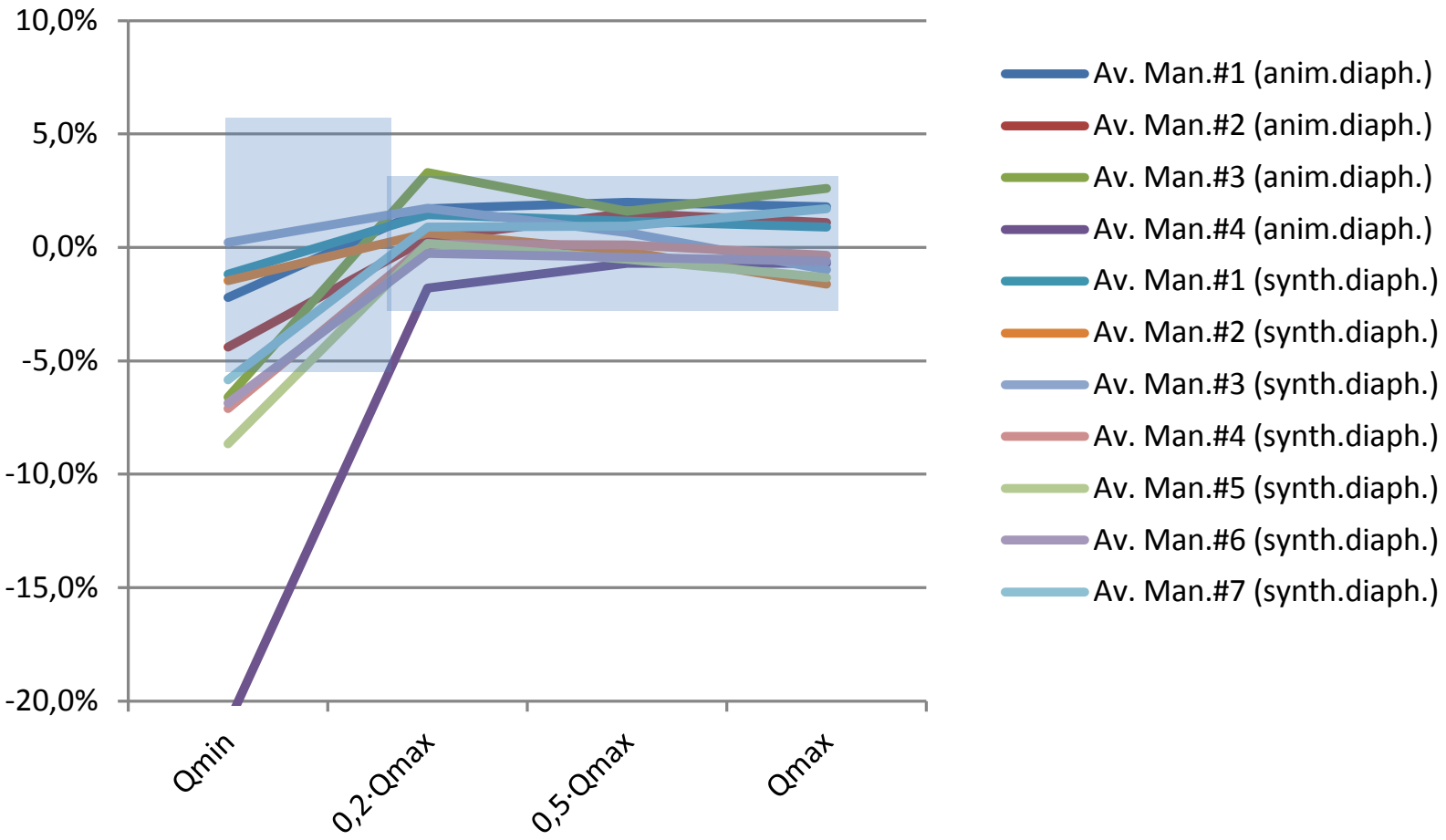


Fig.9 – Average error of indication of the animal diaphragm gas meters tested, grouped by manufacturer and compared to the conformity area in subsequent verification*

Results (by average yearly consumptions)

Table 3 – Average error of indication of the diaphragm meters grouped by class of yearly consumptions

Average year consumptions (m^3/year)		Number of meter tested	Average E%				WME	% of meters presenting at all the test flowrates	
			Q_{min}	$0,2 \cdot Q_{max}$	negative errors	negative errors		negative errors	positive errors
synth	<100	33	-2,5%	1,0%	0,4%	-0,5%	-0,1%	24,2%	9,1%
	100<C<500	57	-4,0%	0,5%	-0,1%	-1,0%	-0,5%	17,5%	10,5%
	>500	40	-2,4%	0,8%	0,2%	-0,9%	-0,4%	20,0%	7,5%
animal	<100	37	**-9,2%**	-0,8%	0,7%	0,6%	0,4%	16,2%	16,2%
	100<C<500	38	-3,7%	1,3%	1,3%	1,5%	**1,4%**	2,6%	23,7%
	>500	42	-3,8%	1,8%	2,1%	1,6%	**1,7%**	7,1%	21,4%
overall	<100	70	-5,6%	0,1%	0,5%	0,1%	0,2%	20,0%	12,9%
	100<C<500	95	-3,9%	0,8%	0,5%	0,0%	0,2%	11,6%	15,8%
	>500	82	-3,0%	1,3%	1,1%	0,4%	0,7%	13,4%	14,6%
*MPE in subsequent verification**			±6,0%	±3,0%	±3,0%	±3,0%	±1,2%	-	-

* equal to twice the MID MPE (to be confirmed in a specific italian decree).

Results (by average yearly consumptions)

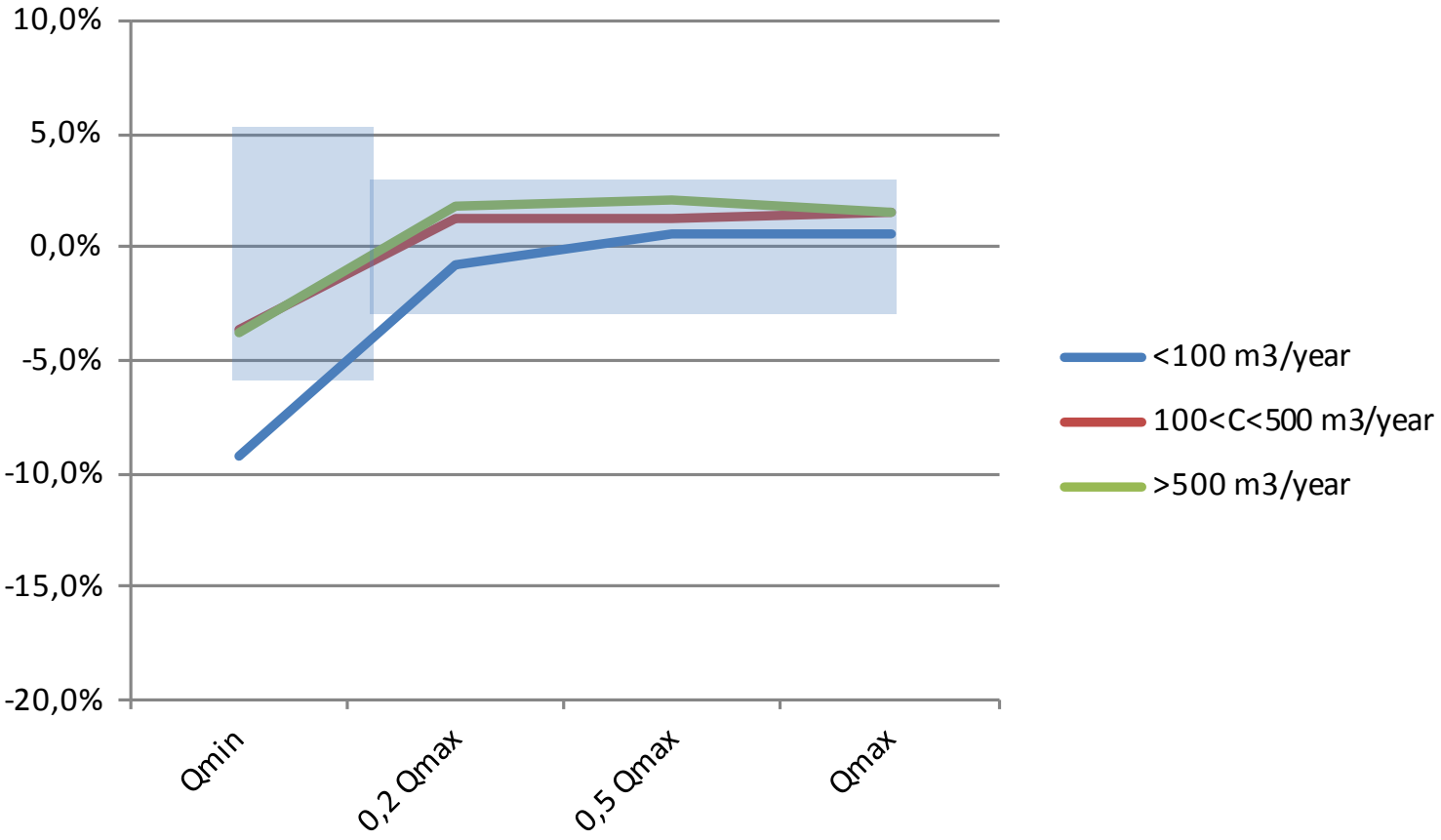


Fig.11 – Average error of indication of the animal diaphragm gas meters tested, grouped by class of average yearly consumptions and compared to the conformity area in subsequent verification*.

Results

- All the meters tested for the **pressure absorption** have been found largely within the predicted limit of 2 mbar, even if the synthetic diaphragms meters present average pressure absorption values higher than the animal diaphragms ones and this is probably due to the lower cyclic volume of the synthetic diaphragms in respect to the animal diaphragm one.
- During **disassembly** and visual inspection no tampering have been found.
- Only few animal diaphragm meters failed the **external leak tightness** and the **resistance to internal pressure** tests:
  - 5 meters (4 %) failed the external leak tightness test;
  - 14 meters (12 %) failed the resistance to internal pressure test

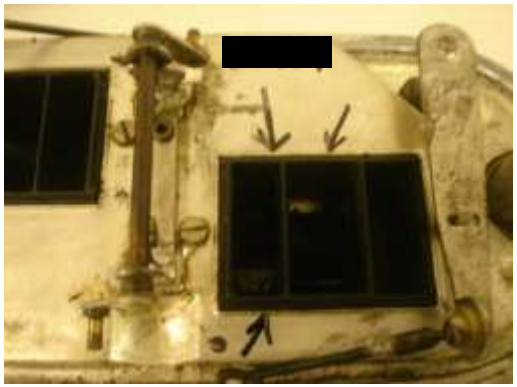


Figure 12 – Leakage from the grid of an animal diaphragm meter.

Figure 13 – Leakage from the internal case of an animal diaphragm meter

Summary/Conclusions

- The results of the tests performed are particularly encouraging both in terms of **consumers protection** and of **integrity of supplying**, as the average error of the meters tested is normally close to zero and the weighted mean error of the overall population is significantly lower than the permissible value in initial verification.
- The old **animal diaphragm** meters lie within the range ±6% at high flowrates and up to -30% (i.e. in consumer advantage) only at Q_{min}
- the **synthetic diaphragm** meters show a quite regular behaviour, with average errors very close to 0 except at Q_{min} with scattered errors (generally negative in consumer advantage) up to -15%.
- Some **manufacturers** present significant negative errors at Q_{min}
- These results seems to be encouraging also at **unaccounted for gas** level.

  In such scenario, with a very large number of similar meters (for size and measuring principle) installed in the distribution networks, the reduction strategies for UAG can rely on generally good metrological performance of the meters in terms of overall average error and systematic drift.

THANKS FOR YOUR ATTENTION