Report on the ageing study of gas meters for industrial use

This concise technical report presents the main results of an in-depth statistical analysis conducted on a significant sample of data collected during the periodic verification activities of static meters for industrial use (thermal-mass technology), in order to assess their performance behaviour over time.

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Introduction

The authors of this report have a long history of study and experimental experience in the field of fluid measurement instrumentation, and in particular for the metering of natural gas, in various fields. For more than two decades, they have been particularly active in the field of scientific and legal metrology, participating in various capacities in a multitude of scientific and technical activities.

The purpose of this metrological study is purely scientific. In view of the fact that the recent regulations regarding the periodic verification of natural gas meters are coming into force, it was considered useful to carry out an analysis of the performance of the gas meters for industrial use (≥ G10) after an initial period of use. In particular, given the different periodicity currently foreseen for the periodic verification of meters of new technology (i.e. with an electronic flow rate sensor, such as ultrasonic and thermal-mass meters) compared to the so-called 'traditional' ones (i.e. the mechanical ones, based on the volumetric measurement principle), cautiously introduced during the initial extension of the implementing decrees, it was deemed interesting to analyse the performance of the new static meters based on thermal-mass technology (in Italy there are still no significant samples of industrial gas meters with ultrasonic technology). All this is intended to contribute **to create that cultural as well as experimental, technical and scientific knowledge support useful to the entire community of insiders** (regulatory and ministerial institutions, research institutions, the Chamber of Commerce and Business Management). In other words, the Authors intend to make available to the"National Metrological System" (in the broadest sense) the results of a robust experimental campaign of periodic verifications and the consequent representative statistical analysis to verify whether, from the technical point of view, this prudential frequency (8 years for innovative technologies vs. 16 years for traditional technologies) is still justifiable today, or whether, in the light of the evidence of experimental observations, the innovative technology introduced a few years ago should be considered differently.

We would like to thank 2i Rete Gas for having shared these insights and for having made available to the Authors the results of a widespread campaign of periodic checks carried out on a sample of adequate number of homogeneous industrial gas meters (thermal-mass), after 8 years of service.

Description of the data set used

The statistical analyses presented in this Technical Report refer to a dataset collected during periodic verification activities and owned by 2i Rete Gas, kindly made available to the authors solely for the stated scientific and cultural purposes.

The sample analysed is highly significant, as it is represented by data from periodic verifications carried out at an Accredited Laboratory (Inspection Body) on 1582 homogeneous gas meters, all based on thermal-mass technology (all produced by a single supplier), all of G25 class, all installed in 2013 and all verified in 2021 (after 8 years of service).

From a statistical point of view, the sample is particularly favourable as it is extremely homogeneous, thus allowing an analysis that is not influenced by "spurious" factors and difficult to assess/quantify (although potentially very interesting), such as the effect of different meter classes, different moments of installation (as instruments installed at different moments could belong to different versions of the same model), of different moments of verification (as verifications at different moments could be carried out with different versions of the procedure) etc.

As regards the tests performed, the meters were experimentally verified at a third and independent Laboratory (Inspection Body), accredited UNI CEI EN ISO/IEC 17020 (using a 'standard' procedure approved by the accreditation body, compliant with current standards and DM 93/17). Laboratory tests were conducted with reference to five different flow rates (Qmin, Qt, 0.4 Qmax, 0.7 Qmax and Qmax), i.e. with a number of flow rates greater than the minimum flow rates (3) required by the Standard. For each test flow rate, 3 repetitions were carried out. The average values of the deviations and errors were subsequently investigated.

This allowed a more in-depth metrological analysis and statistical characterisation of the results, having more data available.

General Analysis

An initial analysis of the data consisted of a simple numerical evaluation of the meters that obtained three main evaluations, namely: "Not Verifiable" (instrument switched off or not functioning), "Verifiable Positive" (error contained within the range "in service MPE" or "in service accuracy": [± 6.5% ÷ ± 3.5%]), and "Negative Verification" (error outside the range [± 6.5% ÷ ± 3.5%]).

The result of this first analysis is considered quite encouraging. In fact, as can be observed in Table 1, the percentage of instruments that passed the verification is very high (about 97%).

	Absolute Number	Percentage of the total (%)
Meters Analysed	1582	100
Not Verifiable	41	2.59
Positive Verification	1534	96.97
Negative Verification	7	0.44

Table 1 - Overall results

In particular, it should be noted that the percentage of meters with Negative Verification is less than 0.5%; on the other hand, the percentage of instruments that could not be verified is clearly higher (over 2.5%), although this value can be considered physiological, as it covers all possible cases of *failure* (display failure, low battery, etc.). Nor should we overlook the fact that, as will be seen later, all these cases could be due to problems during transport to the Metrological Laboratory.

Numerical Results

A more detailed analysis was then carried out. The calibration results of all meters with positive verification were first diagrammed together with the standard limit curves, showing that the response curves were, in most cases, well within the above-mentioned limits. This suggested that the limit curves for new meters should also be included in the graph (i.e. the limit curves of first installation).

The diagram shown in Figure 1 was thus obtained. In this diagram, the red lines represent the limit curves for periodic verification [± 6.5% ÷ ± 3.5%], while the green lines represent the limit curves for pre-test measurement verification [± 3.5% ÷ ± 2.0%]. As can be seen, a large number of measurement points fall within the limits for pre-test verification. It was therefore considered interesting to assess how many instruments had a response curve entirely within the pre-test verification limits. The result was that 1260 meters (82.1 % of the meters with positive verification of the meters analysed) fall into this category, thus showing excellent resistance to ageing.

Positive Verification

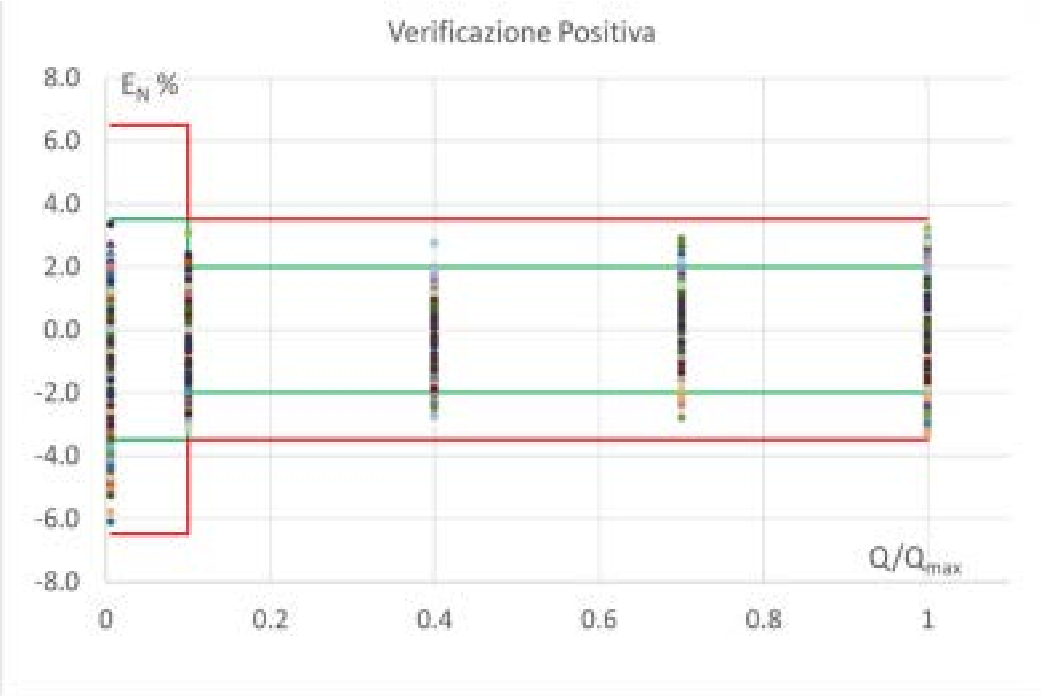

Fig. 1 - Response curves of meters with positive verification

The next step was a more detailed analysis of the experimental results. In particular, for each test flow rate, the statistical distributions of EN % were analysed in relation to the instruments that passed the verification; this analysis led to the graphs shown in Figures 2 to 6.

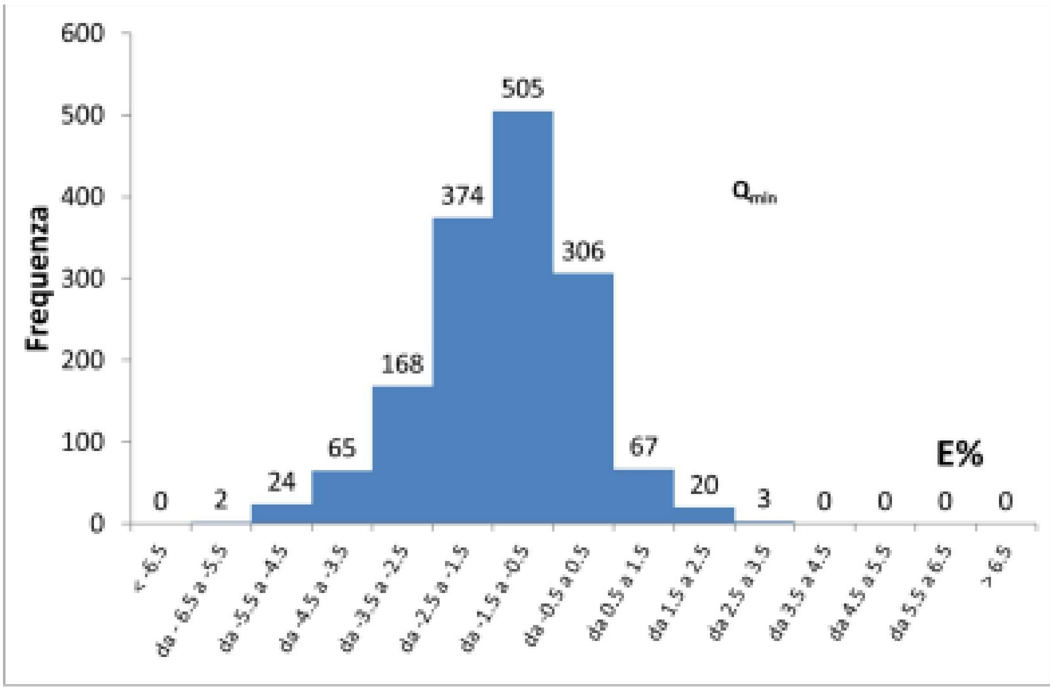

Fig. 2 - Frequency of percentage deviations EN % at flow rate Qmin

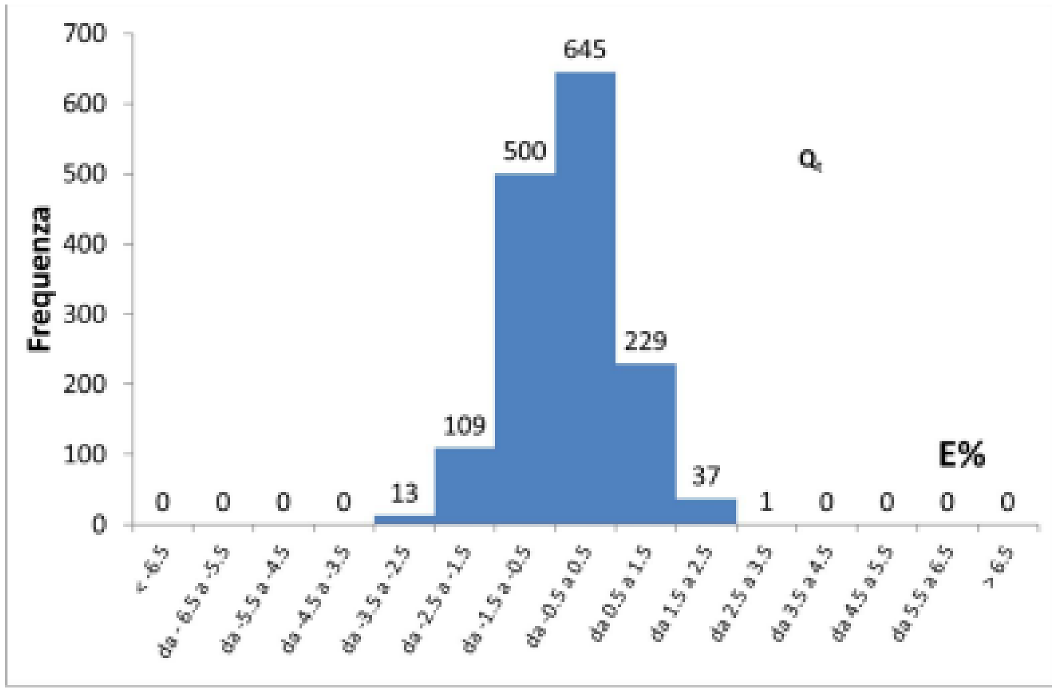

Fig. 3 - Frequency of percentage deviations EN % at flow rate Qt

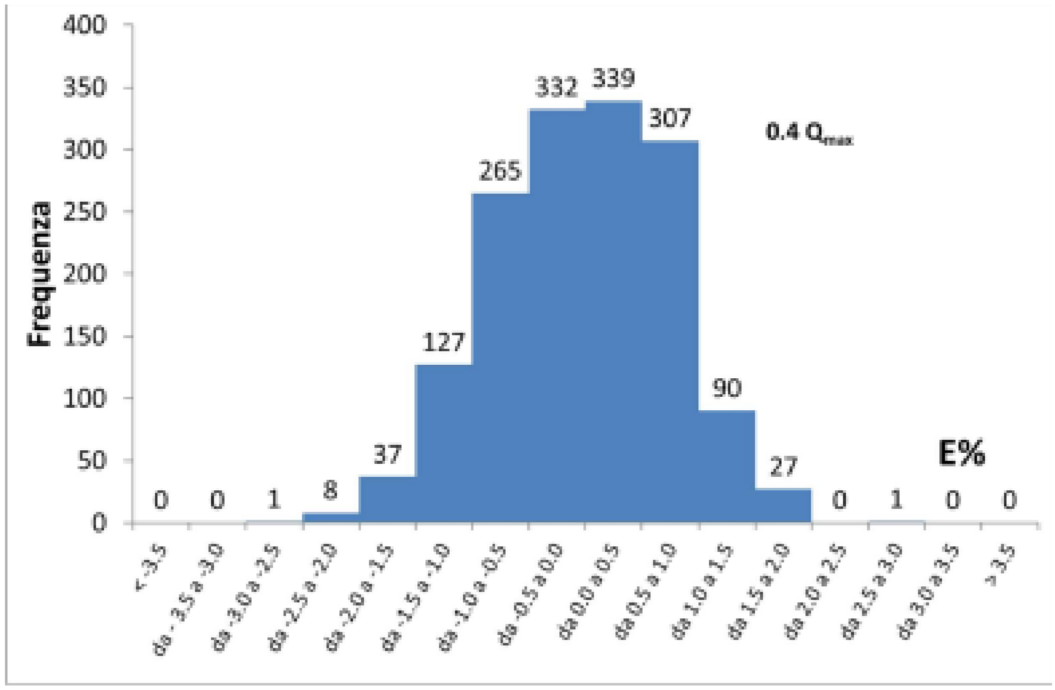

Fig. 4 - Frequency of percentage deviations EN % at flow rate 0.4 Qmax

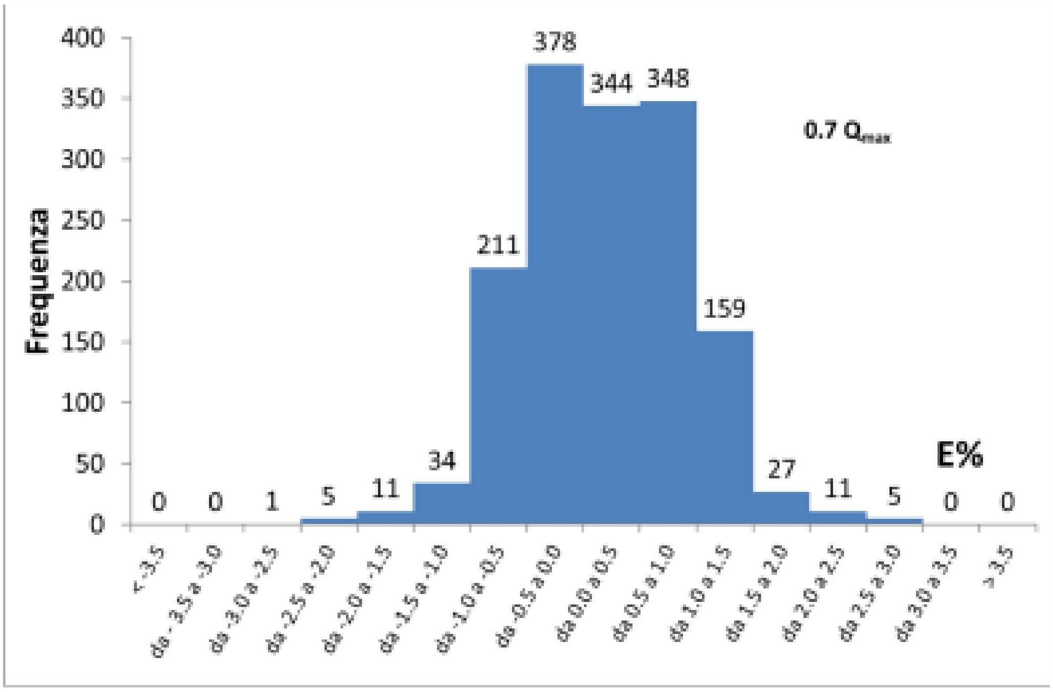

Fig. 5 - Frequency of percentage deviations EN % at flow rate 0.7 Qmax

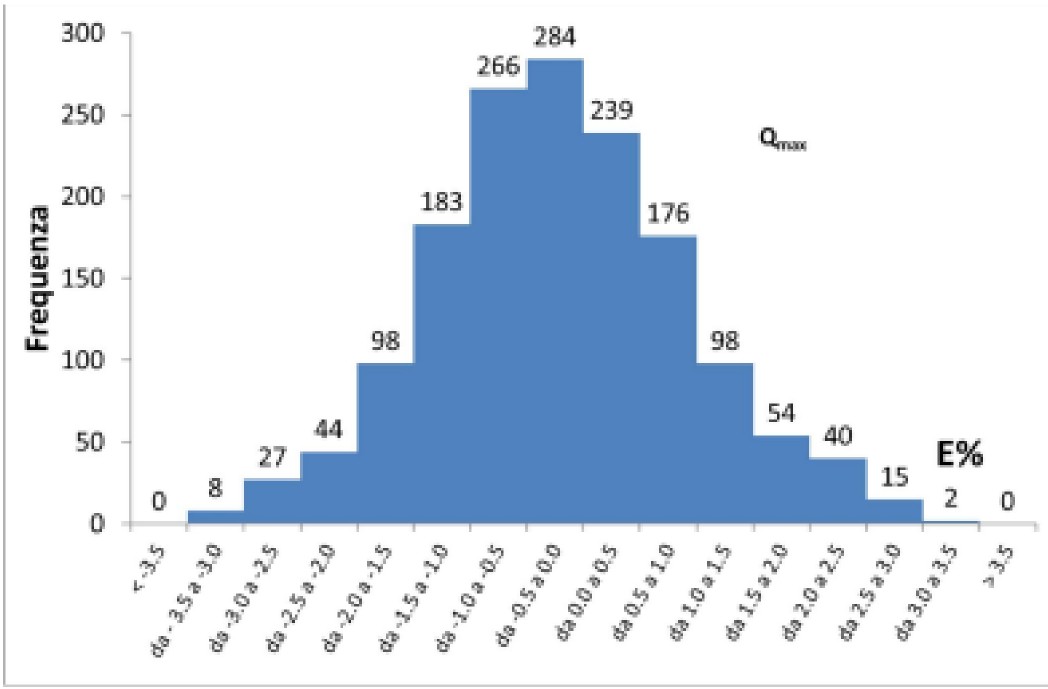

Fig. 6 - Frequency of percentage deviations EN % at flow rate Qmax

As can be observed, in almost all cases a symmetrical distribution is obtained, which well approximates a Gaussian curve (except in the cases of the flow rates 0.4 Qmax and 0.7 Qmax where the distribution appears asymmetrical). From these graphs, one can also observe the predominance of periodically verified indications that comply with the pre-test verification values.

Subsequently, an analysis of the performance of the instruments according to the 'state of use'was made, i.e. depending on the value recorded on the totaliser (marker or display reading), detected at the time of their dismantling. First of all, it should be noted that this datum could be recorded for all 1582 instruments in the original sample; this fact indicates that, at the time of dismantling, each individual meter was able to provide an indication, from which it can be deduced that the instruments for which the verification could not be carried out suffered some kind of malfunction following their disassembly, which in turn implies that, as long as they remained in place, they were functioning correctly.

The gas meters were then divided into six groups, of approximately the same consistency, according to the measured totaliser value. The general data for the six groups are shown in Table 2.

Totaliser	Number of the group	Results Not Verifiable	Verification(% of group) Negative	Positive
Up to 38000	261	0.00	0.38	99.62
38000 to 70000	290	3.79	0.34	95.86
70000 to 100000	291	2.41	0.69	96.91
100000 to 130000	277	1.81	0.00	98.19
130000 to 180000	264	3.79	0.76	95.45
Over 180000	199	4.02	0.50	95.48

Table 2 - Verification results divided by totaliser value

As can be seen, there is no noticeable effect of the totaliser value on the overall distribution of the results, or in other words, it is not detectable, at least from these data, an"ageing effect" resulting from the greater or lesser use of the instruments. On the other hand, this result is not particularly surprising, given that the measurement technology analysed (static) does not involve the presence of moving parts or in any case subject to wear and tear associated with usage time.^

Conclusions

Thanks to a specific database made available to the authors by 2i Rete Gas, it was possible to carry out a statistical study on verification results after 8 years of operation, with reference to a very homogeneous sample of industrial gas meters (G25), with thermal-mass measuring technology.

All the statistical analyses carried out showed a very convincing response of these instruments eight years after first installation. The vast majority (approximately 97%) complied with the limits of the so-called *in-service accuracy* (± 6.5% ÷ ± 3.5%); a considerable percentage (more than 80%) even compliant to the pre-test verification limits (± 3.5% ÷ ± 2.0%).

Based on the above, it can be stated with good evidence that the thermal-mass technology tested is practically insensitive to the effects of operating time, confirming the typical performance of static measurement technologies, widely documented in technical literature.

^ The components of the instruments tested are clearly not immune to deterioration associated, for example, with presence of abrasive or corrosive substances in the measured fluid. However, this effect is not evident through this analysis, which at most can detect wear associated with usage alone.