AnMar Research Laboratories B.V.

Comments on

Kiwa-Gastec Report ``Correctheid van de gasmeting bij kleinverbruikers" (26 september 2007)

Background

Recently, Kiwa-Gastec initiated a combined theoretical, experimental and field-study on the quality of residential gas metering in the Netherlands. This initiative is by request of the Dutch Minister of Economic Affairs, and is in reply to two reports by AnMar Research Laboratories of March and June 2007 under the title ``Residential Gas Metering: How Good is It?"

The Kiwa Gastec report of September 2007 focuses on Phase I: a consideration of the metrological quality of bellow meters (mostly G4) and a theoretical and laboratory studies on heat-transfer in the pipes, connecting the bellow meter inside homes to the outside residential gas network.

Summary of Comments

The proposed Kiwa-Gastec research plan is comprehensive, as outlined in Section 2 of their report.

The data in the Kiwa-Gastec report confirm the main assertions made by the AnMar Research Report:

1. The gas temperature in the bellow meter assumes the ambient temperature within about 3 degrees Celsius, independent of the temperature in the outside gas network.

2. Residential gas usage is highly intermittent with a duty cycle of about 10%. As a result, most gas usage is in the form of bursts of 30 minutes or less (with a burst volume of 1m3 or less). This is equal to or less than the thermal time-scale of the bellow-meter and its connection to the outside gas network, as may be seen also from the step-response shown in Fig. 3 of Kiwa-Gastec. As a result, the 3 degrees Celsius temperature deviation mentioned above is a conservative estimate—the true deviation will be less on average.

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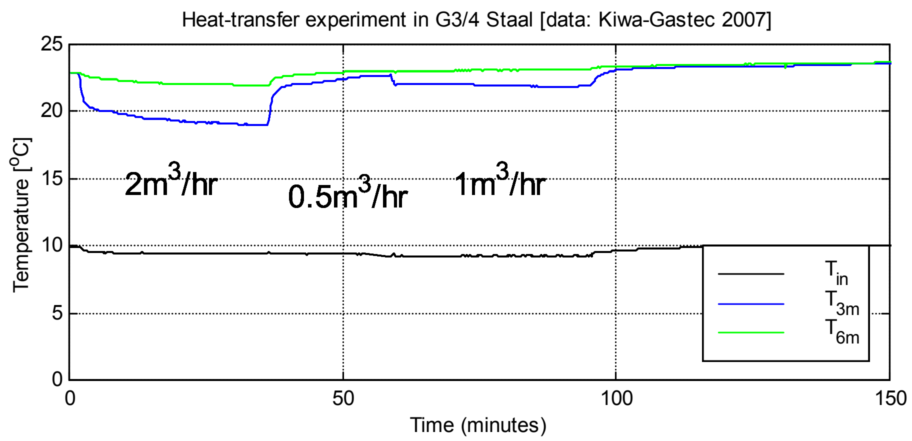
3. In the two field-studies A and B reported in the AnMar Research Report of June 2007, the ambient temperature assumes a mean value of 20.1 degrees Celsius.

4. There is an over-registration of 4.7% due to a discrepancy between true temperature at metering and the 7 degree Celsius method presently used for billing.

5. The metrological data show that in the most-commonly used flow-regime of around 0.2Qmax, i.e., 32 L/min for a G4, the average error is 0.92 with a standard deviation of 1.43%. With 65% probability, the error in the bellow meter of an individual user, therefore, is within -0.52% and +2.35%, giving a total between 4.18% and 7.05%.



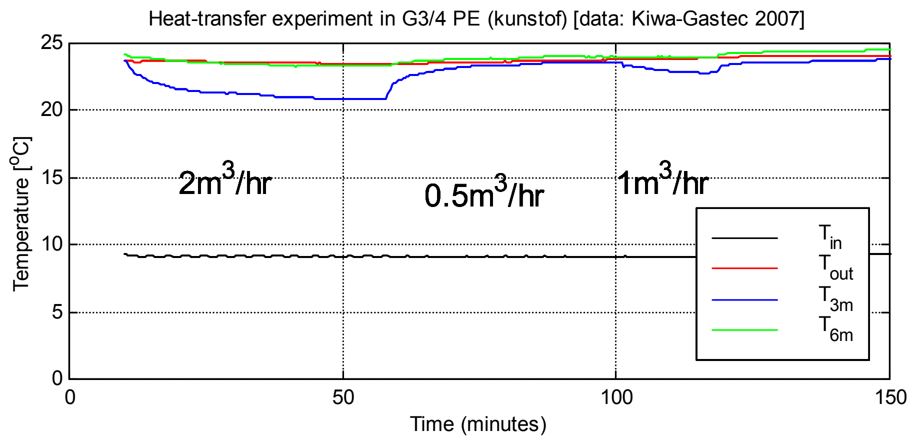


Figure 1. Shown are the Kiwa-Gastec data on two heat-transfer experiments performed on a long tube steel and PE tube, connecting a low-temperature air supply to a bellow meter. The results clearly show that the "metering temperature" (here in the form of a 3m and 6m distance to the air supply) remains close to the ambient temperature to within about 3 degrees Celsius, and associated thermal time-constant of about 30 minutes or more. The results See Kiwa-Gastec report for details.

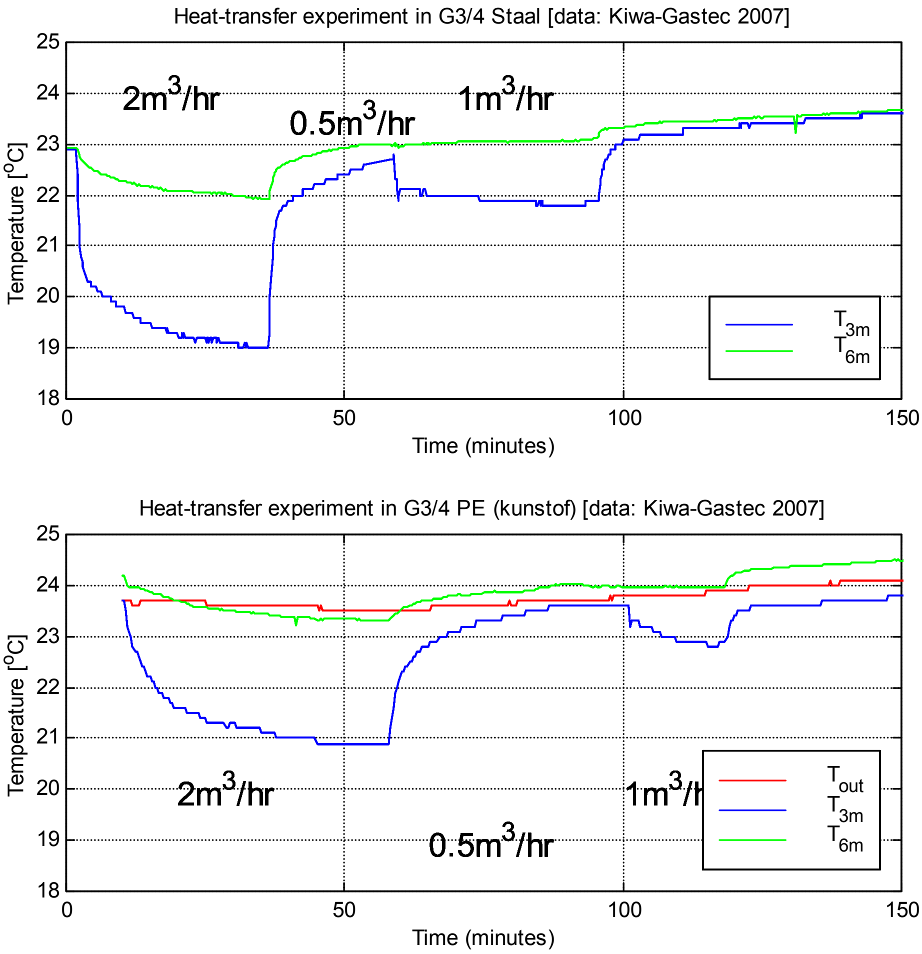


Figure 2. Shown are the Kiwa-Gastec data as in Fig. 1, enlarged to show the induced temperature fluctuations.

Note 1. It is noted that the Kiwa-Gastec report does not have any references to the scientific literature, and therefore does not, in its current form, meet the standards for publication in a refereed journal.

Detailed comments

Heat-Transfer

Heat-transfer, as mentioned in Appendix F of the AnMar Report of June 2007, is a well-developed topic in theoretical, computational and experimental fluid dynamics. It is surprising that the Kiwa-Gastec Report lacks a single reference to this body of scientific literature. In particular, it does not mentioned the fluid dynamical quantities known as Reynolds and Nusselt number, which are of particular importance to the subject matter at hand.

While it is laudable that Kiwa-Gastec has performed laboratory experiments on heat-transfer in pipes, these experiments are well-known and well-described by correlation functions between Reynolds and Nusselt numbers. Existing experiments show that for a fully developed turbulent flow, which is the regime of interest to natural gas streaming into a residential bellow-meter through a G3/4 pipe, heat-transfer is strongly enhanced according to the Dittus-Boelter correlation. As a result, the characteristic length-scale for heating depends only very weakly on flow-rate (i.e.: Reynolds number). In fact, this is precisely the result recovered in the Kiwa-Gastec experiments at 6m distance for the PE tube experiment, as shown in their Figure 5.

Note 2. It should be noted that the experimental measurements of Kiwa-Gastec should have included measurement of the ambient temperature in the laboratory. These data are not included in any of their figures. Moreover, the outlet temperature in the experiments on the steel tube are also missing (it is included in the PE experiment).

A detailed consideration of the data, kindly provided by Kiwa-Gastec in Excell format, shows that there are considerable fluctuations in the asymptotic, late-time temperatures. For example, in the experiment on the PE tube, the outlet temperature at 3:00 hr is lower than the (inlet) temperature of the gas at 6m. Either there is some information missing, or there is a temperature offset between the temperature probes, to account for this puzzling result. Consequently, the measurements do not appear allow for high-precision data-analysis, and this may be a result of too large variations in indoor ambient temperatures.

Theoretical Modeling and Existing Literature

As noted by the authors, the Kiwa-Gastec results disqualify the theoretical model in Appendix II of their report. Indeed, their model does not take into account the enhanced heat-transfer in turbulent flows. Nevertheless, the authors draw the erroneous conclusion"

"It is evident that with an increase in gas velocity, the [characteristic] length-scale for heating becomes larger. In the figure this is apparent from the graph shown. An enhancement of the gas velocity from 1m/s (curve 1) to 5 m/s (curve 2) results in a significantly larger length-scale for heating."

In reality, there is no "significantly larger length-scale for heating." As the Dittus-Boelter correlation shows, the characteristic length-scale for heating varies only very slowly with Reynolds number (in the regime of a fully developed turbulent flow, i.e., Reynolds numbers much larger than 2500).

Here, consultation of the existing refereed literature would have prevented this mis-interpretation.

Also, the authors could have consulted the detailed KNMI data for the De Bilt weather station (1902-2006) and the available KNMI soil temperature data for the same location (1981-2006). The former shows that, for the Dutch climate, pressure variations are essentially uncorrelated to temperatures during Winter, see Fig. B.1 in the AnMar Research Report of June 2007. Averaged over years, there is no apparent impact of pressure variations on billing (should be relatively negligible).

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