Flow Measurement - An Objective Tool for Inspection of Water Distribution Systems

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The availability of drinking water in Germany is one of the basic needs of its population. Beyond this, it is also necessary to provide water for other purposes. This demands a sophisticated logistical system. Drinking water quality must be kept consistently high on its journey from source, through treatment, to consumer. An intact transport network is an important factor in the security of the supply. In Germany, water is transported by a water distribution network comprising around 500,000 km of underground pipes. These must be operated without leakage.

The supply of drinking water is regulated by law. As such, the water supply companies carry a special responsibility in fulfilling the requirements of the legislation. This legislation governs not only the construction of the public water supply network, but also the operation, maintenance and repair of its associated systems. Specifically, supply companies must comply with the requirements of the Drinking Water Ordinance (TrinkwV) and the regulations for general engineering standard practice as specified by DVGW (German Technical and Scientific Association for Gas and Water).

In certain federal states, the requirement to handle drinking water economically is laid down in the Federal State Water Supply Laws. In these states, the water supplier is obliged by law to consistently minimise the volume of their primary asset, water that is lost.

This requirement is also reflected in the DVGW rules for general engineering standard practice. These rules describe various measures for the inspection of the drinking water pipe network as the basis of a safe, secure and economical pipe network operation. Measures are also described for avoidance of harm to people or damage to property. Ecological reasons also form part of the basis for the measures described.

In its 2006 study entitled "The German Water Sector", the Federal Ministry for the Environment wrote:

"The percentage of leakage in a distribution system is no doubt the most important quality parameter for the state of repair of pipelines and pipe fittings, including operation and the condition of maintenance. If the pipe system is out-of-date, in a bad condition of maintenance, or poorly operated and monitored (so that, for example, water is illegally abstracted), a correspondingly high rate of leakage results. Even though Germany is a country that is abundant in water, the water utilities have been required for decades to minimise leakage - whereby hygienic and ecological aspects also play a role, next to economic considerations (Every cubic meter of transported and treated water that is lost also means a wasted use of energy, chemicals, etc. Not only treated drinking water is lost through leakage; under certain circumstances, pollutants may also enter into the water system, which results in a contamination of the drinking water). A high leakage rate in a water distribution system signals deficiencies in the condition of the pipes and fittings, old age and pending need for renewal, and / or deficiencies in the ongoing maintenance and leakage-monitoring." It is clear then that supply companies must pay very close attention to the condition of their networks.

Water networks must therefore constantly be monitored with respect to their condition during operation in order to meet the requirement for preventative, goal-oriented, targeted maintenance. To achieve this, every affected component and operational facility in the system must be regularly inspected. In certain cases, inspections may also be necessary because of special circumstances.

Monitoring the water network

DVGW Code of Practice W 392 (A) (05/2003) requires drinking water networks to be monitored and/or inspected for leaks. The primary factor in determining the type and scope of the necessary measures, and the amount of time between inspections, is the amount of water leaked (Fig. 1). In cases of low water loss, as defined in the guideline levels given in the table (Fig. 2), direct leak detection methods are deemed sufficient and leak testing is not necessarily required.

Specific water loss range (q_{VR})		Low	Medium	High
Recommended time between inspections in years		Max.6[1]	3	1
Flow measurement	- Continuous	●	●	●
	- Instantaneous	●	●	●

Alternatives

Prelocation methods	Pin-pointing methods			
Listening stick (metallic materials)	Diaphragm geophone	●		
Test rod	Ground microphone	●		
Correlation	Correlation	●		
---	Gas inpection method	●		
Noise Level measurement	---	●		
Pressure measurement	---	●		
Temperature differential measurement	---	●		
Dye testing	Pig method	●		

[1] Unless additional inspections are necessary due to circumstances defined in Sect 4.2

Figure 1: Water loss, required measures and intervals, DVGW W 392 (A)

For leak testing, Code of Practice W 392 (A) recommends the inspection intervals specified in Figure 1.

Information about leaks in drinking water networks can be obtained by a water volume balance, but also by flow measurements. Essentially, this means determining all inflow and outflow quantities, all the way to the end customers. Individual consumption volumes, plus all additional outflows of drinking water that cannot be calculated, must be established. These figures can then be used to calculate the specific real water loss. The value calculated serves as a key indicator for evaluating the condition of the network and is compared to the reference values in the regulations

Supply area		Water loss area (q_{VR}) Low $[m^3/(km \times h)]$	Medium $[m^3/(km \times h)]$	High $[m^3/(km \times h)]$
Area 1	City	< 0,10	0,10 - 0,20	> 0,20
Area 2	Town	< 0,07	0,07 - 0,15	> 0,15
Area 3	Rural	< 0,05	0,05 - 0,10	> 0,10

Figure 2: Reference values for specific real water losses, q_{VR} in pipe networks as per German Technical and Scientific Association for Gas and Water (DVGW) W 392 (A)

According to the DVGW regulations, flow measurement is the standard method for conducting the leak testing required on the drinking water network. This method has the following advantages:

- Objective method of reducing water leaks
- Determine overnight minimum consumption levels
- Measurement-based determination of leakage volumes

Special software is used to evaluate the data gathered.

Requirements and methodology

There are two basic methods of flow measurement:

- Continuous flow measurement
  - o Overnight minimum consumption measurement
  - o Water leaks can be detected with relatively good reliability
  - o The ratio of consumed volume to inflow volume must be available as a reference value
- Instantaneous flow measurement
  - o Zero-consumption measurement
  - o Water loss detected immediately
  - o Residual consumption can be evaluated

There are a number of prerequisites that must be satisfied (Fig. 3). If any of the valves do not seal properly, then flow measurement will not be possible. One of the prerequisites is therefore that comprehensive maintenance is carried out on the fittings.

Prerequisite	Flow Measurement Continuous	Instantaneous
Flowmeter	Stationary	Mobile
Slide gates properly sealed	Yes	Yes
Zoning of pipe network	Yes	Yes
Length of pipe network in zone	4-30 km	1-10 km
Measuring time	Min. 1-2 h/d	Min. 20 min.

Figure 3: Prerequisite conditions for flow measurements as per DVGW W 392 (A)

The big advantage of both methods lies in the fact that relatively large areas (Fig. 4) can be tested for leaks within a relatively short amount of time. It is then possible to successively

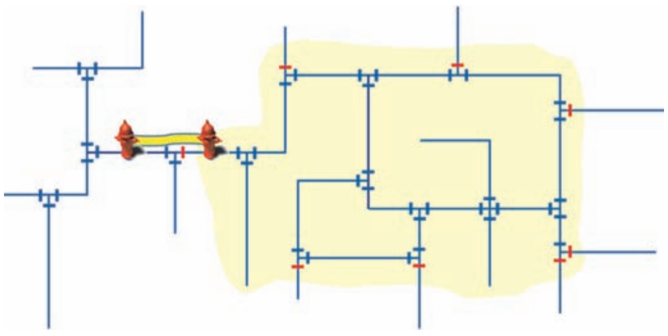

Figure 4: The principle behind setting up an instantaneous flow measurement

narrow down the location of the leaks within the measuring area by varying the test zone by closing different valves to those first selected.

The common feature of both alternatives is that the entire network must be divided into zones, which can be shut off individually from the remainder of the network. This often represents a considerable problem, particularly in aging, tightly interconnected or 'evolved' sections of the network. Figure 4 illustrates the principle behind setting up an instantaneous flow measurement.

Figure 5: Portable measuring unit

Once the measuring area has be shut off (marked red), water is fed from a hydrant outside the test zone to another hydrant inside the zone being investigated via a bridging hose and a portable measurement unit (Fig. 5). Information about pressure and flow rate is recorded via the evaluation software. The results of the measurements can then be processed and used for a variety of evaluation and documentation procedures.

Value range		Residual consumption volume (Q_{Verbr}) (per 1,000 inhabitants supplied)
1	[m³/h]	0,4 - 0,8
or		
2	[l/min]	7,0 - 14,0
Pipe network zone	Inhabitants	2.000 - 40.000

Figure 6: Reference values for residual consumption volume Q_{Verbr} as per DVGW W 392 (A)

When a measurement is performed for a specific area, the times of lowest consumption need to be established. At the same time, the volume of water flowing into the area is measured.

The number of inhabitants in the measuring area also has to be considered at the planning stage. As the number of inhabitants increases, the base load in the area will reach a point (dependent on the diversity factor of the consumption in the area) at which it is so high that a meaningful measurement is no longer possible.

Supply area		Pipe network inflow (q_N) [m³/(km x a)]
Area 1	City	> 15.000
Area 2	Town	5.000 - 15.000
Area 3	Rural	< 5.000
Range	Total	2.000 - 40.000

Figure 7: Reference values for specific pipe network inflow q_N as per DVGW W 392 (A)

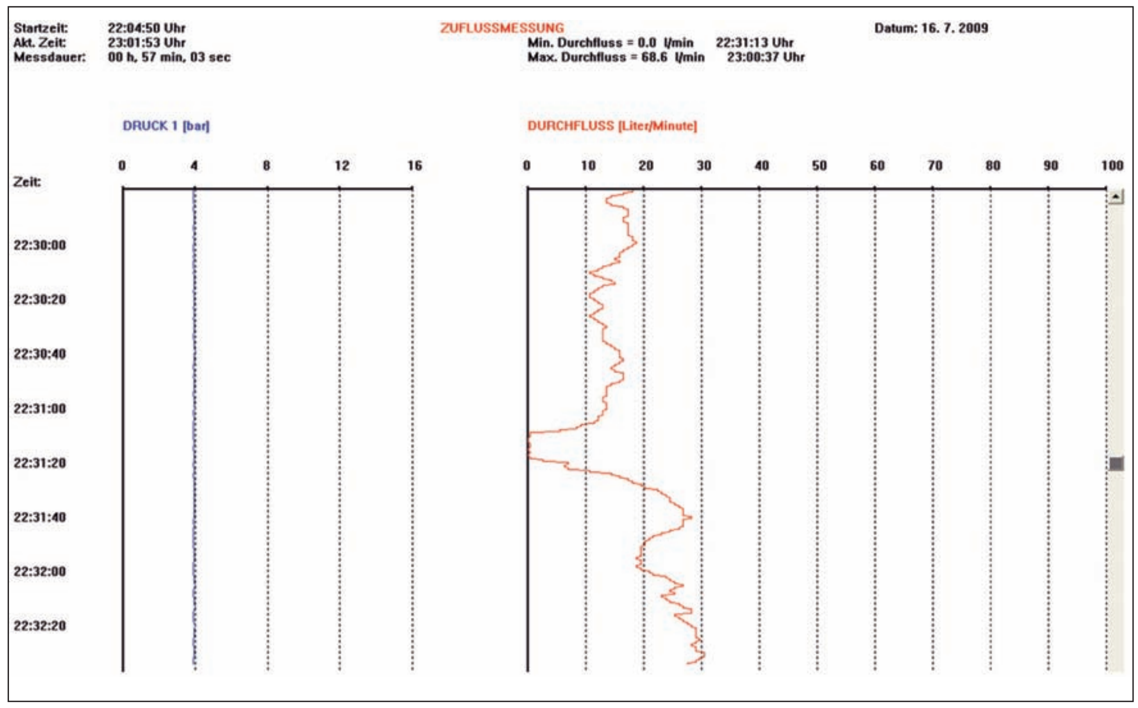

Figure 8

DVGW Code of Practice W 392 (A) lists reference values for the residual consumption volume with respect to the number of inhabitants in the area (Fig. 6). Additionally, the specific water network inflow (Fig. 7) must be taken into consideration with regard to the structure of the supply area.

Flow measurement in practice

The fundamental principle behind flow measurement is that every measuring area that is established will have to be continuously supplied with an almost constant volume of water. This volume corresponds to the sum of all individual losses within the measuring area and forms the basis for the real consumption. The volume of water supplied at the time of lowest consumption in a sealed-off measuring area is defined as the zero consumption.

In order to be able to evaluate the flow levels recorded during the measuring period, a previously calculated base value is required. This takes into account losses from both attrition and drips, as well as the average consumption based on the number of inhabitants.

During the measurement itself, a magnetic inductive flowmeter (MIF) is used to transmit measurement data to a computer.
The evaluation software shows the flow in the measurement area on a graphical display. If the hydrograph fluctuates up and down, this generally indicates the measurement area does not have any leaks - it is to be expected that a zero consumption level will be reached during the course of the measurement. If a point of zero consumption is observed during the measurement, this indicates that there are no leaks in the measurement area (Fig. 8).

If the display shows a relatively straight hydrograph reading, then it is highly likely that there is a water leak within the measuring area. In the latter case, the valves within the affected area must be successively closed off in order to narrow down the source of the leak. Once the last remaining section has been closed off, the location of the damage must be pinpointed using acoustic techniques.

The evaluation software will produce a measurement log without any gaps. In addition to the measured values, an electronic form is also provided that allows comments to be entered manually. These comments should be used to provide explanations in the measurement log for identifiable variations in the flow curve, for example the points at which valves were opened and closed.

An additional valve and/or hydrant log will also be produced by the system. This documents all state changes at the fittings, e.g. "opening" or "closing". Using this log, the operator can check whether the valves have all been returned to their original positions. This data is accessible at any time.

The logs that are created during the measurement, plus any additional documentation, will form the basis for subsequent investigations.

Additional options for flow measurement

When carrying out a flow measurement, the operator has access to the following functions:

- Calibration and adjustment of the measuring equipment before the measurement to check the measuring instrument.
- Checking leak tightness of valves in the measuring area using pressure tests.

This ensures that the measuring area is completely sealed off and that an objective measurement is therefore possible.

- Calculation of the "real" volume lost from the total flow. This is achieved by analysing the flow fluctuations.

With a view to the possibility of self-monitoring, clients are particularly interested in receiving information about the specific water consumption and water loss.

The evaluation of the measurement results provides the following figures:

- Overnight minimum consumption for each measurement area in cubic meters per hour (m³/h) as an average value over the entire measurement period, not including proportion of water lost through leakage.
- Water loss figure for the measuring area in cubic meters per hour per kilometre (m³/ (h x km)), not including proportion of water lost through leakage.

Summary

Flow measurement provides water supply companies with a means of preparing data suitable for comparison with the reference values defined in DVGW Code of Practice W 392 (A) for specific water loss.

As well as identifying leaking sections of the network, flow measurement is also able to determine the minimum consumption in the area inspected. These figures can in turn be used to determine the consumption patterns of customers connected to the network.

The ability to test the functionality of the valves and hydrants in the measuring area is a useful additional benefit that should not be underestimated.

Flow measurement can be used with pipes made of any material. Consequently flow measurement is a particularly efficient method of checking for leaks in non-metallic networks. It is an integral part of any maintenance strategy and provides valuable key data for evaluating the condition of the network. As a result, operators can establish what additional measures need to be taken to inspect and renew the network.

Planning and execution of inspection, maintenance and repair work should be carried out by a certified specialist company in accordance with DVGW Code of Practice W 491-1 (A).

In conclusion flow measurement is the optimum test method for meeting the obligation to maintain a sustainable, reliable pipe network that guarantees the supply of clean, safe drinking water and the conservation of value of the water supply companies' assets.