OTT CBS – The New, Compact Pneumatic Bubble Sensor

Figure 1: OTT CBS Bubble Sensor

Introduction

Today, the physical measurement principle of the bubble method in determining level in flowing waterways is known as a robust and reliable measurement principle. Its advantages, such as the minimum amount of work needed for installation, its suitability for use in very contaminated waters and its resistance to freezing, have led to the bubble method being selected as the measurement principle for more and more measurement stations.

OTT has been developing bubble gauges for more than 35 years for the continuous measurement of water level for surface waters. The result of its most recent development is a very compact bubble sensor, the OTT CBS. A special feature of this completely newly developed measurement system is its compact design, its low power consumption, high measurement precision, drift-free measurement and its ability to operate without an air drying unit.
The OTT CBS combines all the advantages of a robust and proven measurement principle with the most modern and reliable measurement technology.

Advantages of the Bubble Method

In addition to the advantages of the measurement method just described, there are other strong arguments in favor of using an OTT CBS in hydrology, in particular in comparison to pressure probes:

- Maximum protection against lightning strikes
- No contamination of the measurement cell membrane
- Very precise long-term measurement
- Low installation and maintenance requirements

Design and Functionality of the CBS

The OTT CBS essentially consists of 3 assemblies integrated into a single housing:

- Motor-gear-pump unit
- Pressure measurement unit
- Evaluation electronics with electronic interfaces

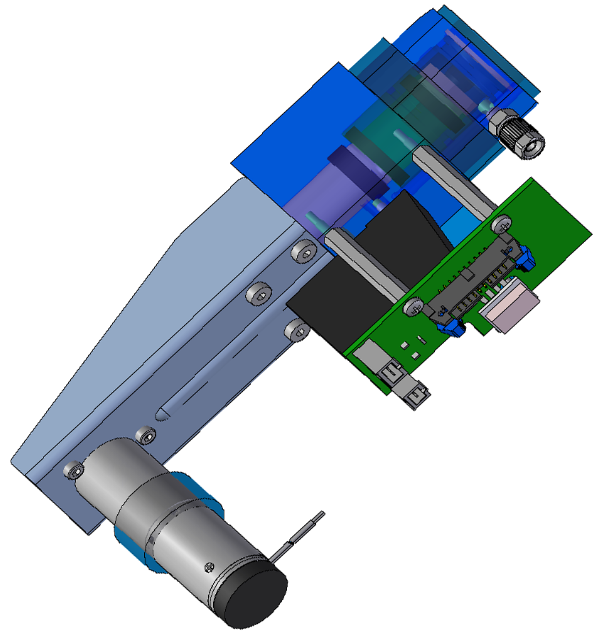

Figure 2: Motor-gear-pump Unit + Pressure Measurement Unit

A durable and fail-safe motor-gear-pump unit produces the pressure necessary for bubbling. This pressure is measured via the pressure measurement unit. The measured values are processed in the evaluation electronics and made available to a data logger via the 4 … 20 mA or the SDI-12 interface.

The OTT CBS bubble method has some design and measuring differences when compared with previous conventional designs which utilize constant flow via a compressor or a compressed air bottle; these include the use of a compact piston pump and air bubbling only for each actual measurement. These innovations have led to a reduction in the requirements for technical devices and significant energy savings.

The measurement process to determine the water level is done in 4 phases:

1. First, the current atmospheric air pressure is measured. This measurement is used to simultaneously perform a zero adjustment of the pressure measurement cell, which compensates for the influence of temperature on the beginning of the measurement – i.e. the thermal change of the zero signal and consequent errors as a result.
2. Then, pumping begins, i.e. bubbling into the measurement medium begins. In the process, an intelligent pumping strategy is used that meters the exact amount of air necessary to guarantee a precise measurement. In addition, this strategy provides for an optimum power usage and life of the pumping unit.
3. In the next step, the system is in an idle state in which the entire pneumatic measurement system (measuring tube – pressure measurement cell – bubble chamber) is allowed to stabilize/equalize.
4. In the last step, the pressure is measured above the bubble chamber opening after pressure equilibrium is reached ("steady state").

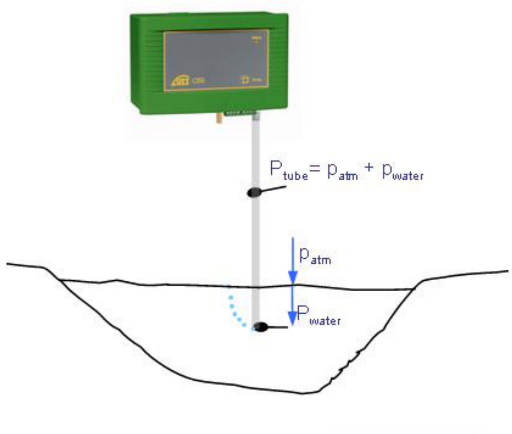

Figure 3: Determination of water level

The pressure above the bubble chamber opening is composed of the atmospheric pressure and the hydrostatic pressure itself. By finding the difference of the values measured at almost the same time in steps 4 and 1, the exact value of water level is determined.

Comparison of OTT CBS with Constant Flow Systems

Due to the measurement procedure described above, this method achieves considerable advantages when compared with measurements taken using the constant flow method.

Precision – Constant flow systems must be viewed as one single dynamic system. Similar to electronics, the entire pneumatic system – consisting of the measuring tube, the pressure measurement cell and the bubble chamber – is considered to be a single resistance R (a function of air friction). The pressure difference between the two ends of the system – at the pressure sensor and the bubble chamber opening – can be defined as Δp and the air flow can be defined as I.

Thus, $\Delta p = R \times \Delta I$.

In an "ideal" system, the resistance R and the air flow I are constant, i.e. ΔI is equal to 0 and thus Δp is also equal to zero and the measured pressure corresponds to the pressure present at the bubble chamber opening. During constant air flow, this is not the case. Due to water level changes, the air flow can not always be kept constant and this leads to errors. Measurement imprecision in a constant flow system arises from the control of the air flow and because the pressure measured is not constant throughout the entire measurement system.
In a static system such as the OTT CBS, the air flow is I=0. In the overall system, the pressure can be allowed to equalize, in other words the same pressure is found throughout the system (above the bubble chamber opening and at the pressure measurement cell). Measurement imprecision in the OTT CBS is thus only determined by the pressure measuring cell itself.

Drift-free measurement and offset compensation through relative measurement – the successive measurement of air pressure and measuring tube pressure, and the difference of the two signals being used for calculation purposes, allow drift-compensated measurement.
The differential pressure measurement process guarantees the highest long-term stability of the pressure measurements by generating a new reference value (zero point) for each measurement. The typical drift of pressure measurement cells caused by aging is thus completely compensated and thermal errors in pressure measurement are significantly reduced.

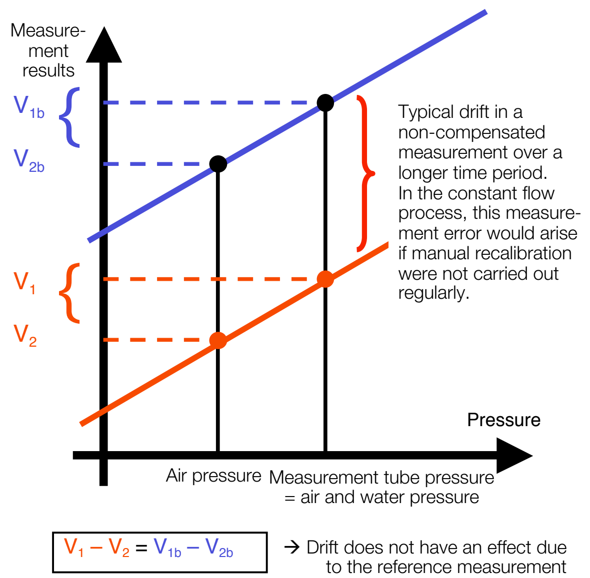

Figure 4: OTT CBS Drift-free Measurement Principle

Water level changes – in order to enable constant flow systems to provide reliable values, they must be set to a specific stage rising rate during installation. This is allowed to vary within narrow ranges. If the variance is larger, considerably measurement errors occur.

Durability – in a constant flow system, the pneumatic portion of the design is in continuous operation and thus subject to higher loads and higher wear.

Desiccant-free Operation

In contrast to constant flow systems, an OTT CBS system with a 15 m measurement range requires no air drying unit. In constant flow systems, the air for bubbling is provided via a pressurized tank filled under a high pressure. Air is compressed using a compressor for this purpose. During compression, the water vapor density of the air, which is the maximum ability of air to absorb water vapor, is exceeded. For example, if air at a relative humidity of 60 % and a temperature of 15°C is compressed to a pressure of 5bar and then cooled back to 15°C, about 33 g of condensate precipitates for every cubic meter of compressed air. For a 10 liter tank, this corresponds to an amount of about 1.6 g of water for each complete tank filling. Thus, it is clear that in a constant flow system, for disruption-free use an air drying unit is absolutely necessary, which adds to maintenance requirements.

In contrast, in the OTT CBS, air bubbling is only done at each measurement. In the process, air is pumped into the measuring tube using a compact piston pump. A special differential pressure valve opens the entrance to the measuring tube when the pump pressure is approx. 0.1 bar higher than the measuring tube pressure. Thus, at low water levels only low pump pressures are needed to measure the water level. This likewise reduces condensate buildup considerably. At a water level of 10 m, a pressure of about 1.1 bar is required in order to cause bubbling to occur. Under the same assumptions as in the above calculated example, 3.3 g of condensate precipitates in an OTT CBS. The pump of the OTT CBS has a volume of 3.6 cm^3 or 0.0000036 m^3. With one pump stroke per measurement, this amounts to 0.000012 g or 12 µg of condensate per measurement that precipitates.

In Diagram 2, it can be seen that even with a higher humidity (here 80 %) extremely low amounts of condensate precipitate in the OTT CBS in comparison to a constant flow system.

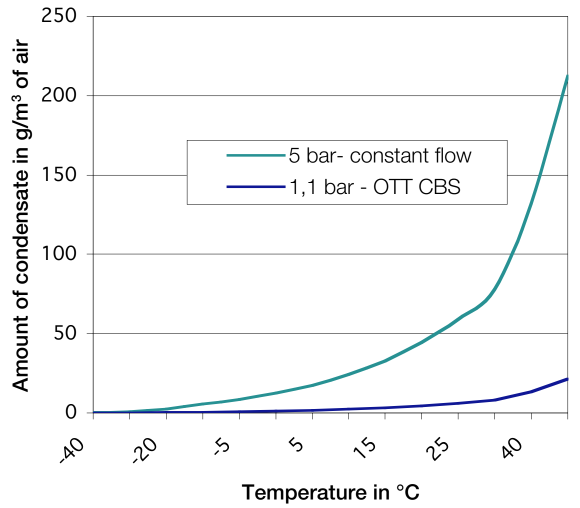

Diagram 1: Condensate at 60 % relative humidity per m^3

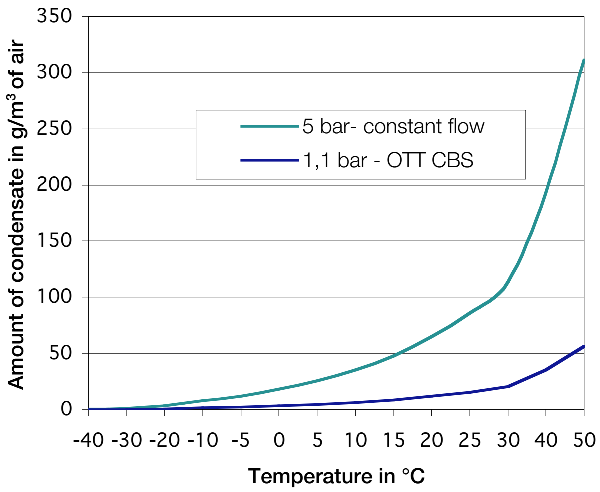

Diagram 2: Condensate at 80 % relative humidity per m^3

Calibration of the Pressure Measuring Unit

Each pressure measuring unit is calibrated in a climate chamber in a process lasting many hours at –20°C to +60°C, with a total of 1000 pressure-temperature values. These values are stored in the pressure measuring unit in a non-volatile memory. This procedure allows the pressure measuring unit to be used independently, i.e. the pressure measuring unit can be replaced easily in case of errors.

Low power consumption due to an intelligent pump strategy

By means of an intelligent pump strategy, the pumping time in the OTT CBS, or the number of pump strokes, is dynamically adjusted to the changes in level.
Level changes of up to 3 m per measurement interval can be detected in 14 seconds of pumping time up to a water level of 5 m. At a level of 15 m, a maximum level change of 1 m can be detected within a measurement interval. In waters with minimum level changes, it is sufficient to pump only once or twice per measurement interval. This intelligent pumping strategy thus makes possible optimum measurement of dynamic events at a minimum of power usage. In the following diagram, the daily power use of the OTT CBS is shown as a function of measurement interval at different water levels and minimal level changes. With a 15-minute measurement interval and a water level of 5 m and minimal level changes, the OTT CBS has a power consumption of 23 mAh per day.

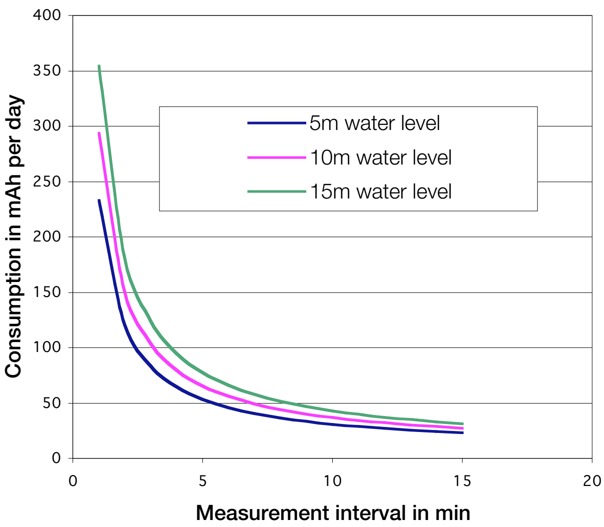

Diagram 3: Power consumption with minimal water level changes

Error diagnoses

The OTT CBS is capable of recognizing various error incidences. These errors are evaluated and output for each measurement query. The errors can be sent to a data logger via the SDI-12 interface. Errors can be read out via the status LED in 4 … 20 mA mode without the need for an external interface. Thus, it is possible to easily diagnose and correct errors when they occur.

Summary

The use of the bubble method in hydrometry is superior to the classical float method and to pressure sensor measurement when considering reliability, freezing resistance, and installation and maintenance effort.

Disadvantages of the bubble method known up till now, such as higher power consumption, larger measurement errors when levels increase rapidly, as well as drift, and maintenance expenses due to regular desiccant replacement, were justifiable objections to the use of constant flow systems.

Since the introduction of the static bubble method of the OTT CBS, these physically-related disadvantages are a thing of the past. Through design changes and modification of the measurement process, the average power consumption (in a typical hydrological application) was reduced to less than 1 mA. In addition, no measurement errors due to rapid level increases occur, and the system's measurement precision and long-term stability is better than 3 mm over a 3 m measurement range, and this precision lasts for a period of 5 years.

For the reasons illustrated above, the OTT CBS is the ideal level sensor for precise and reliable long-term measurement of levels in flowing waters or lakes for most hydrological measuring stations.

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