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METAS Calibrates Hydrometric Measuring Instruments

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The Federal Office of Metrology (METAS) operates on behalf of the Federal Office for Environment (FOEN) the calibration laboratory for hydrometric measuring instruments in Ittigen. It is accredited to ISO/IEC 17025/2005. It undertakes the calibration of measuring instruments employed to determine water flow velocity. It also conducts tow tests in order to assess measuring equipment prototypes and other devices for a wide range of applications.

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Edited by Christian Antener

Watercourses can only be monitored and controlled if the prevailing water flow rates are known. These velocities are regularly determined on site using hydrometric measuring instruments. Manufacturers and operators of these measuring instruments in Switzerland and abroad value the measurement, calibration and testing facilities offered by the METAS calibration laboratory for hydrometric measuring instruments.

Important hydrometric data

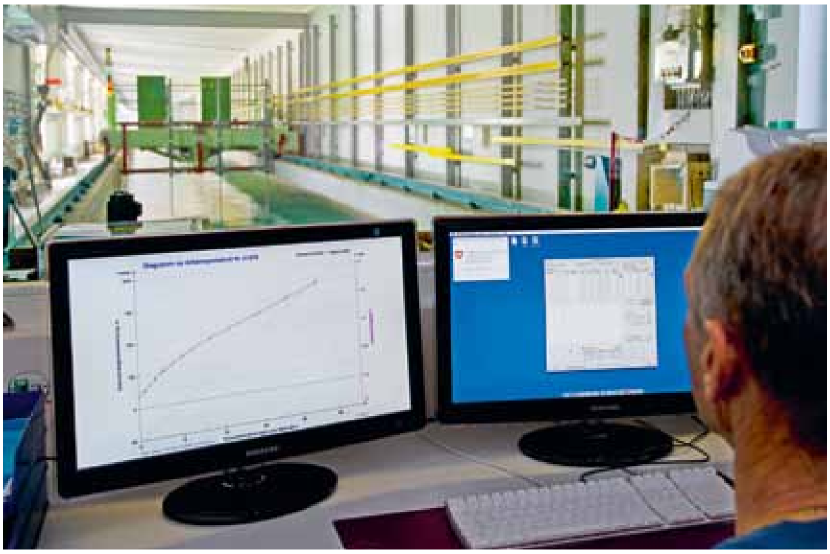
Flow measurements over extended periods of time provide information on maximum and minimum water volumes in rivers. The data sets gathered from these measurements are indispensable for flood prevention; however, they also serve to protect watercourses against overexploitation. Regular flow measurements help to ensure that power stations adhere to the prescribed obligatory water volumes. In addition, the flow data allow determination of the water charges which have to be paid by the power stations to the public authorities for making use of the water.

In order to determine the efficiency of hydroelectric power stations, it is necessary to know the exact flow rate and thus the velocity of the water ahead of the turbines. Calibrated hydrometric measuring instruments are therefore of vital importance for the energy and water sectors, for the turbine, pump and hydraulic engineering industries as well as for the upkeep, monitoring and maintenance of waterways.

Hydrometric measuring equipment

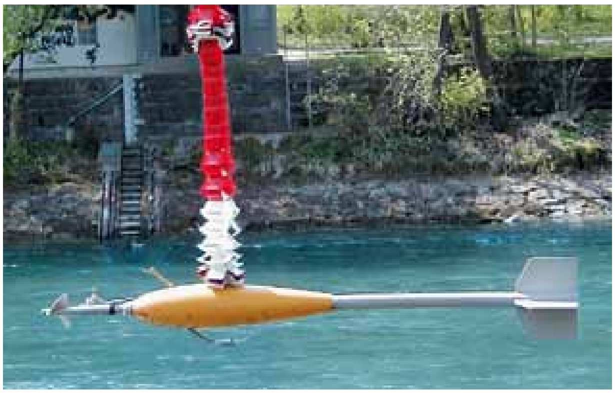
Impellers

Hydrometric impellers are the most widely used measuring instruments. Although they date from the early days of flow velocity measurement, they are still extremely popular, robust and accurate measuring instruments. They are calibrated in the METAS calibration channel under realistic and accurately controlled conditions. Factors such as banking-up, friction and other phenomena acting on the blades of these hydrometric impellers are the same in the calibration channel as in the field. Hydrometric impellers are employed on rods (picture 2) or weights (picture 3), depending on river size and water velocity.



1 The METAS hydrometric calibration facility is monitored from a control computer.

2 Impeller mounted on a rod.



3 Impeller mounted on a weight.

4 Magnetic-inductive measuring instrument.

5 Acoustic Doppler current meter (ADC).

Magnetic-inductive measuring instruments

Magnetic-inductive measuring instruments (picture 4) operate in accordance with Faraday's law of induction. The special feature of the devices used in hydrology is that the water does not flow through a tube within a magnetic field as is customary with this principle, but instead the magnetic field is established around a body and water flows around the outside of this body.

These devices are especially suited for use in sewage plants and in heavily vegetated waters. Since they are prone to interference by external magnetic fields, care must be taken when measuring that there is no interference by magnetic fields generated by electric power lines, for example.

Acoustic Doppler current meters (ADC)

In the 1990s, new types of measuring instruments were developed, especially in the USA, for the purpose of recording and studying ocean currents and stratification. These devices employ ultrasound signals and work in accordance with the Doppler principle. They are known as *Acoustic Doppler Current Profilers (ADCP)* on account of the fact that they not only measure speed at a point, but are capable of measuring entire velocity profiles in the water.

These oceanographic measuring instruments later gave rise to the development of measuring instruments suitable for flow measurements in rivers, known as *Acoustic Doppler Current Meters (ADC)* and *Acoustic Doppler Velocity Meters (ADV)*. These devices are used as an alternative to conventional hydrometric impellers: like impellers, they measure the flow velocity at a point and are employed in the same manner.

The calibration of hydrometric measuring equipment

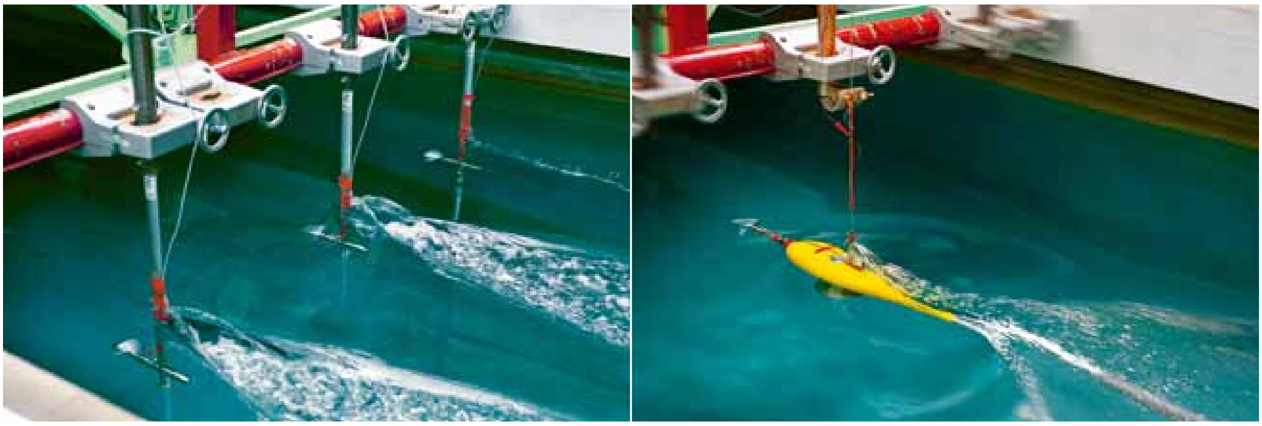
Measurement method

Hydrometric measuring equipment is calibrated by being towed at constant speed through the still water of the calibration channel. This method simulates «flowing water». Here, the distance travelled during the measurement and the time required are recorded. These two values are used to calculate the speed.

Measuring procedure

The measuring instruments to be calibrated are secured to a holding device (rod) located on the back of the tow carriage (picture 6). The carriage is subsequently accelerated to the desired measuring speed, which is then kept constant. A series of ten partial measurements is taken at this speed.

In the case of an impeller, the water resistance causes its blades to move. The impellers generate a specific number of pulses per revolution, depending on the design. After an individually selectable number of counted impulses for each impeller, the distance covered by the tow carriage is recorded to a hundredth of a millimetre and the time in ms. From these data, the tow carriage's actual speed of travel is determined.



6 Hydrometric impellers – mounted on rods in the left-hand picture, on a weight (yellow) in the right-hand picture – are calibrated under realistic conditions in the METAS calibration channel.

For hydrometric impellers, in order to comply with the ISO provisions, the number of impeller revolutions is chosen so as to make the measurement path at least 20 m. For instruments based on other measuring principles (such as magnetic-inductive devices or acoustic Doppler instruments), the measurement path is given by the prescribed measuring time.

After the first series of measurements, the tow carriage is run up to a new speed and a further series of ten partial measurements is carried out. After the final series, the carriage is returned to the starting point. The next measuring run is only started when the water disturbances in the calibration channel have dissipated.

All measuring runs and sequences are pre-programmed from the control computer in the control room (picture 1). Once the start instruction is given by the operating personnel, the runs are carried out totally automatically. The speed of the tow carriage and the impeller impulses can be followed on the monitor screen in the control room.

Capturing the measurement values

The measuring instruments fixed to the rear of the tow carriage are towed through the water on each run. The critical factor is an accurate count of the impeller impulses during the preselected number of revolutions. A highly accurate path/time electronic system has been developed for this purpose. The path travelled by the tow carriage is captured with an accuracy of 0.01 mm by means of a measuring wheel. A quartz crystal with a frequency of 10 MHz forms the time basis. This entails a relative measurement uncertainty of 1 ppm.

The recording system is capable of processing impulses, electrical voltages and currents as well as digital displays. The measurement values and parameters recorded on the tow carriage are transmitted wirelessly to the control computer. The displayed measurement values from measuring instruments with digital or analogue displays are captured by a video camera and transmitted to the control computer via a separate directional beam connection.

The calibration of a measuring instrument calls for a number of measuring runs on account of the fact that the characteristics of the instruments can only be reliably described with a number of calibration points. The ISO 3455 standard stipulates the requested number of calibration points and speeds.

Type of measuring instrument	Speed measurement range (m/s)	Relative measurement uncertainty
Hydrometric impellers	0.02 … 10	for impulses resp. contacts: $4.0 \cdot 10^{-4}$ for analogue signals: $7.0 \cdot 10^{-4}$
Hydrometric impellers with weight	0.02 … 7	
Magnetic-inductive measuring instruments	0.02 … 5	for digital displays: $4.0 \cdot 10^{-4}$ for analogue signals: $7.0 \cdot 10^{-4}$
Doppler ultrasound measuring instruments	0.02 … 5	

7 The METAS hydrometric calibration facility is used to calibrate measuring instruments for the determination of water flow speeds, to establish the margins of error of the devices, to test the measuring instruments for flawless function and to test newly developed hydrometric measuring equipment and prototypes for the most diverse applications by means of tow trials.

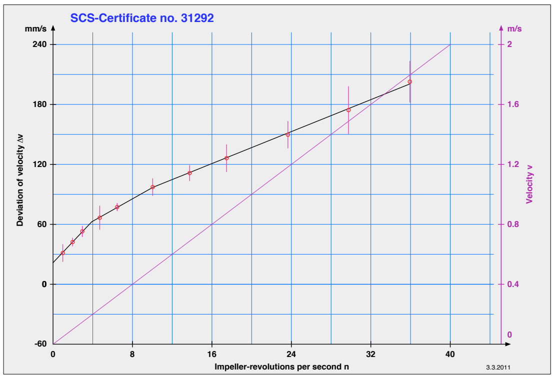
Appendix to SCS Certificate No. 31292 — Annex A

Calibration lines

	> n	<= n	Velocity v =
Line A	0.0000	3.8980	0.0216 + 0.0605 n
Line B	3.8980	10.0625	0.0407 + 0.0556 n
Line C	10.0625	35.9479	0.0568 + 0.0540 n

n = Number of impeller revolutions per sec. v = Velocity in meters per second

Diagram



Description of diagram

The graphic shows up that a band of variability is illustrated to each measuring point which is determined by the partial measuring. This band of variability represents the whole uncertainty of measuring caused by the instrument which has to be calibrated as well as by the fixation and the calibration Laboratory. The so-called "Eppereffect" may appear in the range of speed from v = 3.0 m/s up to 4.5 m/s. Measuring points which are burdened with the "Eppereffect" will be less assessed by inserting the regression equation than measuring points below and above mentioned range of speed.

Swiss Calibration Service
Accreditation no. SCS 003

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8 Evaluation of the calibration of an impeller together with the formulae for the three calibration lines.

Evaluation of the measurement values

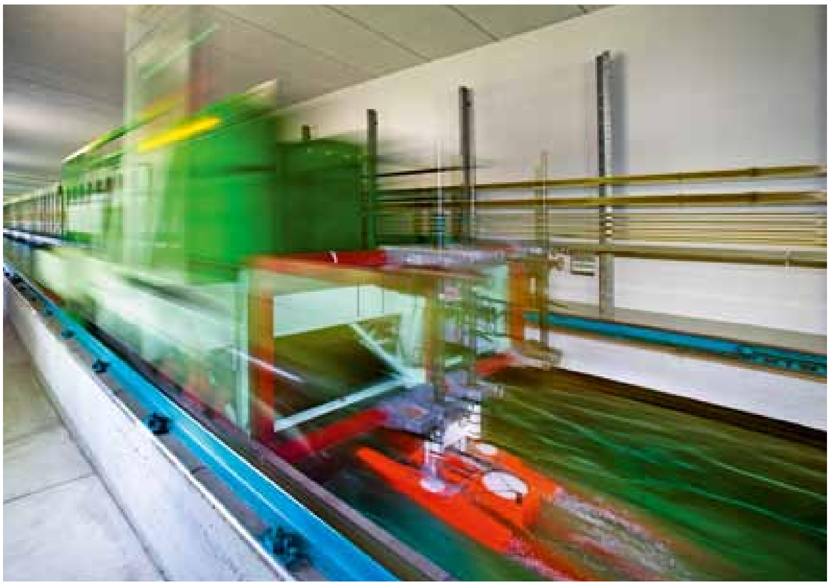
The captured measurement values are stored in the control computer database from where they are processed. In order to be able to state a measurement uncertainty for each measurement point, each measurement series is carried out with ten partial measurements so that from these partial measurements, the average can be determined together with the respective standard deviation.

The measurement points are summarised in a diagram. They are connected with a one to four part line. If this so-called calibration line is depicted as a formula, it enables the user to obtain the corresponding water speed for each number of impeller revolutions measured in the water.

Diagram 8 is a graphical representation of the results of an impeller calibration: it shows the «calibration lines» for an impeller, that is to say the deviation of the measuring instrument from the target value in relation to the number of impeller revolutions per second.

SCS calibration certificates

At the end of the process, the customer receives an SCS calibration certificate (SCS = Swiss Calibration Service). This certificate contains all recorded data with the relevant measurement uncertainties and an annex that includes the determined calibration lines and their equations. With the aid of these data, the water speed and hence the flow rate in a watercourse can now be determined with any of the calibrated measuring equipment.



9 Test run with an acoustic Doppler current profiler (ADCP).

The calibration facility

The heart of the facility consists of the water-filled channel, the tow carriage and the electrical, hydraulic and mechanical control, measurement, transmission, evaluation and safety equipment.

The calibration channel

The channel is 140 m long, 4 m wide, 2.4 m deep, concreted into a firm gravel bed. It is housed in a hall. The normal water level is 1.8 m, giving the channel a capacity of a million litres of water. The ambient temperature in the hall lies between 15 °C and 25 °C, depending on the time of year, the water temperature between 10 °C and 20 °C and the relative air humidity between 45 % and 60 %.

The tow carriage

The tow carriage runs on precisely aligned rails. It can be set to operate at any desired constant speed in the range from 0.02 m/s to 10 m/s. It is designed in such a way as to carry both the measuring instruments to be calibrated and the measurement, test and monitoring equipment needed for the task. Should the need arise, passengers can also ride along for tasks such as video recordings.

Three DC motors, supplied via microprocessor-controlled four-quadrant rectifiers, power the tow carriage. It is supplied with power via bus bars attached along the side wall of the channel. Three independent braking systems – mechanically, electrically and pneumatically operated – ensure safe operation.

International measuring basis for hydrometric calibrations

The calibration facility in Ittigen is one of the oldest in the world and has long been regarded as an important international measuring basis for the calibration of hydrometric measuring instruments. Each year, around 500 speed measuring devices of this type are calibrated. The assignments come from a customer base that is both diverse and international: it includes hydrological services from Switzerland and abroad, federal, cantonal and communal agencies for the prevention of water pollution, but also power station operators, research institutions at technical universities, consulting engineers and environmental bureaus as well as industrial enterprises (manufacturers of hydrometric measuring instruments, turbine, pump and hydraulic engineering industry companies). The Federal Office for Environment (FOEN) is the most important client.

The METAS experts are in close contact with the *International Group for Hydraulic Efficiency Measurements (IGHEM, www.ighem.org)*.

Reference

Thomas Schott, Christian Antener: Das METAS übernimmt neue Aufgaben im Bereich der Hydrometrie (METAS undertakes new tasks in the field of hydrometry), METinfo, Vol. 18, No. 1, pp. 26–27, 2011.

Hydrometric calibration laboratory

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10 Contact persons of the hydrometric calibration laboratory.

In 1896, the «Calibration Laboratory for Hydrometric Impellers» commences operation in Ittigen. Professor Joseph Epper, the first Director (in the front of the picture, wearing a beard), is regarded as one of the pioneers in the use of hydrometric impellers for flow velocity measurements in watercourses.

The pragmatic approach adopted by Professor Epper to calibrate the impellers is remarkable: a measurement assistant accelerated the measuring carriage to a constant speed. The moment the impeller generated an impulse, Epper started a stopwatch with one hand while triggering a rifle shot with the other at the same time. The rifle shot a bolt into a wooden slat attached alongside the rail. After a predetermined number of impulses, Epper halted the stopwatch while simultaneously firing a stop mark into the wooden slat with a second rifle shot. He was then able to measure the distance travelled to the nearest millimetre using a measuring tape. The stopwatch gave him the time down to a tenth of a second. The largest measurement uncertainty was Professor Epper's reaction time. In 1914, the manual operation is replaced with an electrically powered measuring carriage.

Due to difficult economic conditions, the idea of constructing a larger facility can only be realised in 1951: a new hall is built alongside the open-air facility, covering the calibration channel that is still in use today. With a length of 140 m, a width of 4 m and a depth of 2.4 m, the channel can hold around a million litres of water.

Thanks to the know-how and experience of the operators, an ever-increasing number of orders is being won, including from other countries. Because customers keep calling for calibration of their hydrometric measuring instruments at higher speeds as well, a total refurbishment becomes essential: in 1968, the Hamburg-based company Kempf & Remmers constructs a new state-of-the-art measuring carriage weighing 4.6 tonnes. New rails are installed.

Since the electronic control system has become outdated and spare parts are no longer available, a new, semi-automatic measuring system is designed in 1992 by Gebrüder Meier AG, electrical machinery and equipment, Regensdorf, and A. P. Kern AG, Software Engineering, Bern, and installed on the existing measuring carriage. At the same time, the bus bars and signal transmission rails are replaced. The same year, the Swiss Accreditation Service (SAS) issues the first accreditation (SCS 003) to the calibration laboratory for hydrometric measuring instruments.

In 1999, the facility is expanded in order to be able to calibrate differential pressure and magnetic-inductive measuring instruments as well. These calibrations are included in the re-accreditation dated 2 December 1999.

The further expansion of the facility in 2009 for Doppler ultrasound measuring instruments is also included in the range of validity of the 20 November 2009 re-accreditation, conducted in accordance with ISO/IEC 17025/2005.

On 1 January 2011, the Federal Office of Metrology (METAS) takes over from the Federal Office for the Environment (FOEN) as the operator of the facility, which remains in Ittigen.

11 The METAS hydrometric calibration laboratory has had a long and eventful history.

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