Traceable laser-optical flow standard for hot water measurement in thermal power plants

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At the Physikalisch-Technische Bundesanstalt (PTB) a new test rig for hot water flow is being established. The projected flow range is from 2 m³/h up to 200 m³/h at an operating temperature between 3 °C and 230 °C and a pressure rating of 4MPa. Due to the high temperatures and pressures which are involved, a Laser-optical Flow Standard (LFS) based on Laser-Doppler Anemometry (LDA) has been developed. The new LFS can be operated continuously, without the need to shut down or divert the flow. Thus common temperature, pressure or sealing induced challenges can be avoided. The derived traceable uncertainty is below 0.2 % (k=2).

The LFS consists of a rugged commercial sight-glass-armature as a pressure containment combined with an insert in the shape of a Venturi nozzle. The throat of the metrological relevant Venturi contour is equipped with a calibrated precision glass pipe, thus allowing optical access to the flow. Two symmetric LDA systems are employed to measure the axial velocity distribution in the cross-section. The flow rate is obtained by integration. The uncertainty of the LFS has been evaluated according to the Guide to the Expression of Uncertainty in Measurement (GUM).

Special care has been taken to ensure the critical positioning of the LDA measuring volumes. Therefore, precise linear stages have been aligned with the help of a coordinate measuring machine. A ray tracing method for the measuring positions has been applied and incorporated in the uncertainty analysis.

Near wall and gradient effects of the LDA measurement have been identified. Corrections and remaining uncertainties of these effects are derived through adapted analytical velocity profiles and emulated LDA measurements.

Optimized sample positions for the measurement of the velocity profile are derived to ensure a low uncertainty of the quadrature.

The resulting traceable uncertainty can be stated to be lower than 0.2 % (k=2) and has been confirmed through comparison with a gravimetric flow standard. The new LFS can be applied to the calibration of flow meters under process conditions. It is expected that the uncertainty of flow measurement under high temperatures can be reduced significantly.