BIPM Capacity Building & Knowledge Transfer Programme

2018 BIPM - TÜBİTAK UME Project Placement

REPORT

Project Name	Improvement of skills and knowledge transfer in the field of Fluid Mechanics
Description	This project was based on improving skills and knowledge transfer in area of Fluid Flow Measurements. In order to gain better theoretical knowledge as well as practical skills, the candidate worked in Fluid Mechanics Laboratory within TUBITAK UME, together with high level experts in this field.
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Motivation& Introduction

The aim of this project develop technical skills and provide knowledge transfer to the Institute of Metrology of Bosnia and Herzegovina (IMBIH) the field of fluid flow measurements. The Water Flow Laboratory at TUBITAK UME has published CMCs in various flow ranges demonstrating their ability to assist the IMBIH in developing scientific/research capabilities and technical competence in this area.

The Laboratory for Volume and Flow at IMBIH possesses a test rig for calibration of liquid flow meters (up to 150 m3/h), which is still not fully operational. The project will contribute to establishing needed services at IMBIH in this important metrological field.

The Institute is also preparing to initiate activities in the area of small liquid flows because of the increasing demand from healthcare (drug delivery), pharmaceutical and chemical industries. A part of the project addressing this field is aimed at preparing the candidate and IMBIH for future activities in this area.

Research

At the beginning, the project was designed to consist of two parts:

- Calibration of liquid flow meters- up to 100 m3/h
- Calibration of small liquid measuring instruments- mili and micro flow

For calibration of various flowmeters, it was first necessary to gain theoretical knowledge in the field of liquid flow. The theoretical part was based on observing the system, studying documents describing in detail the operation of the system in the Water Flow Laboratory at TUBITAK UME. For this purpose, laboratory procedures and related standards (ISO 4185 Measurement of liquid flow in closed conduits- Weighing method; ISO 4064-Water meters for cold potable water and hot water) for both gravimetric and volumetric calibration methods were analysed.

The necessary theory for the evaluation of measurement uncertainty was summarized in the international standard, ISO 5168- Measurement of fluid flow- Procedures for evaluation of uncertainties, as well as in various laboratory documents. The equations in existing excel sheets for the measurement uncertainty budget were re-created as part of the training. Additionally, the calculations were made step by step once again by hand, which contributed to a complete understanding of the complex structure of the mathematical model for calculation of measurement uncertainty.

Summarized Uncertainty - "*Flowrate measurement*"

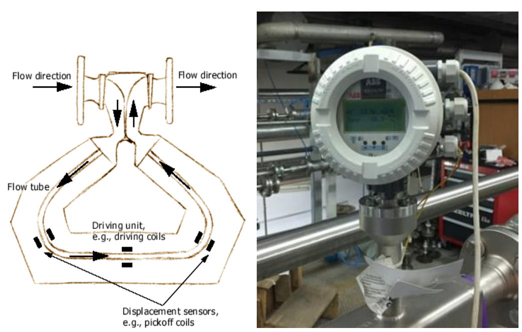
Symbol	*Source of uncertainty*	*Value* ± %	*Probability distribution*	u_i*(FLOW)* ± %
$u_c(W_x)$	Combined uncertainty (MASS)	3,945E-02	normal	3,94E-02
$u_c(D_w)$	Combined uncertainty (DENSITY)	6,707E-03	normal	6,71E-03
$u_c(t_x)$	Combined uncertainty (TIME)	3,810E-08	normal	3,81E-08
$u_c(V_{IP\_Error})$	Combined uncertainty (IP volume)	3,719E-04	normal	3,72E-04
$u_c(V_{DTE})$	Combined uncertainty (Time error)	1,166E-03	normal	1,17E-03
$u_c(D_{air\_B})$	Combined uncertainty (Air buyoncy)	8,177E-05	normal	8,18E-05
$u_c(Q_m)$	Combined uncertainty (meter)	7,119E-04	normal	7,12E-04
S(R)	Repeatability uncertainty	1,089E-01	normal	1,09E-01
u_c(FLOW)	Combined uncertainty (FLOW)		normal	0,116
U(FLOW)	**Expanded uncertainty (FLOW)**		**normal(k = 2)**	**0,232**

Table 1. Combined measurement uncertainty for calibration of water flow meter

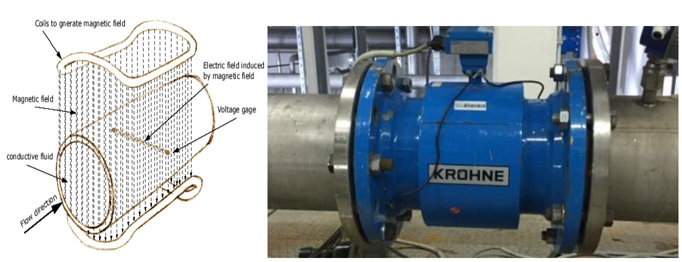
Based on the output quantity of the device under test, within the capacity of the Water Flow Laboratory, various flow measuring instruments can be grouped into three main categories:

- Those with digital output (unit: pulse/kg)
- Those with analogue output (unit: m^3)
- Those with flowrate output (unit: kg/min)

For the practical part, in order to accomplish calibrations for different output units, calibrations of coriolis flowmeters (with digital output and current output), a domestic watermeter, and a electromagnetic flowmeter were performed. The method used for calibrations in the Water Flow Laboratory is the flying start and stop method with the gravimetric weighing system being used as a reference. The flying start and stop method is based on using a continuous flow of water and a diverter which diverts the water either to a tank or a by-pass line and pool. After every calibration, the collected data was analysed and the measurement uncertainty was calculated.



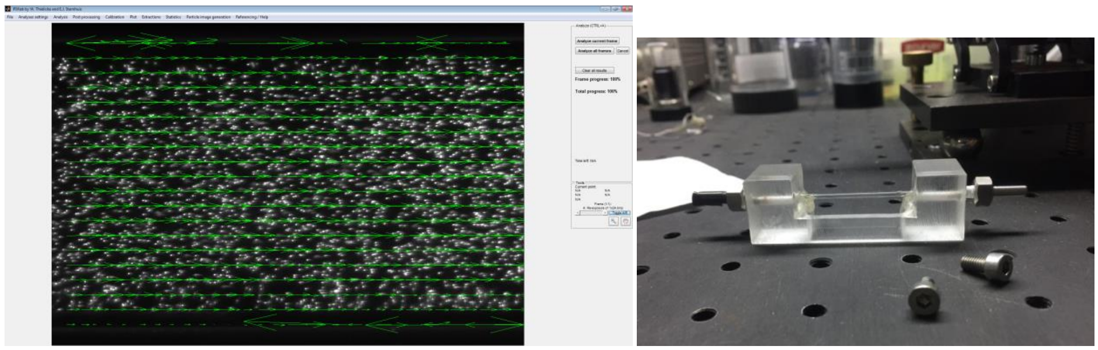
a)



b)

Fig.1. a) Coriolis meter, b) Electromagnetic flowmeter

Since calibrations in the field of small water flow are not performed in the Water Flow Laboratory, theoretical lectures about mili- and microflow were presented, then PIV (Particle Image Velocity) measurements were performed and the data was analysed. PIV is a non-invasive, fullfield optical measuring technique, which is a good tool used for obtaining information about velocity in fluid motion.



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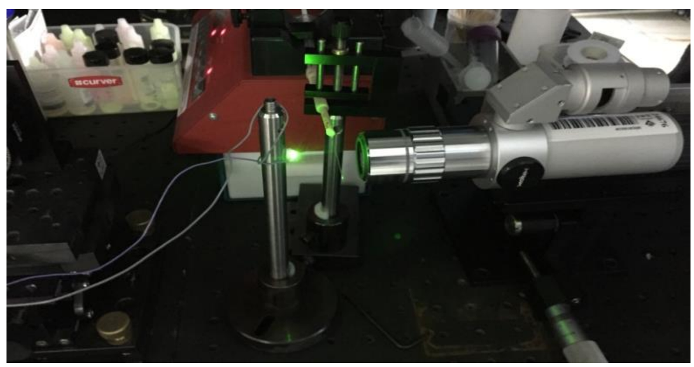


c)

Fig.2 a) PIV motion vectors in PIVlab Software, b) Mikro channels of PIV system c) PIV system setup

Because of the long duration of project and in order to take advantage of the capacity of Fluid Mechanics Laboratory within Tubitak UME, spare time was used to also learn more about the Gas Flow Laboratory and the Air Speed Laboratory. Together these three laboratories constitute of the Fluid Mechanics Group Laboratory.

These additional activities consisted of studying laboratory procedures and standards that are used in both of these laboratories and performance of calibrations of domestic gas meters and dust sampler with the Bell Prover and Dry Cal System as a reference in the Gas Flow Laboratory.

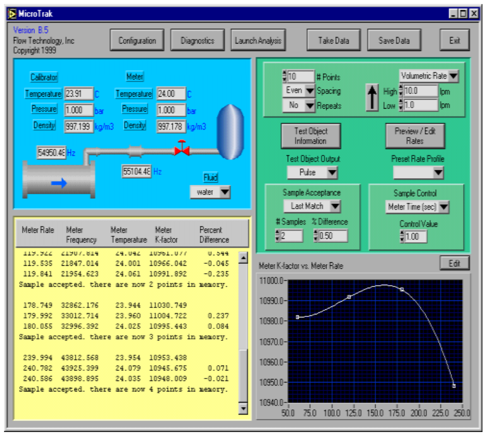
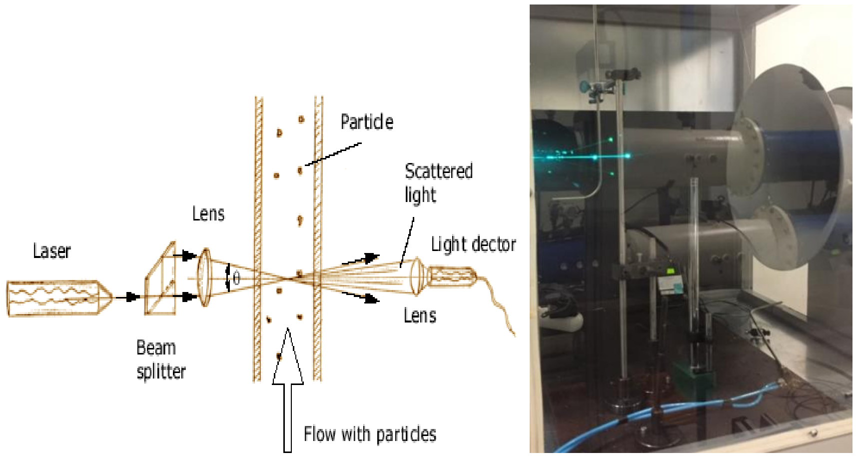


Fig.3 Software for collecting data in Gas Flow Laboratory

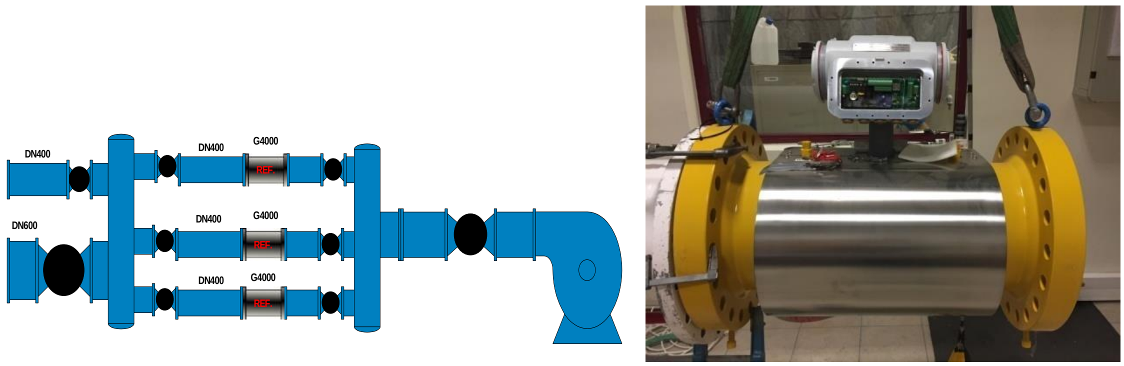
The basic working principles of LDA (Laser Doppler Anemometry) were explained in the Air Speed Laboratory, after which calibration of a Pitot Tube was done. LDA is a measurement technique for measuring the velocity of small particles injected in a fluid flow. It is based on the measurement of laser light scattered by particles that pass through a series of interference fringes (a pattern of light and dark surfaces).



a) b)

Fig.4 a) LDA measurement principle, b) Scattered light in LDA measurement technique

Calibration of a high flow turbine meter was performed by comparing the flow rates indicated by reference turbine type gas meters, under fixed pressure and temperature conditions, with the flow rates indicated by the gas meters under test. Depending on the calibration range, the desired flow rate was selected by using the appropriate frequency value of the fan, as well as the appropriate valve(s) on the line.



a) b)

Fig.5 a) High flow test rig, High flow turbine meter

An interesting and unusual check of inlet and outlet temperature of a heat exchanger was performed in such a way that the air flow is released through the shield of the exchanger, and the temperature is measured in a special hot water baths.

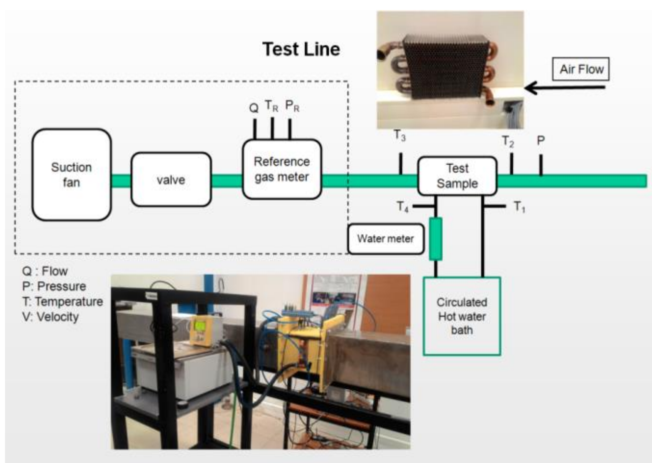


Fig.6Heat Exchanger Test

In order to gain some knowledge in Computational Fluid Dynamics, basic examples of simulations of flow development in pipes were done using ANSYS Fluent Software.

After two-day seminar on the international aspects of metrology and guidelines on participation in the mechanisms of the CIPM MRA, all information regarding planning, initiating and conducting inter-laboratory comparisons and starting the procedure of CMC (Calibration and Measurement Capability) registration into the KCDB database was much clearer.

Since the Laboratory for Volume and Flow at IMBIH is under development, this project will contribute to the extension of knowledge and improvement of practices in the existing laboratory.

All information gained including information gained on both practice and theory will be shared with laboratory personnel at IMBIH. Based on the gained knowledge, the measurement uncertainty budget in the field of liquid flow will be created in the near future for the system in laboratory. This will enable the laboratory to participate in ILCs and it will expedite future declaration of CMCs in various ranges.

Conclusions and Future Work

This project work provided comprehensive and intense training on fluid flow measurements. All three parts of Fluid Mechanics Laboratory were included in this training, while the emphasis was placed on the activities of the Water Flow Measurements Laboratory. Different kinds of calibrations were performed, together with the calculation of their measurement uncertainty budgets.

New measurement techniques such as LDA and PIV, which are also used in large body of research, were shown, with the aim of gaining knowledge for future work.
Furthermore, a future ILC in the field of small gas flow was discussed and then proposed at the last EURAMET TC Flow meeting.

As mentioned above, this project will certainly contribute to broadening the knowledge of IMBIH's personnel in the area of fluid flow measurements and calibrations. The knowledge and skills gained will assist in the development of the existing flow laboratories through the deployment of new methods for calibration and new measurement uncertainty budgets.

Acknowledgements

First of all, I would like to thank the organizers from TUBITAKUME and BIPM for the opportunity to participate in this kind of research programme. It was a pleasure to work in UME together with people who were always willing to help. I would particularly like to thank Ms. Başak Akselli from Water Flow Laboratory and Mr. Hakan Kaykısızlı from the Gas Flow and Air Speed Laboratories for their unselfish transfer of knowledge and their great effort to make my project in UME useful for me, as well as for IMBIH.