Fluid Machinery
Introduction to the laboratory measurements

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1 Requirements related to the measurement part of the subject

1.1 Preparing for a laboratory measurement

- Students being late are not allowed to attend the measurements. At the end of the semester there is the opportunity to retake (only) one laboratory measurement. Student missing two or more laboratory measurements fail the subject.
- Table for measured data has to be prepared.
- Millimetre paper, pocket calculator, pencil and rubber are needed.

1.2 Requirements of report

The report can be prepared by hand or by computer as long as it is readable, clean and the figures and tables look nice. The sections of the reports are:

- the aim of measurement,
- description of the system (with figures) and steps of the measurement,
- calculations (mostly the equations used for data processing) and results,
- derivation of error propagation,
- measured data, computed quantities,
- graphs
- and short summary.

Tables have header with denomination and unit of the quantities, the measured and computed columns are separated consistently as it is illustrated in Table 1.2.

Requirements of diagram are shown in Figure 1.

Measured				Computed				
No.	a	b	c	d	e	f	g	h
	[unit1]	[unit2]	[unit3]	[unit4]	[unit5]	[unit6]	[unit7]	[unit8]
1								
2								

Table 1: Example for the format of the table employed in the laboratory report.

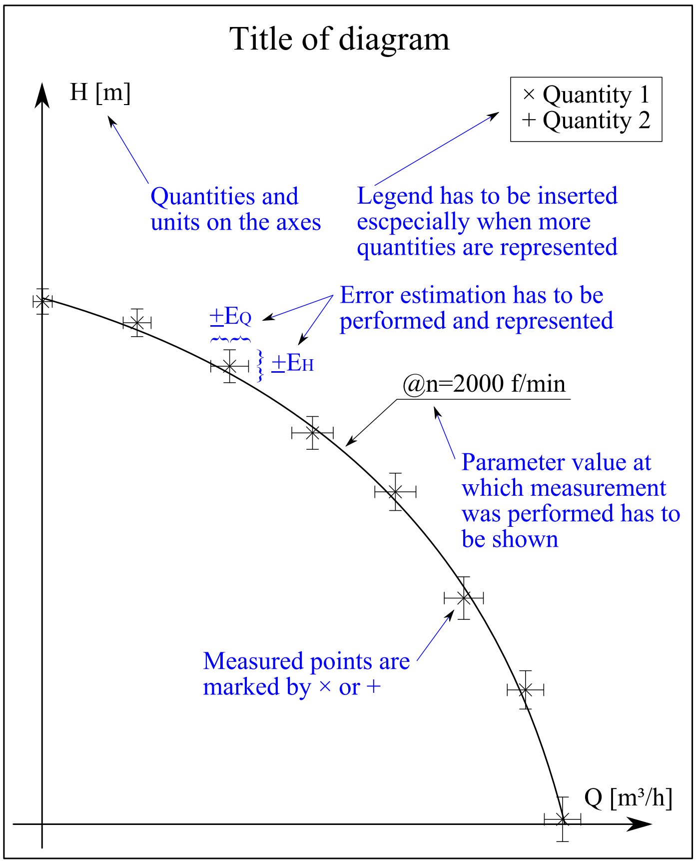

Figure 1: Format of diagram.

2 Measuring devices frequently used in laboratory measurements

2.1 Measuring pressure

Liquid column gauge–U tube manometer

Liquid column gauges consist of a vertical column of liquid in a tube whose ends are exposed to different pressures. The column will rise or fall until its weight is in equilibrium with the pressure differential between the two ends of the tube. A very simple version is a U-shaped tube half-full of liquid, one side of which is connected to the region of interest while the reference pressure (which might be the atmospheric pressure or a vacuum) is applied to the other. The difference in liquid level represents the applied pressure. Although any fluid can be used, mercury is preferred for its high density ($\rho = 13534\, g/cm^3$) and low vapour pressure. For low pressure differences well above the vapour pressure of water, water is commonly used.

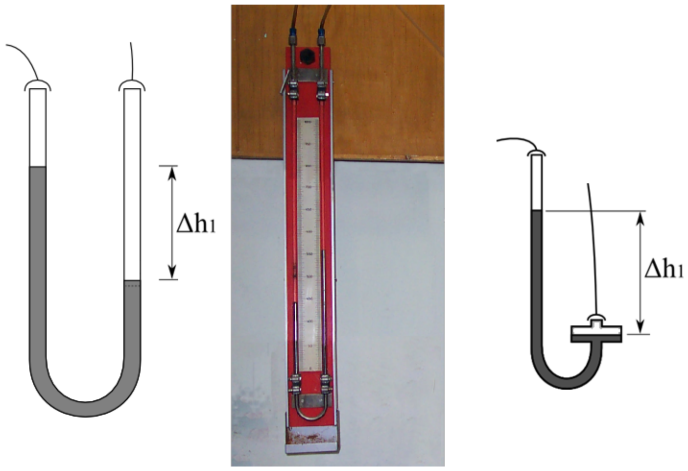

Figure 2: Left: Schematic draw of a liquid column gauge. Middle: Liquid column gauge. Right: Schematic draw of a single column gauge.

Inclined manometer

Similar to the single column gauge the inclined manometer has a reservoir with relatively large area and a scaled column. Its column can be inclined thus a more precisely reading is achievable.

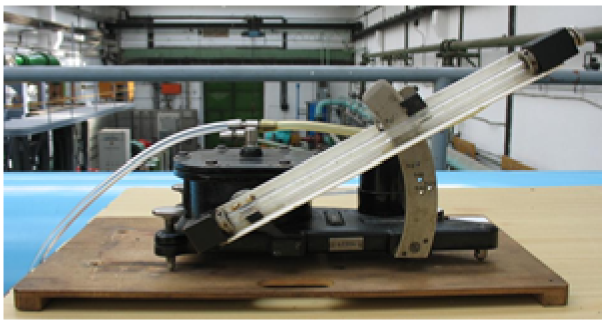

Figure 3: Inclined manometer.

Bourdon gauge

The Bourdon pressure gauge uses the principle that a flattened tube tends to change to a more circular cross-section when pressurized. Although this change in cross-section may be hardly noticeable, the displacement of the material of the tube is magnified by forming the tube into a C shape or even a helix, such that the entire tube tends to straighten out or uncoil, elastically, as it is pressurized.

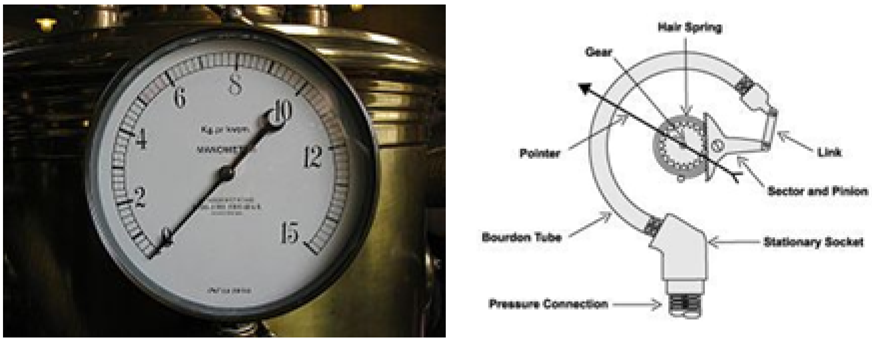

Figure 4: Left: Bourdon gauge. Right: Mechanism of the Bourdon gauge.

In practice, a flattened thin-wall, closed-end tube is connected at the hollow end to a fixed pipe containing the fluid pressure to be measured. As the pressure increases, the closed end moves in an arc, and this motion is converted into the rotation of a (segment of a) gear by a connecting link which is usually adjustable. A small diameter pinion gear is on the pointer shaft, so the motion is magnified further by the gear ratio. The positioning of the indicator card behind the pointer, the initial pointer shaft position, the linkage length and initial position, all provide means to calibrate the pointer to indicate the desired range of pressure for variations in the behaviour of the Bourdon tube itself. Bourdon tubes measure gage pressure, relative to ambient atmospheric pressure, as opposed to absolute pressure; vacuum is sensed as a reverse motion. When the measured pressure is rapidly pulsing, such as when the gauge is near a reciprocating pump, an orifice restriction in the connecting pipe is frequently used to avoid unnecessary wear on the gears and provide an average reading; when the whole gauge is subject to mechanical vibration, the entire case including the pointer and indicator card can be filled with an oil or glycerine. Typical high-quality modern gauges provide an accuracy of $\pm 2\%$ of span, and a special high-precision gauge can be as accurate as 0.1% of full scale.

Electronic pressure sensors

A pressure sensor measures pressure, typically of gases or liquids. A pressure sensor usually acts as a transducer; it generates an electronic signal as a function of the pressure imposed. Although there are various types of pressure transducers, one of the most common is the strain-gage base transducer. The conversion of pressure into an electrical signal is achieved by the physical deformation of strain gages which are bonded into the diaphragm of the pressure transducer. Pressure applied to the pressure transducer produces a deflection of the diaphragm which introduces strain to the gages. The strain will produce an electrical resistance change proportional to the pressure.

2.2 Measuring flow rate

Metering tank

Perhaps the simplest way to measure volumetric flow is to measure how long it takes to fill a known volume container. A simple example is using a bucket of known volume, filled by a fluid. The stopwatch is started when the flow starts, and stopped when the bucket overflows. The volume divided by the time gives the flow:

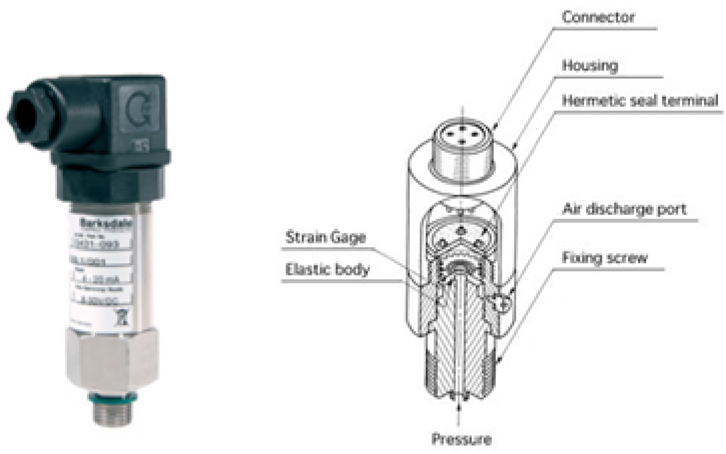

Figure 5: Left: Cut-away of an electronic pressure sensor. Right: Pressure sensor.

$$Q = \alpha \frac{\Delta m}{\Delta t} \left[\frac{dm^3}{s} \right] \tag{1}$$

where

- $\alpha \, [dm^3/mm]$ is the constant of the tank being the volume of a $1 \, mm$ high quantity of liquid in the tank,
- $\Delta m \, [mm]$ is the rising of the level,
- $\Delta t \, [s]$ is the time taken for rising.

Orifice plate

An orifice plate (metering orifice) is a plate with a hole through it, placed in the flow; it constricts the flow, and measuring the pressure differential across the constriction gives the flow rate.

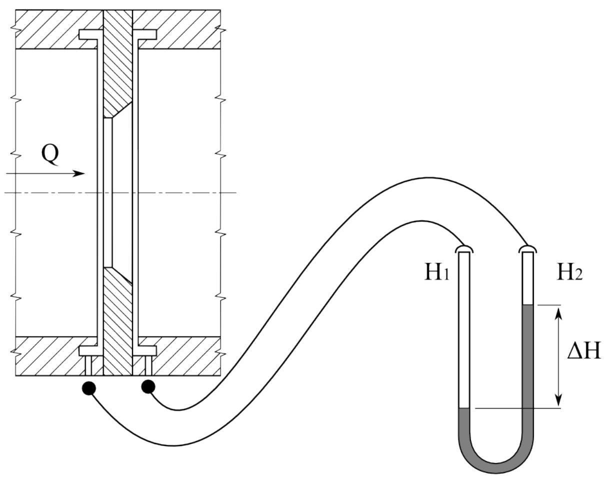

Figure 6: Cut-away of a metering orifice.

The square root of measured pressure difference is proportional to the flow rate

$$Q = \alpha \epsilon A \sqrt{2 \Delta p_{mo} / \rho} \tag{2}$$

where

- $\alpha \, [-]$ is the discharge coefficient through the plate,
- $\epsilon \, [-]$ is the expansion factor of the discharge,
- $A \, [m^2]$ is the cross-sectional area of the orifice hole ($A = d^2\pi/4$),
- Δp_{mo} is the pressure drop through the metering orifice,
- ρ is the density of the working medium.

2.3 Measuring revolution speed

Mechanical tachometer

Mechanical tachometers count the revolutions only for a fixed time, generally for 6 seconds. The time measuring device of the instrument connects its pointer for 6 seconds with that shaft of the instrument which joints the rotating machine part. After these six seconds there is no more connection which means at the same time the end of the measurement. A widely used example of this device is the Jacquet indicator. With pressing the starting button the instrument is zeroed and after releasing it the counting and the clockwork starts.

Electric tachometer

Electric tachometers operate with the same principle (counting the number of revolutions during some period of time), but the number of revolutions is measured in an optical way.

Figure 7: Left: Jaquet indicator. Right: Electric tachometer.

2.4 Measuring torque of an electrical motor

Balancing motor

Balancing machines (motor or generator) are special machines, whose housing is free to rotate and arms are mounted onto it. The torque is to be measured in motor running is

$$M = (G - G_0)k \tag{3}$$

where

- $M\,[Nm]$ is the shaft torque to be measured. This torque is produced by the power machine and is transmitted by the coupling to the rotating part of the generator,
- $G\,[N]$ is the weight needed for balancing the stationary part,
- $G_0\,[N]$ is the weight needed for unloaded operation,
- $k[m]$ is the length of arm.

3 Measuring electric quantities

Universal multimeter, multi tester

A multimeter or a multi tester, also known as a volt/ohm meter or VOM, is an electronic measuring instrument that combines several measurement functions in one unit. A typical multimeter may include features such as the ability to measure voltage, current and resistance. Multimeter may use analogue or digital circuits - analogue multimeter and digital multimeter (often abbreviated DMM or DVOM.)

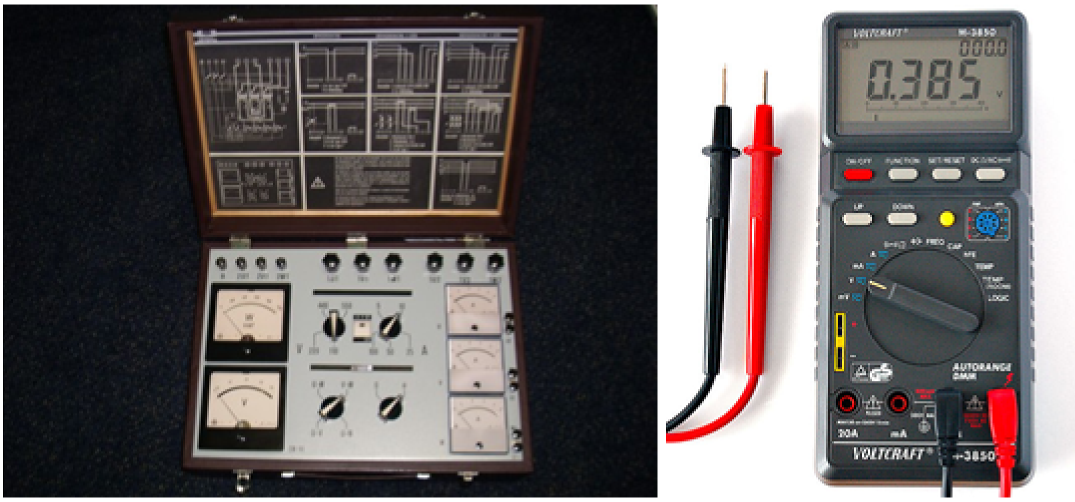

Figure 8: Left: Multimeter. Right: Multi tester.