Discharge measurements
DISCHARGE MEASUREMENTS

Suitability of methods and equipment for measurements – where, under what conditions and for what reason discharge is measured

- determination of discharge in channels, hydrological balances
- water uptake (industry, power engineering, water supply) → payment
- waste water draining → payment

- technological processes (water and waste water treatment plants, chemical and food-processing industry ...)

- volume flow (of incompressible liquid) $Q = \frac{V}{t}$ [m$^3$s$^{-1}$]
- mass flow (of compressible liquid, pollutants,..) $Q_m = \frac{m}{t}$ [kgs$^{-1}$]
METHODS OF DISCHARGE MEASUREMENTS

**Volumetric and weight method**
- the most precise
  but: only for relatively small discharges
  (necessary volume of tank), mainly for calibration of flow meters

**Pipe flow meters based on flow contraction**

\[ Q = \mu_v S_2 \sqrt{2g \frac{\Delta p}{\rho g}} \]
\[ \mu_v = f\left(\frac{S_2}{S_1}, Re\right) \]

- **orifice meter** – the simplest, small laying-out length, but: large losses
- **nozzle meter**
- **Venturi meter** – more complicated shape, large laying-out length
  
  **but**: small losses

Knee-shaped flow meter

- **measurement**: pressure difference $\Delta p$ in outer and inner side of bend knee pipe
- **determination of discharge**: the same equation as for nozzle meter
Measuring spillways

- sharp-crested spillways → one of basic measuring devices
  uncertainty of measurements: 1-3 %
- upstream face of spillway – vertical, smooth
- requirement: precise set-up of crest

Determination of discharge

- **measurement**: height of overflow head $h$ under free overfall
- **evaluation of discharge**: corresponding equation $Q = f(h)$
  - for standard conditions of the type of spillway, its construction and flow conditions in approach channel ⇒ **calculation of discharge coefficient** $m$ (corresponding empirical formulae)
various shapes of notches in vertical wall are used:

- **rectangular notch** without side contraction (**Bazin weir**) for larger discharges
- **rectangular notch** with side contraction (**Poncellet weir**)
- **triangular notch** with right angle \( \alpha \) (**Thomson weir**), for small discharges
- **trapezoid notch** (slope of side edges 4:1 - **Cipoletti weir**)
- **hyperbolic notch** (linear, or proportional, or **Sutro weir**) with increasing overflow head discharge increases linearly
Measuring flumes

→ devices utilizing decrease of water level under sub-critical flow
  - contraction of flow, if significant ⇒ critical flow is created in the most contracted section (width b)

measurement: upstream water level, i.e. overflow head $h$

- Parshall flume has smaller laying-out length that Venturi flume, however, dependency $Q = Q(h, b)$ is more complicated
- if contracted section is affected by down water, also down water level has to be measured → accuracy of determination of $Q$ grows worse
Method of velocity field

- widespread method for discharge measurement both in open channels and in pipes, standard method for discharge determination in the course of guarantee tests of water machines

measurements: point velocities \( u \):
current meter, inductive flow meter, floats, …
after systematic measurements of point velocities in cross section
→ determination of discharge from continuity equation

\[
Q = \int u \, dS = \sum_{S} u_i \, \Delta S_i
\]

characteristic velocity distribution along a vertical in open channel
Instruments for measurements of point velocities

Current meter → measurements of number of turns of c. m. in stream

Inductive flow meter → voltage and intensity of magnetic field between 2 electrodes
**Volume flow meters (water meters, gas meters)**

- based on various principles, generally on rotation of blade wheel in measuring box of device
  → current devices measuring volume of a medium passed throw them (flow meters in households and industry)
  If time is measured, it is possible to figure out mean discharge in given time interval

**Float flow meters - rotameters**

Principle: hydrodynamic uplift force of liquid flowing upwards in a vertical broaden tube acts on rotating float - it will firm up in the heights equal to discharge

→ For precise measurements of small discharges of liquids, suspensions and gases