Lecture 6

Water Distribution

and

Network

Water distribution / Pipings 22

Feeder pipings *(Zubringerleitungen)* connect the area of water catchment (Wassergewinnungsgebiet) with the area of supply *(Versorgungsgebiet)* and lead usually to an elevated water tank *(Hochbehälter)*.

Distribution pipings *(Verteilungsleitungen)* lead from the reservoir *(Speicher)* to the area of supply *(Verwendungsort)*.

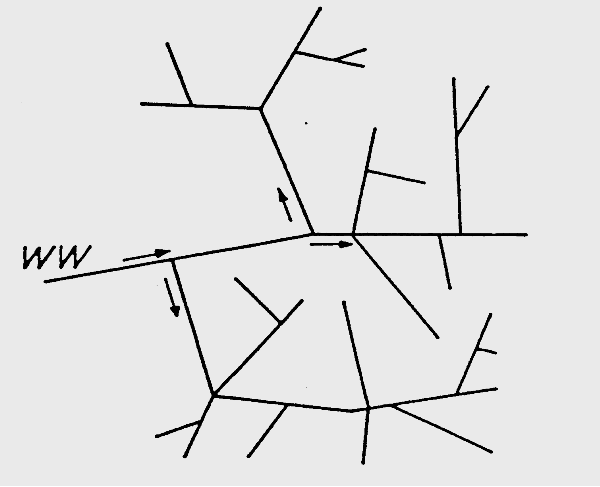
The distribution pipings network consists of main-, supply- and connecting pipings *(Haupt-, Versorgungs- und Anschlussleitungen)*.

The main pipings begin at the reservoir or at a larger junction *(Knotenpunkt)* within the area of supply. The supply pipings connect the household with the water meter *(Wasserzähler)* and the main shutoff *(Hauptabsperrorgan)* device in the property.

Distribution network

Branched Network

(Verästelungsnetz)



Disadvantages: therefore

- Water consumption *(Wasserbezug)* only from one direction, low flexibility *(wenig anpassungsfähig)*
- Uneven pressure conditions *(Druckverhältnisse)*
- Interruption of the water supply *(Wasserlieferung)* in case of pipe bursts *(Rohrbrüchen)* and fires *(low operation security)*
- Degradation of the water quality *(Wasserbeschaffenheit)* and temperature in the final pipes (frequent flushing *(Spülen)* necessary)

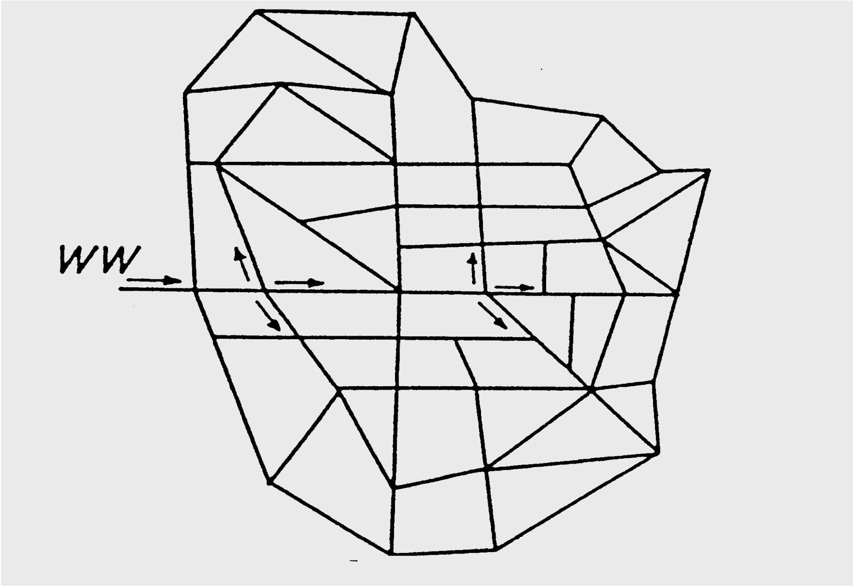
Advantages:

- Low costs

Distribution network

Ring distribution network

(Ringnetz)



Advantages:

- High supply reliability *(Versorgungssicherheit)*
- Adjustment to varying water consumption *(schwankender Wasserverbrauch)*
- Favourable pressure conditions
- High water quality

Basics for dimensioning of piping network

The dimensioning of water pipings are commonly based on the following simplifications:

- Steady flow, i.e. velocity is constant (constant water discharge).
- Uniform stream, i.e. constant flow conditions (Bed gradient, friction, constant cross section).
- (Assumption that the middle velocity *(mittlere Fließgeschwindigkeit)* of flow is uniformly distributed over the cross-section area.
- Incompressibility of the water, as far as no larger amounts of gas are not contained in it.

Basic hydraulic equations

Continuity equation

$$Q = A_1 \cdot v_1 = A_2 \cdot v_2 = \text{constant}$$

with:

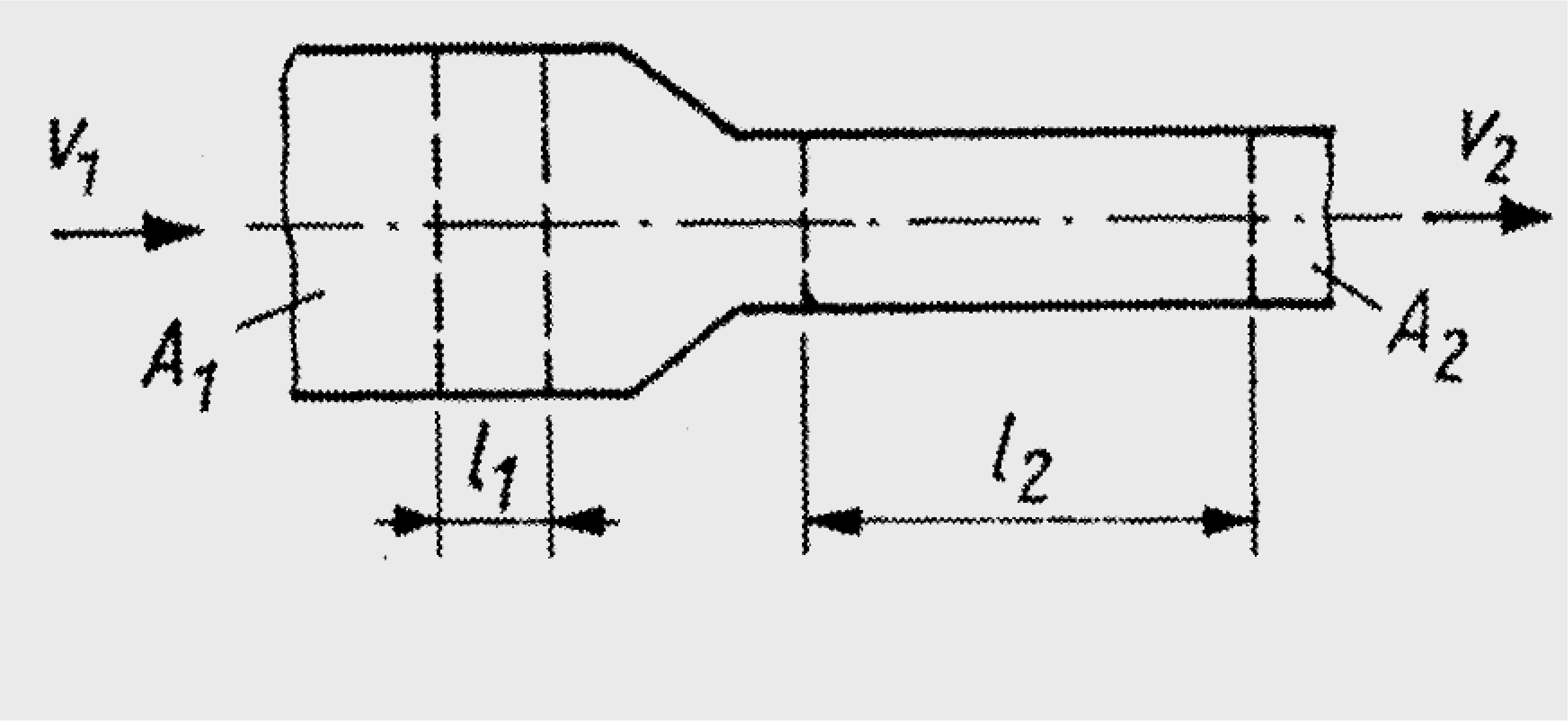
with:	Q	Volume flow [m³/s]
	v	Flow velocity [m/s]
	A	cross sectional area [m²]

Energy equation (Bernoulli equation)

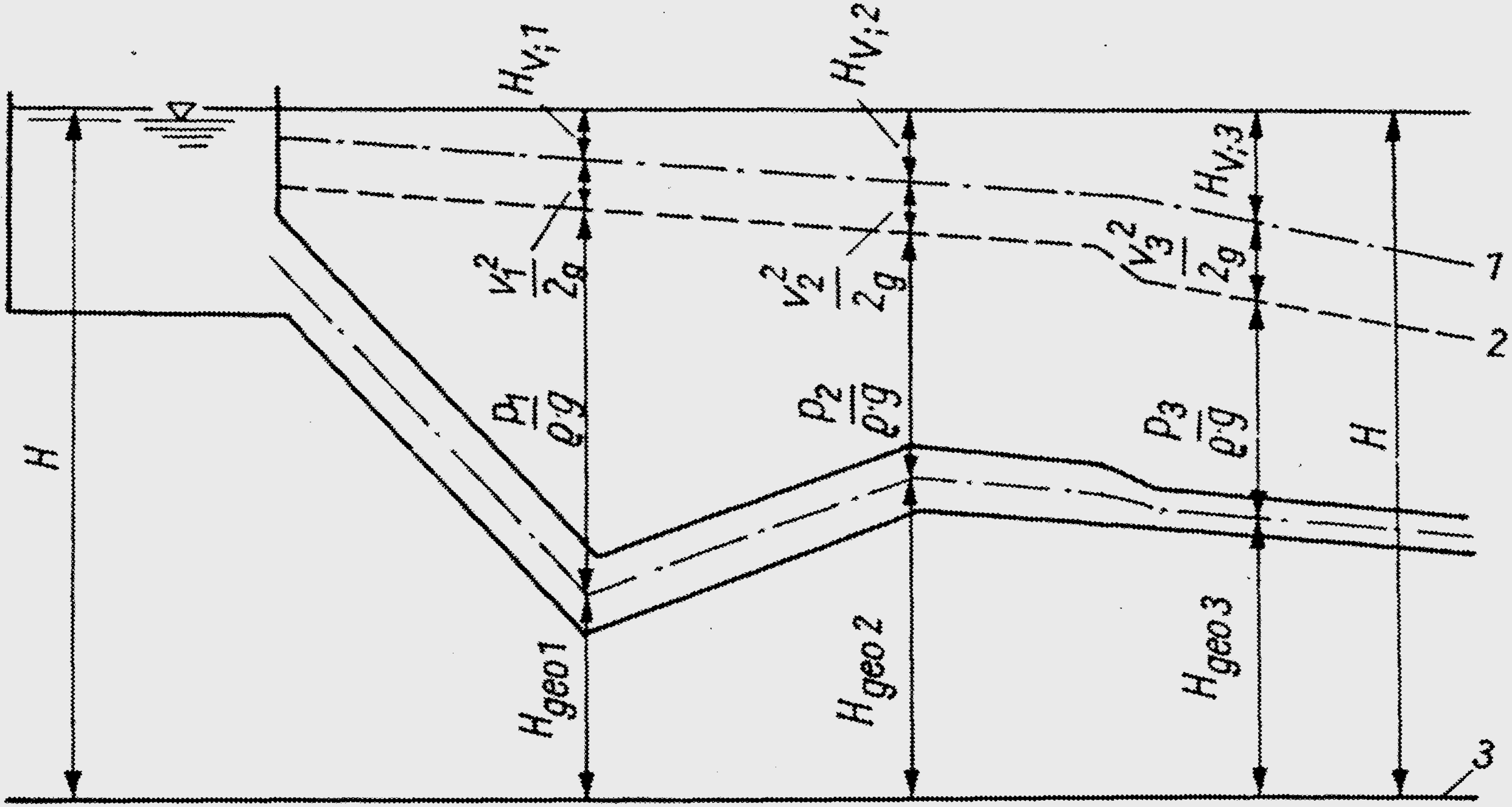
$$h_E = \frac{v_1^2}{2g} + \frac{p_1}{\rho \cdot g} + z_1 = \frac{v_2^2}{2g} + \frac{p_2}{\rho \cdot g} + z_2 + h_v$$

with:	h_E	Energy head [m]
	p	Pressure [bar]
	ρ	Density of the fluid [kg/m³]
	z	Geodetic height [m]
	h_v	Energy loss through friction [m]

Stream piping



Bernoulli equation illustrated with a pressure pipeline



$$H = H_{geo1} + \frac{p_1}{\varrho \cdot g} + \frac{v_1^2}{2g} + H_{V;1} = H_{geo2} + \frac{p_2}{\varrho \cdot g} + \frac{v_2^2}{2g} + H_{V;2} = H_{geo3} + \frac{p_3}{\varrho \cdot g} + \frac{v_3^2}{2g} + H_{V;3}$$

Basic hydraulic equations

Darcy-Weisbach equation

$$h_v = \lambda \cdot \frac{l}{d} \cdot \frac{v^2}{2g}$$

with: h_V Head loss due to friction [m]

Friction coefficient

$$\lambda = f\left(\frac{k}{d}, Re\right) \qquad with: \frac{k}{d} = \text{relative roughness}$$

for non circular pipes and channels the hydraulic diameter d_{hy} is used instead of the diameter d

$$d_{hy} = 4\, r_{hy} = \frac{4A}{l_p}$$

with: l_p Wetted perimeter [m]

Main hydraulic equations

For flow in a pipe or tube, the Reynolds number is generally defined as:

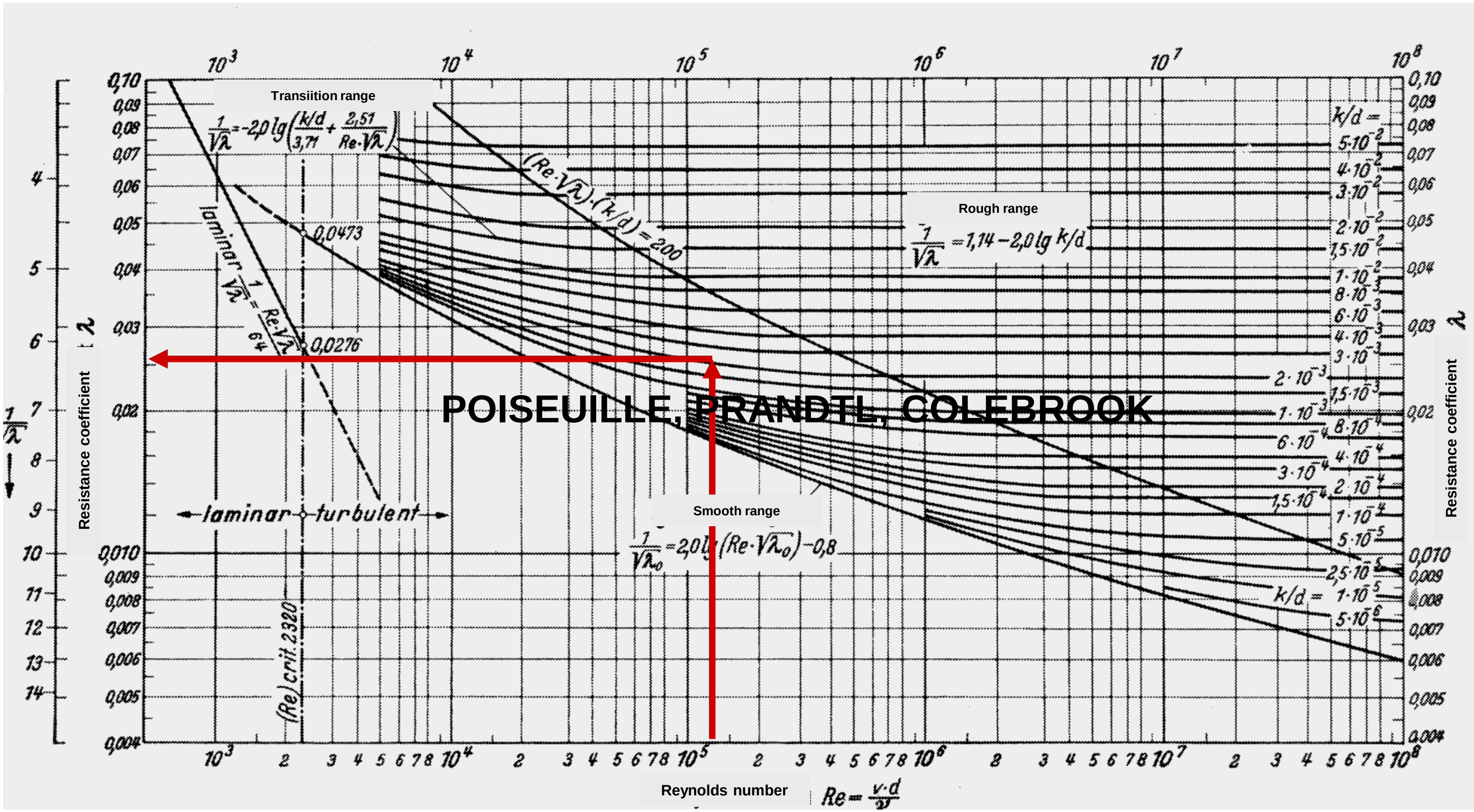
$$Re = \frac{v \cdot D}{\nu}$$

with:	ν	kinematic viscosity	
	ν_{water}	$1{,}2 - 1{,}8 \cdot 10^{-6}$	[m^2/s]
	$\nu_{waste\ water}$	$1{,}31 \cdot 10^{-6}$	[m^2/s]

For the **friction coefficient λ** there can be differentiated 3 ranges:

1. Smooth range: λ depends only on Re and is therefore independent of the condition of the pipe wall.
2. Rough range: λ depends only on the condition of the pipe wall, in other words on the so-called relative roughness k/d, however not on Re.
3. Transition range: λ is dependent on Re as well as on k/d.

Friction coeffcient for full circular pipes after POISEUILLE, PRANDTL, CO



Determination of the pipe friction loss

The calculation of pipe friction loss *(Rohrreibungsverlusten)* is based on the already presented Darcy-Weisbach equation:

$h_v = h_r = \lambda \cdot L/D \cdot v^2/2g$

with:	λ	friction factor [-]
	L	length of the pipe [m]
	D	pipe diameter [m]
	g	gravitational acceleration = 9,81 [m/s²]

If one refers the determined friction loss height h_v (m) on the projection length L' of the actual piping length L (km), then the gradient of energy *(Energieliniengefälle)* or gradient of friction *(Reibungsgefälle)* I_E can be calculated according to the following formula:

$$I_E = \frac{h_v}{L'}$$

Determination of the pipe friction loss

Using the “individual concept”, the pipe friction losses h_r and the local losses $h_{v,L}$ (curves, armatures, etc.) are calculated separately. The total losses h_v over the whole tubing distance amount to: :

$$h_V = h_r + h_{v,L} \quad [m]$$

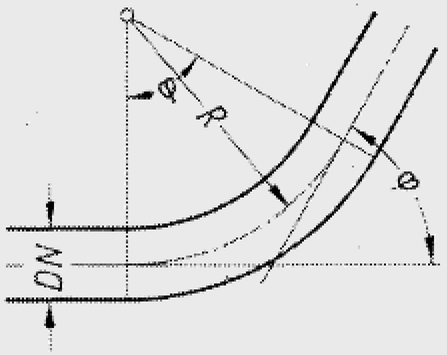
For the local losses $h_{v,L}$, the following relationship is valid:

$$h_{v,l} = \zeta_K * v^2/2g$$

Determination of the pipe friction loss

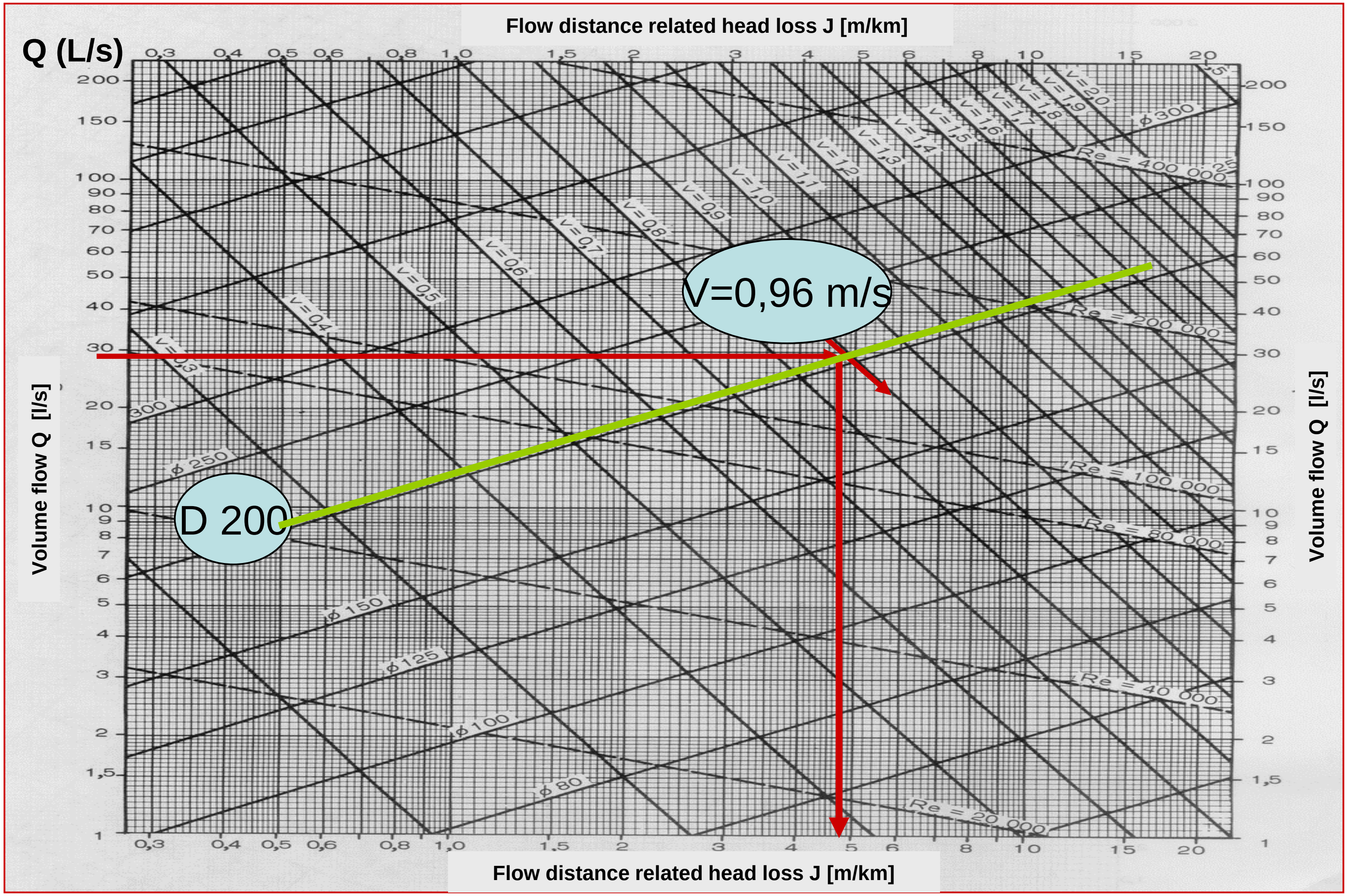
Coefficients ζ_k for pipe curvatures

	Curvature radius: nominal size = R : DN					
φ	1	2	4	5	6	10
15°	0,03	0,03	0,03		0,03	0,03
22,5°	0,045	0,045	0,045		0,045	0,045
45°	0,14	0,09	0,08		0,075	0,07
60°	0,19	0,12	0,10		0,09	0,07
90°	0,21	0,14	0,11	0,1	0,09	0,08



4 Pipe curvature

General Concept



Head loss diagram

For k_i = 0,4 mm

According to DVGW-W302

Determination of pipe friction head loss (DVGW W 302)

Flow distance related head loss for k_i = 0,4 mm
Ø = inside diameter (mm)

Q	Ø 100		Ø 125		Ø 150		Ø 200	
L/s	**v m/s**	**J m/km**	**v m/s**	**J m/km**	**v m/s**	**J m/km**	**v m/s**	**J m/km**
1	0,13	0,302	0,08	0,101	0,06	0,041		
1,5	0,19	0,638	0,12	0,210	0,08	0,085		
2	0,25	1,094	0,16	0,356	0,11	0,144		
3	0,38	2,359	0,24	0,759	0,17	0,304	0,10	0,073
4	0,51	4,095	0,33	1,307	0,23	0,520	0,13	0,124
5	0,64	6,301	0,41	2,001	0,28	0,791	0,16	0,187
6	0,76	8,977	0,49	2,839	0,34	1,118	0,19	0,262
7	0,89	12,123	0,57	3,821	0,40	1,501	0,22	0,350
8	1,02	15,738	0,65	4,948	0,45	1,938	0,25	0,449
9	1,15	19,822	0,73	6,219	0,51	2,431	0,29	0,562
10	1,27	24,375	0,81	7,635	0,57	2,979	0,32	0,686
15	1,91	54,182	1,22	16,876	0,85	6,546	0,48	1,489
20	2,55	95,719	1,63	29,723	1,13	11,490	0,64	2,595
30			2,44	66,229	1,70	25,509	0,95	5,715
40			3,26	117,154	2,26	45,034	1,27	10,044
50					2,83	70,064	1,59	15,582
60					3,40	100,601	1,91	22,328
70							2,23	30,283
80							2,55	39,447
90							2,86	49,819
100							3,18	61,400

Basic hydraulic equations

Manning-Strickler

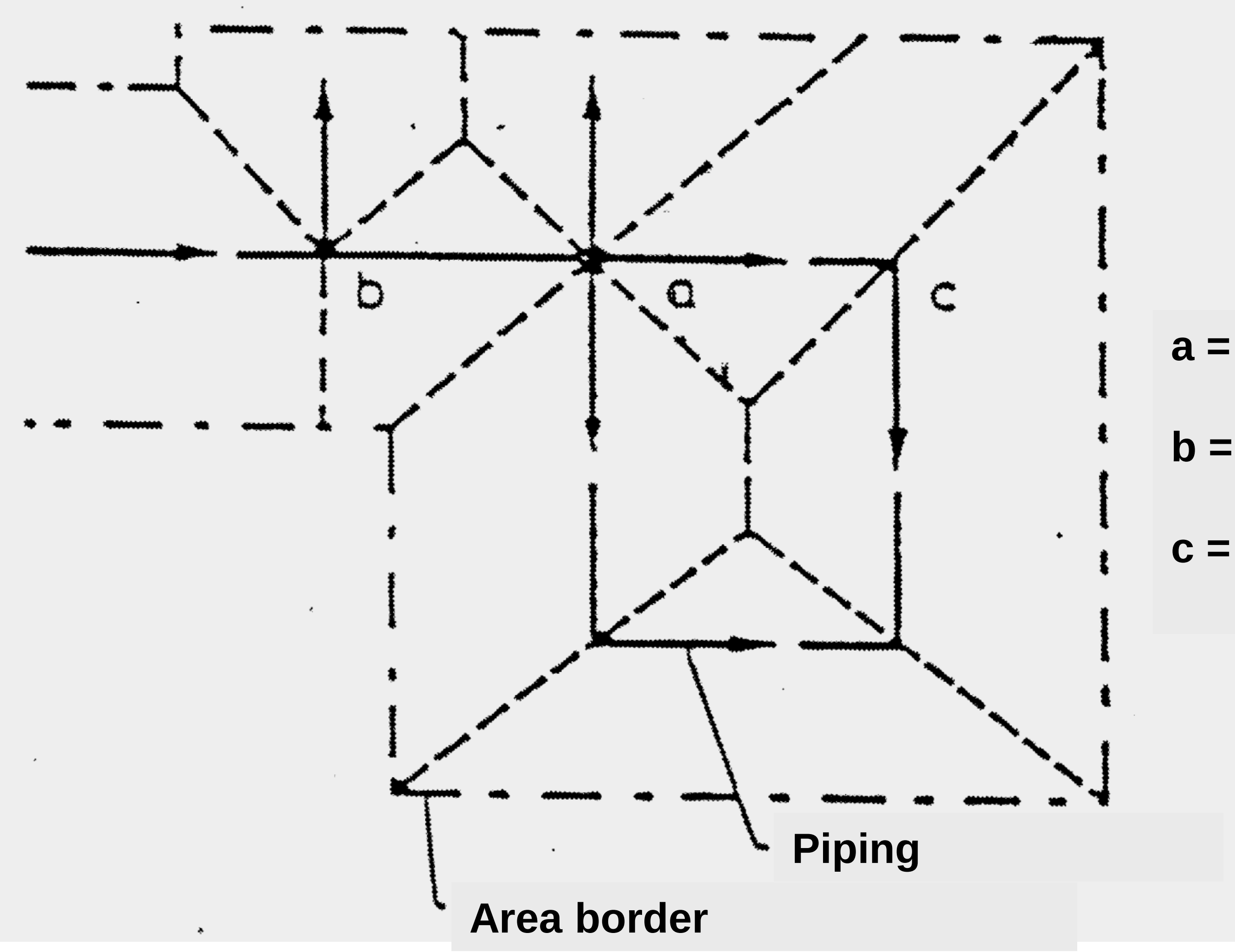
$$v = k_{St} \cdot r_{hy}^{2/3} \cdot I_E^{1/2}$$

with	$r_{hy} = A / l_u$ = hydraulic radius	[m]
	k_{St} = Manning-Strickler roughness coefficient	[m1/3s-1]
	I_E = energy gradient	[-]

k_{St} values

Soil canal	30 - 50
Stonewalled canal	50 - 75
Concrete canal	50 - 95

Area segmentation for the calculation of water flow quantities

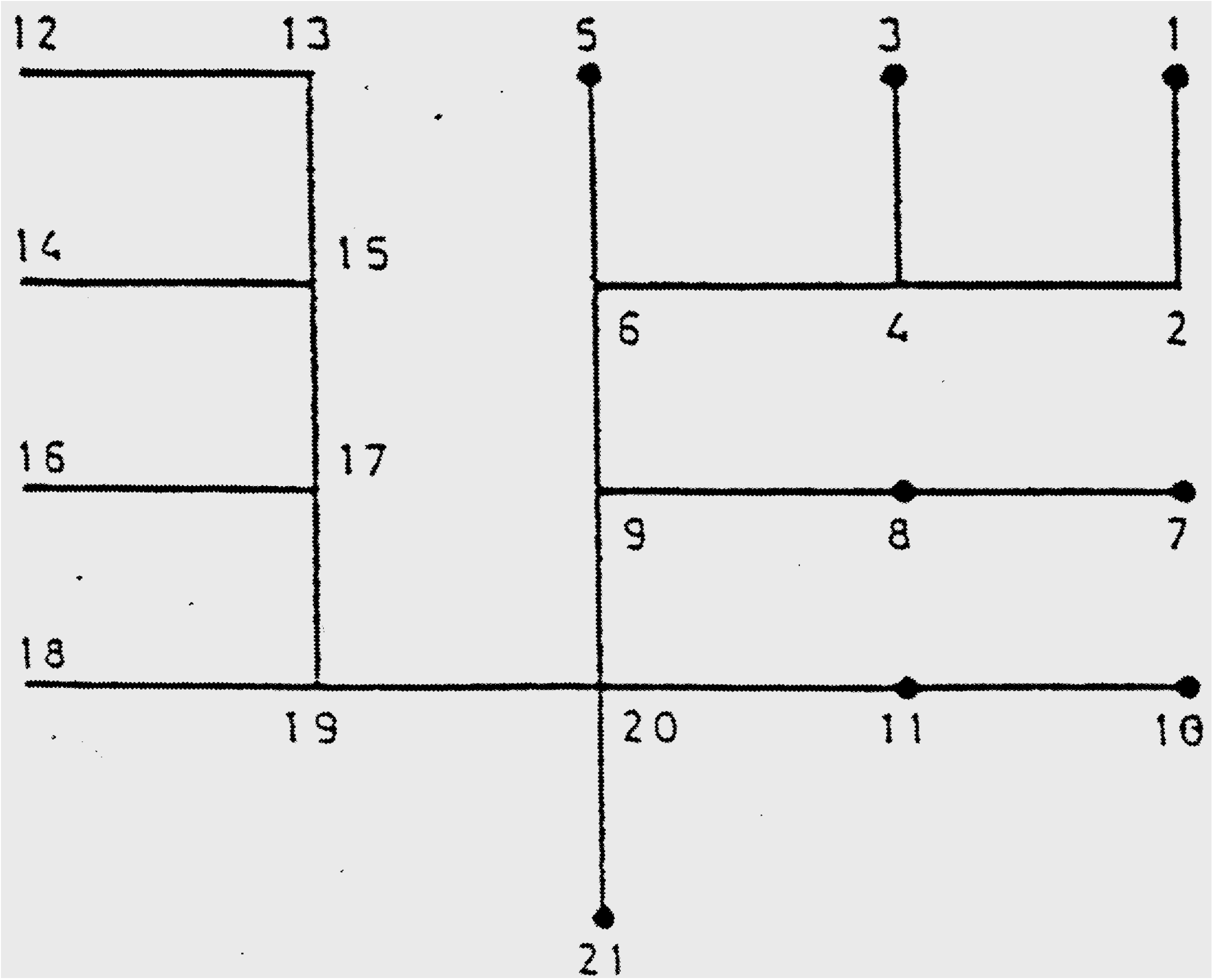


a = junction

b = branch

c = inflection point

Determination of calculation points



Distance quantity value

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Assuming that the consumption within the area of supply along the lines is constant, and that the total consumption Q and the entire pipe length L is well-known, than the distance quantity value *(Metermengenwert)* and/or surface quantity value *(Flächenmengenwert)* can be calculated as follows:

$$\mathbf{q_m = \frac{Q}{L}}$$

[m³/m*s*1000 = (l/s)/m]

Considering the area and population, q_m can be calculated with:

$$q_m = \frac{A \times E \times \max Q_h}{S l' \times 3600}$$

[(l/s)/m]

l' = comparison length, e.g. = 2 L when bilateral/double-sided construction, max Q_h in l/inhabitant·h, e.g. 10 - 15 l/inhabitant·h

Reference values for the determination of distance quantity values

Type of development	Built-up area %	Inhabitants per ha	Pipe length per ha	Distance quantity value q_m [l/s/m]
very dense (downtown area)	50	400 - 800	230	0,0048
dense (row houses)	40	250 - 350	220	0,0034
middle dense (houses)	30	150 - 200	200	0,0028
spacious (one-family-house)	20	100 - 120	130 - 150	0,0025
outer region	10	60 - 90	90 - 100	0,0023

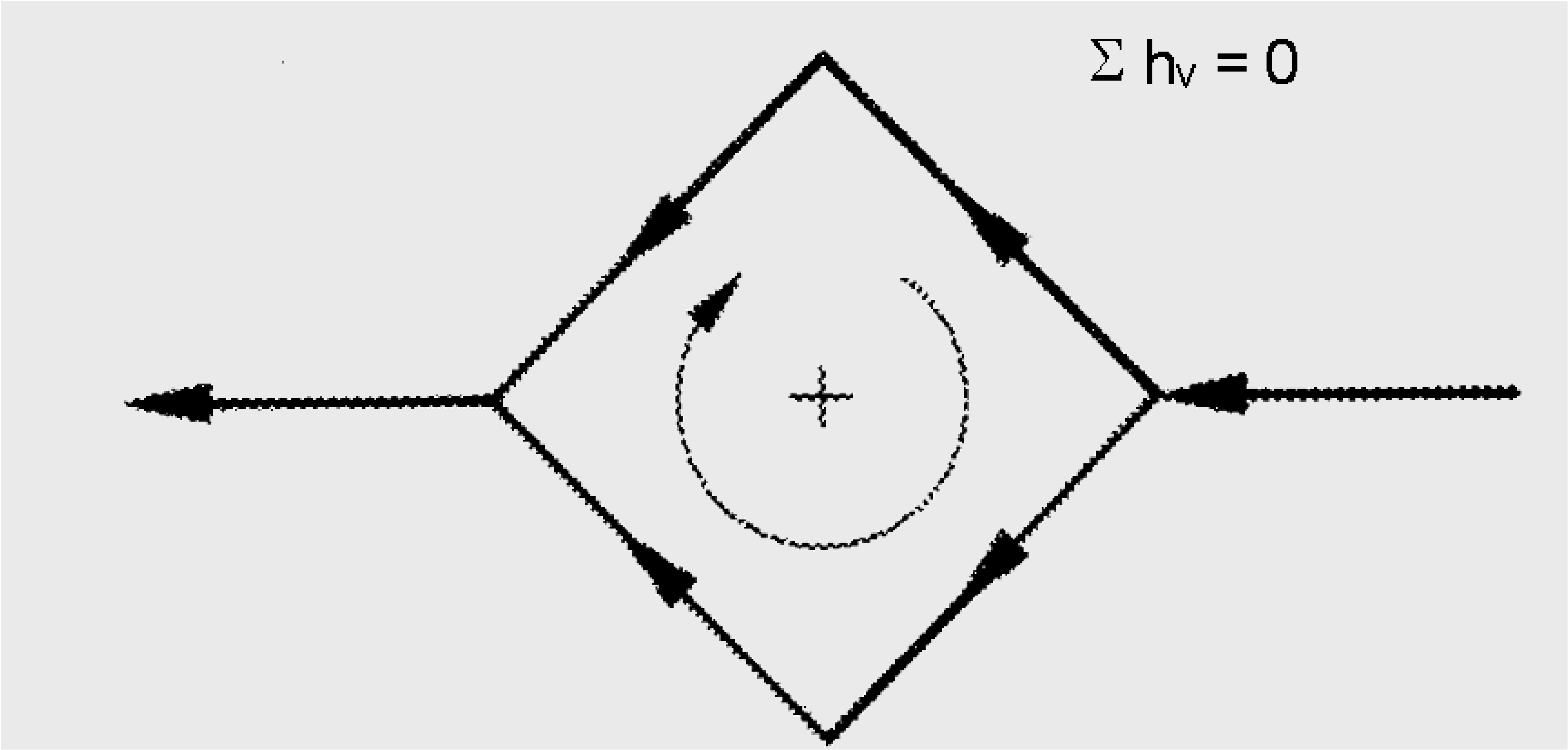
Calculation of ring networks

A ring distribution network can be calculated with the iterative Cross-method

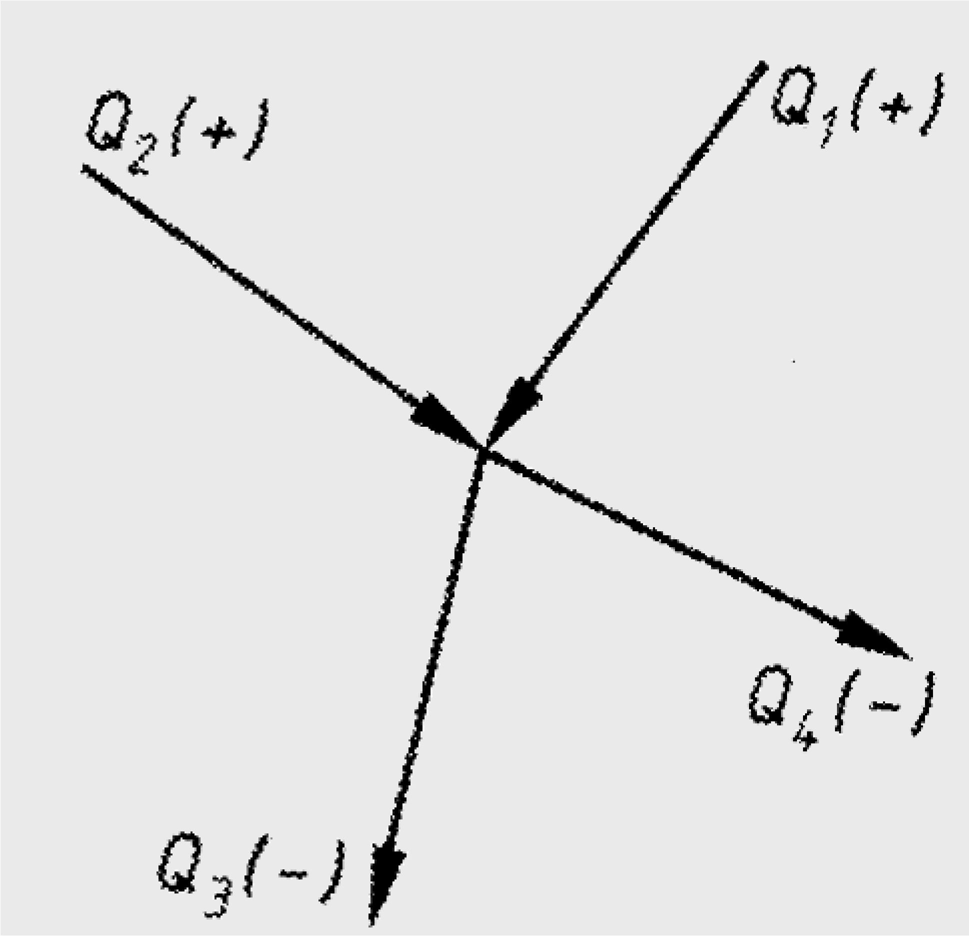
In meshed pipe distribution networks the two Kirchhoff Laws are valid:

1. **Mesh rule** *(Maschenbedingung)*
2. **Nodal-rule or knot-rule** *(Knotenbedingung)*

Mesh rule according to CROSS

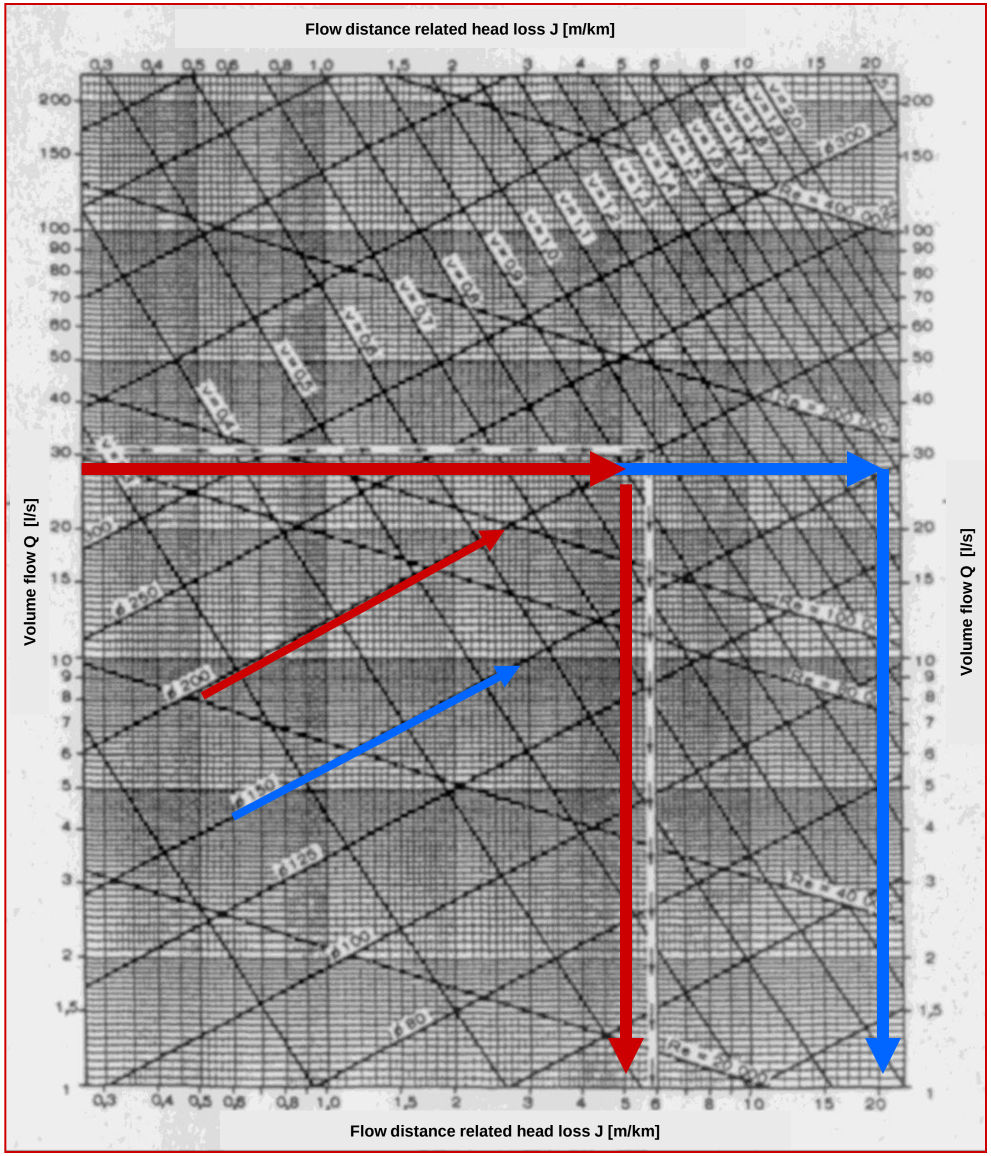


Nodal rule or knot-rule



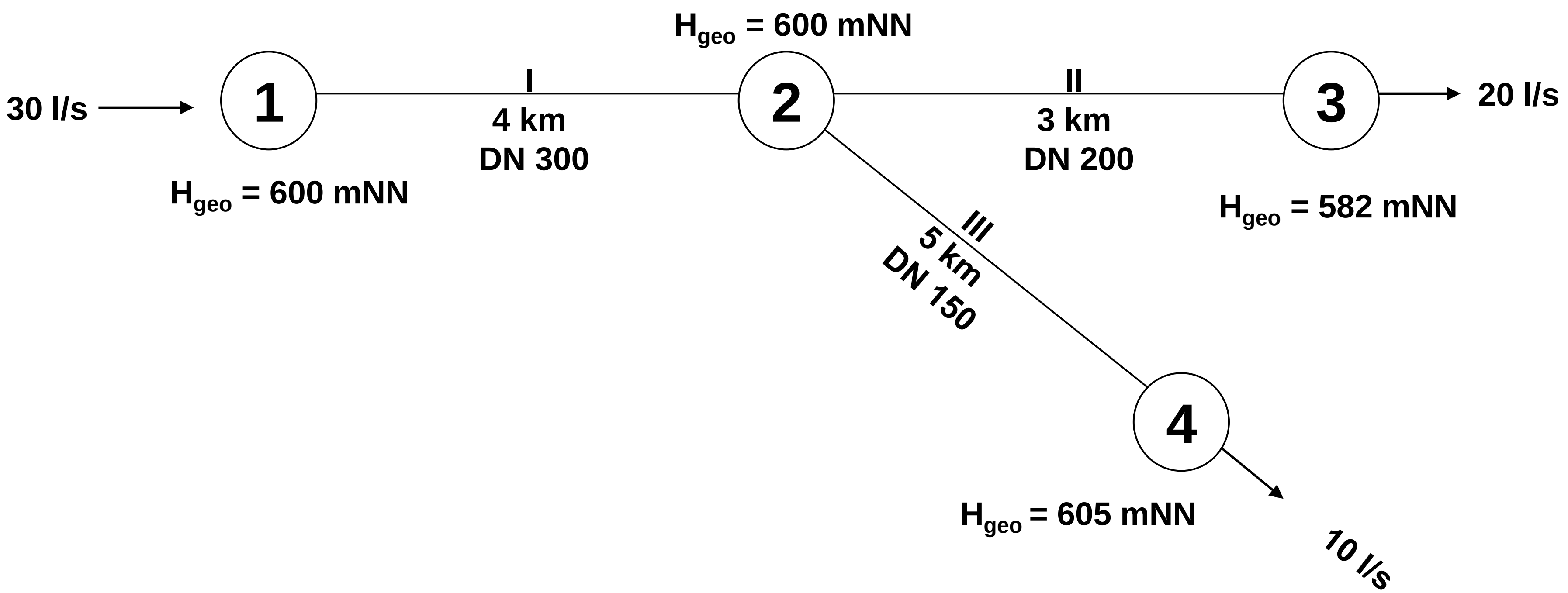
$\Sigma Q = 0$

Calculation of a distribution network



Calculation of a distribution network

The following system is given:



Pipe line construction

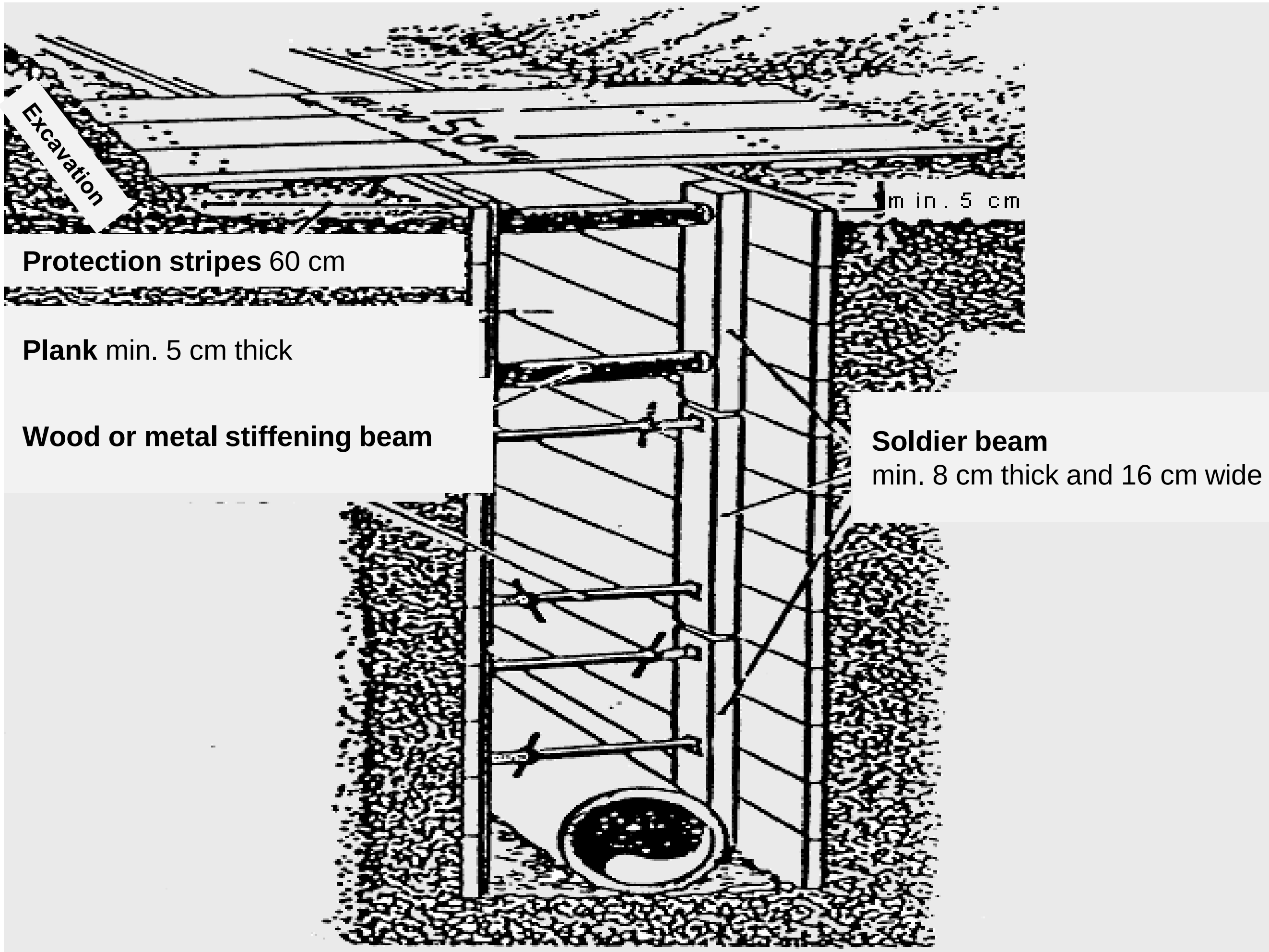
Piping materials:

- Grey iron-cast pipe *(Graugussrohr)*
- Steel pipe *(Stahlrohr)* (at high pressures)
- Asbestos cement pipe *(Asbestzementrohre)* (forbidden since 1989) nowadays fibre-cement-pipes
- Pre-stressed concrete pressure pipe *(Spannbetondruckrohr)* and reinforced concrete pressure pipe *(Stahlbetondruckrohr)* (for big diameters (2.25 m), e.g. long-distance pipe line)
- Plastic pipes *(Kunststoffrohre)* (PVC and PE, corrosion-resistant and hydraulically smooth)

Piping construction

- Minimal depth of cover of pipes 1.5 m (frost danger).
- Marked-out pipe lines to be kept free from tree planting.
- Pipe must be laid out properly.
- Pipe must be cleaned carefully.
- Afterwards pressure proof for 24 h with nominal pressure + 5 bar extra, valid pressure decrease 0.1 bar with PN 10.
- Before start-up flush pipeline thoroughly and disinfect with chloric Water. Chlorine solution should have a reaction time of 24 h. Afterwards pipes have to be rinsed.

Horizontal trench lining



Valve with push-in, flexible joint

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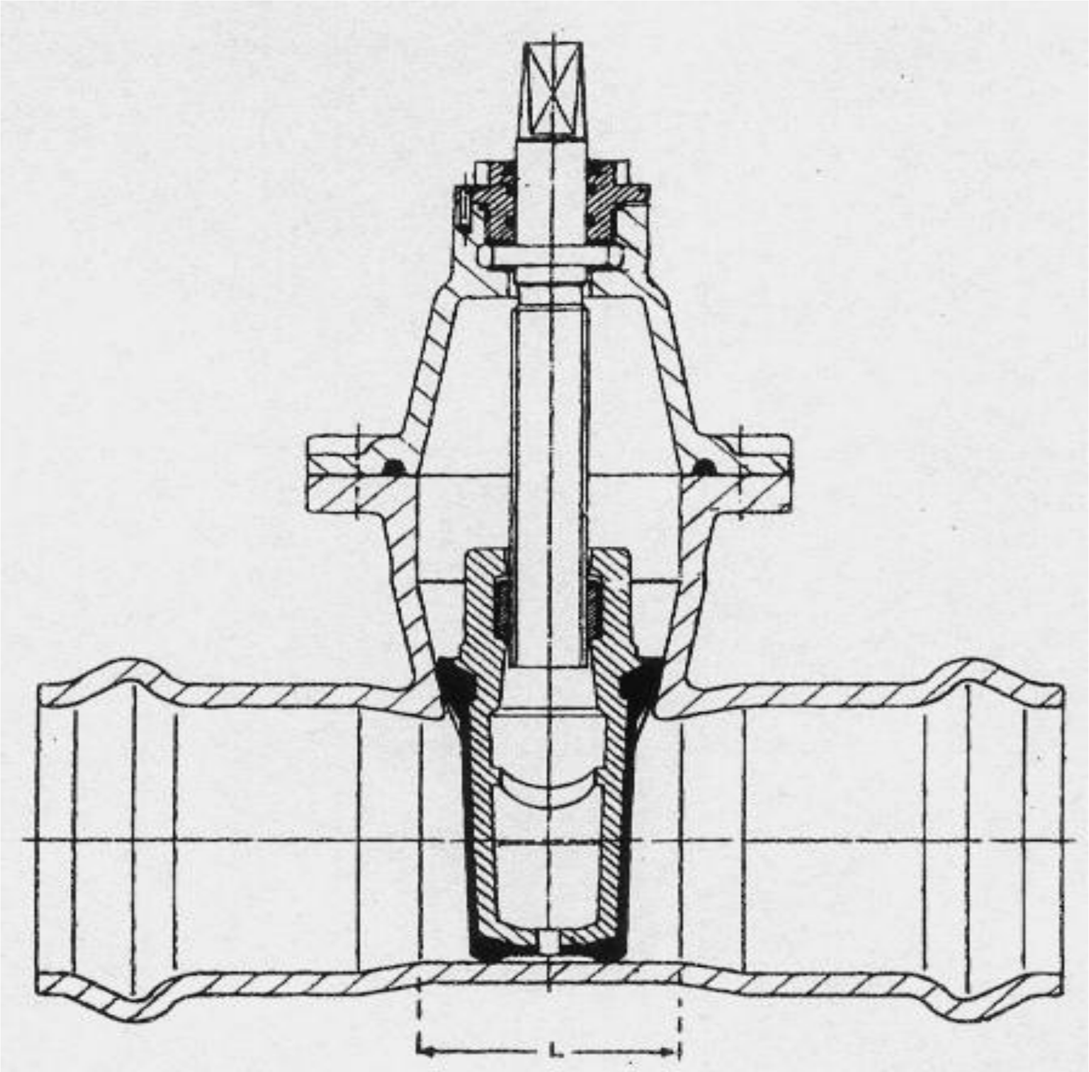
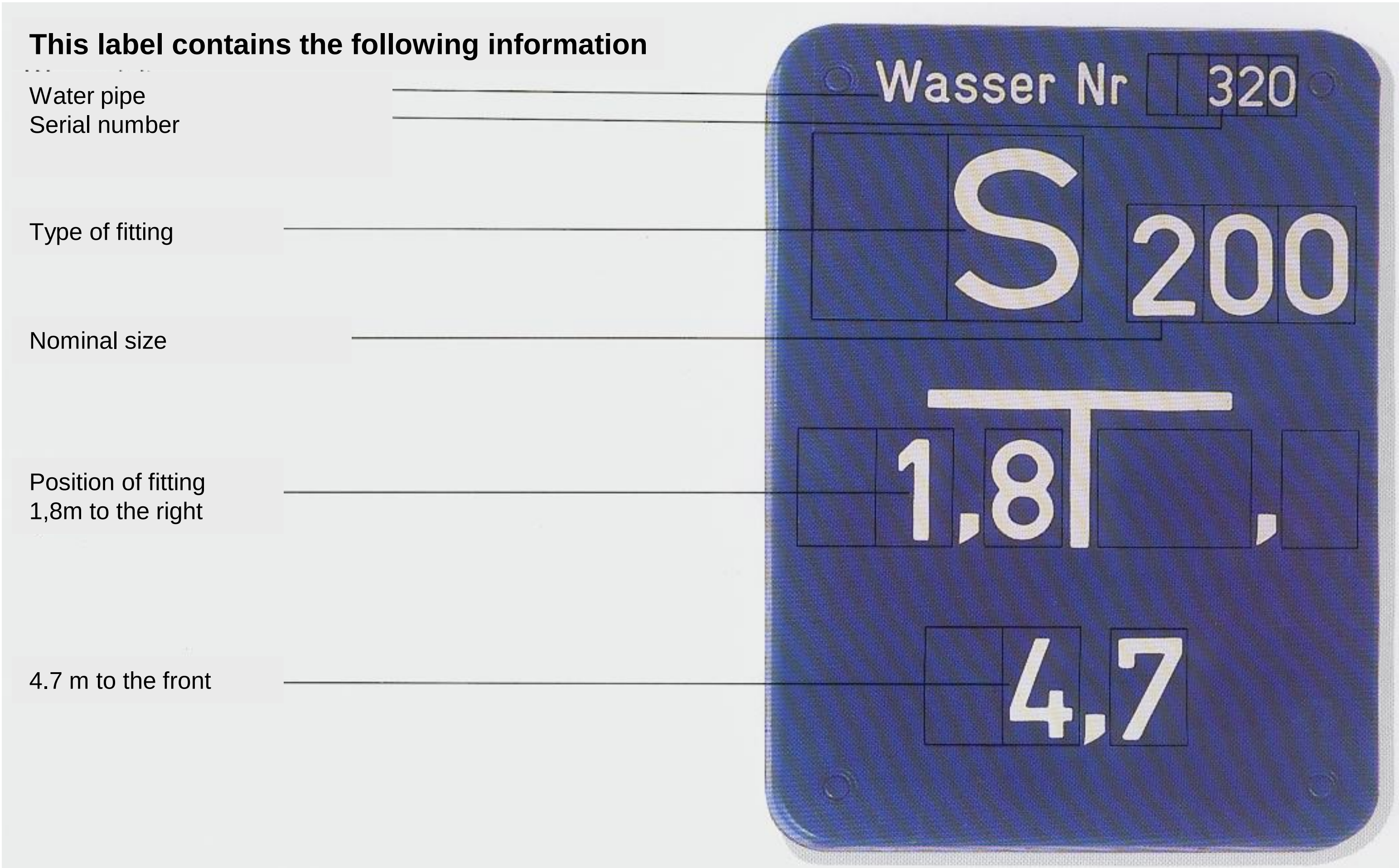
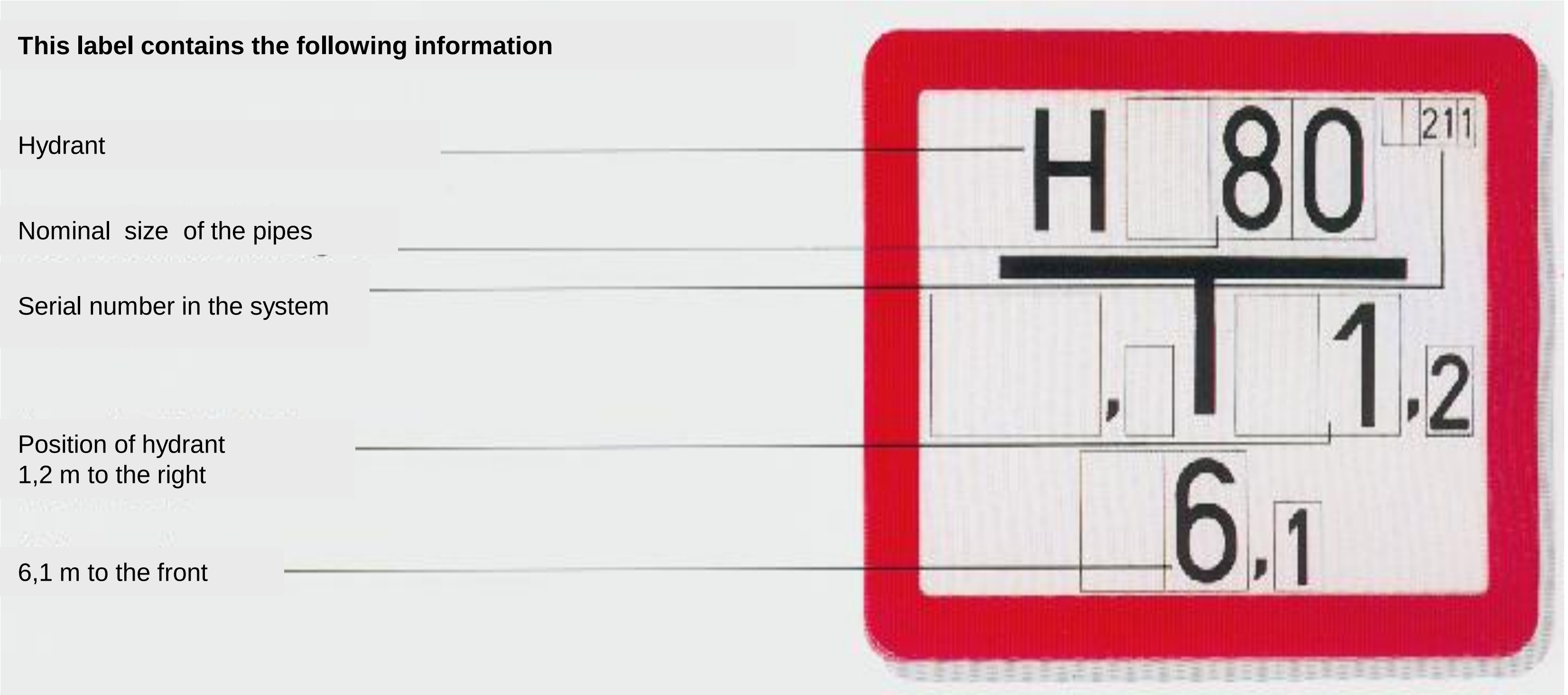


Labeling of water pipes DIN 4067



Hydrant DIN 4066



Sewage DIN 4068

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This label contains the following information:

Sewage

Serialnumber in the system

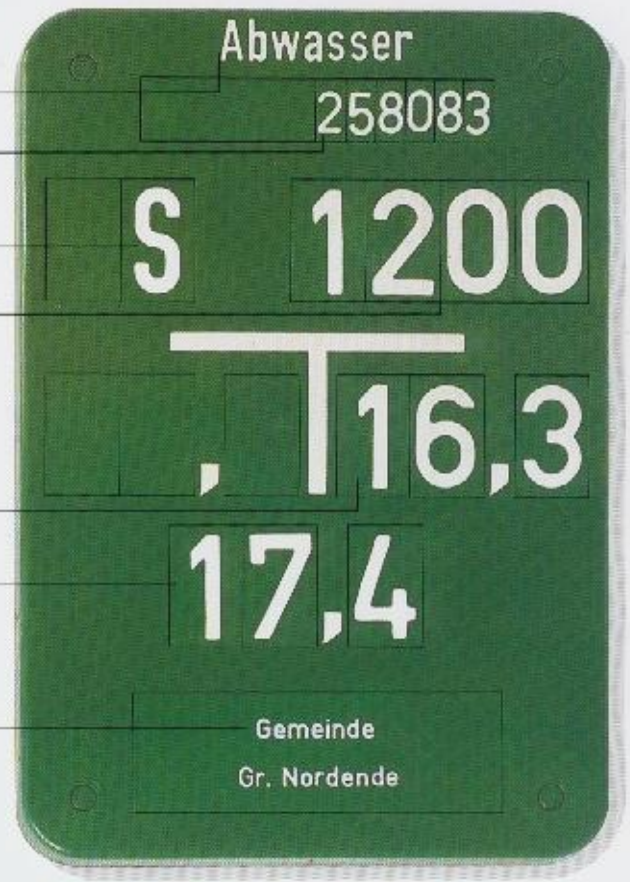
Valve type

Nominal size of the pipes

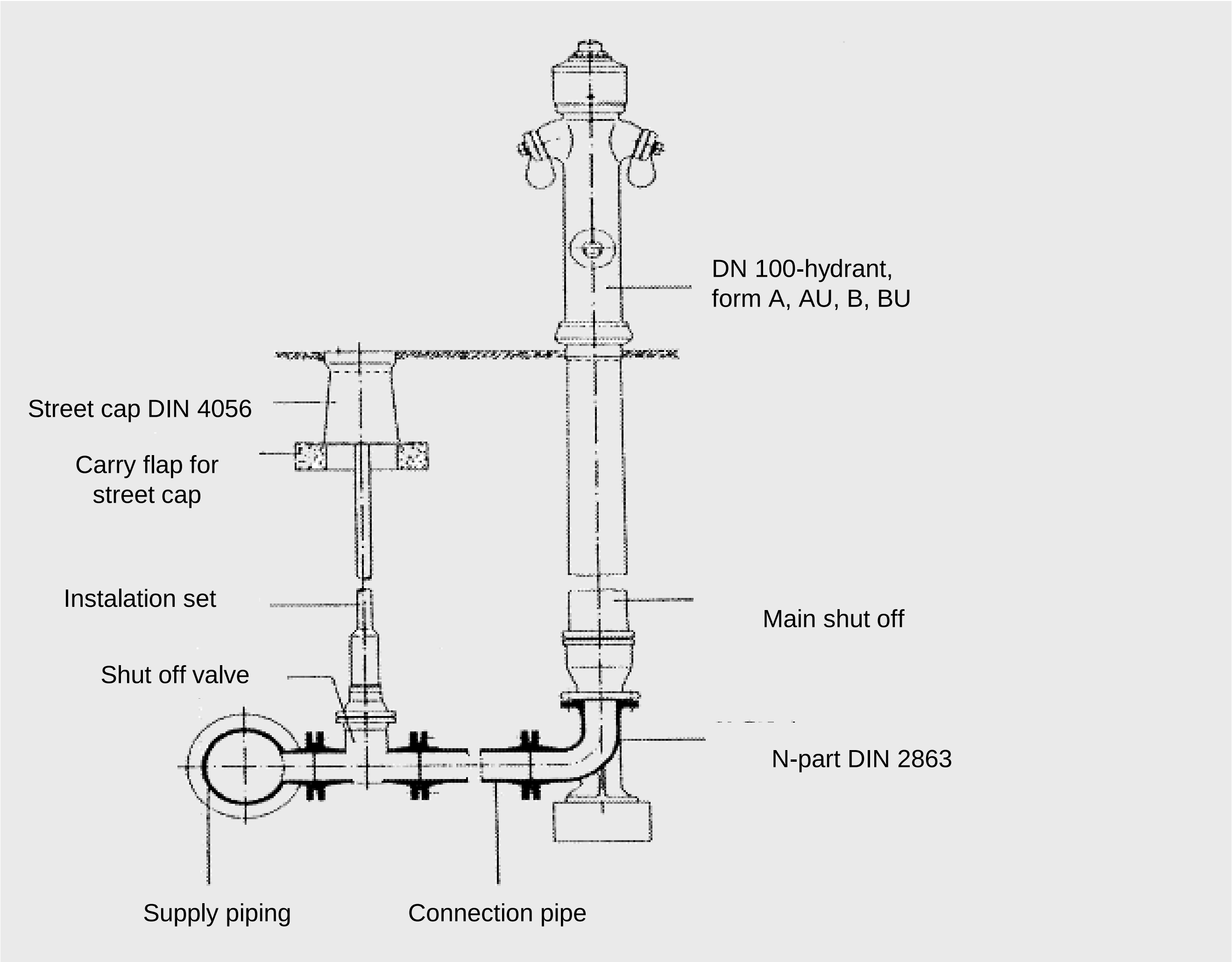
Position of fitting 16,3m to the right

17,4m to the front

Information for the control of operations and special indications e.g. name of operator and tel. number in case of emergency



Piping system equipment
Fire-fighting-hydrant

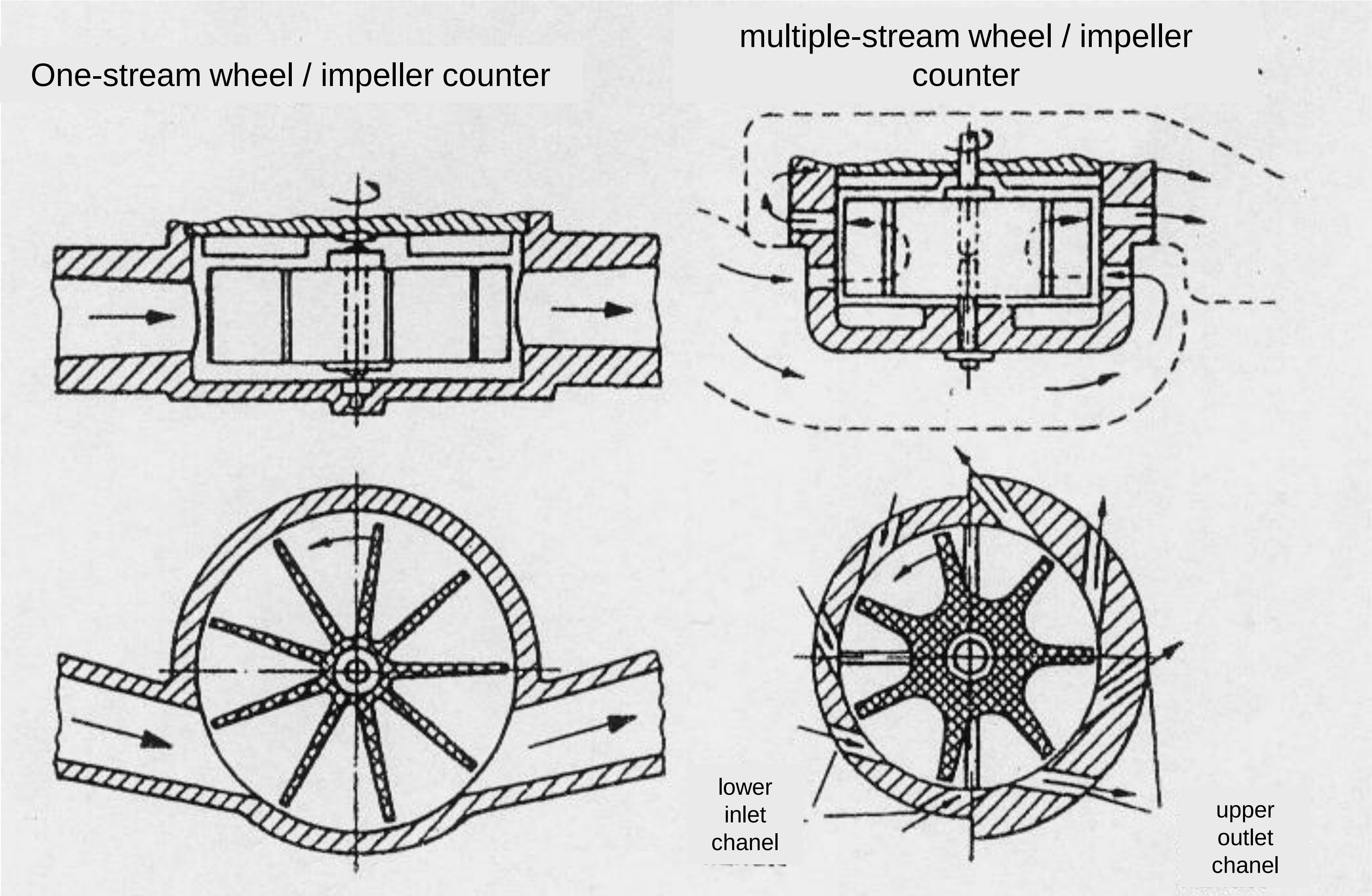


Flow counter (water-meter)

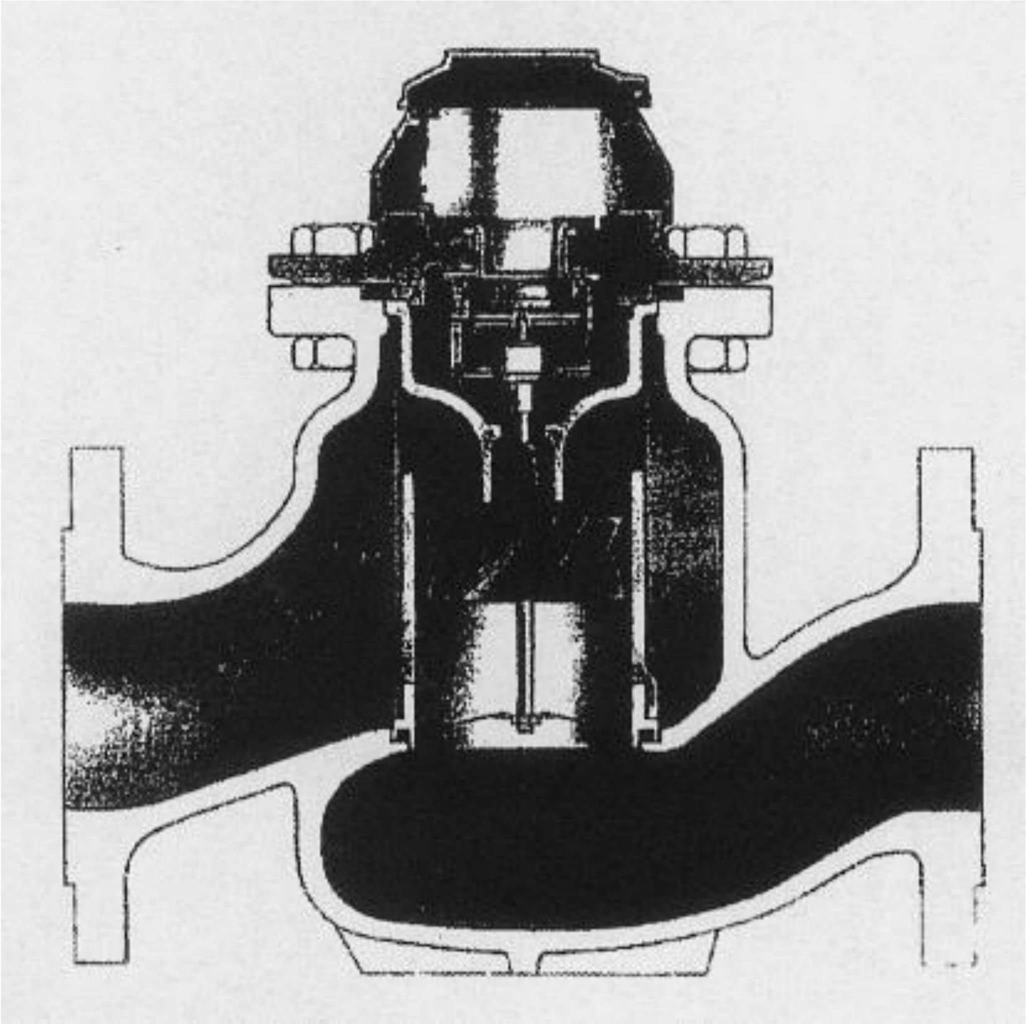
Water meters are subject to the law over the measuring and calibration of 1970.

According to this law must all in the trade of water used water meters be calibrated or certified by a state-approved inspection station.

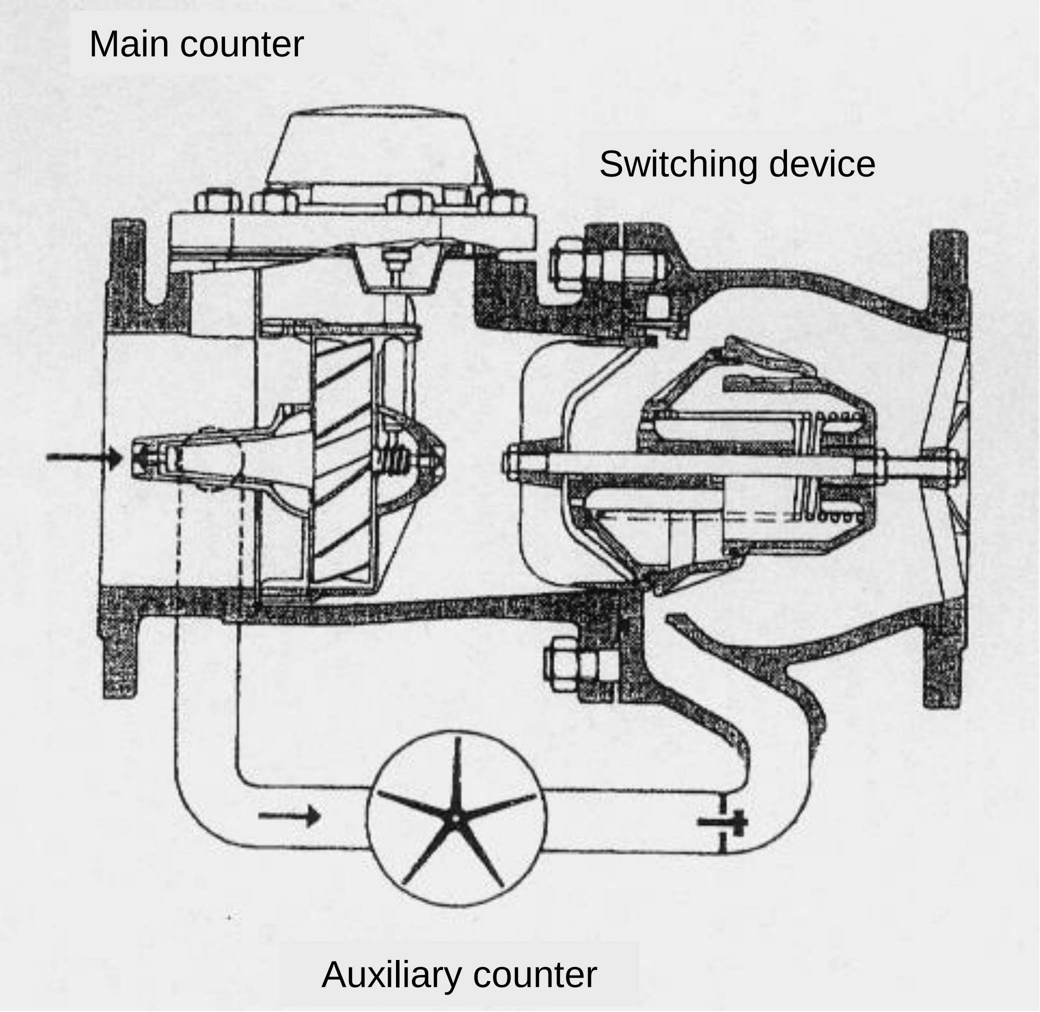
Wheel counter *(Flügelradzähler)*



Woltmann counter

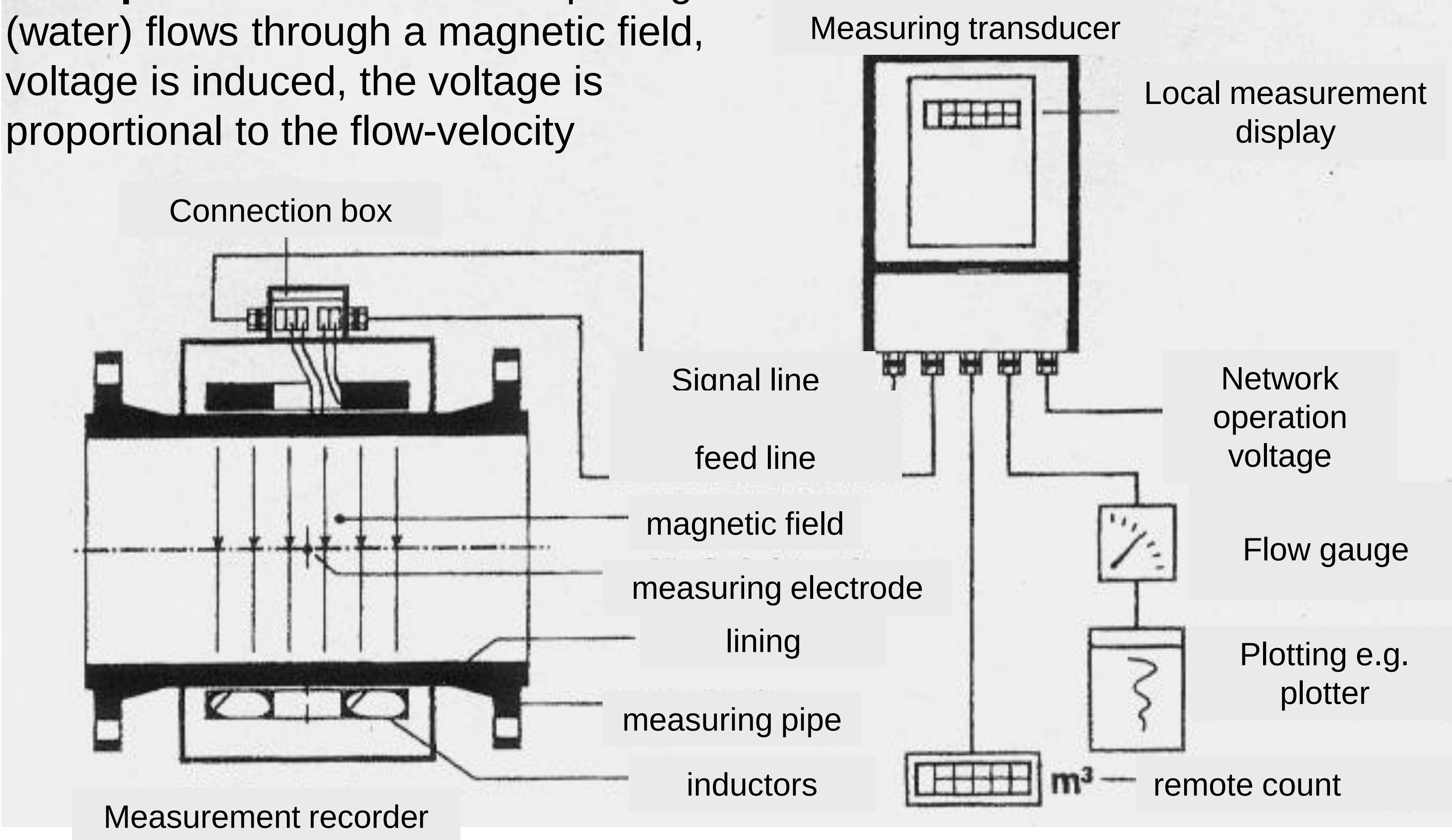


Compound counter *(Verbundwasserzähler)*

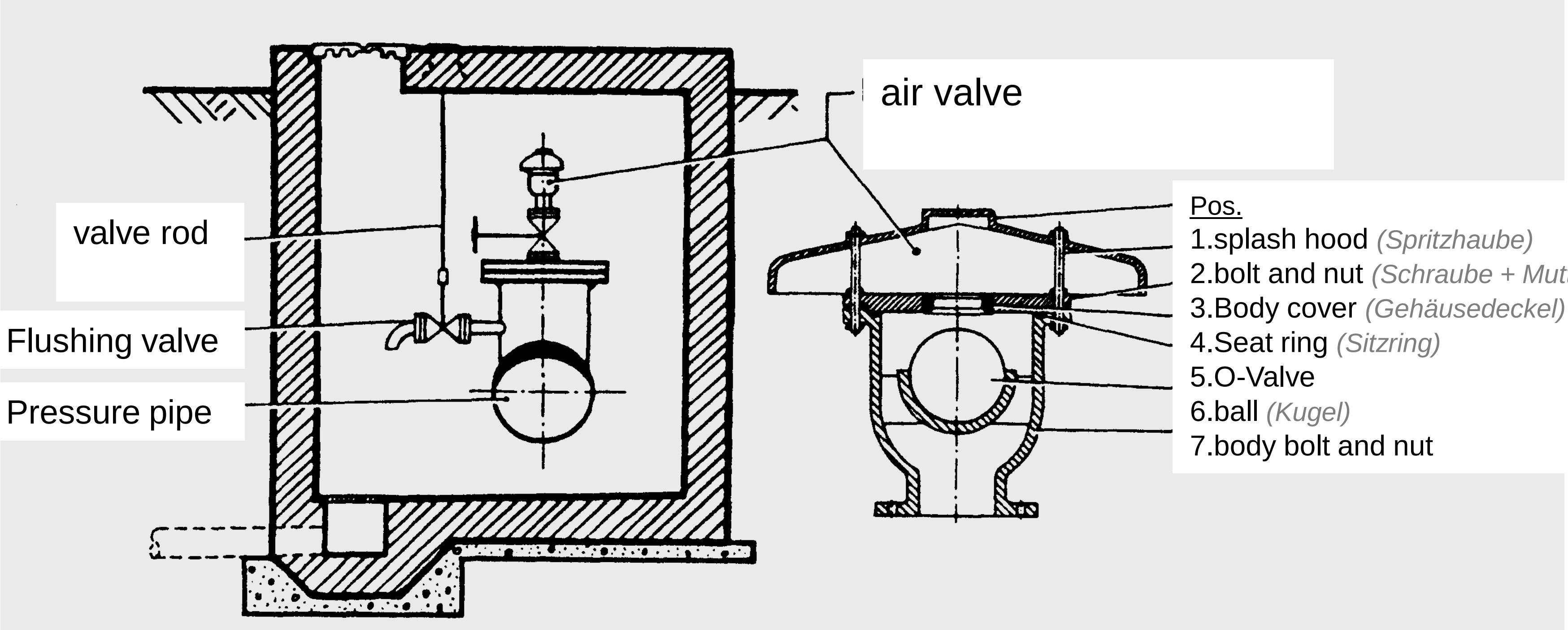


Magnetic inductive flow measurement

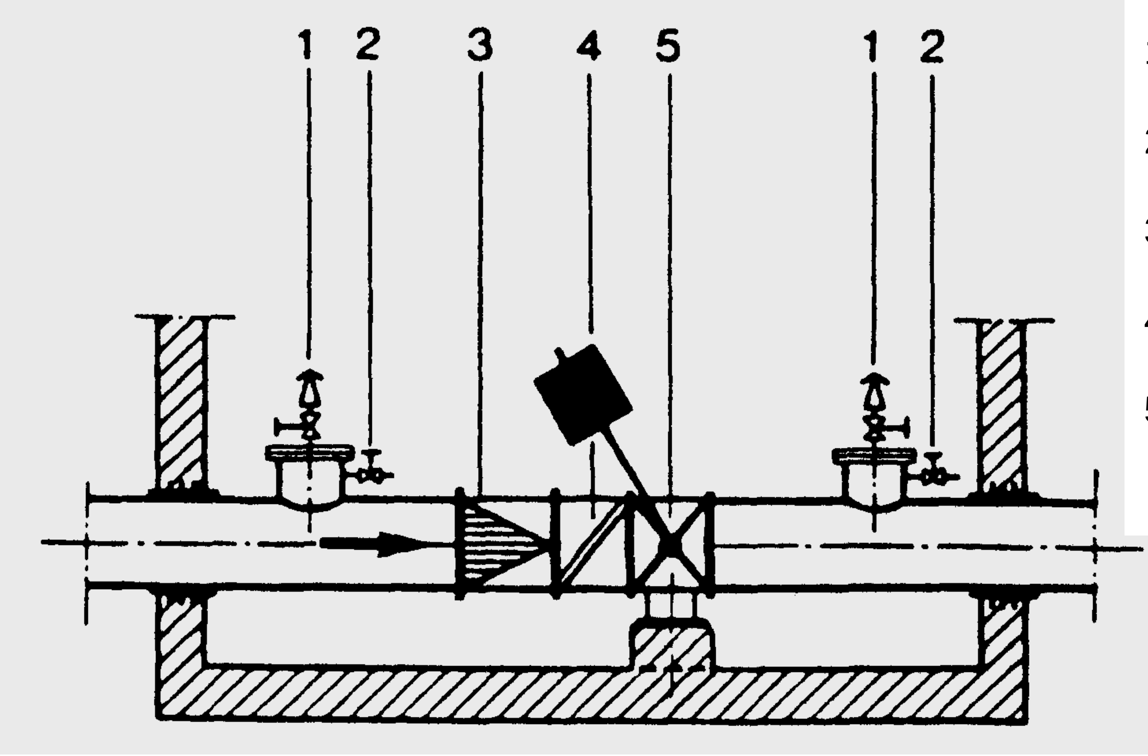
Principle: when electron-transporting material (water) flows through a magnetic field, voltage is induced, the voltage is proportional to the flow-velocity



Aeration and degassion valves



Example for pipe burst protection



1. Air valve
2. Manual ventilation system
3. Flow measurement device
4. Disassembling device
5. Pipe burst protection „instrument“