Lecture 5

Methods of Drinking Water Treatment and Storage

Part a) Treatment

Water purification

Quality requirements according to DIN 2000

Water that does not need a purification is to be preferred to water that should be considered for treatment.

Measures for the water purification are basically:

• Complete removal of the human related (anthropogenic) contaminants that cannot be found in nature (toxic substances), e.g. According to § 12 (13) TrinkwV (Drinking water regulation)

• Extensive reduction of undesirable substances (impurities), e.g. Iron, manganese

• Adjustment of specific substances in order to reach a desired concentration, e.g. components of the lime-carbonic acid-balance

• Addition of O_2 until saturation, pH-balance

Aeration

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Open (unpressurized)

The aim is a gas exchange *(Gasaustausch)*.

Procedure: cascade aeration *(Kaskadenbelüftung)*, spraying tower *(Turmverdüsung)*

Disadvantage: possible nitrogen accumulation *(Stickstoffanreicherung)* in the filter bed

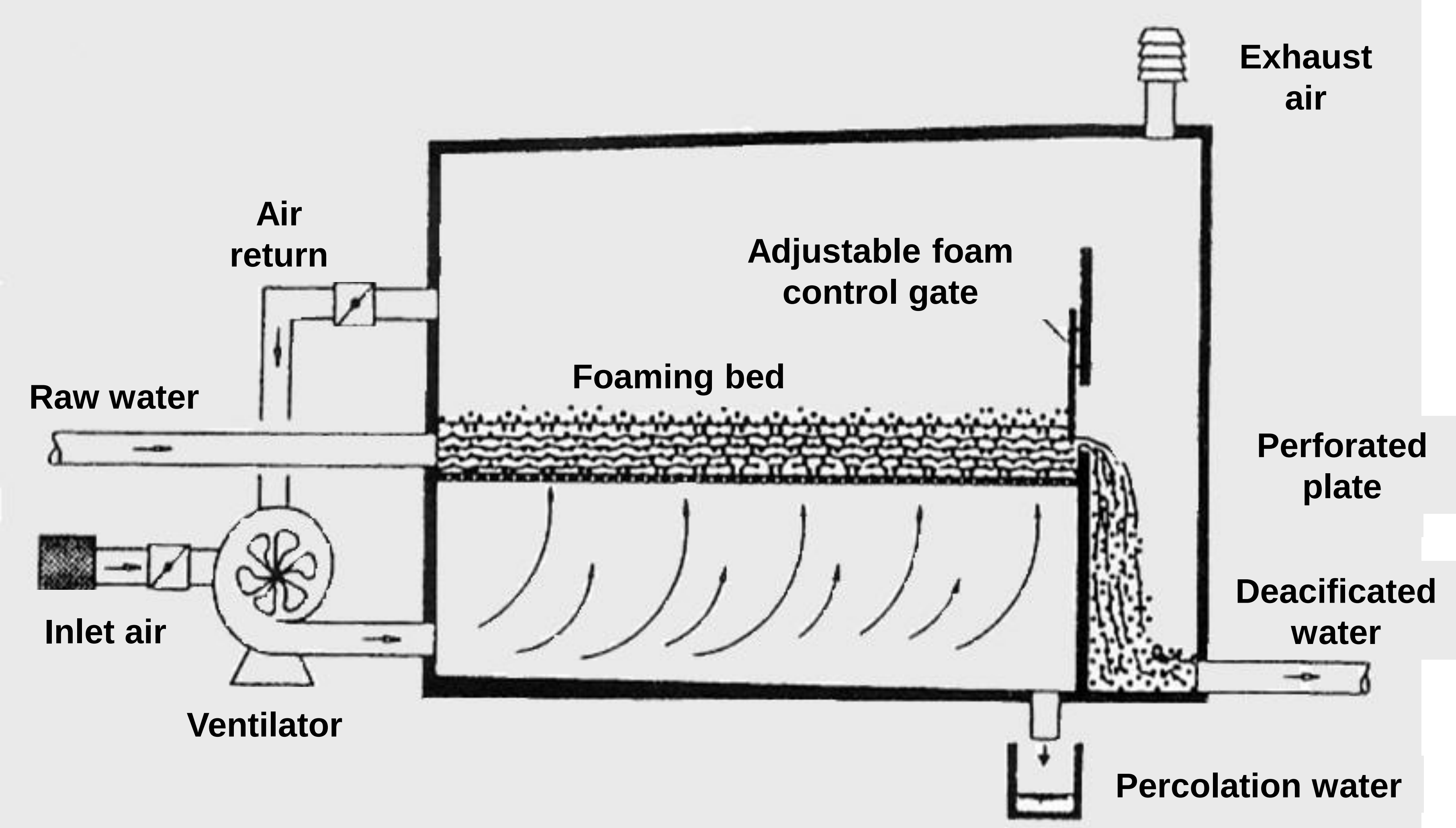
Closed (pressurized aeration)

The aim is the oxidation, transformation of Fe^{2+} in Fe^{3+}.

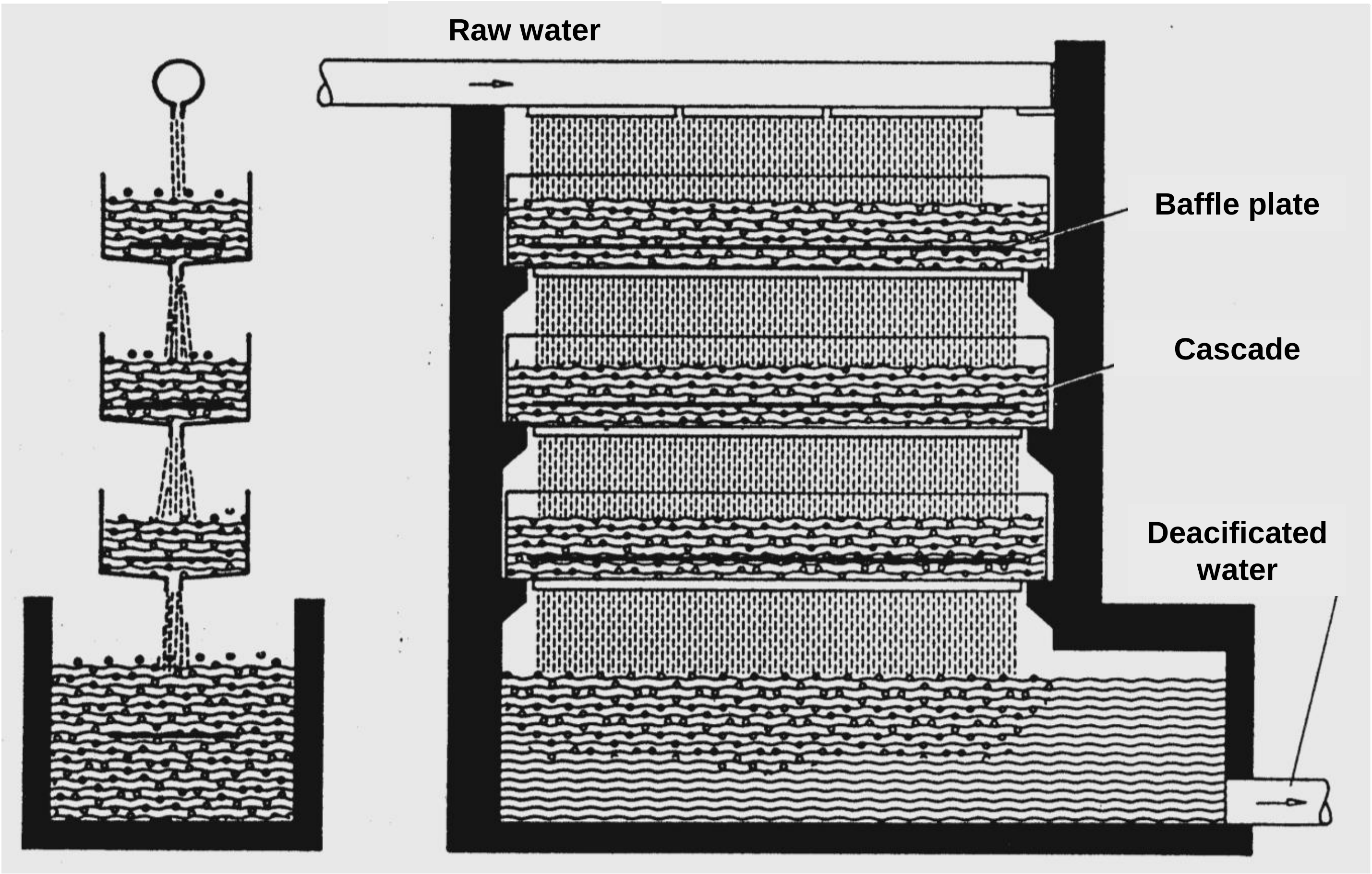
Oxygen requirement 0.14 mg O_2 for 1 mg Fe^{2+}

Procedures: oxidation, liquid oxygen, contact filter columns *(Füllkörperkolonne)*

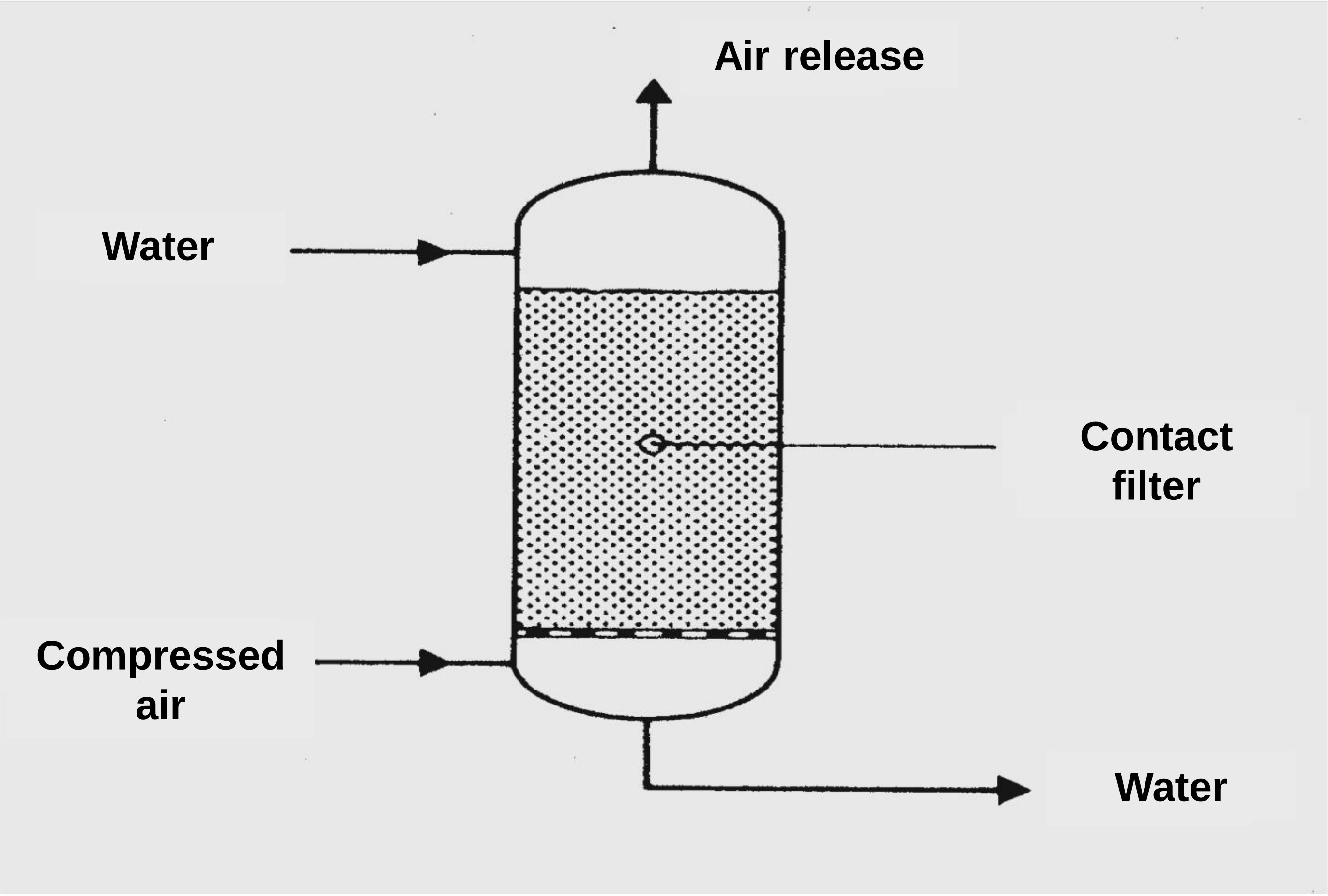
INKA- Cross-Flow Aeration



Cascade aeration



Contact filter column with reverse-flow (Gegenstrom)



Technical data & applications for gasification and degasification

Method	Surface load in m^3/m^2*h	Necessary admission pressure in m WC	Total power demand in Wh/m^3 air	CO_2- removal efficiency	O_2- diffusion efficiency
Spraving	6 - 15	10 - 15	60	70	100
Piping grid cascade	bis 250	10	30	65	100
Corrugated-sheet tickler (multi-stages)	bis 800	2	20	90	95 - 100
Contact filter column	45 - 60	10	55	70 - 95	k. A.
INKA	15 - 30	3 - 4	30	80 - 95	95 - 100

Filtration of aerated/ventilated water

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Filtration:

concentration change, mostly reduction of specific substances in water *(Wasserinhaltsstoffe)* by percolation *(Durchströmen)* through a filter material.

Filter effect:

- melchanical-physical (adsorption), e.g. by silica sand *(Quarzsand),* anthracite
- chemical by lime rock, e.g. marble, semi calcinaded dolomite (magnesian limestone),
- biological through microorganisms

Filter velocity: $v_F = Q / A_F$ (Inflow related to the surface area)

Slow sand filter

Sterilization effect 3-4 decimals reduction, precondition TSS in feed inlet < 3 - 10 g/m³.

Operation parameters for slow sand filter *(Langsamsandfilter):*

- Sand filter grain diameter 0.8 – 1.2 mm
- Filter velocity *(Filter-Geschwindigkeit)* (related to the full cross section) 10 – 20 cm/h
- Filter layer height *(Filterschicht-Höhe)* 0.4 – 1.0 m
- Water level *(Wasserüberstand)* 0.8 – 1.2 m
- Retention time *(Verweilzeit)* in filter ca. 10 h

Open rapid sand filter

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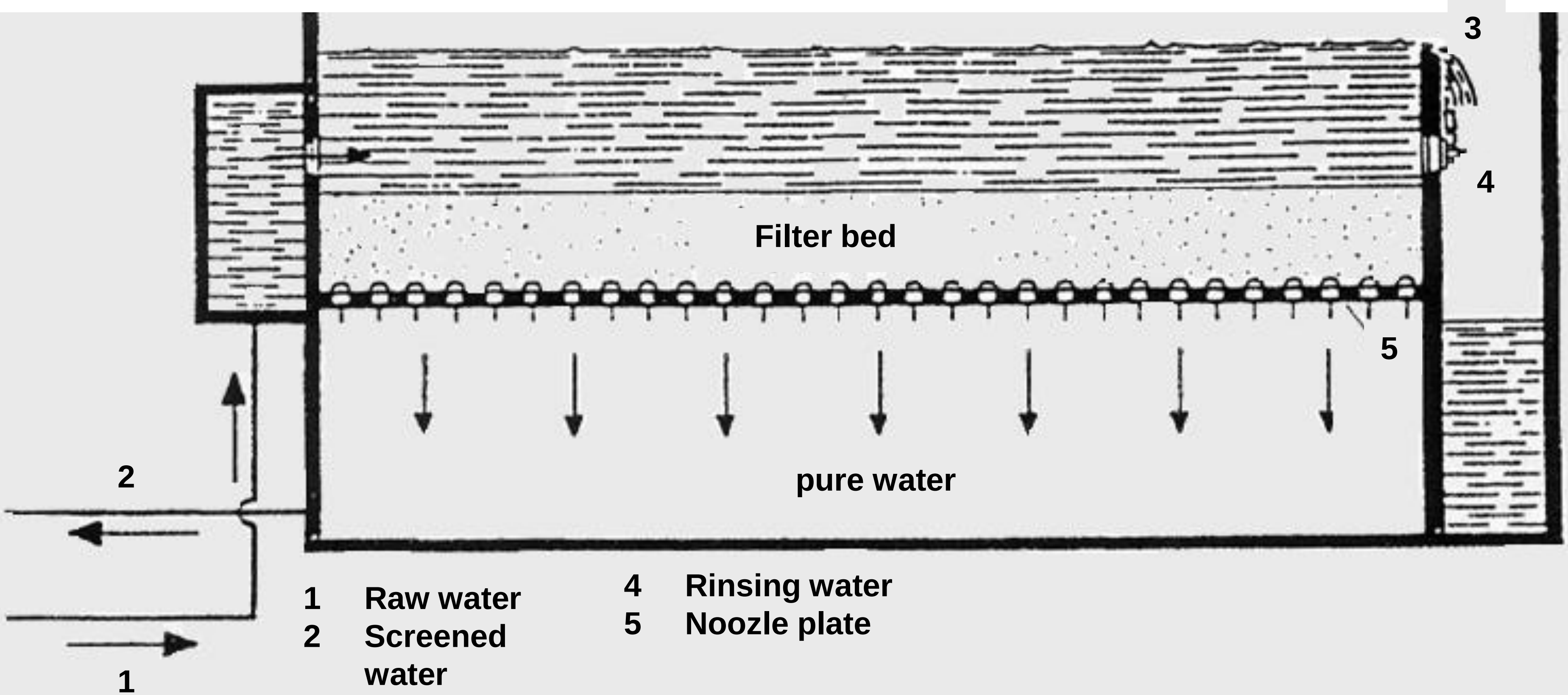
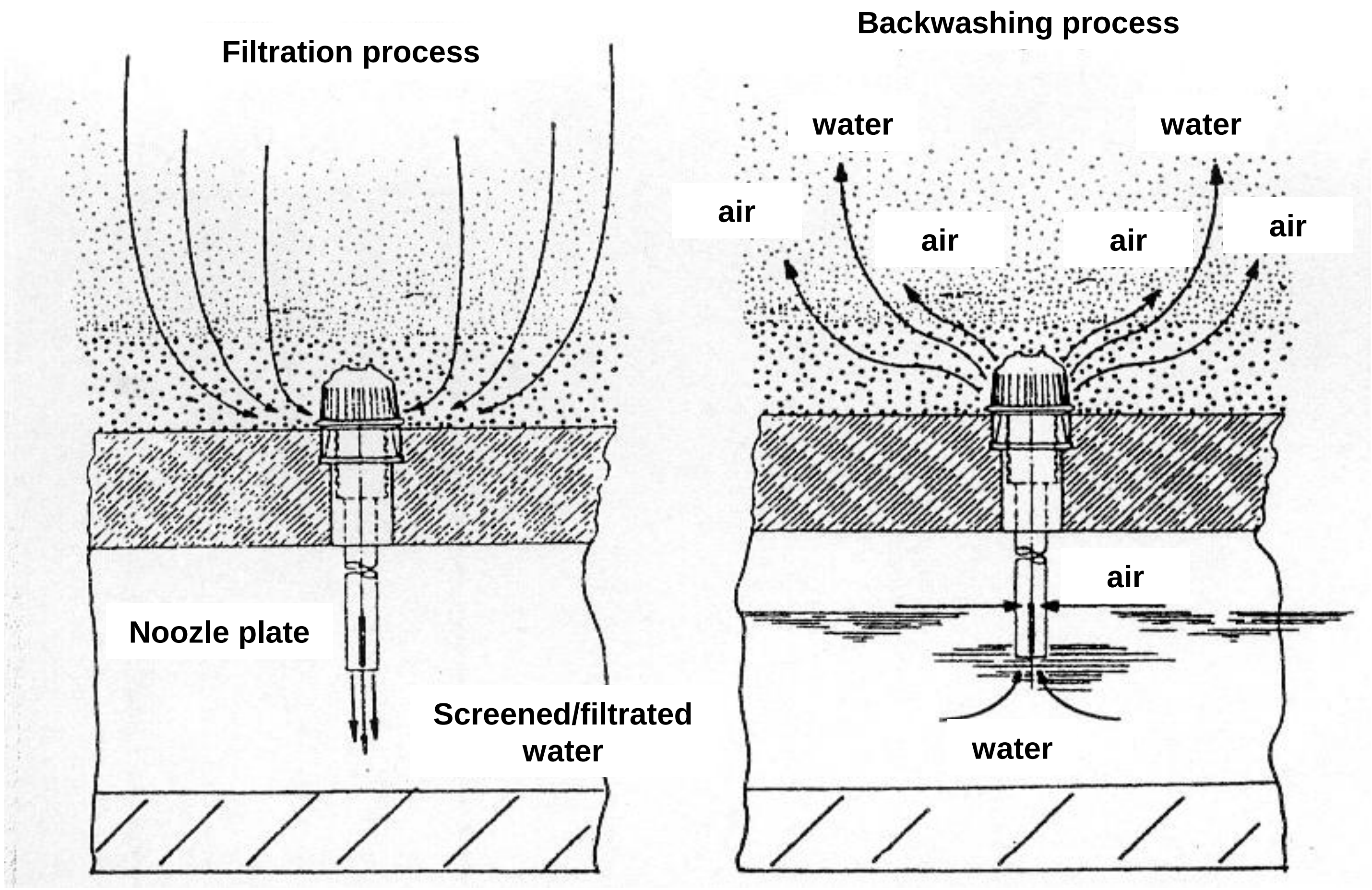
Base area B ≤ 3, L ≤ 20 m, v_f = 4 -7 m/h



1 Raw water
2 Screened water
3 Emergency spillway
4 Rinsing water
5 Noozle plate

Filtration and backwashing process – open rapid sand filter -

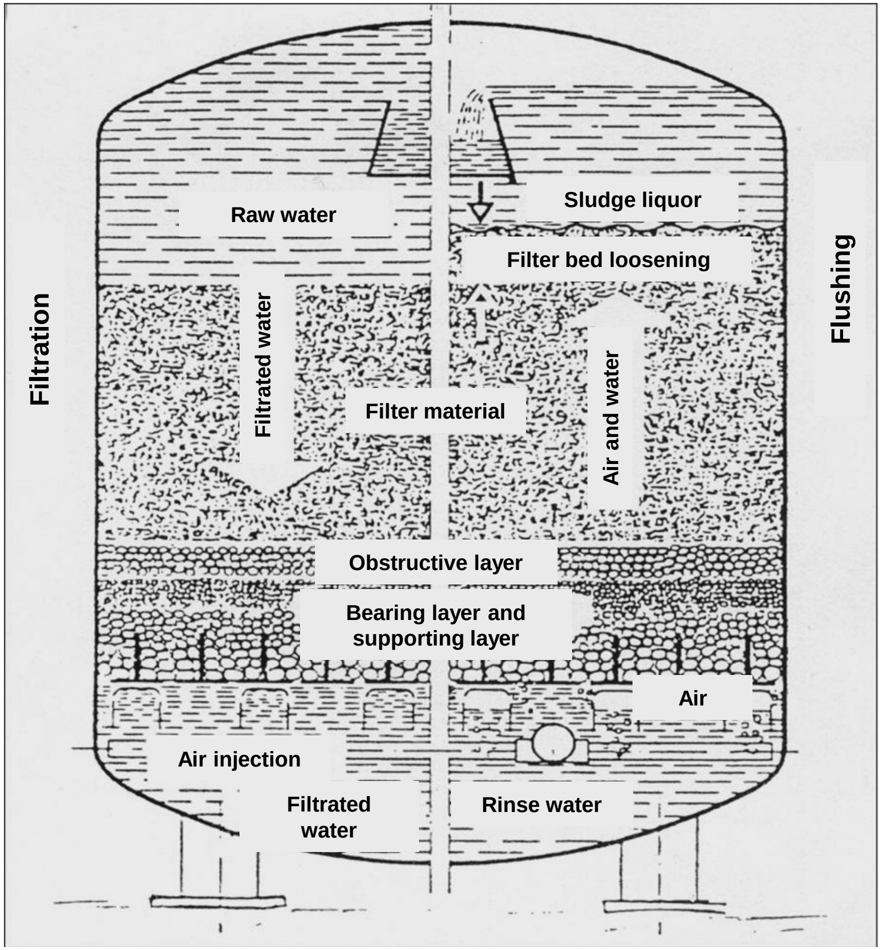


Dimensioning of a rapid sand filter

Filter grain size:	
- diameter	0.8 – 1.2 mm
Filter velocity:	
- open rapid sand filter	4 – 7 m/h
- closed rapid sand filter	> 10 m/h
Filter bed height *(Filterbetthöhe)*, for a retention time of	10 -15 min
with minimal height	0.8 m
Clear = Backwashing *(Rückspülen)* **with water and air**	
amounts of	
- water	3 – 4 l/(s · m²)
- air	25 l/(s · m²)
duration 10 – 30 min backwashing, when	
Filter resistance	
- open rapid sand filter	> 1 m WS
- closed rapid sand filter	> 10 m WS
Filter velocity	
- water	$v_W = 4 * 3.6 = 14.4$ m/h
- air	$v_A = 25 * 3.6 = 90$ m/h

Filtration and backwashing process in a closed rapid sand filter (pressurised filter)

Grain size 0.8 – 1.2 mm, H ≥ 0.8 m, t_R = 10 – 15 min, v_F ≥ 10 m



Filtration

Multilayer filter: spatial filter, hydro-anthracite and quartz, v_F = 10 – 20 m/h

Activated carbon adsorption: (W 239, 240)

Disinfection: chlorine, ozone, chlorine dioxide, hydrogen peroxide, UV radiation

Deacidification: Filtration through lime, dolomitic filter material (magnesium lime), dosage of hydroxides (limestone slurry, caustic soda solution, sodium carbonate, related with the adding of hardness and pH-increase)

Softening: Calcium-ion precipitation, dosage of lime, caustic soda solution, sodium carbonate for the purpose of precipitation, ion exchange

Rohwasseranalyse - Auszug (Hannover, 1996)

Raw water October till December 1996	Units of measurement	Limit value according to TrinkwV. (Filtered water)	Minimum value	Mean value	Maximum value
Odour	qualitative	–	H_2S	H_2S	H_2S
Coloring	qualitative	–	yellowish	yellowish	yellowish
Turbidity	qualitative	–	without	without	low
Water temperature	°C	25	9,2	9,3	9,5
pH-value at specific water temp.	–	>6,5 – <9,5	6,44	6,57	6,70
Permanent hardness	°d	–	10,8	11,0	11,2
Temporary hardness	°d	–	3,3	3,4	3,5
Calcium	mg/l	400	71	72	73
Magnesium	mg/l	50	3,8	4,2	4,6
Iron, total	mg/l	0,2	14,5	15,0	15,6
Iron (Fe^{2+})	mg/l	–	14,5	15,0	15,6
Manganese	mg/l	0,05	1,10	1,16	1,20
Ammonium	mg/l	0,5	0,71	0,75	0,78
Nitrite	mg/l	0,1	<0,01	<0,01	<0,01
Nitrate	mg/l	50	0,3	0,5	0,6
org. carbon, DOC	mg/l	–	9,1	9,6	10,5
Permanganate-Index	mg/l	–	26,4	28,9	30,1
Oxidizabilty	mg/l	5	6,68	7,30	7,62

Process Schema of water treatment in Ground Water Works Fuhrberg, city of Hannover

Withdrawal

↓

Mixing in mixing/storage tank

↓

Cascade aeration, deacidification, O_2-improvement, H_2S-removal

↓

H_2O_2 dosage, humates destruction, residue oxidation

accelator (flocculation/sedimentation)

↓

Process Schema of water treatment in Ground Water Works Fuhrberg, city of Hannover

↓

pH-value elevation ($Ca(OH)_2$)

↓

$KMnO_4$ dosage, oxidation for demanganazing

↓

Filtration (residual iron removal, nitrification, demanganizing in an open rapid sand filter, single-layer, quartz 0.7 – 1.2 mm, backwashing at nights with 70 - 90 m/h

↓

pH-value adjustement for lime-carbonic acid-balance (NaOH) to pH 7.5 – 7.7 and PO_4-P dosage as inhibitor

Lecture 5

Part b) Water Storage

System components and design

The main components of a water supply plant are:

Water catchment: *(Wassergewinnung)*
spring catchment, border spring, groundwater catchment with vertical filtration well *(Vertikalfilterbrunnen)*, bore well, subsurface drain, horizontal filtration well *(Horizontalfilterbrunnen)*, surface water catchment with reservoir, sea water catchment, river water catchment.

Water treatment: *(Wasseraufbereitung)*
oxidation, ozonation, flocculation *(Flockung)*, filtration *(Filterung)*, deacidification, deferrisation, demanganisation, water softening, desalination, disinfection.

Water pumpage: *(Wasserförderung)*
pumps, engines with electric drive.

Water storage: *(Wasserspeicherung)*
elevated earth tank *(Erdhochbehälter)*, water tower, underground tank *(Tiefbehälter)*, collection tank, pressure tank, fire water tank.

Water distribution: *(Wasserverteilung)*
public plant with interconnection pipeline, Long-distance pipeline, supply pipeline, plant with connecting pipeline, consumption pipeline.

Requirements of a water supply system

A water supply plant *(Wasserversorgungsanlage)* **must provide drinking water**

- in sufficient quantity
- of flawless quality
- at all times with sufficient pressure
- everywhere in the area of supply *(Versorgungsgebiet)*.

Capital investment percentages of a water supply infrastructure:

- water catchment: 2 - 6 %
- water treatment: 1 - 3 %
- water pumpage: 9 - 11 %
- water storage: 6 - 15 %
- water distribution: 65 - 82 %

Tasks and requirements of water storage

Tasks:

- storage of drinking water
- compensation of consumption peaks
- Bridgeover of operation disturbances
  (Betriebsstörung)
- pressure stabilisation
- fire fighting water
- reserve volume for pumps
- reserve capacity for filter flushing

Requirements:

- ensure water quality
- stable and permanent service
- reliable and efficient operation
- esthetic construction
- conforming to standard regulations

Types of water storage tanks

The most common types of water tanks *(Wasserspeicher)* can be differentiated according to different criteria, e.g. into:

- pressure
- altitude *(Höhenlage)*
- position to the supply network
- structural shape

Differentiation according to the position to the supply area

Run-through tanks *(Durchlaufbehälter)*

Run-through tanks are positioned between the water catchment and supplying area.

Advantages:
- pressure fluctuations in the supply area are small
- the stored water is always exchanged and thereby held fresh

Disadvantages:
- the entire water must flow through the container and must accordingly be lifted on to the tank height
- the supply network is feeded from just one side
- low supply security *(Versorgunssicherheit)*

Location of pumping stations, watertanks and local piping networks

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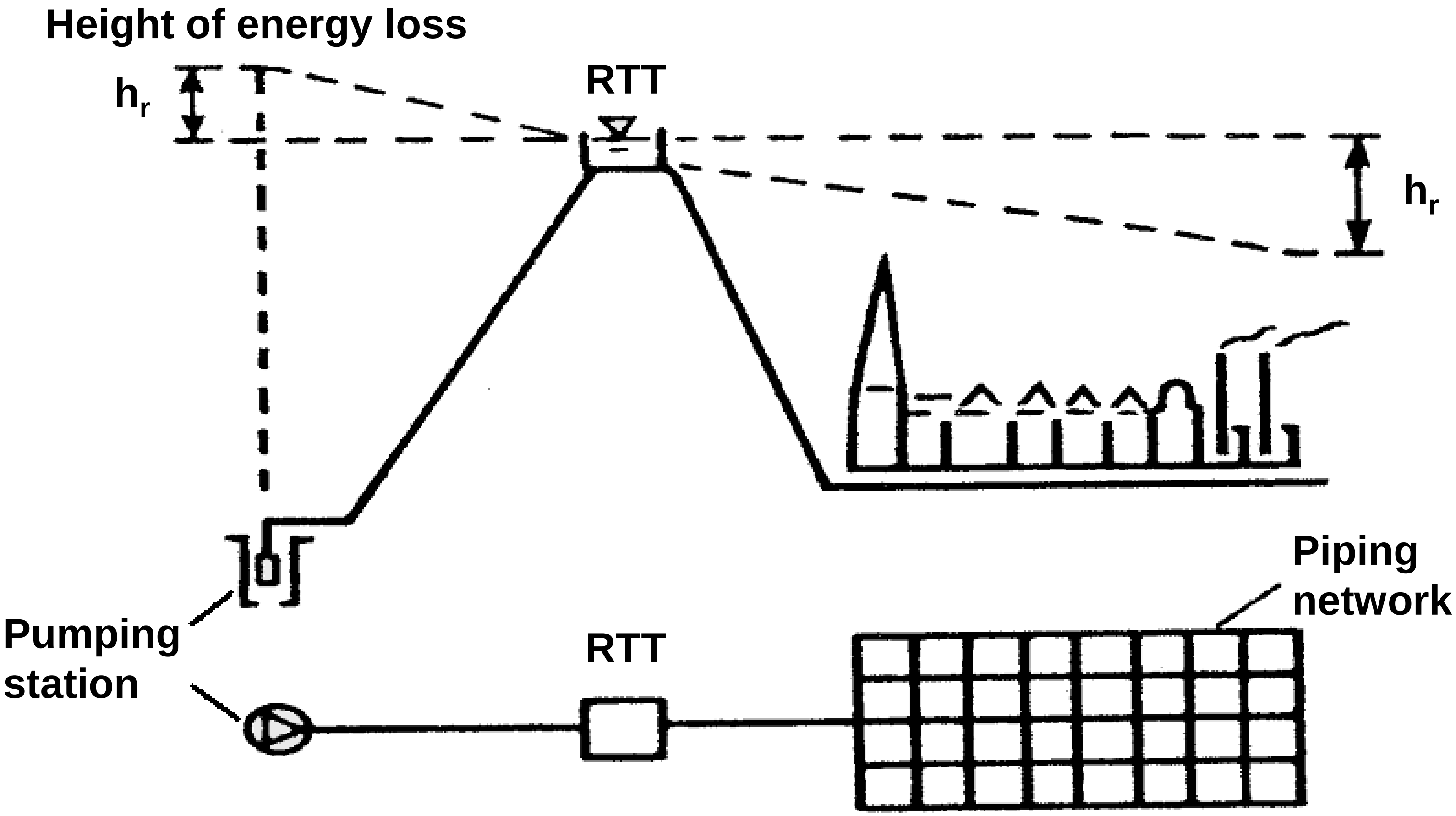
Run-through tank (RTT)



Differentiation according to the position to the supply area

Counter tanks *(Gegenbehälter)*

Counter tanks are positioned, seen from the inlet side, behind the supply area.

Advantages:

- only the not needed water of the supplying area has to be pumped into the tank. Thus the tank can be constructed smaller
- the supply network is fed from 2 sides. This leads to a smaller loss of pressure (low flow rates)
- higher operation-security *(Betriebssicherheit)*

Disadvantages:

- Water renewal in the tank is lower, possibly longer stagnation

Location of pumping stations, watertanks and local piping networks

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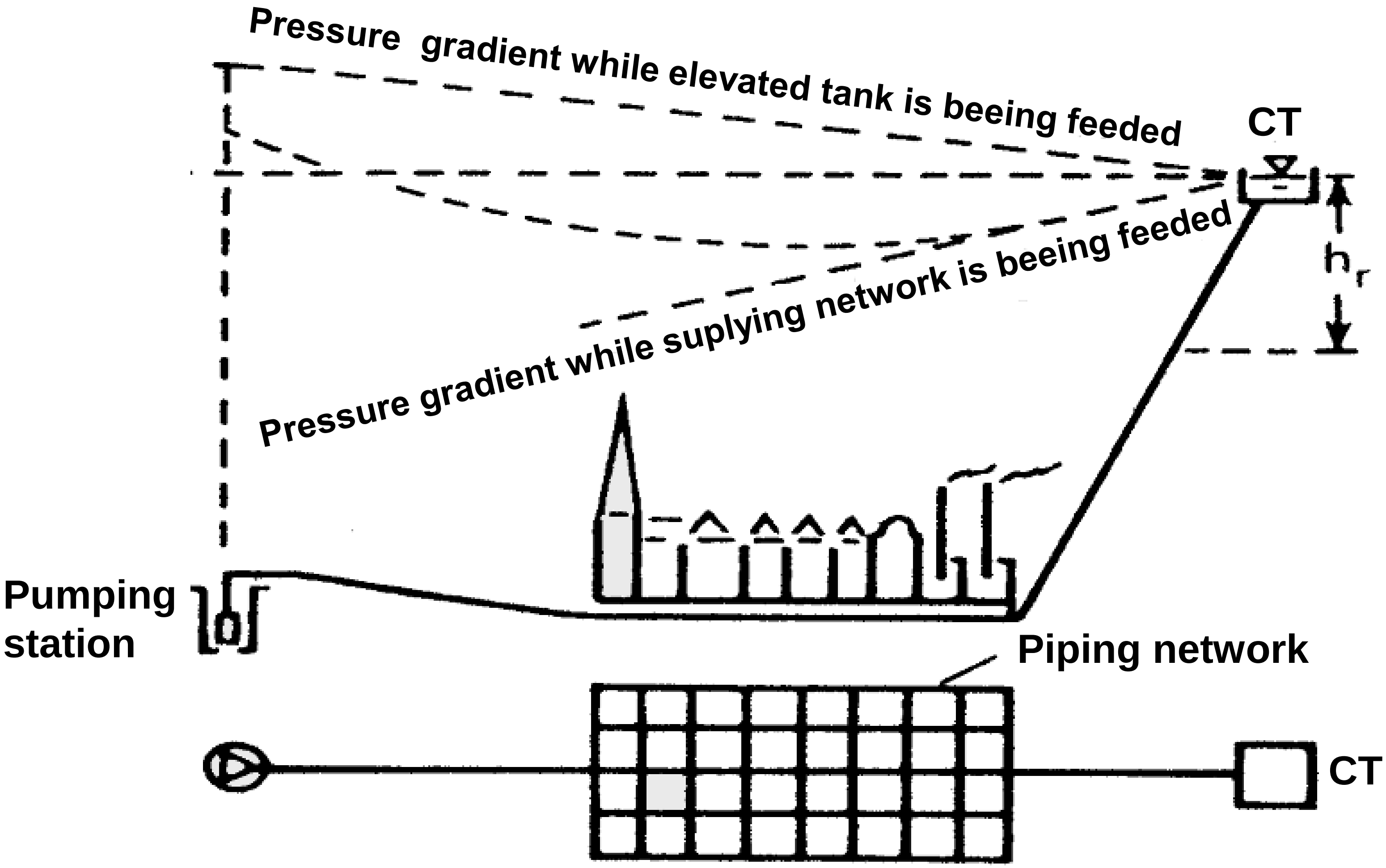
Counter Tank (CT)



Location of pumping stations, watertanks and local piping networks

Center of gravity tank *(Schwerpunktbehälter)*

If topographic conditions allow a suitable location or a water tower is provided, the water tank can be built near or in the centre of the supply area. This leads to a shorter piping network, a constant supply pressure and less pressure losses.

→ can be implemented rarely

Differentiation according to the altitude

Water tanks can be classified into underground and elevated tanks, depending on the relative altitude to the supply area.

Underground tanks *(Tiefbehälter)*

The water level in underground tanks lies beneath the supply area. They are positioned in front of the supply area (in flow direction) and behind the water treatment plant *(Aufbereitungsanlage).* The water has to be pumped to the necessary pressure height in order to feed the supply network (Tank pumping station *(Pumpwerk)*).

Differentiation according to the altitude

Elevated tanks *(Hochbehälter)*

Elevated tanks guarantee the supply pressure, their water level *(Wasserspiegel)* lies above the supply area. The stored water is fed into the piping network with a gravity gradient. Their storage volume increases the supply security.

Topographic conditions determine whether elevated earth tanks or water towers have to be constructed.

Differentiation according to the altitude

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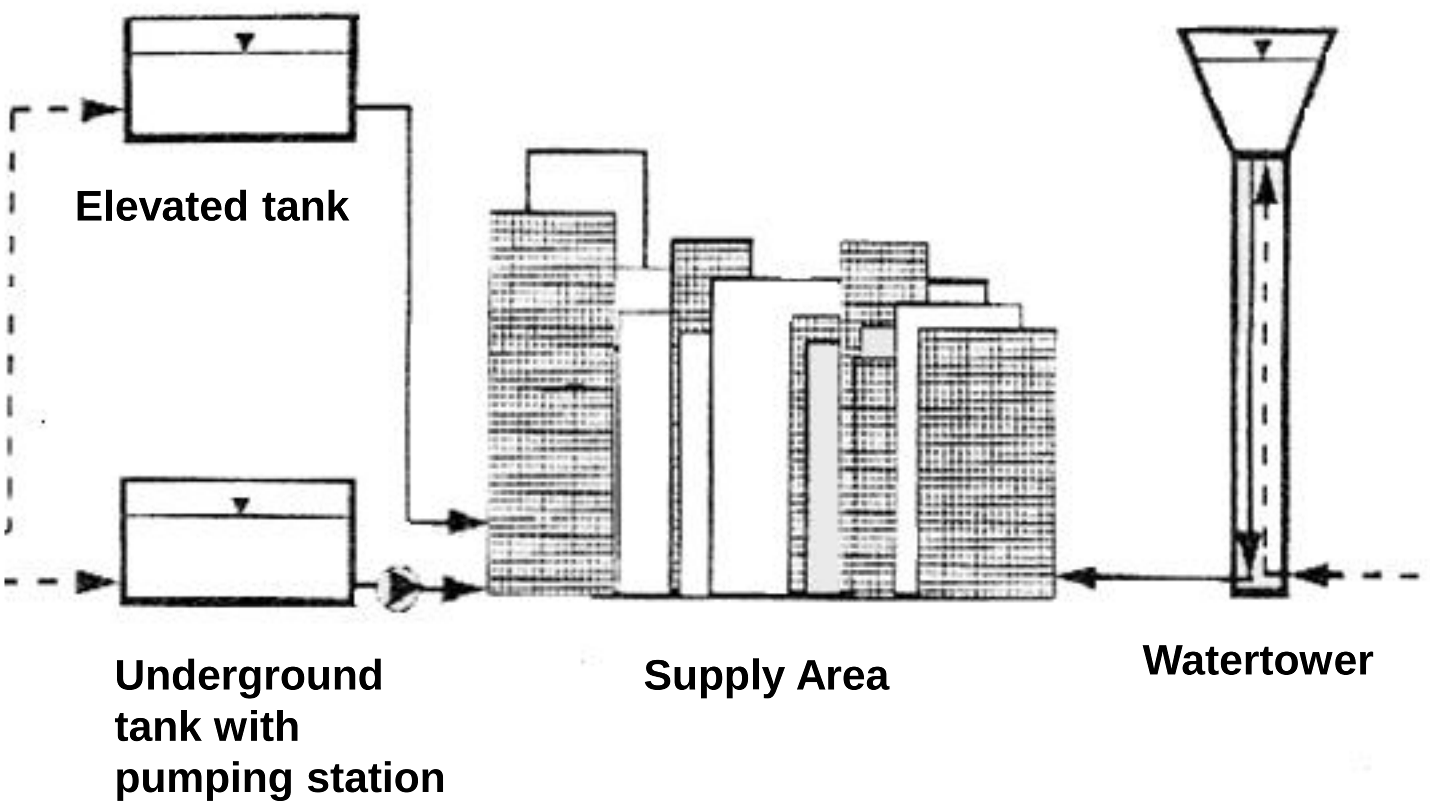
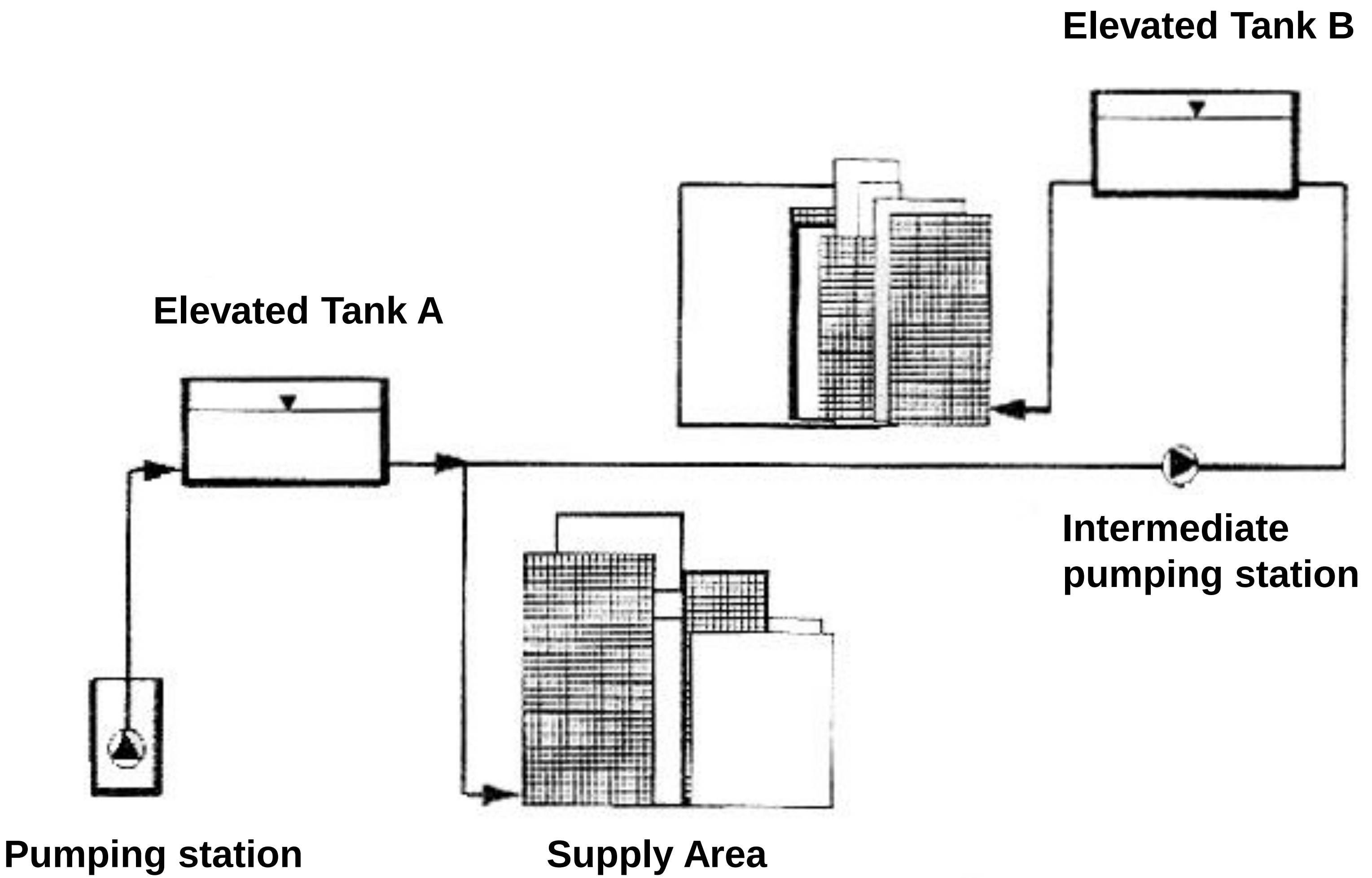
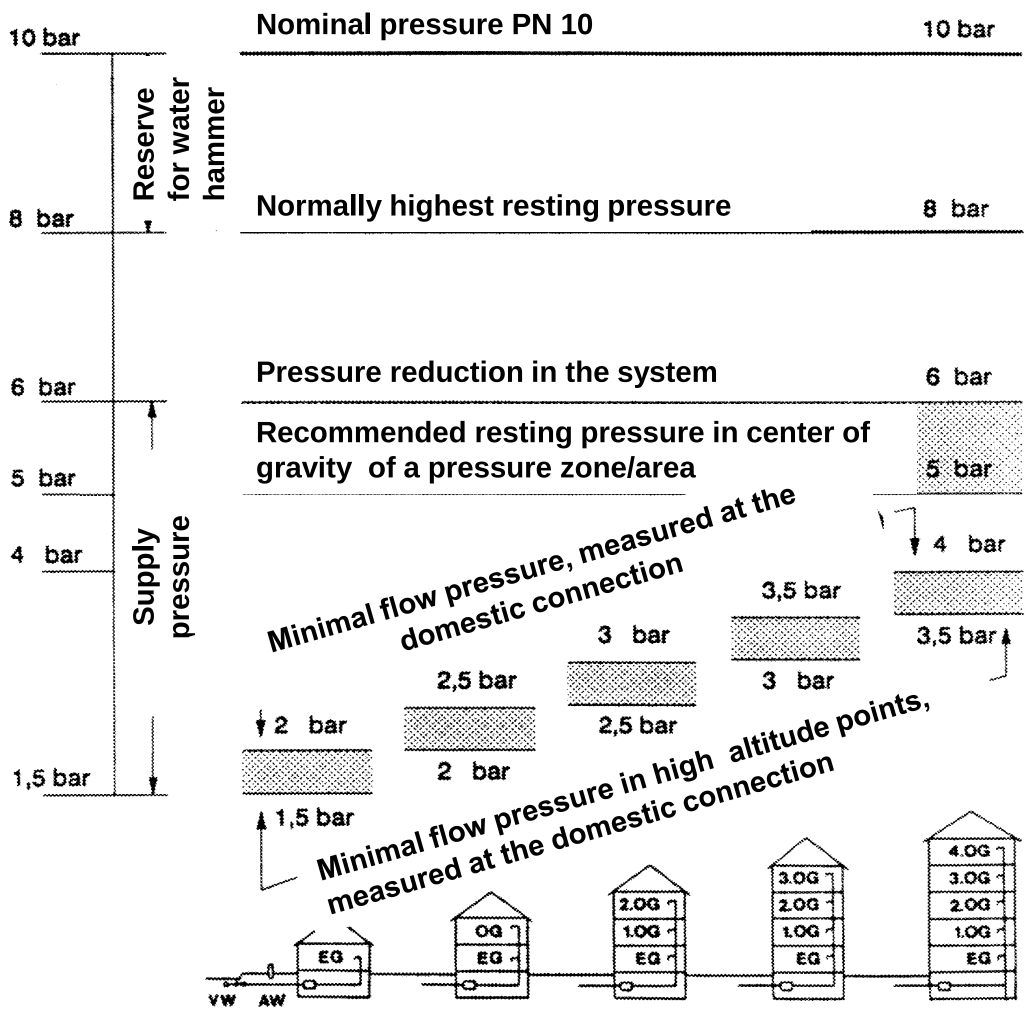


Several supply areas



Recommended pressure ratios in water pipe nets (W 403)



Location of the tanks in relation to the groundlevel

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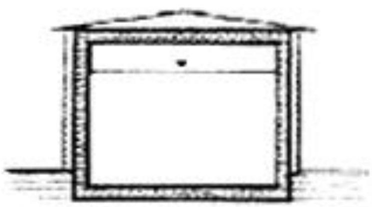
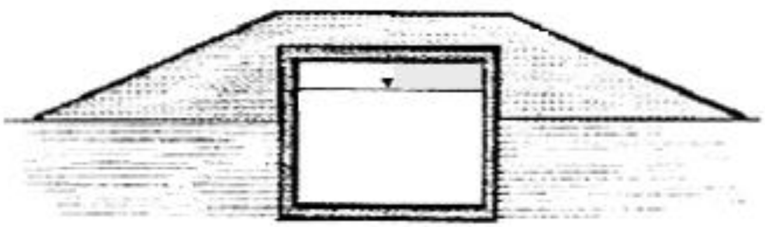
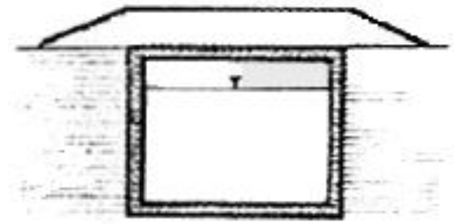


Above groundlevel



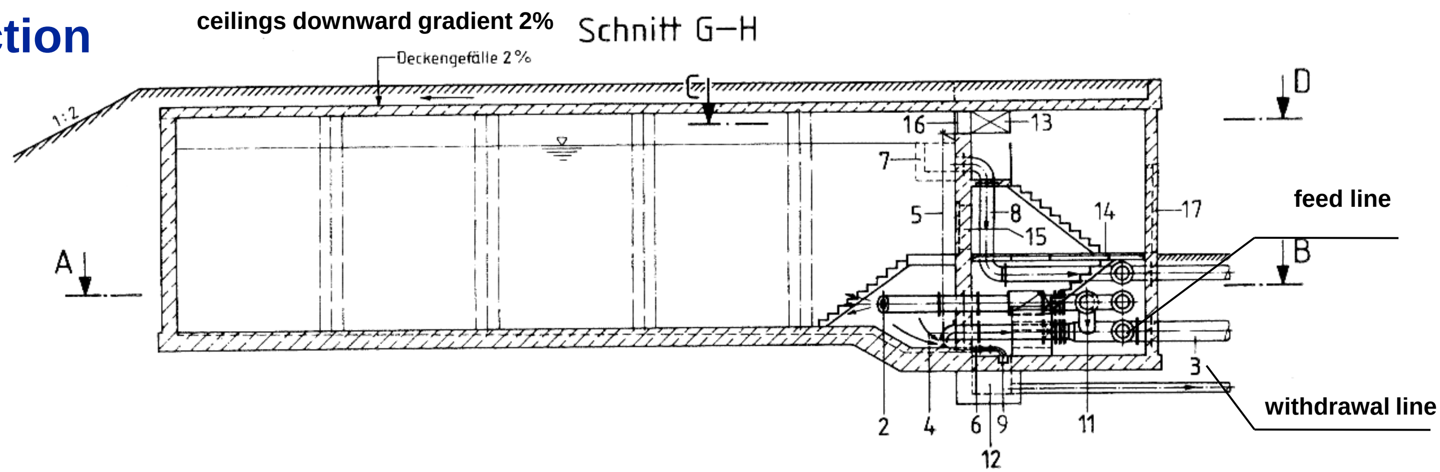
Partly above the groundlevel

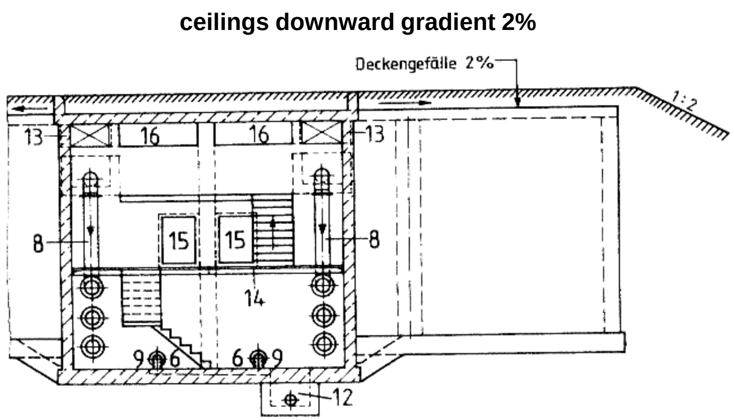


Beneath the groundlevel

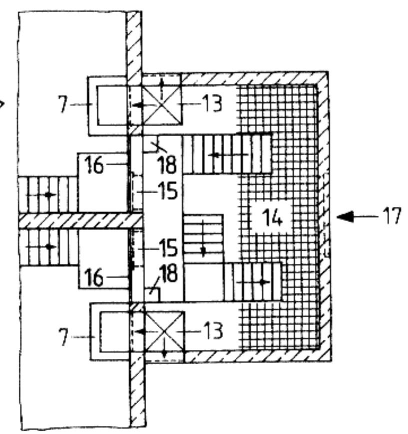
Squaretank 2·1000 m³ usable capacity, covered with soil

Cross section





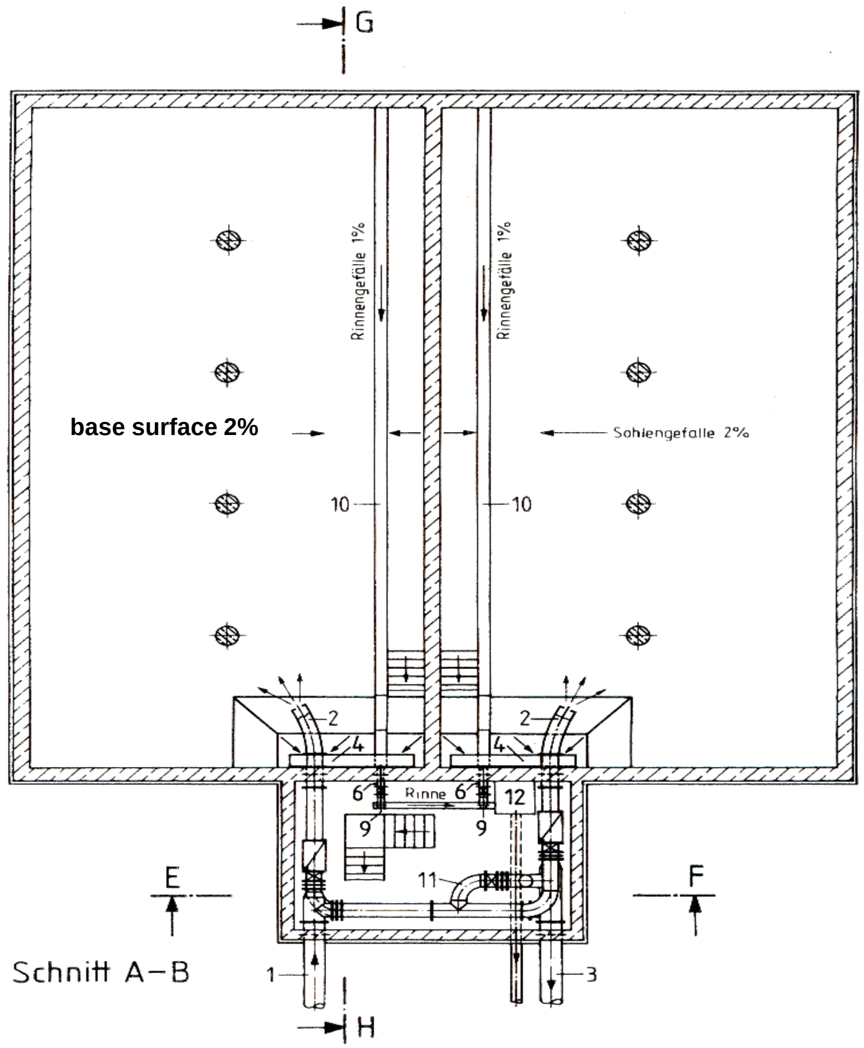
Schnitt E–F



Schnitt C–D

Squaretank 2·1000 m³ usable capacity, covered with soil

Top view



Layout of ground tanks

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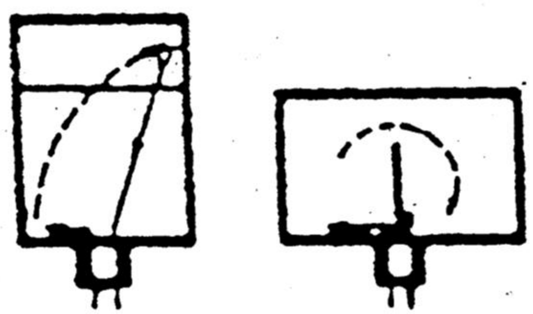
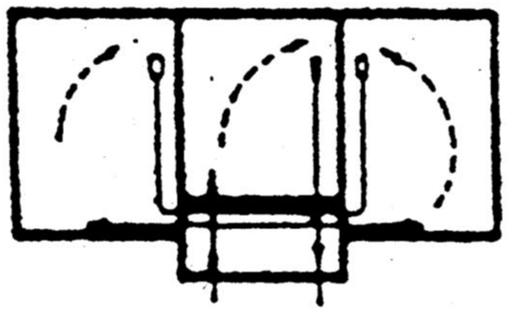
Square form

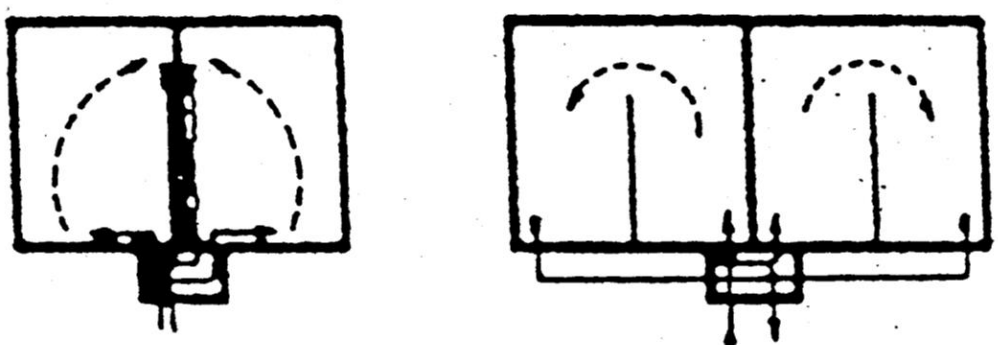
One-chamber tanks



Three-chamber tank

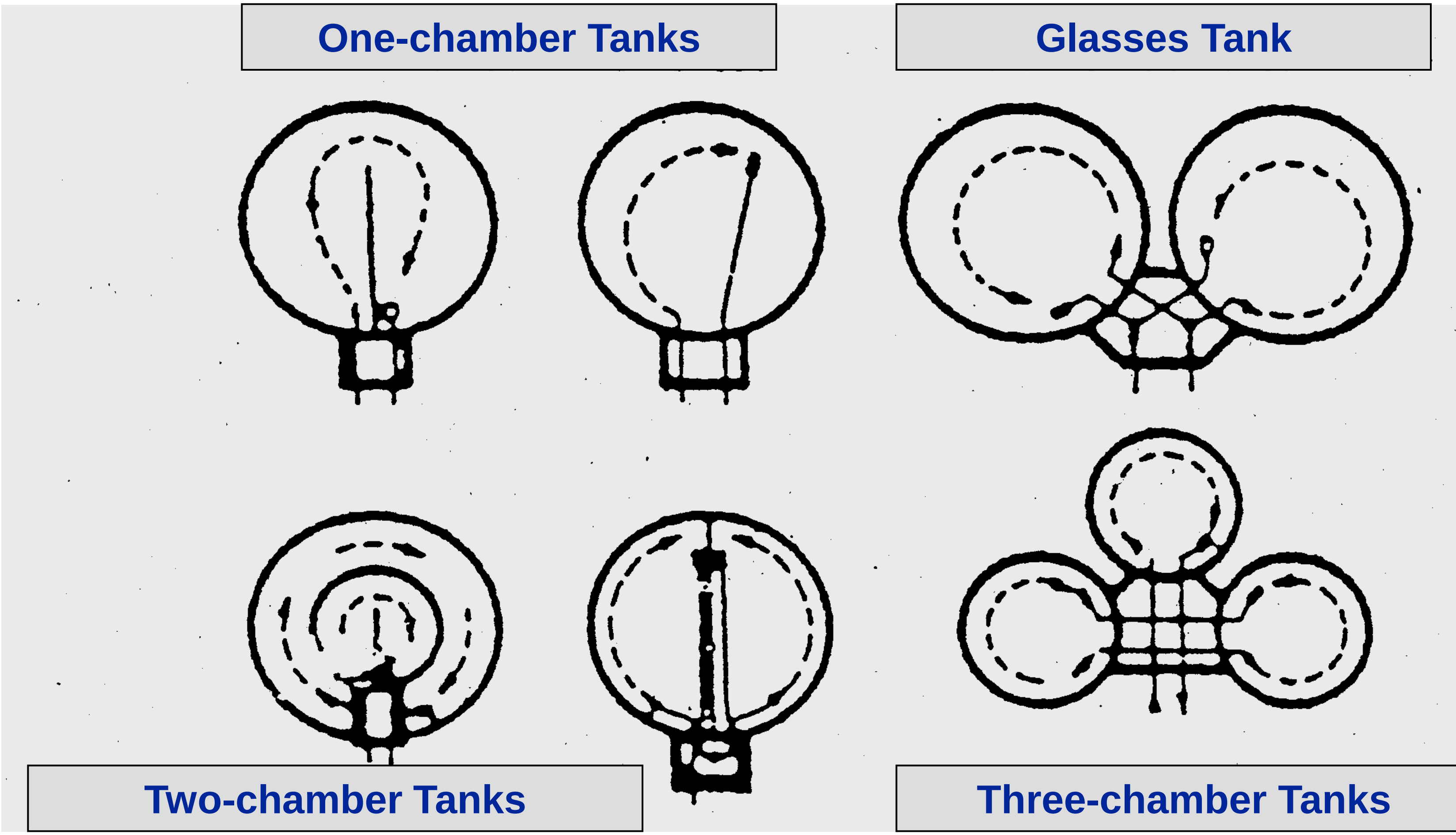


Two-chamber tanks

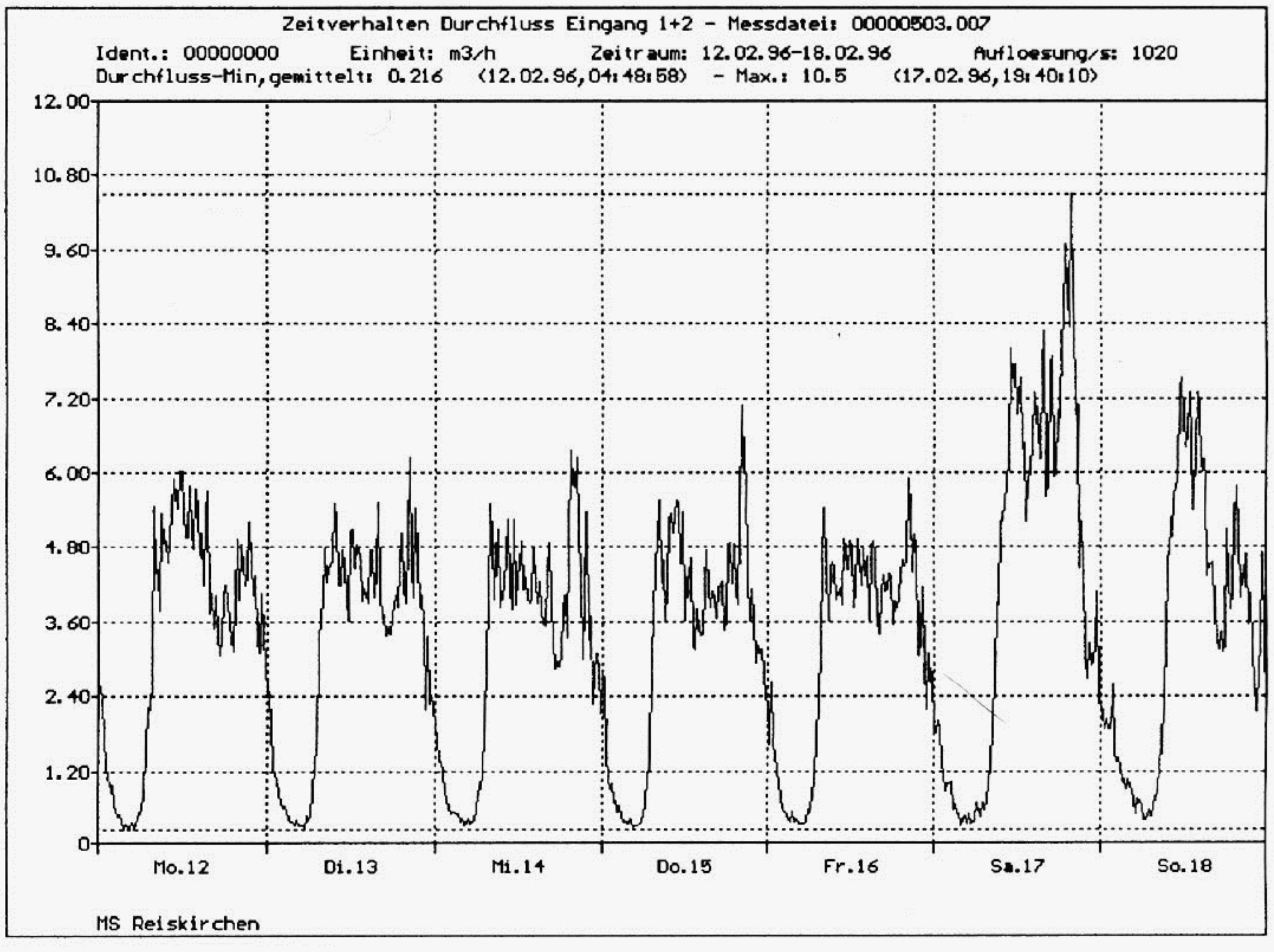


Layout of ground tanks

Circle form:

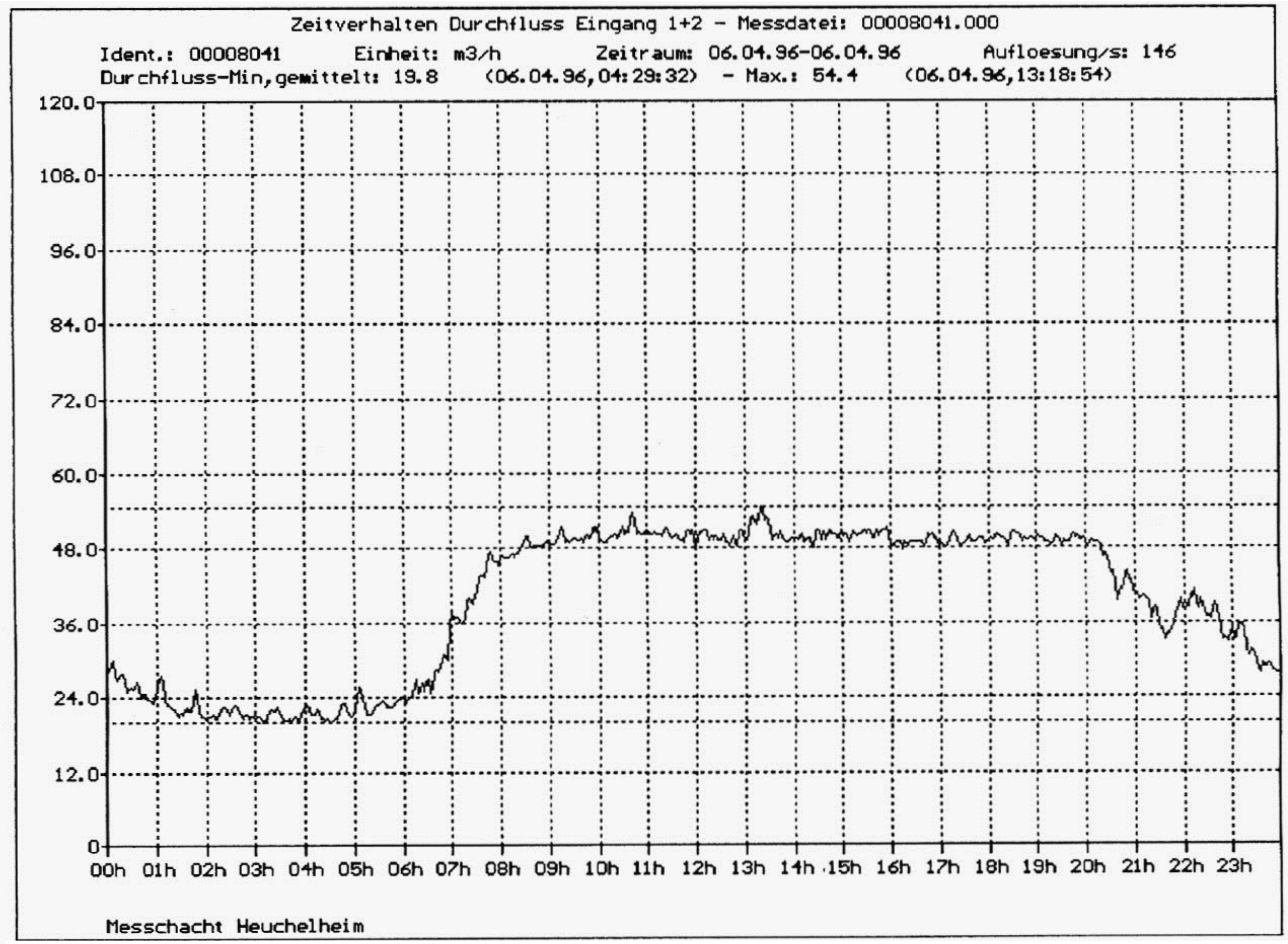


Storage volume



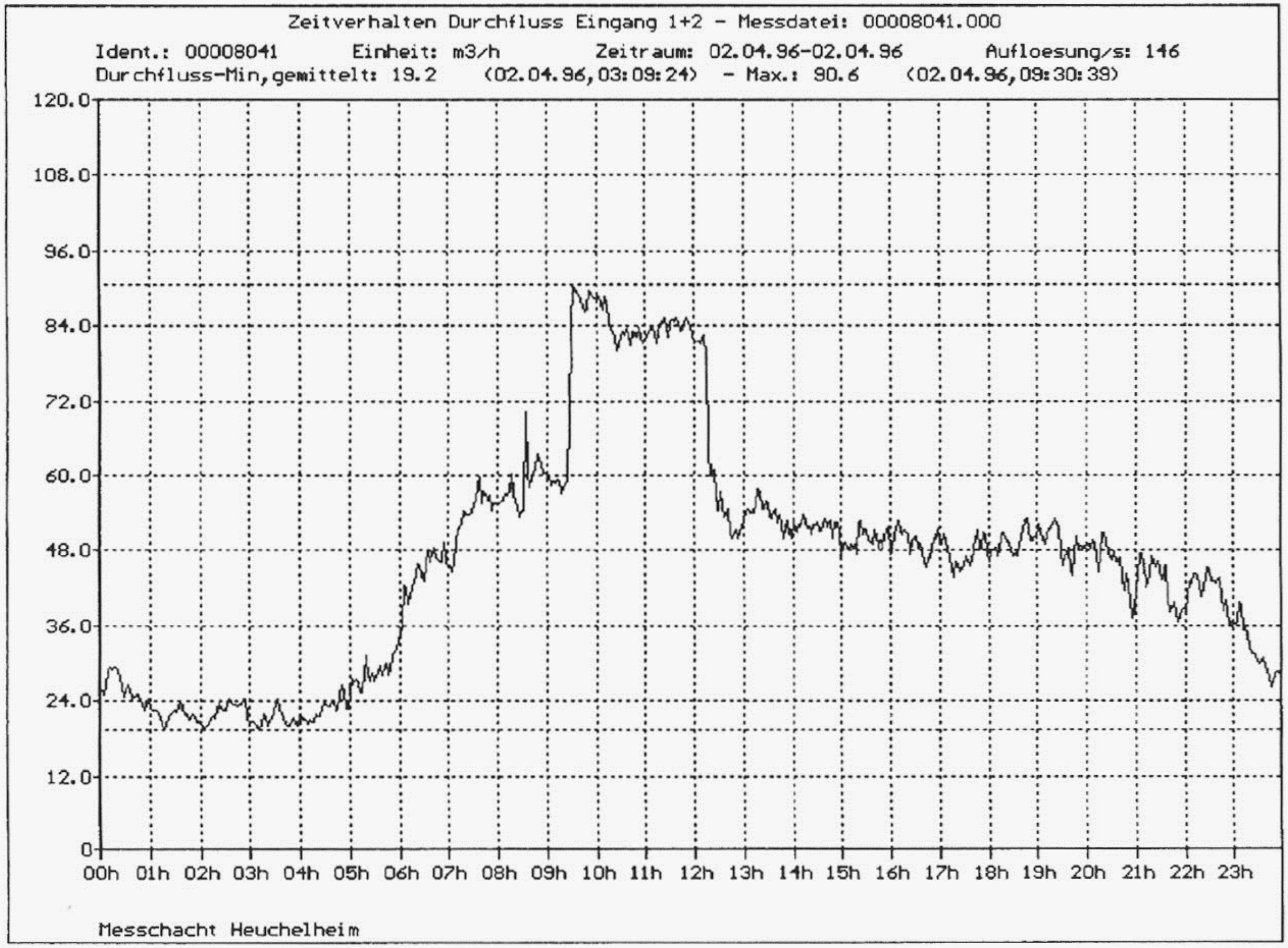
Consumption behavior of a locality with 865 inhabitants during one week in February

Storage volume



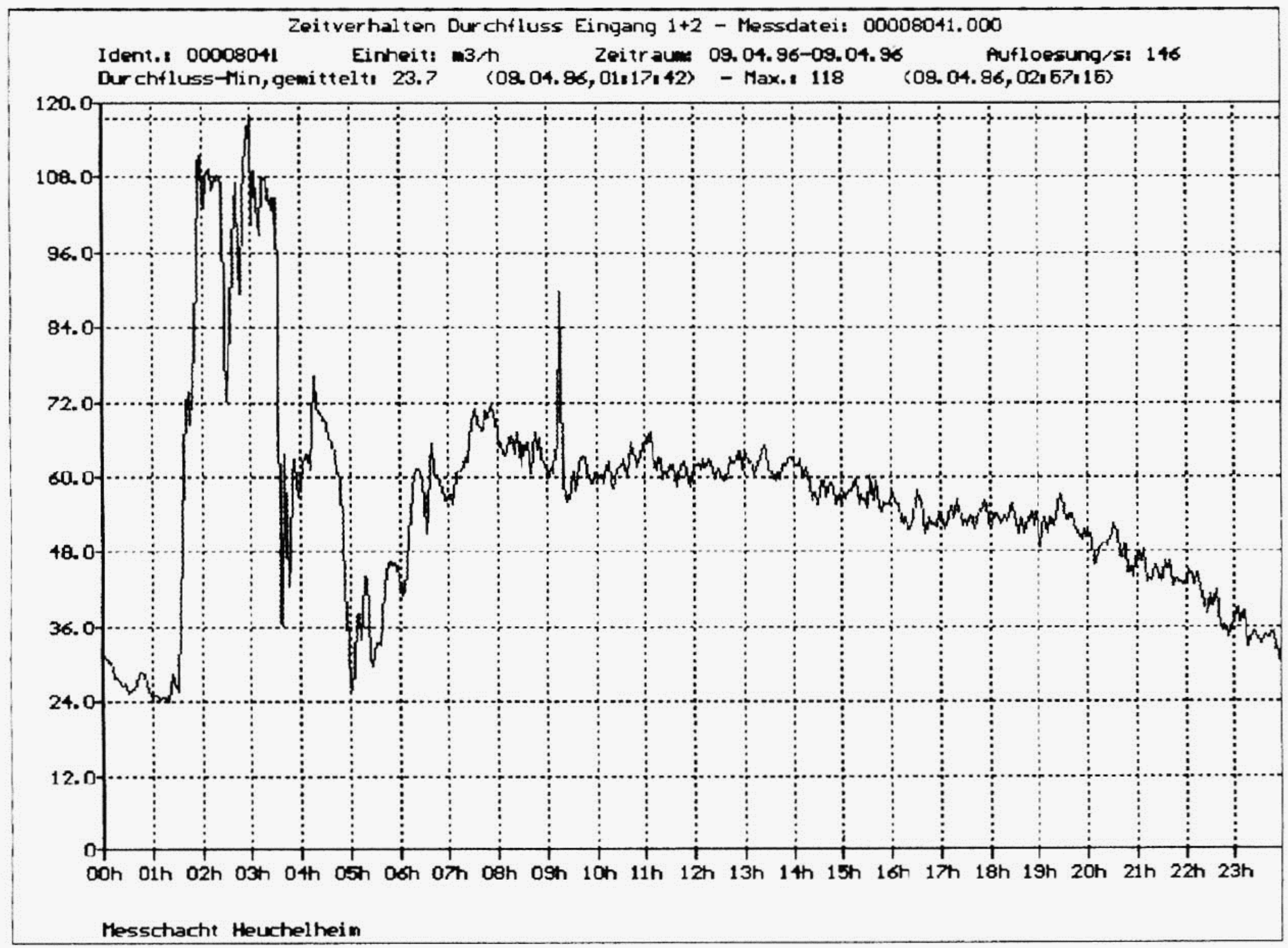
Consumption behavior of a town with 5.845 inhabitants on one Saturday

Storage volume



Consumption behavior of the same town on a weekday

Storage volume



Increase of the consumption in a city during a fire extinction

Schematic segmentation of a reservoir volume

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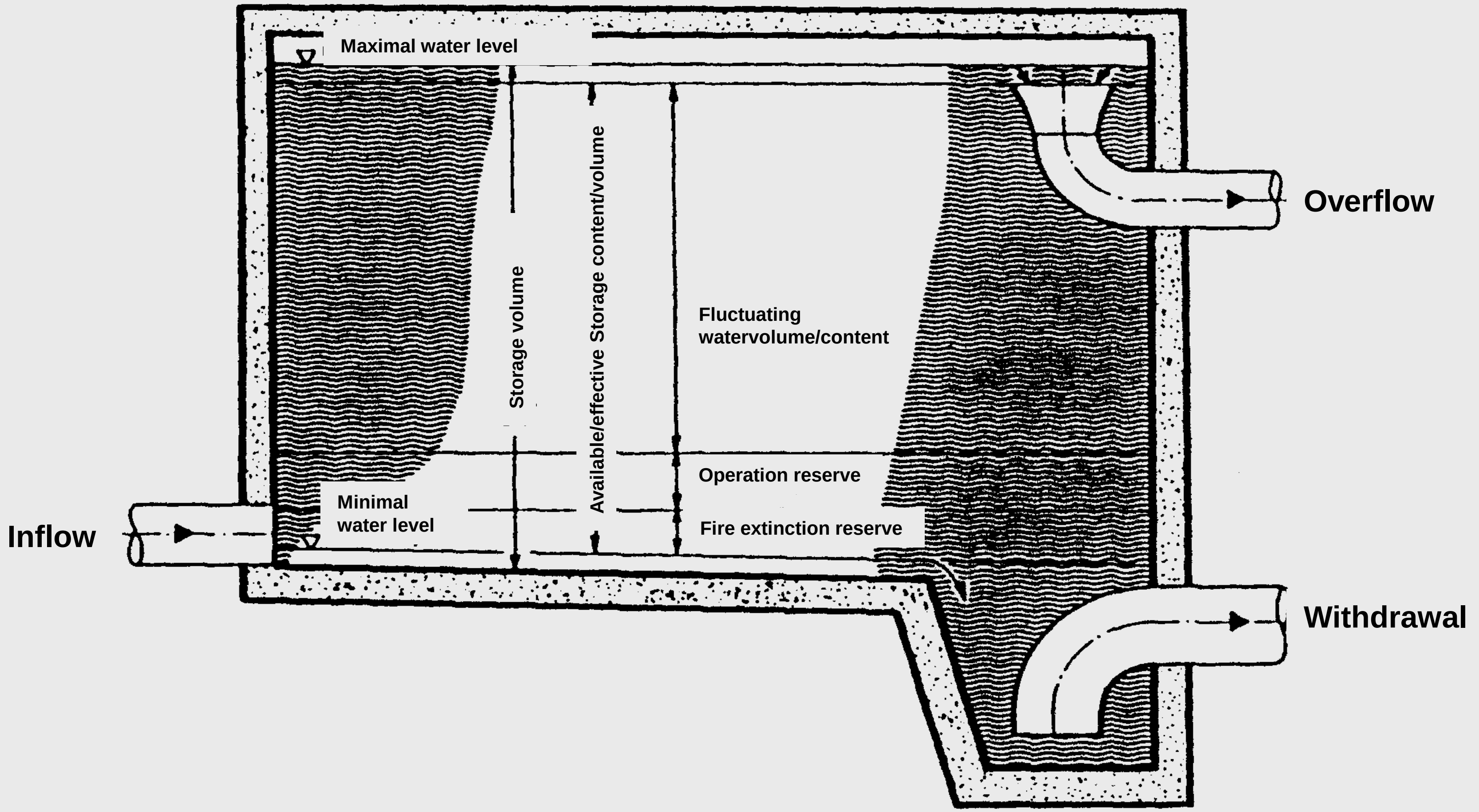
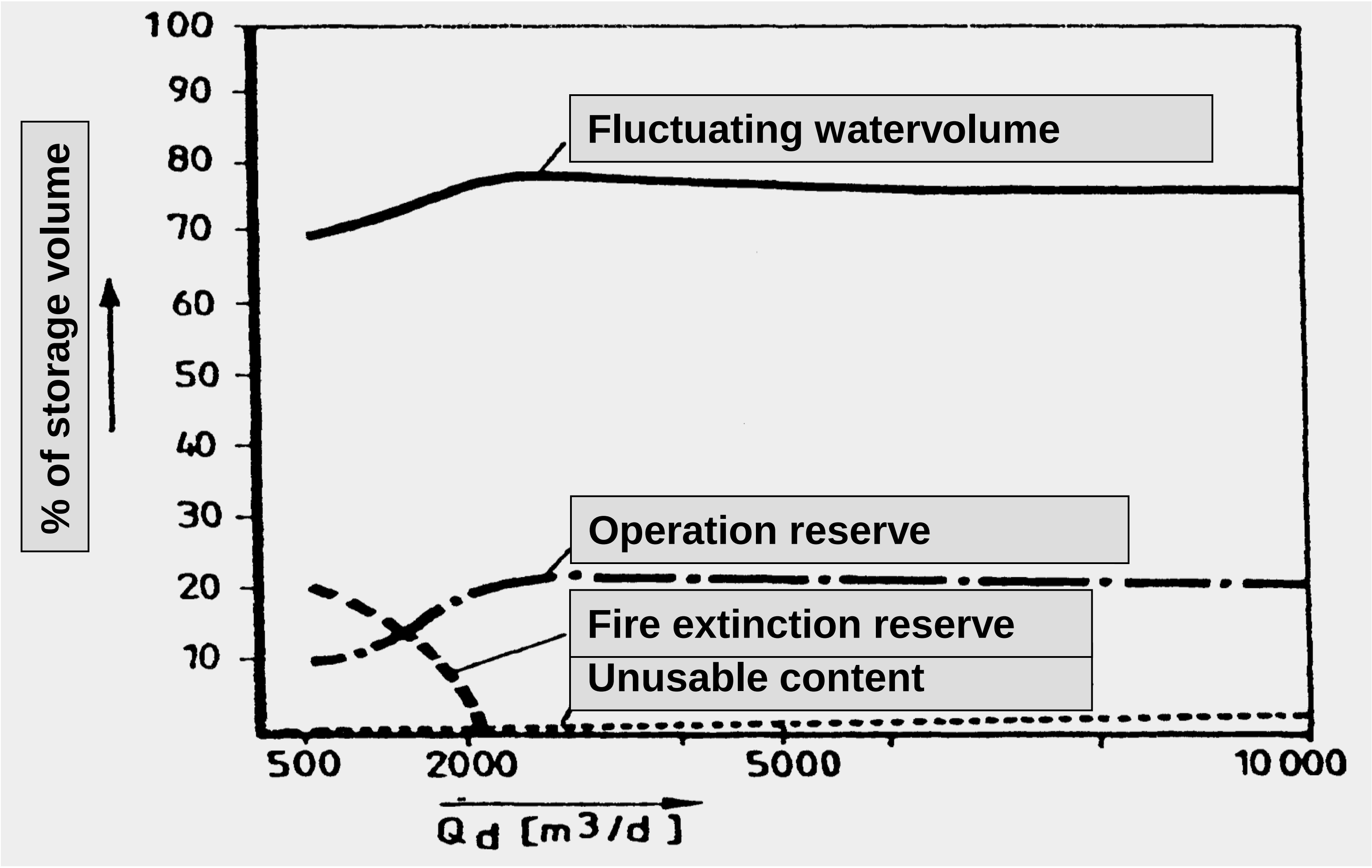


Segmentation of a reservoire volume as a function of the daily withdrawal



Standard value for the effective storage content of waterreservoirs

Future highest daily demand $Q_{d,max}$ [m^3]	Effective storage content of underground-reservoirs in % of $Q_{d,max}$	Effective storage content of water towers in % of $Q_{d,max}$
≤ 1000	100	35
≤ 2000	100	25
1000 bis 4000	100 - 80	25
2000 bis 4000	80	25
> 4000	80 bis 30	20

Storage volume

$V_{st.} = V_{fluct.}$ + fire reserve + 20 % safety margin *(Sicherheitszuschlag)*

Type of sypply area	Fire reserve for underground-reservoirs [m³]	Fire reserve for water towers [m³]
Village- and residential area	100 bis 200	75 bis 100
Trade- and industrial area	200 bis 400	150

Exercise: Reservoir design

For the design of a drinking water reservoir it is necessary to determine the storage volume. Therefore the fluctuating quantity of water is to be determined

Given:

Discharge from reservoir	02 am – 05 am	per hour	1 % of max Q_d
	05 am – 11 am	per hour	5 % of max Q_d
	11 am – 06 pm	per hour	7 % of max Q_d
	06 pm – 12 pm	per hour	3 % of max Q_d

max Q_d = 16.500 m³/d

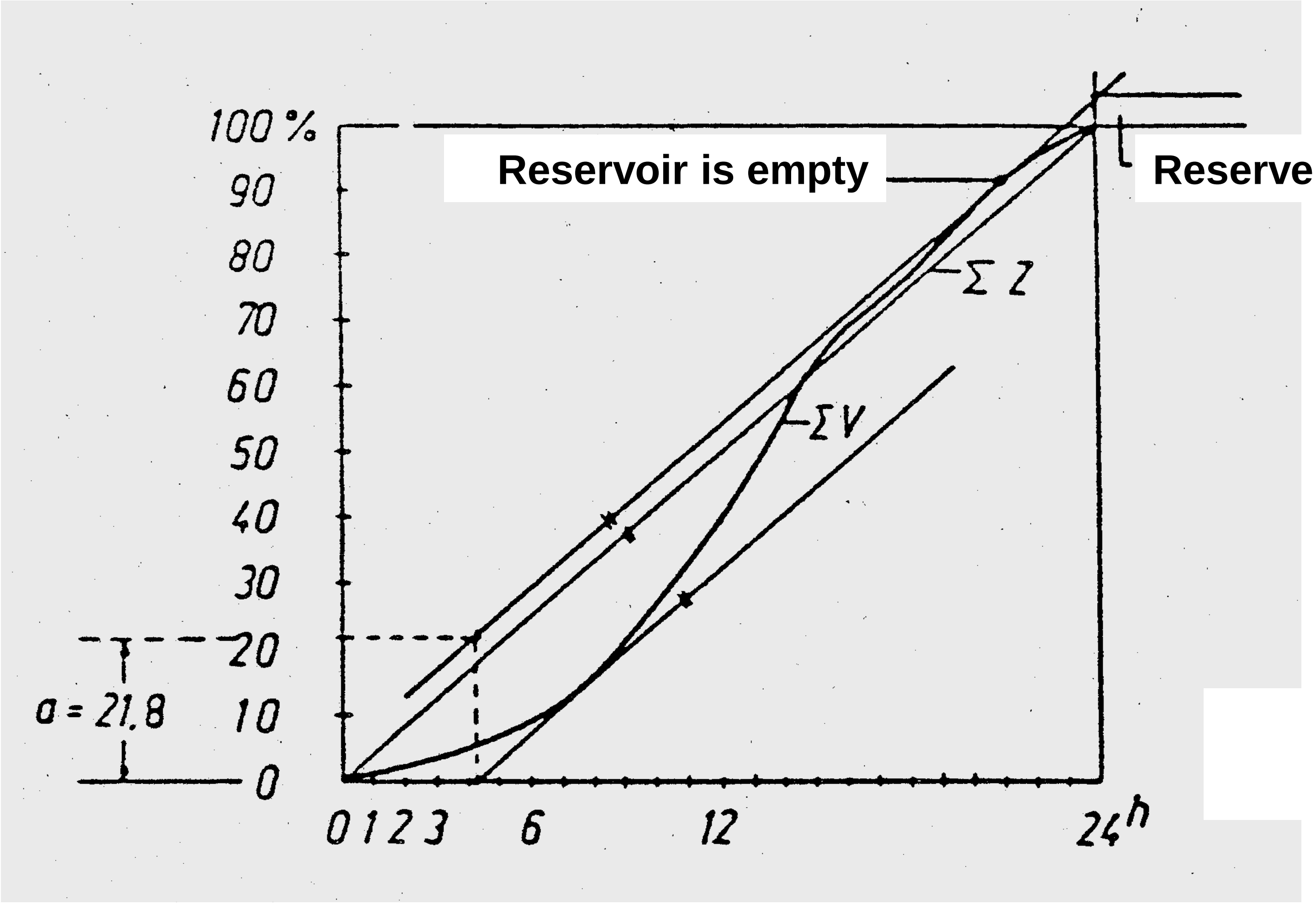
Pumping time for filling the high reservoir: 10 pm – 8 am

Exercise: Reservoir design

Time	Hourly consumption	Intake	Deficit (-)/ Surplus (+)	Sum: Deficits + Surplusses
	%	%	%	%
0 - 1		10	10	10
1-2		10	10	20
2-3	1	10	9	29
3-4	1	10	9	38
4-5	1	10	9	47
5-6	5	10	5	52
6 - 7	5	10	5	57
7-8	5	10	5	62
8-9	5		-5	57
9-10	5		-5	52
10-11	5		-5	47
11-12	7		-7	40
12 - 13	7		-7	33
13-14	7		-7	26
14-15	7		-7	19
15-16	7		-7	12
16-17	7		-7	5
17-18	7		-7	-2
18 - 19	3		-3	-5
19-20	3		-3	-8
20-21	3		-3	-11
21-22	3		-3	-14
22-23	3	10	7	-7
23 - 24	3	10	7	0
24 Std.	100	100	0	

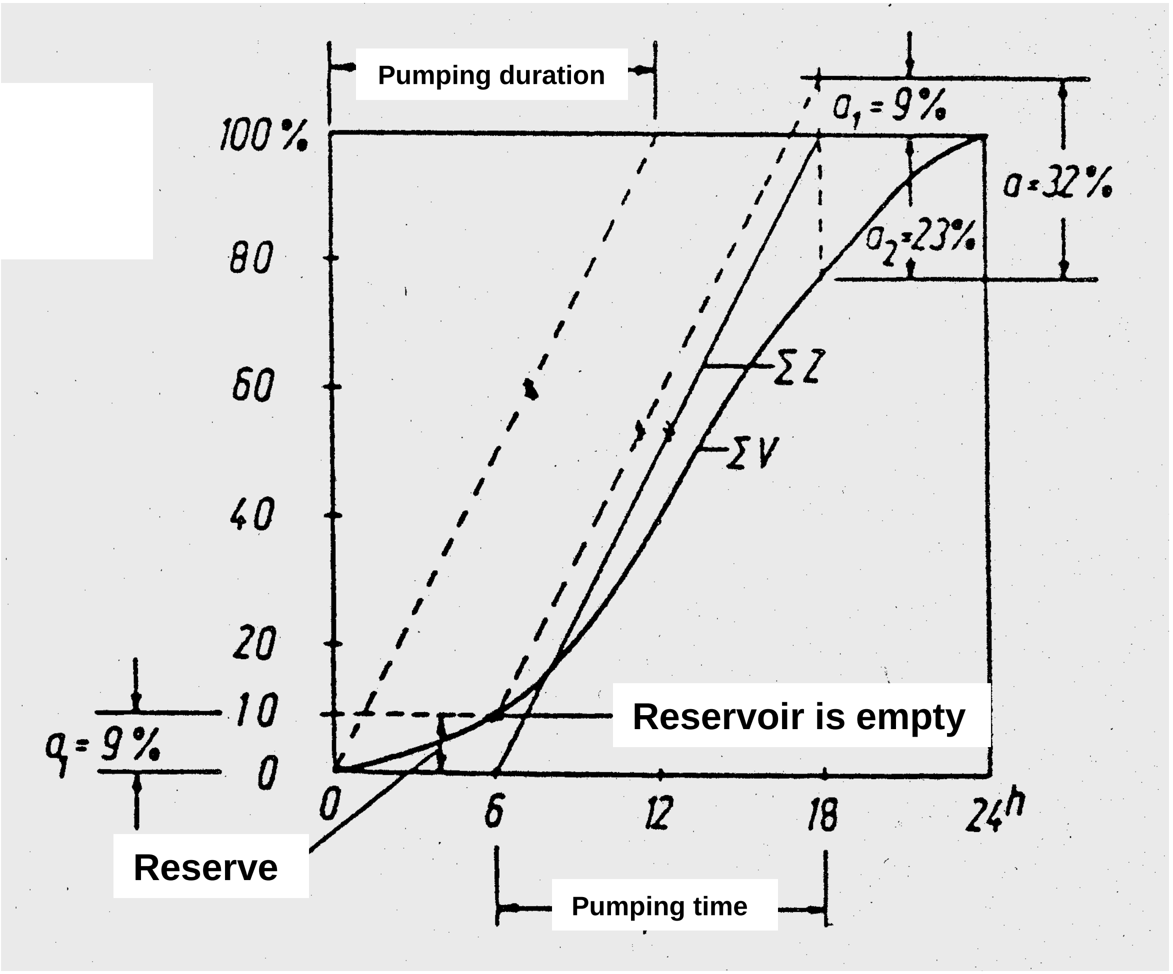
Required storage volume

Cumulative line for continuous intake for 24h

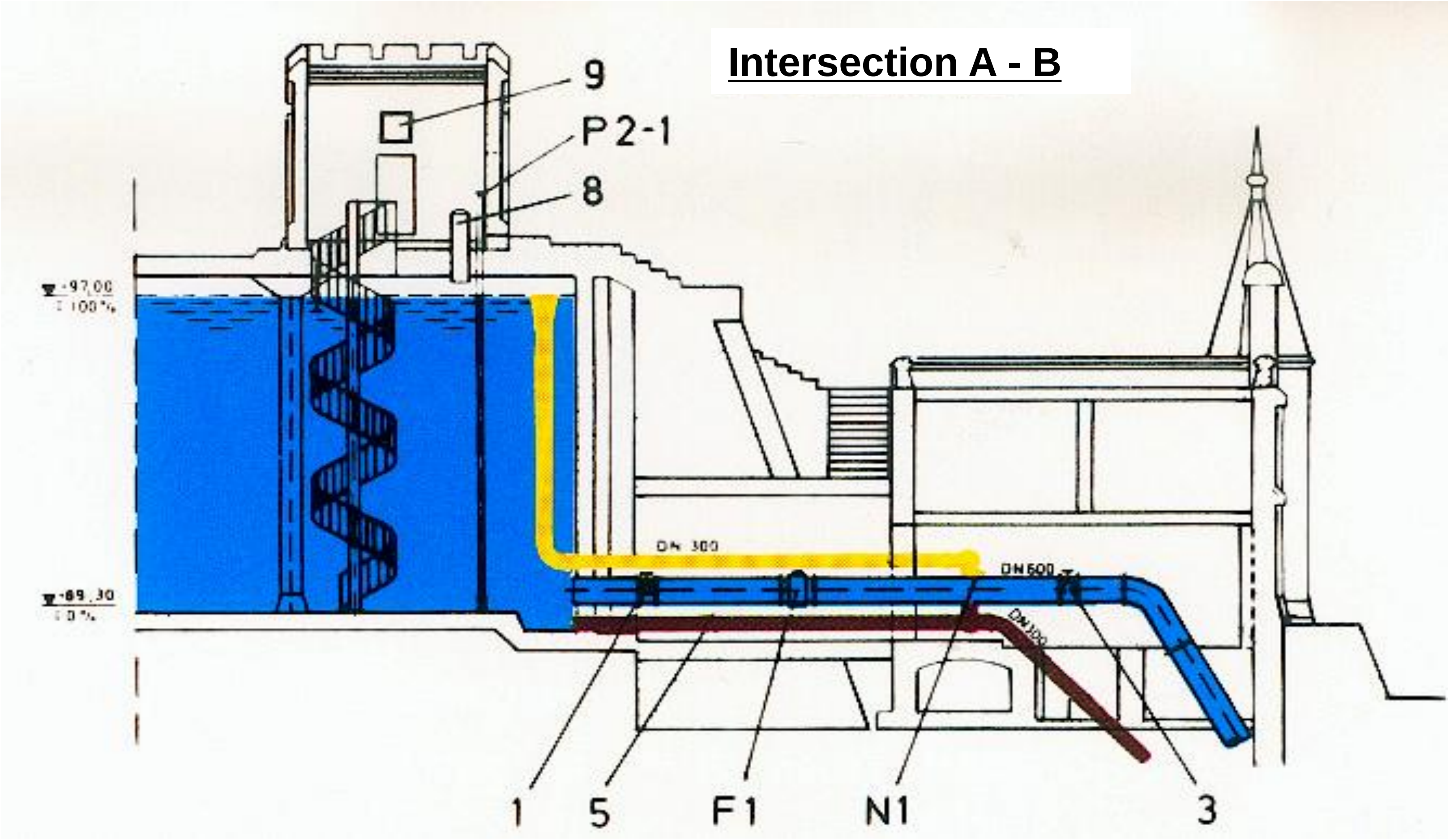


Required storage volume

Cumulative line for intermittent intake for 12h



Elevated tank Lindener Berg / Hannover



Elevated tank Lindener Berg / Hannover

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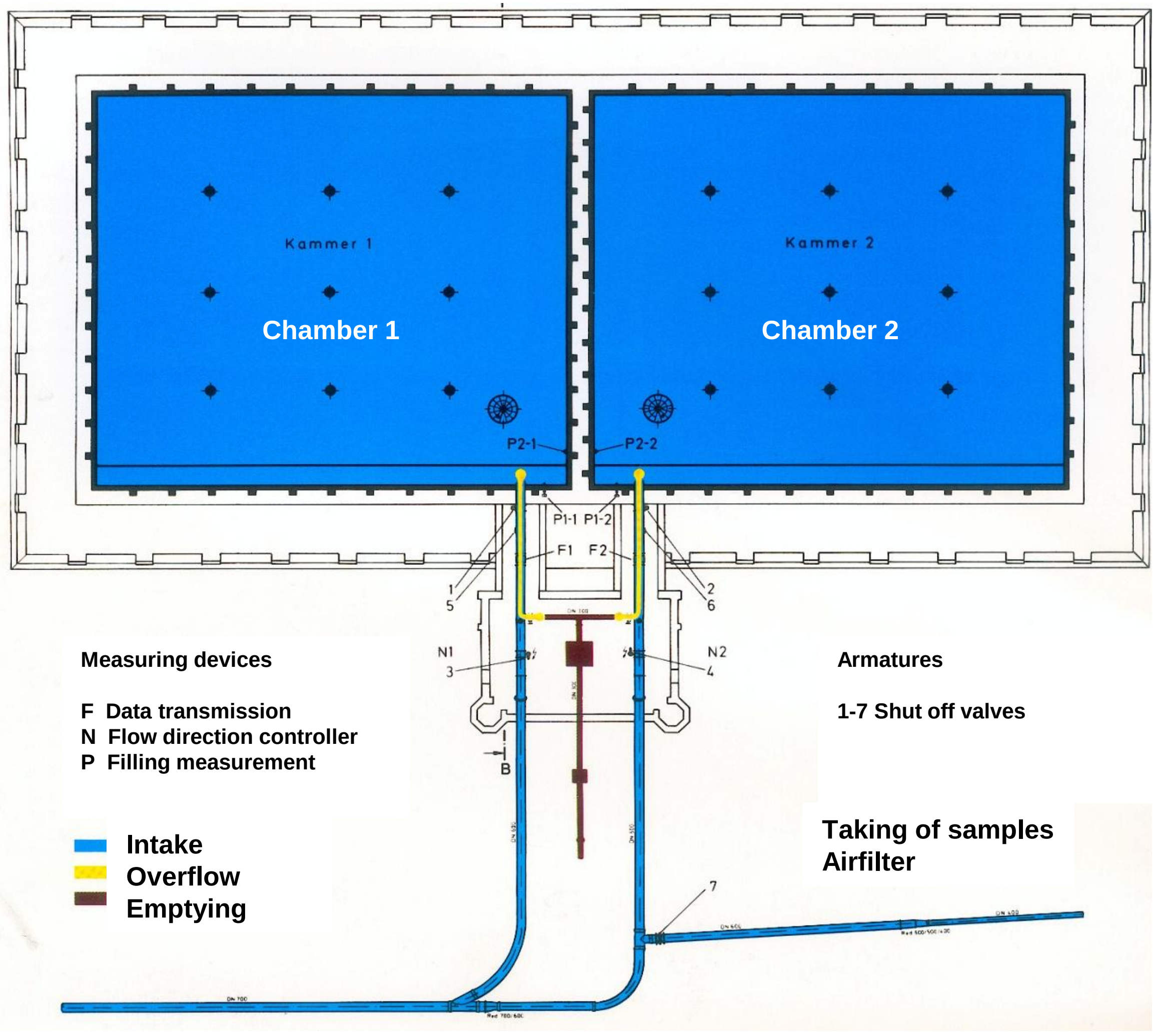

Technical data of the elevated tank Lindener Berg

Tanktype:	Counter tank
Overall dimension:	77.0 x 39.0 x 9.5 m
Number of chambers:	2
Total storage content:	13,200 m³
Effective filling height:	7.7 m
Level range:	89.3 ...97.0 m a.s.l.