Abdelhafid Bousouf University Center - Mila

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Drinking water supply

– Lesson 4 –

Chapter 4 : Drinking Water Reservoirs

teaching staff			
Name	**Institute**	**Grade**	**E-mail address**
Boumessenegh Amel	MCB Science and Technology		a.boumessenegh@centre-univ-mila.dz

Students concerned			
Institute	**Department Year**		**Speciality**
GC **Science and Technology**	License 3	Hydraulics	Urban hydraulics

Course Objectives 4

This course aims to provide a thorough understanding of drinking water reservoirs, of their role in a water supply and distribution network, as well as design principles and management.

1. Understanding the role of drinking water reservoirs

- Ensure sufficient storage to meet water demand.
- Regulate pressure and compensate for variations in consumption.
- To serve as a backup in case of failure or incident in the network.
- Contribute to water resource management and energy cost reduction.

1. Introduction

The waters that are generally collected too far from the urban area, or at a distance of too great a distance, are transported via pipelines to distribution points, what is called the point of storage.

So storage takes place in tanks, these tanks differing in their shape, their storage capacity, their position relative to the urban area, and even their role. But despite This difference between the tanks is generally only found at the most high in the urban area to ensure gravity distribution and energy saving.

1.2 Definition of a reservoir

A reservoir is a container holding a liquid, this liquid is usually water, or potable. Among the liquids other than water, the most common are bedbugs and hydrocarbons. Reservoirs can be built open or, conversely, equipped with a dome or a slab. Flat. Tanks can be simple or complex and made up of several cells. The shape the plan can be any (figure 04.1).

However, most of the time small tanks are square or rectangular, but the circular shape and less expensive.

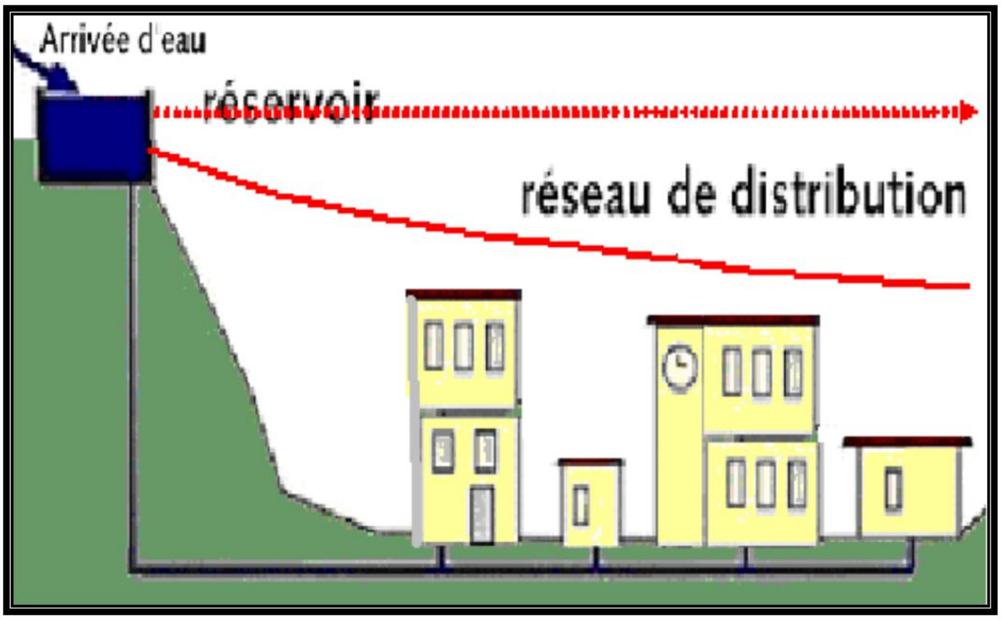


Figure 1: General diagram of the production and distribution phases of a drinking water supply system

1.2 Role of the reservoir

- To meet the water needs of the metropolitan area.
- To allow for more uniform operation of the pumps.
- To ensure the maximum flow rates requested during peak hours.
- Regulate pressures in the distribution network.
- Keep the water free from the risk of contamination and protect it against strong variations of temperature.

1.3 Classification of reservoirs

1.3.1 Based on the nature of the materials, we distinguish:

- Masonry reservoirs.
- Reinforced, ordinary or prestressed concrete tanks.

1.3.2 Depending on the location, they may be:

- Buried.
- Semi-buried.
- Elevated on towers (water tower) (figure 4.02).

Figure 2. Illustration of the variety of elevated tanks in terms of shape, size and height

1.4 Tank Characteristics

Tank shape

The shapes of the reservoirs are varied:

- **Cylindrical shape** (most commonly used for elevated tanks)
- **Parallelepiped shape** (the simplest for underground tanks)
- **Aesthetic shapes :** Flower shape, mushroom shape, ... But these shapes cost too much expensive in their realization.

The most economical shape is the cylindrical shape.

- It offers the best pressure distribution.
- It requires the minimum amount of concrete for a given volume of water to be stored.

1.5 Tank location

1.5.1 Gravity (normal) distribution

Distribution is gravity-fed when the reservoir is located at a certain level relative to the urban area. will be high enough.

1.5.2 Staged Distribution

Sometimes a city has significant differences in elevation. Now, we're locking ourselves out, regarding... urban distribution, which should avoid excessive pressure on the network, and that Water pressures of around 40.00 m constitute a limit that should not be exceeded in the city.

For example, in figure 4-3, for a city built on a hillside between elevations (30.00 m) and (70.00 m), an **R1** reservoir may be provided to supply the area between (30.00) and (50.00).

R1 will be established at an elevation of 70.00 m and the ground pressure will therefore vary from 70 – 30 = 40 m of water to 70 – 50 = 20 m of water. In addition, an **R2** reservoir at elevation 90 will supply the area between 50 and 70 m.

These reservoirs can be supplied either by a common station or by sources different. They can also be connected to each other to potentially provide assistance.

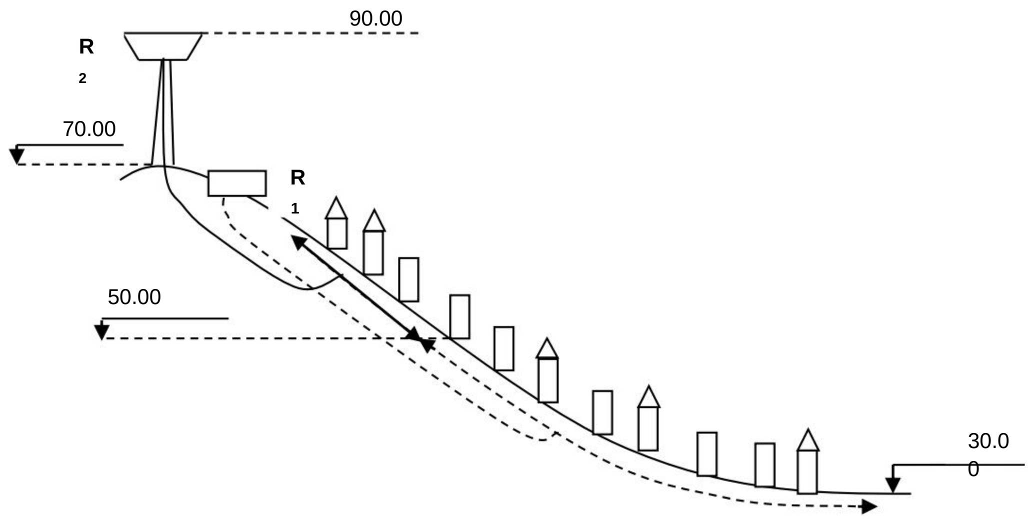


Figure 3. Static distribution

2. Additional balance tank

Assuming an urban area expands in a given direction, the reservoir A single unit may become insufficient and, at the network's end, provide only excessively low pressures. during peak hours. One or more balancing reservoirs are then used, connected to the main tank, which fills up during periods of low consumption, i.e., at night mainly, and, partially, during the day.

The connecting pipe, by virtue of its diameter and hydraulic slope, determines the flow rate which will supply the second reservoir (**II**). This flow rate must be sufficient so that (**II**) is full at the beginning of the morning figure 4 – 4.

The pressure at point B must be at least equal to the minimum pressure to be satisfied between the two tanks.

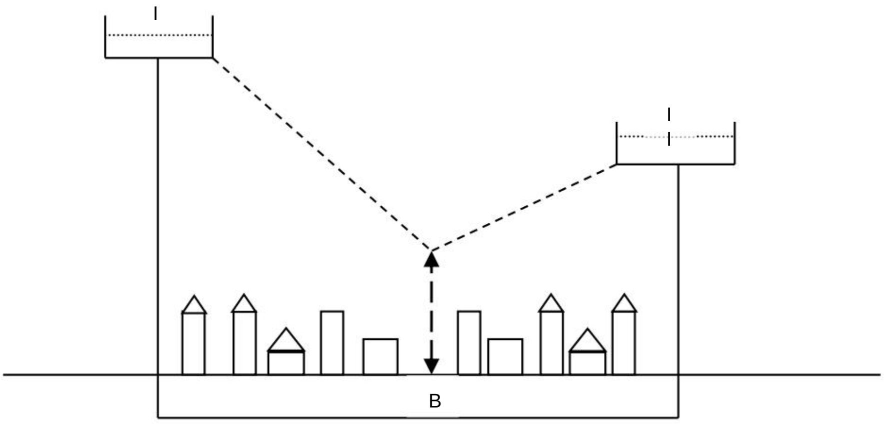


Figure 4. Equilibrium reservoirs.

3. Principle for calculating the capacity of a tank

The capacity of the reservoir is determined by taking into account variations in the incoming flow rate and outflow rate from the tank. The tank volume is obtained by summing the absolute values of the largest positive value and largest negative value of the distribution adjustment

Increase the volume of the fire reserve and the safety volume using the following formula:

$$V_R = V_u + V_s + V_{inc}$$

With :

VR : the volume of the tank m3

View : the usable volume m3

Vs : the volume of the security m3

Vinc : the fire volume m3

3.1 Determine the usable volume

To determine the usable volume, the water distribution is regulated; it is given by the following formula:

$$V_u = |\Delta V^{+}_{max}| + |\Delta V^{-}_{max}|$$

With :

|ÿV+ max| : water surplus m3

|ÿV- max| : water deficit m3

To determine the value of the useful volume, the hourly coefficients (ch) are used (table 4–1).

Table 4 – 1 : Hourly coefficients ch as a function of number of inhabitants.

Hours	Less than 10,000	10,000<N<50,000	50,000<N<100,000	>100,000
0 – 1	1	1.5	3.25	3
1 – 2	1	1.5	3.25	3.1
2 – 3	1	1.5	3.3	3.1
3 – 4	1	1.5	3.2	2.6
4 – 5	2	2.5	3.25	3.5
5 – 6	3	3.5	3.4	4.5
6 – 7	5	4.5	3.85	4.5

7 – 8	6.5	5.5	4.45	4.1
8 – 9	6.5	6.25	5.2	4.9
9 – 10	5.5	6.25	5.05	5.6
10-11	4.5	6.25	4.85	4.8
11 – 12	5.5	6.25	4.6	4.7
12 – 13	7	5	4.6	4.4
13 – 14	7	5	4.55	4.1
14-15	5.5	5.5	4.75	4.2
15-16	4.5	6	4.7	4.65
16-17	5	6	4.65	4.4
17 – 18	6.5	5.5	4.35	4.1
18 – 19	6.5	5	4.4	4.5
19 – 20	5	4.5	4.3	4.5
20-21	4.5	4	4.3	4.3
21 – 22	3	3	4.2	4.8
22 – 23	2	2	3.75	4.5
23 – 24	1	1.5	3.7	3.3

3.2 Determine the fire volume

The following relationship is used to calculate the fire volume:

$$V_{inc} = q_{inc}\, t$$

With :

qinc : the fire flow rate l/s.

t: sufficient for the collapse, an average fire generally t = 2 hours.

The fire flow rate is calculated according to the size of the city and the architectural texture and the existing equipment Table 4–2.

Table 4 – 2: Fire rate as a function of the number of inhabitants and the importance of the building.

Number of inhabitants	Number of fires at same time	qinc l/s	
		One-story building	Building of 3 stories or more

Less than 5000	1	5	5
5000 – 10,000	1	10	10
10,000 – 25,000	2	10	10
25,000 – 50,000	2	10	15
Over 50,000	2	17	17

According to the regulations, the fire volume is equal to 120 m3 with a flow rate of 17 l/s for the subsidence of a fire in 2 hours provided that the pressure in the fire hydrant not less than 10 m of water.

3.3 Determining the safety volume

The safety volume is given by the following relationship:

$$V_s = (10 - 15)\% \, (V_u + V_{inc})$$

We generally use a percentage of 12%, so the security volume will therefore be:

$$V_s = 12\% \, (V_u + V_{inc})$$

Noticed :

According to A. Dupont, the volume of the reservoir in the case of continuous pumping is on the order of 30 for one percent of the maximum daily flow rate: ***Vr = 30% Qmaxj***

4. Tank sizing

The height of the tank (H = 3 – 6 m) must be chosen according to the importance of the urban area and its drinking water needs.

To determine the diameter of the tank, the following relationship is used:

$$V = S\,H = \pi \frac{D^2}{4} H \Rightarrow D = \sqrt{\frac{4\,V}{\pi\,H}}$$

Example: Let the volume of the reservoir be R = 200 m^{3}[3] Given a height H = 3 m, determine the diameter of the reservoir.

$$D = \sqrt{\frac{4 * 200}{3.14 * 3}} = 9.21 \approx 9.50\ m$$

4.1 Calculation of the reservoir base elevation

The reservoir's location takes into account the terrain, allowing for minimal expenses. investment and operating costs, therefore we are led to take into account the following factors:

- The highest point to be supplied.
- The height of the tallest building.

• The pressure losses from the reservoir to the most unfavorable point in the city.

To determine the side of the base of the Cr reservoir, the following formula is used, which takes into account several factors:

$$C_r = CTN + H + h_s + P_s + \Delta H_t$$

With :

CTN: the natural ground level of the most unfavorable point.

H: the height of the tallest building (a function of the number of floors).

hs : singular pressure loss in buildings (2 – 4 m) we generally take hs = 4 m.

P.S .: Additional water column taking into account water heaters and other water appliances (3–5 m) we take Ps = 3m

ÿHt : linear and singular head loss on the section connecting the reservoir to the lowest point unfavorable.

The first step is to calculate the approximate elevation of the foundation slab:

$$C_r = CTN + H + h_s + P_s$$

The calculation of linear pressure losses is carried out along the distribution pipe and along pipes connecting the most unfavorable point in the network, which is why we must first determine the dimensions of the main distribution pipe and the network pipes.

4.1.1 Calculation of linear pressure loss

Linear pressure losses are given by the following formula:

$$\Delta H_L = j\,L = \frac{\lambda\, v^2}{2\, g\, D}\, L$$

j: hydraulic gradient of head loss m/m.

v: flow velocity m/s.

D: diameter of the pipe.

L: length of the pipe (m).

The total pressure loss is given by the following formula:

$$\Delta H_t = \Delta H_L + \Delta H_s \text{ With } \Delta H_s = (15-20)\%\, \Delta H_L$$

ÿ is given by iteration according to Colebrook:

$$\frac{1}{\sqrt{\lambda}} = -2\log\left[\frac{\varepsilon}{3.7\, D} + \frac{2.51}{R_e\sqrt{\lambda_0}}\right]$$

With :

ÿ: roughness coefficient ÿ = 10ÿÿ for PVC pipes

Regarding the Reynolds number, it is calculated using the following formula:

$$R_e = \frac{v\,D}{\partial}$$

ÿ : kinematic viscosity of water ÿ = 10-6 m/s If Re> 106

the flow regime is transient regime.

In transient regime ÿ0 can be determined by Nikuradze's formula:

$$\lambda_0 = \left(1.14 - 0.86\,\ln\frac{\varepsilon}{D}\right)^{-2}$$

Application :

Determine the total head loss for a pipe of length L=136m with a diameter of

200mm and a speed of 0.60m/s.

Solution :

•Determine ÿ0:

$$\lambda_0 = \left(1.14 - 0.86\,\ln\frac{\varepsilon}{D}\right)^{-2} = \left(1.14 - 0.86\ln\frac{10^{-4}}{0.2}\right)^{-2} = 0.016968453$$

ÿ0 = 0.016968453

•Determine the Reynolds number:

$$R_e = \frac{v\,D}{\partial} = \frac{0.60 * 0.2}{10^{-6}} = 120000$$

Re=120,000

•Determine ÿ:

$$\frac{1}{\sqrt{\lambda_1}} = -2\log\left[\frac{\varepsilon}{3.7\,D} + \frac{2.51}{R_e\sqrt{\lambda_0}}\right]$$
$$= -2\log\left[\frac{\varepsilon}{3.7\,D} + \frac{2.51}{R_e\sqrt{0.016968453}}\right] = 0.020072565$$

ÿ2 = 0.019853374

ÿ3 = 0.019867329

ÿ4 = 0.019866434

ÿ5 = 0.019866492

ÿ6 = 0.019866488

ÿ7 = 0.019866488

ÿ = 0.019866488

•Determine j:

$$j = \frac{\lambda\,v^2}{2\,g\,D} = \frac{0.019866488 * (0.6)^2}{2 * 9.81 * 0.2} = 0.001822613$$

j = 0.001822613

•Determine ÿHL:

$$\Delta H_L = j\ L = 0.001822613 * 136 = 0.247792$$

ÿHL = 0.247792 mcd of water

•Determine ÿHs:

$$\Delta H_s = 15\%\ \Delta H_L = \frac{15}{100}\ 0.247792 = 0.0371688$$

ÿHs = 0.03371688 mcd'water

•Determine ÿHt:

$$\Delta H_t = \Delta H_L + \Delta H_s = 0.247792 + 0.0371688 = 0.2848608$$

ÿHt = 0.2848608 mcd'water

5. Tank equipment

5.1 Water Supply Pipe

The water supply is achieved by pumping, arriving in the tank via a submerged siphon (at the upper part) from the tank), or from the bottom placed opposite the starting pipe, in order to cause mixing, by Consequently, a control device located at the pumping station allows the triggering the stopping or starting of the pumps.

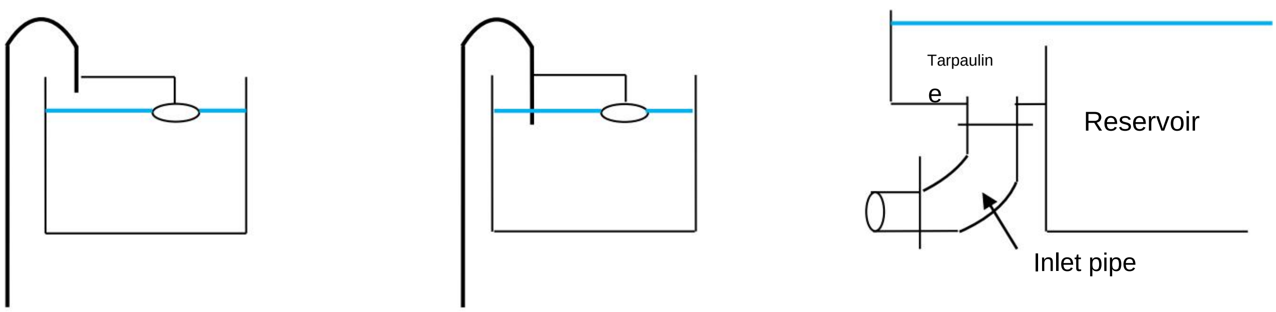


Figure 4-3: Adduction with free fall. Submerged adduction. Arrival by pipe

5.2 Distribution line

This is the pipe that carries water from the reservoir (tank) to the town. Its opening will be located at opposite the inlet pipe; it is placed a few centimeters (15/20 cm) above the bottom of the tank, to prevent the introduction of airborne particles. The end is fitted with a curved strainer to avoid the vortex phenomenon (air penetration into the pipe).

This pipe is equipped with an overspeed valve, switching to rapid closure in case of break in this conduction.

For the pipe sizing, we have:

$$Q_p = v\,s$$

With :

Qp : peak flow rate m3 /s

s: the section of the pipe

v: The flow velocity varies between 0.5 – 1.5 m/s, generally a velocity v = 1 m/s is used

SO : $$D = \sqrt{\frac{4\,Q_p}{\pi\,v}}$$

We then determine the speed $$v = \frac{4\,Q_p}{\pi\,D^2}$$

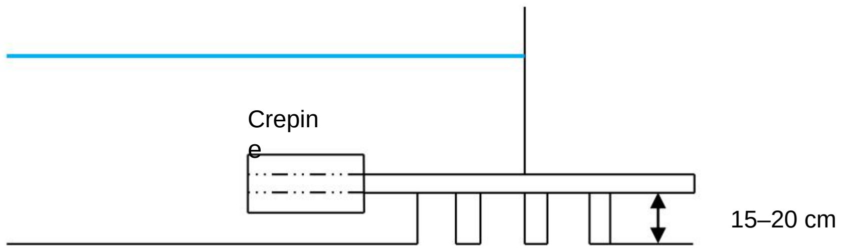


Figure 4. Start of the distribution.

5.3 Overflow

Pipe This pipe is designed to drain excess water entering the reservoir without causing a spill. In case the feed pump fails to stop, the upper end of this pipe is fitted with a funnel acting as a circular overflow to allow this drainage.

The flow rate evacuated under these conditions is given by the formula according to Lancaster:

$$Q = 27.828\,\mu\,r\,h^{3/2}$$

With :

h: the water level on the overflow.

r: the radius of the opening of the truncated cone of the pipe.

ÿ: flow coefficient given as a function of h/r.

Table 3-6: ÿ values

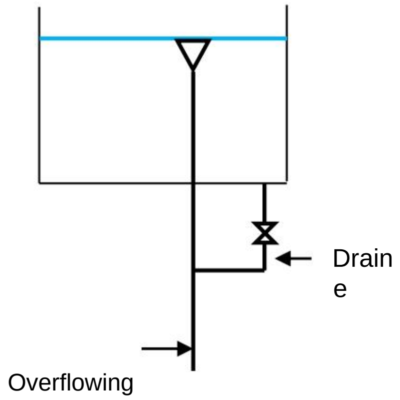
h/r	0.2	0.25	0.30	0.40	0.50
ÿ	0.415	0.414	0.410	0.404	0.394

If we take ÿ = 0.415, we have h/r = 0.2, therefore h = 0.2 r

$$r = \left[\frac{Q}{27.828\,\mu\,(0.2)^{\frac{3}{2}}}\right]^{2/5}$$

The overflow pipe will empty into a nearby outlet, but there is a risk that this will cause problems.

outlet, pollution, or the introduction of animals or mosquitoes that could thus to enter the reservoir. Therefore, a hydraulic seal is provided, consisting of a siphon which keeps the AB section of the overflow filled with water.



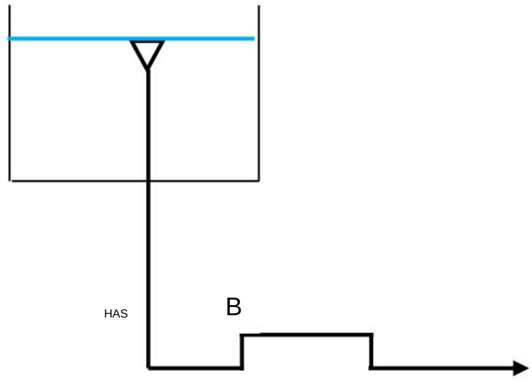


Figure 4–5: Overflow and drain Overflowing siphon

5.4 Drain line

It starts from the lowest point of the tank and connects to the overflow pipe, it It has a valve. Draining is essential for tank maintenance (cleaning, repair, …).

The diameter of this pipe is given by the following relationship:

$$Q = \mu s \sqrt{2gh} = \mu \left[\frac{\pi D^2}{4}\right]\sqrt{2gh}$$

SO :

$$D = \sqrt{\frac{4Q}{\mu \pi \sqrt{2gh}}}$$

With :

h: the height of water in the reservoir m.

Q: the incoming flow rate in m³ /s

ÿ: flow coefficient, we take ÿ = 0.4

Application :

For a 700 m³ tank , what is the diameter of the drain pipe if h = 6 m and we want the Empty in 2 hours.

Solution :

• Determine the flow rate

$$Q = \frac{V}{t} = \frac{700}{2 * 3600} = 0.097$$

Q = 0.097 m³ /s

• Calculate the diameter of the pipe:

$$D = \sqrt{\frac{4\,Q}{\mu\,\pi\,\sqrt{2\,g\,h}}} = \sqrt{\frac{4 * 0.097}{0.4 * 3.14 * \sqrt{2 * 9.81 * 6}}} = 0.168 \approx 200mm$$

D = 200 mm

• Calculate the flow rate in the drain pipe:

$$Q = \mu \left[\frac{\pi\,D^2}{4}\right] \sqrt{2\,g\,h} = 0.4 \left[\frac{3.14 * 0.2^2}{4}\right] \sqrt{2 * 9.81 * 6} = 0.136$$

Q = 0.136 m^3 /s

And the flow rate:

$$v = \frac{4\,Q}{\pi\,D^2} = \frac{4 * 0.136}{3.14 * 0.2^2} = 4.33$$

v = 4.33 m/s

The diameter of the drain pipe is 0.2 m, evacuating a flow rate of 0.136 m^3 /s with a velocity of 4.33 m/s.

5.5 Special Provisions

5.5.1 Bypass

To ensure continuity of distribution, in case of maintenance work or in the case of emptying the tank; the supply line is connected to the distribution line by a section of pipe called By-pass.

When the tank is in use, valves (1) and (3) are open and (2) is closed.
• In the case of cleaning the tank, close (1) and (3) and open (2).

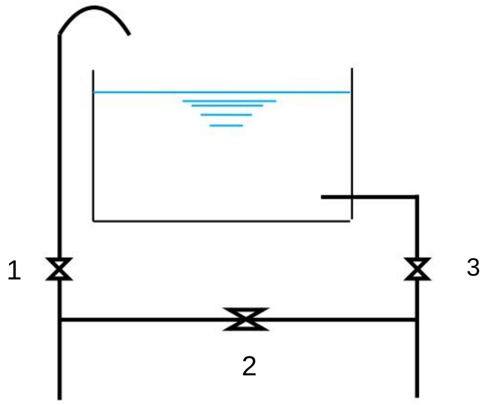


Figure 4-6: Bypass

5.5.2 Materialization of the fire reserve

The reservoir always has a certain quantity of water, approximately 120 m3, stored in case of emergency. fire. A device is adopted consisting of a siphon which disengages when the level of The reservoir is reached thanks to the vent open to the open air.

• In the normal case of distribution, we close (2) and open (1) and (3).

- In case of fire, open (2) and close (1) and (3).

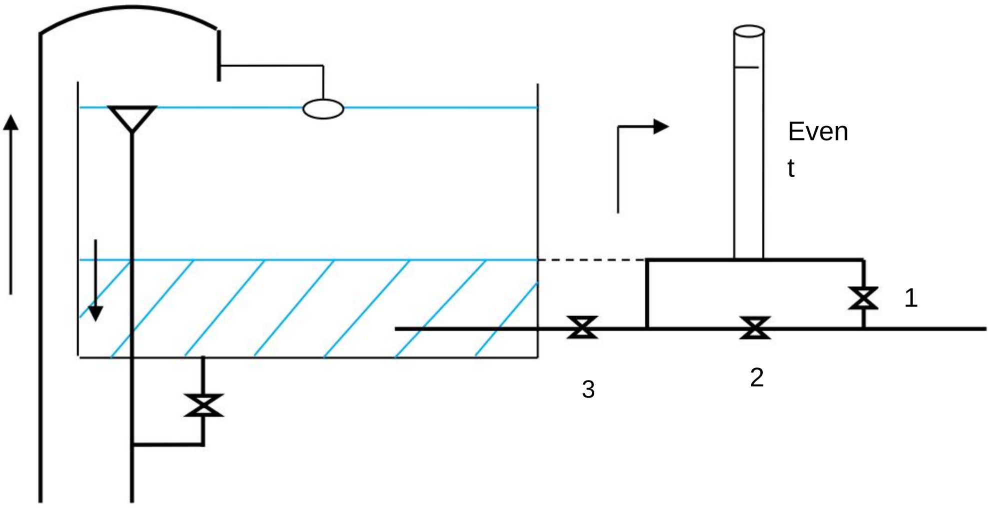


Figure 4 – 7: Materialization of the fire reserve.

5.6 Piping systems

-Pipe : the pipes are circular in shape, made of ductile iron, characterized by excellent mechanical properties (deformability, corrosion resistance).

-Elbows and tees : These are placed in the piping; the elbow allows for a change of direction. The TE allows the secondary pipe connection to the main pipe.

-Valves : Valves are planned at the level of the water supply pipeline in order to isolate the sections In the event of a failure in the pipeline, butterfly valves are permitted at the outlet of the starting pipeline (at overspeed); useful in case of rapid oil change.

-Float valve : It allows you to maintain the water level in the tank at a specific level, and this by closing the inlet pipe when this level is reached.

Conclusion

The supply of drinking water is a major issue for the development of societies and the well-being of the population. Water distribution networks must meet certain requirements. strict standards regarding flow rate, pressure and water quality, while adapting to changes demographic and environmental challenges.

Useful links

- https://youtu.be/WBbjP6GKf00
- https://youtu.be/UPIWMT65Q8g

- https://youtu.be/AKd2CUxpKVw

References

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