Sanitary Systems Design
Part 2

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Cavitation

- Cavitation occurs when the pressure of a flowing fluid drops below the vapor pressure of that fluid. In this two-step process, the pressure first drops to the critical point, causing cavities of vapor to form. These are carried with the flow stream until they reach an area of higher pressure. The bubbles of vapor then suddenly collapse or implode. This reduction in pressure occurs when the velocity increases as the fluid passes through a valve. After the fluid passes through the valve, the velocity decreases and the pressure increases. In many cases, cavitation manifests itself as noise.

Cavitation

- However, if the vapor bubbles are in contact with a solid surface when they collapse, the liquid rushing into the voids causes high localized pressure that can erode the surface. Premature failure of the valve and adjacent piping may occur. The noise and vibration caused by cavitation have been described as similar to those of gravel flowing through the system.

Water Hammer

- Water hammer is a series of pressure pulsations of varying magnitude above and below the normal pressure of water in the pipe. The amplitude and period of the pulsation depend on the velocity of the water as well as the size, length, and material of the pipe.
- Shock loading from these pulsations occurs when any moving liquid is stopped in a short time. In general, it is important to avoid quickly closing valves in an HVAC system to minimize the occurrence of water hammer.

Water Hammer

- When flow stops, the pressure increase is independent of the working pressure of the system. Water hammer is often accompanied by a sound resembling a pipe being struck by a hammer—hence the name. The intensity of the sound is no measure of the magnitude of the pressure. Tests indicate that even if 15% of the shock pressure is removed by absorbers or arresters, adequate relief is not necessarily obtained.
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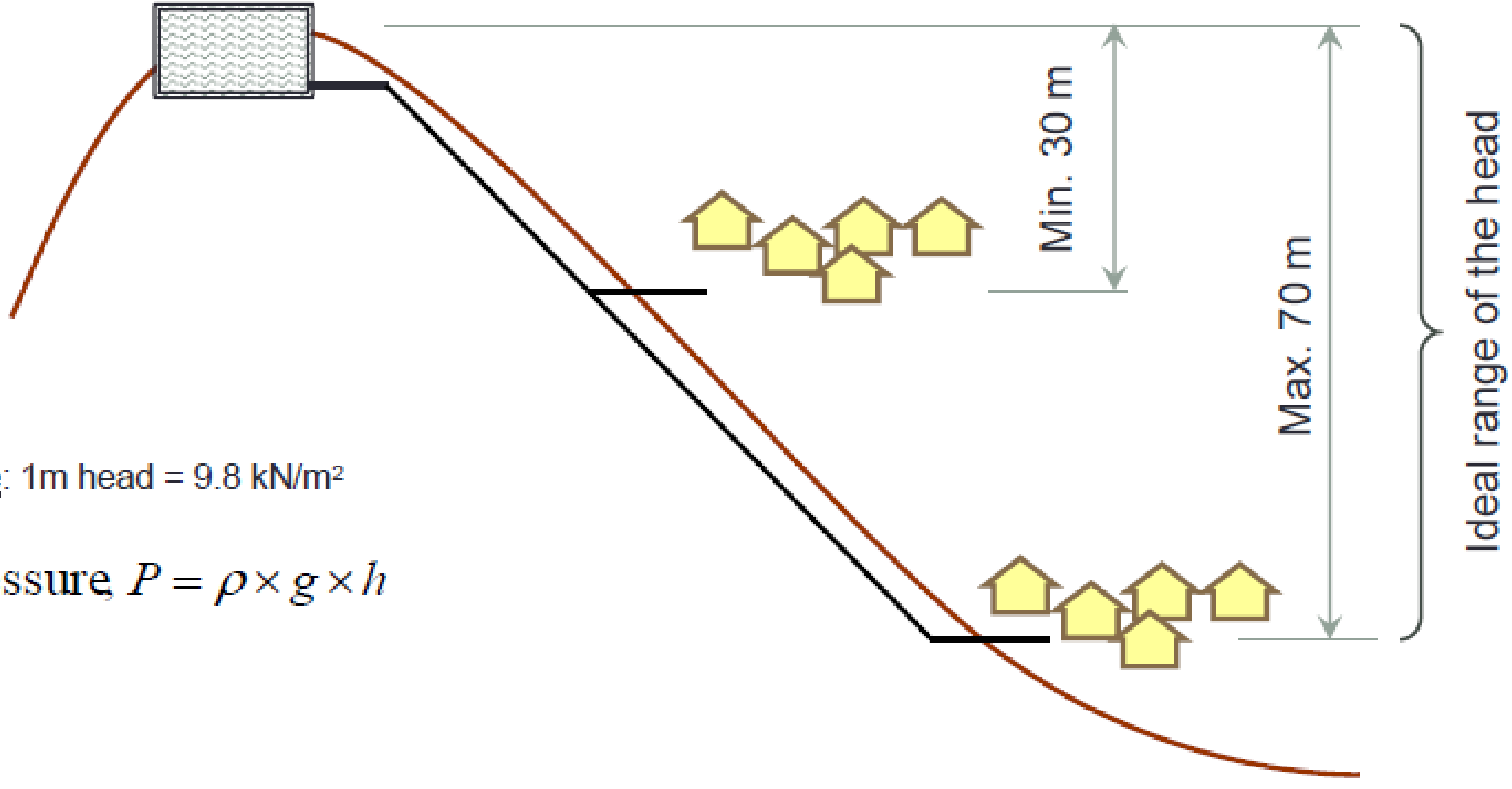
Service Reservoir

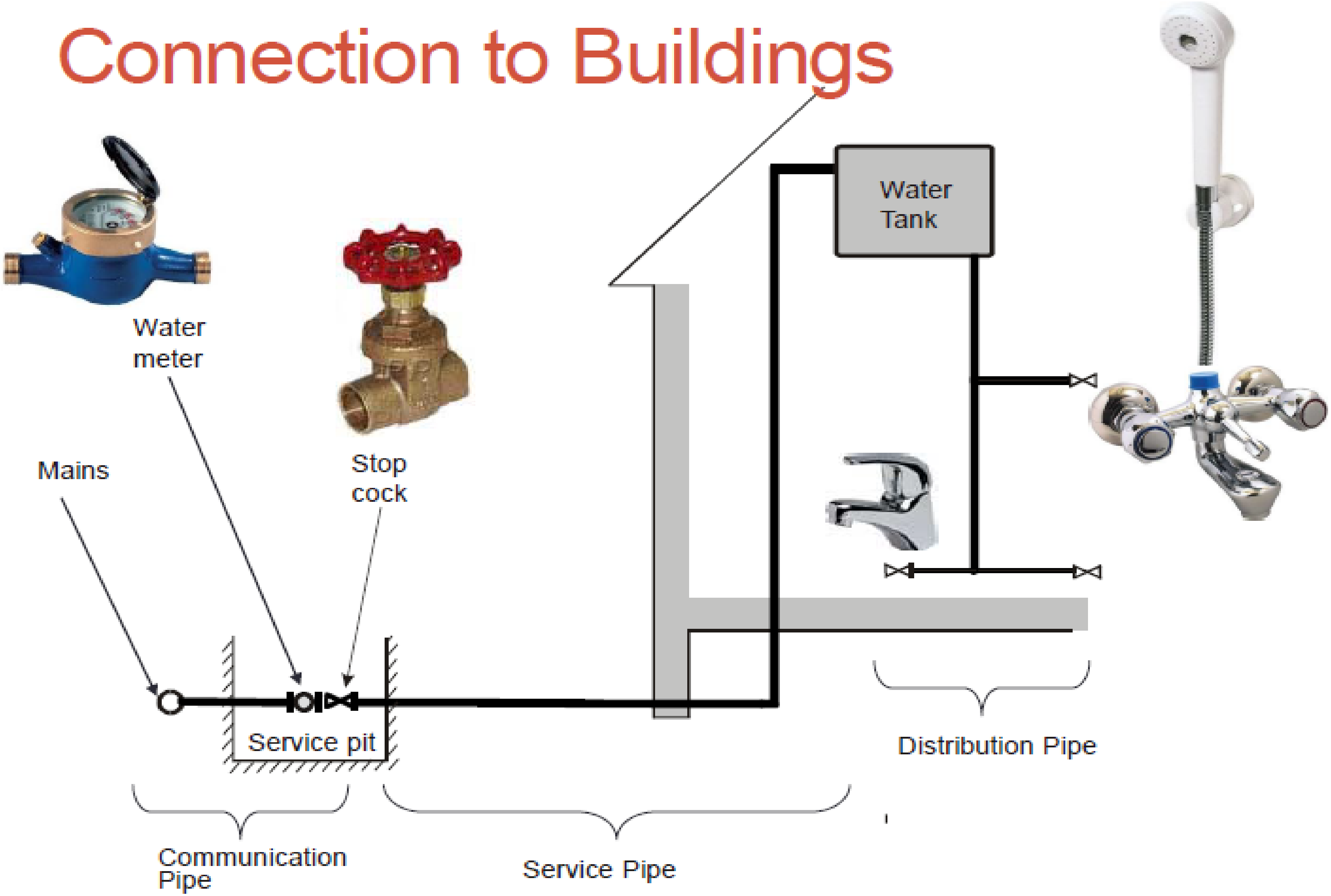
This is a large water tank sited to give ideal range of static head where possible (30m-70m) height.



Note: 1m head = 9.8 kN/m²

Pressure, $P = \rho \times g \times h$

Connection to Buildings



Storage Capacity of Tanks

Storage capacity per person for different building types

Type of Building	Storage per person (Liters)
Dwelling houses and flats	91
Hostels	91
Hotels	136
Offices without canteens	37
Offices with canteens	45
Restaurants	7
Day Schools	27
Boarding schools	91
Nurses homes and medical quarters	114

Volumes of water used by each appliance

Appliance		Volume of Cold water (Liters)
Wash basin		
	Hand wash	5
	Wash	10
	Hair Wash	20
Shower		40
Bath		110
W.C		10
Washing Machine		150
Sink		
	Wash up	15
	Cleaning	10

Example for Determining Storage Capacity of Water Tanks

Example: You are designing a boarding school of 200 students and staff. What should be the volume of the cold water tank?

Solution:

Example for Determining Storage Capacity of Water Tanks

From the first table for a boarding school the storage required is 91 Liters per person. Therefore the total volume required is:

- ***Volume*** = 91 L/person x 200 persons = 18200 L

This is the same as 18.2 m3 or 18.2

Cold Water Storage Calculations

- Cold water storage data is provided to allow for up to 24 hour interruption of mains water supply.

Building purpose	Storage/person/24 hrs	
Boarding school	90 litres	
Day school	30	
Department store with canteen	45	(3)
Department store without canteen	40	(3)
Dwellings	90	(1)
Factory with canteen	45	
Factory without canteen	40	
Hostel	90	
Hotel	135	(2) (3)
Medical accommodation	115	
Office with canteen	45	
Office without canteen	40	
Public toilets	15	
Restaurant	7 per meal	

Cold Water Storage Calculations

At the design stage the occupancy of a building may be unknown. Therefore the following can be used as a guide:

Building Purpose	Occupancy
Dept. store	1 person per $30 m^2$ net floor area
Factory	30 persons per WC
Office	1 person per $10 m^2$ net floor area
School	40 persons per classroom
Shop	1 person per $10 m^2$ net floor area

E.g. A $1000 m^2$ (net floor area) office occupied only during the day therefore allow 10 hours' emergency supply.

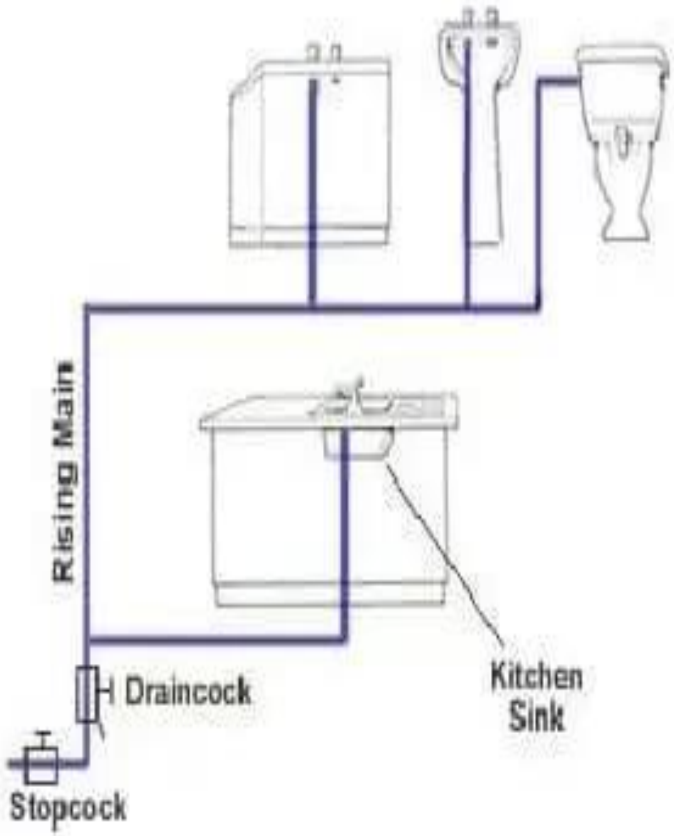
1000/10 = 100 persons × 40 litres = 4000 litres (24 hrs)

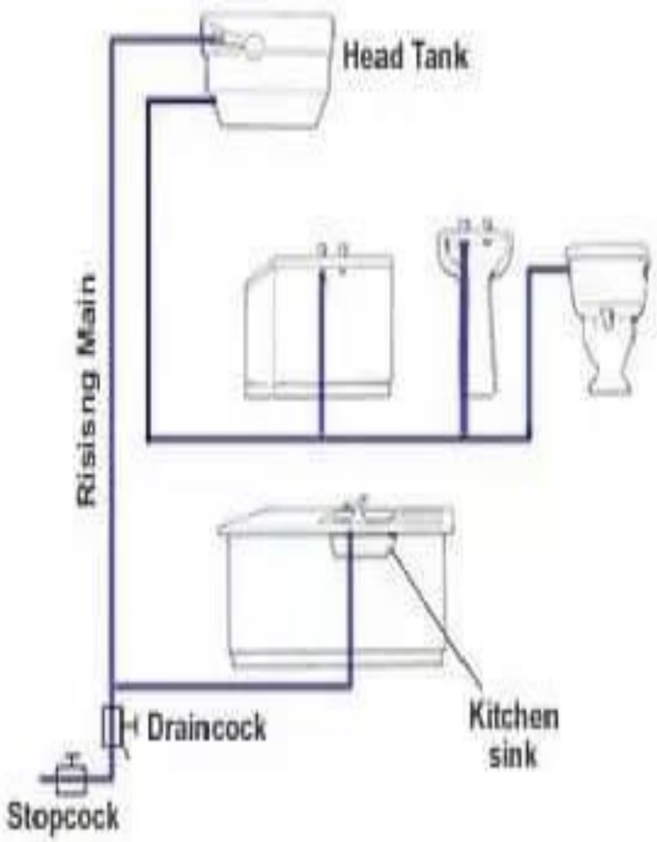
= 1667 litres (10 hrs)

Method of supplying water:

- **Direct Water Supply System**
- All appliances of a house are directly connected to the main supply line of Municipality/city government/ supply company.
- **Indirect Water Supply System**
- Only the kitchen sink and storage tank is connected to the main supply line. All other appliances are fed with water from the storage tank on the terrace of the house.

Direct Vs. Indirect

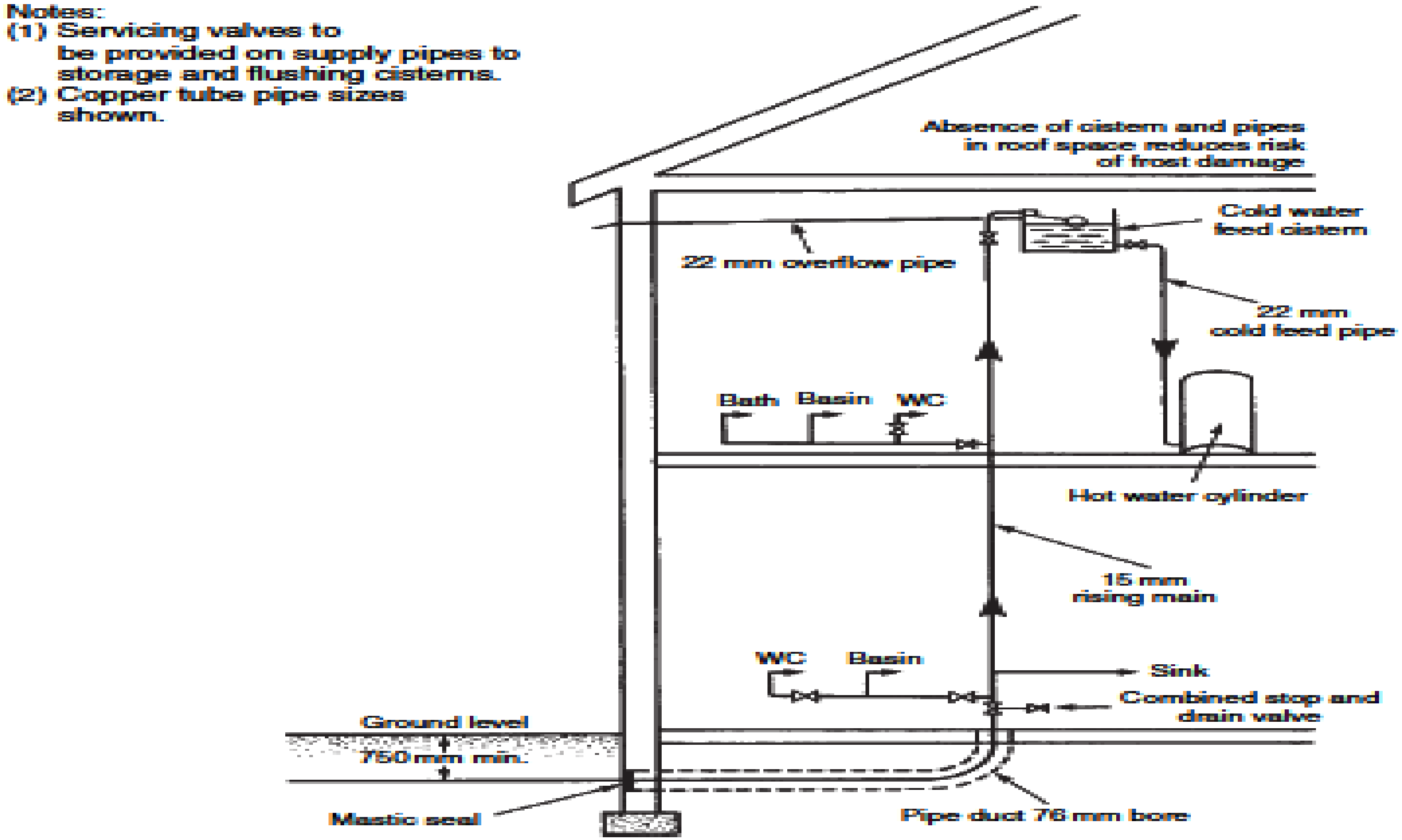




Direct System of Cold Water Supply

- **For efficient operation, a high pressure water supply is essential particularly at periods of peak demand. Pipework is minimal and the storage cistern supplying the hot water cylinder need only have 115 liters capacity. The cistern may be located within the airing cupboard or be combined with the hot water cylinder. Drinking water is available at every draw-off point and maintenance valves should be fitted to**
- **isolate each section of pipework. With every outlet supplied from the main, the possibility of back siphonage must be considered.**

Direct System of Cold Water Supply



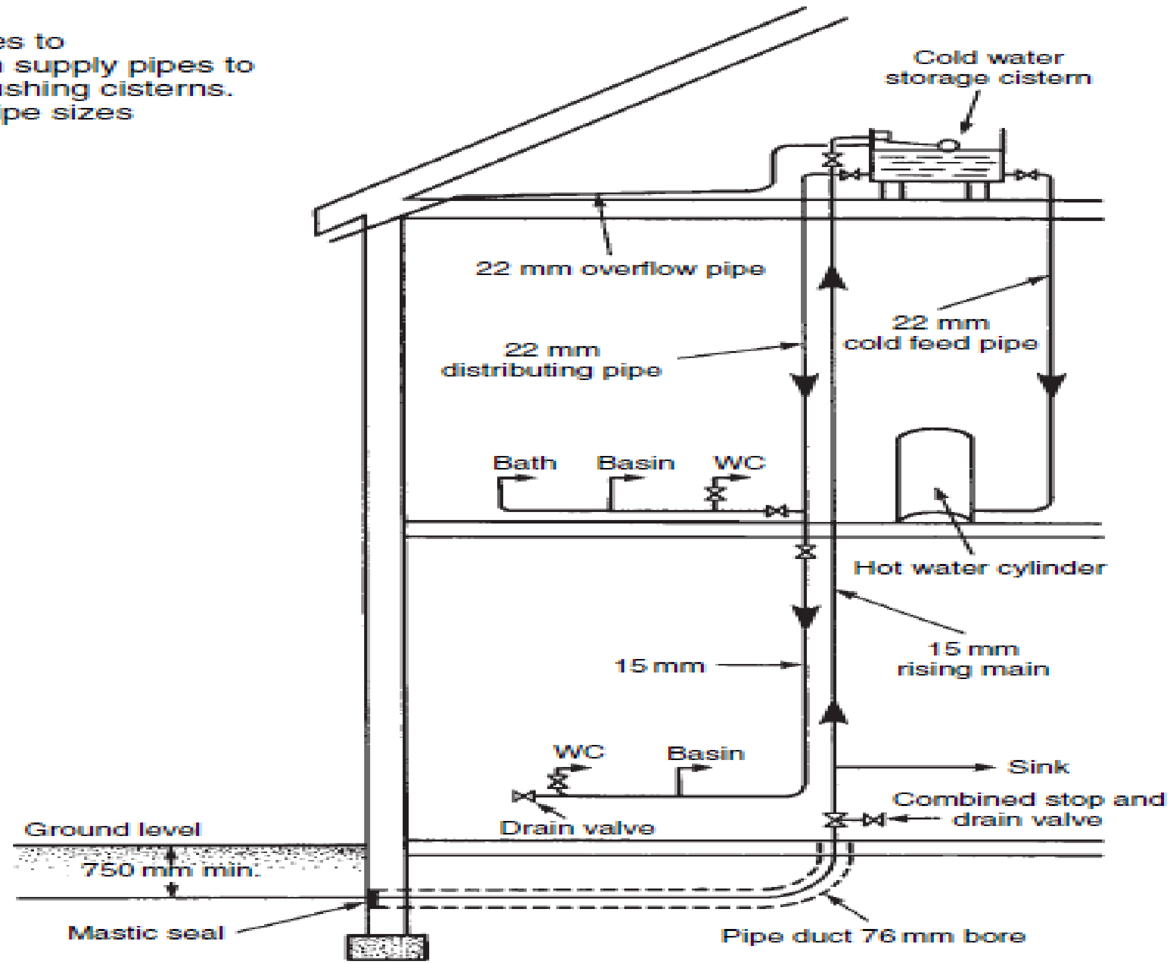
Ref.: The Water Supply (Water Fittings) Regulations 1999.

Indirect System of Cold Water Supply

- **The indirect system of cold water supply has only one drinking water outlet, at the sink. The cold water storage cistern has a minimum capacity of 230 liters, for location in the roof space. In addition to its normal supply function, it provides an adequate emergency storage in the event of water main failure. The system requires more pipework than the direct system and is therefore more expensive to install, but uniform pressure occurs at all cistern-supplied outlets.**

Indirect System of Cold Water Supply

Notes:
(1) Servicing valves to be provided on supply pipes to storage and flushing cisterns.
(2) Copper tube pipe sizes shown.



Ref.: The Water Supply (Water Fittings) Regulations 1999.

Direct water supply

- Direct Water Supply System provides potable water to all fixtures including bath, bathroom basin and kitchen sink. Rising main (the pipe that supplies municipal water to a house) directly supplies water to all the taps (faucets). All fixtures receives water from water supply authority at the pressure same as that of main. Generally, pressure of $0.5 kg/cm^2$ to $1.00 kg/cm^2$ i.e head of 5m to 10m is required at all taps. Main pressure is usually high because mains have to supply water to downstream areas, taking care of level variations.

Direct water supply

- To reduce the pressure and to maintain constant pressure depending on the location at which water enters house, a pressure reducing valve is sometimes introduced at the main and than the water is distributed to other pipes of the house. The pressure of hot water and cold water should be same at the faucet.

Indirect water supply

- Indirect water supply system is the most common type in modern houses, in countries like India, Pakistan, and countries in Asia and Africa. Here, water enters house from the rising main (main pipe from where water enters house), which is branched off into kitchen sink and storage tank either underground or overhead. Only kitchen sink receives potable water directly from municipal mains. All the other appliances receive water from the storage tank. The storage tank is kept at height so that water comes down into fixtures through gravity at sufficient pressure.

Pressure of water

- **Direct Water Supply System**

Water directly comes from main, it has high pressure and sometimes a pressure reducing valve is required to save from damage due to higher pressure.

- **Indirect Water Supply System**

In order to get sufficient pressure, water storage tank has to be at some height, which is not always achieved and hence the user on the floor just below suffer from lower pressure, due to which shower, flush, etc. do not work efficiently.

Quality of water

- **Direct Water Supply System**

Better water quality as water directly comes after treatment.

- **Indirect Water Supply System**

Water quality is affected as water is stored in storage tanks and then supplied to appliances.

Distribution of Pipes

- **Direct Water Supply System**

Water enters house from main supply pipe and is branched off to all fixtures and hence less length and cost.

- **Indirect Water Supply System**

Water enters house from main supply pipe and is branched off to kitchen sink and water storage tank either overhead or underground. Then all other fixtures receive water from storage tank.

Maintanance

- **Direct Water Supply System**

Requires less maintenance compared to indirect water supply system.

- **Indirect Water Supply System**

Tanks (overhead at some level/underground with pumps) require regular maintenance, cleaning, protection from UV rays.

Water Supply

Direct Water Supply System

- Water supply is continuous throughout day. Ifwater supply is only for certain period of time in a day, it is cumbersome, as user would be without water for certain time of day.
- If main supply pipe is damaged, whole water supply of house will have to be stopped till it is repaired.

Indirect Water Supply System

- Once water is stored in storage tank it can be used at any hour of a day, but a definite storage capacity is needed.
- In case if any pipe is damaged only that fixture water supply is stopped. Rest fixtures gets water supply from tank.

Wastage &Leakages

- **. Direct Water Supply System**

More water is wasted compared to indirect water supply system.

- **Indirect Water Supply System**

Minimal wastage of water.

- **Direct Water Supply System**

Pipes may leak due to high pressure water flowing through them.

- **Indirect Water Supply System**

Chances of water leakages from water storage tank.

Capacity of Pumps at Source &Economy

- **Direct Water Supply System: Economical** as less pipe works and no storage tanks.
- **Indirect Water Supply System: Extra** cost of pipes and tanks, which is substantial.

Direct Water Supply System: Huge pressure i.e high capacity pumps are required to reach upper stories.

- **Indirect Water Supply System: Moderate** pressure will do, as water will be supplied only at ground level.

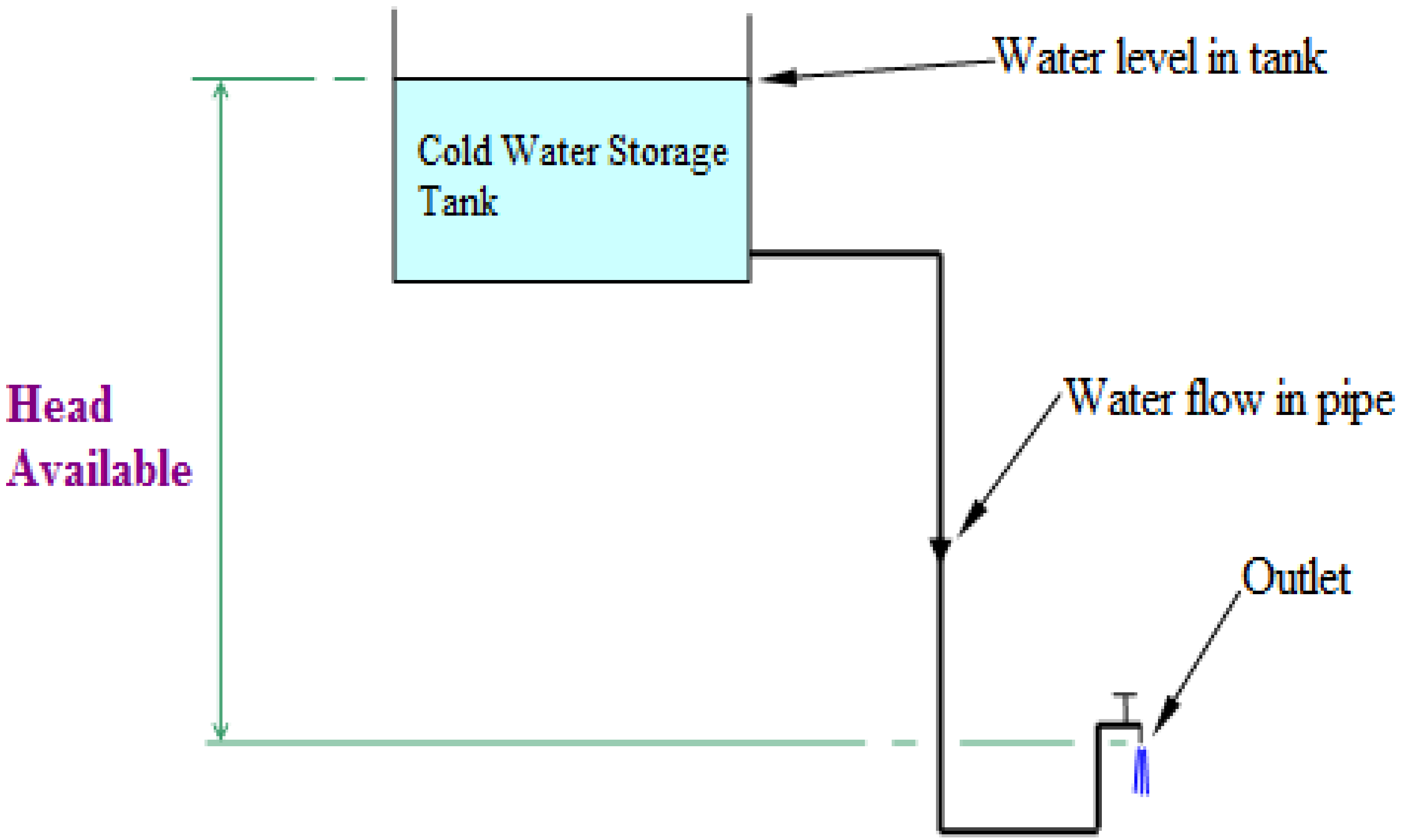
The most common one?

- Direct water supply system is most common in developed countries like America and European countries. Whereas, developing countries like India, Pakistan and other Asian, African countries opt for indirect water supply system.

Pipe Sizing Procedure for water supply system

NON-PRESSURISED COLD WATER PIPE SIZING

- This method is pipe sizing where the pressure available is not from a pump but from the head available from the tank.
- The higher the tank is above the outlets the more head will be available to force the water through the outlets and overcome pipe work resistances.


Water level in tank
Cold Water Storage Tank
Head Available
Water flow in pipe
Outlet

HEAD AVAILABLE

- The Head Available develops water pressure and this water pressure is used up in overcoming the frictional resistance of the pipe and in creating the velocity pressure for water flow at the outlet.
- p1 - p2 = frictional resistance + velocity pressure
- Or,
- h1 - h2 = head loss in pipe due to friction + velocity head
- **Where p = pressure (N/m2)**
- **h = head (m)**

- In practice, to avoid additional velocity pressure calculations, it is usual to calculate the available pressure by considering the difference in levels between the bottom of the storage tank and the height of the draw-off points.
- The pressure losses in the system are frictional pipe losses and velocity pressure loss through sanitary fittings such as taps, cistern ball valves and shower heads.
- Velocity head loss through fittings is as follows:-
- Pillar taps 1m
- Shower head 1.5m
- Ball valve 1m

Fig 1.9 Equivalent pipe length cont…

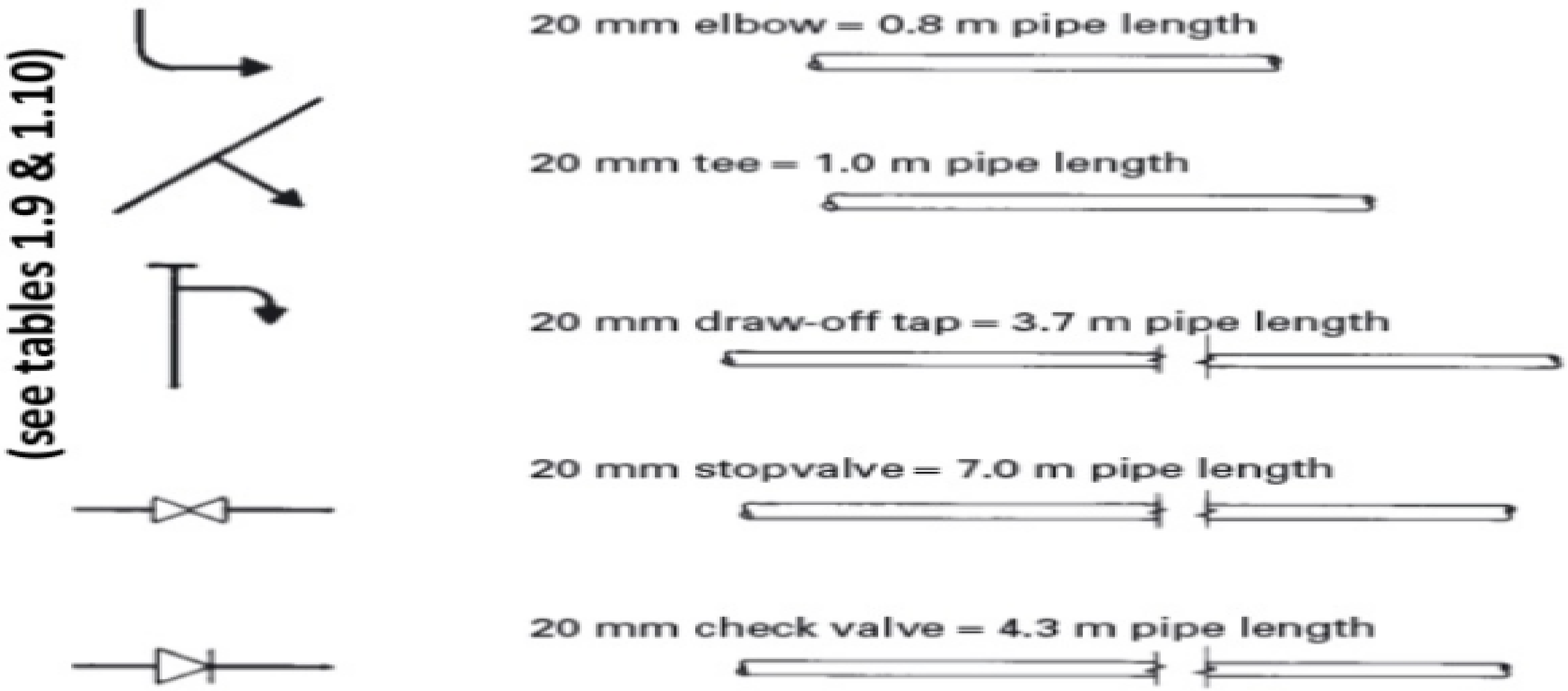


Table 1.9 Equivalent pipe lengths (copper, stainless steel and plastics)

Bore of pipe (mm)	Equivalent pipe length (m)			
	Elbow	Tee	Stopvalve	Check valve
12	0.5	0.6	4.0	2.5
20	0.8	1.0	7.0	4.3
25	1.0	1.5	10.0	5.6
32	1.4	2.0	13.0	6.0
40	1.7	2.5	16.0	7.9
50	2.3	3.5	22.0	11.5
65	3.0	4.5	---	---
73	3.4	5.8	34.0	---

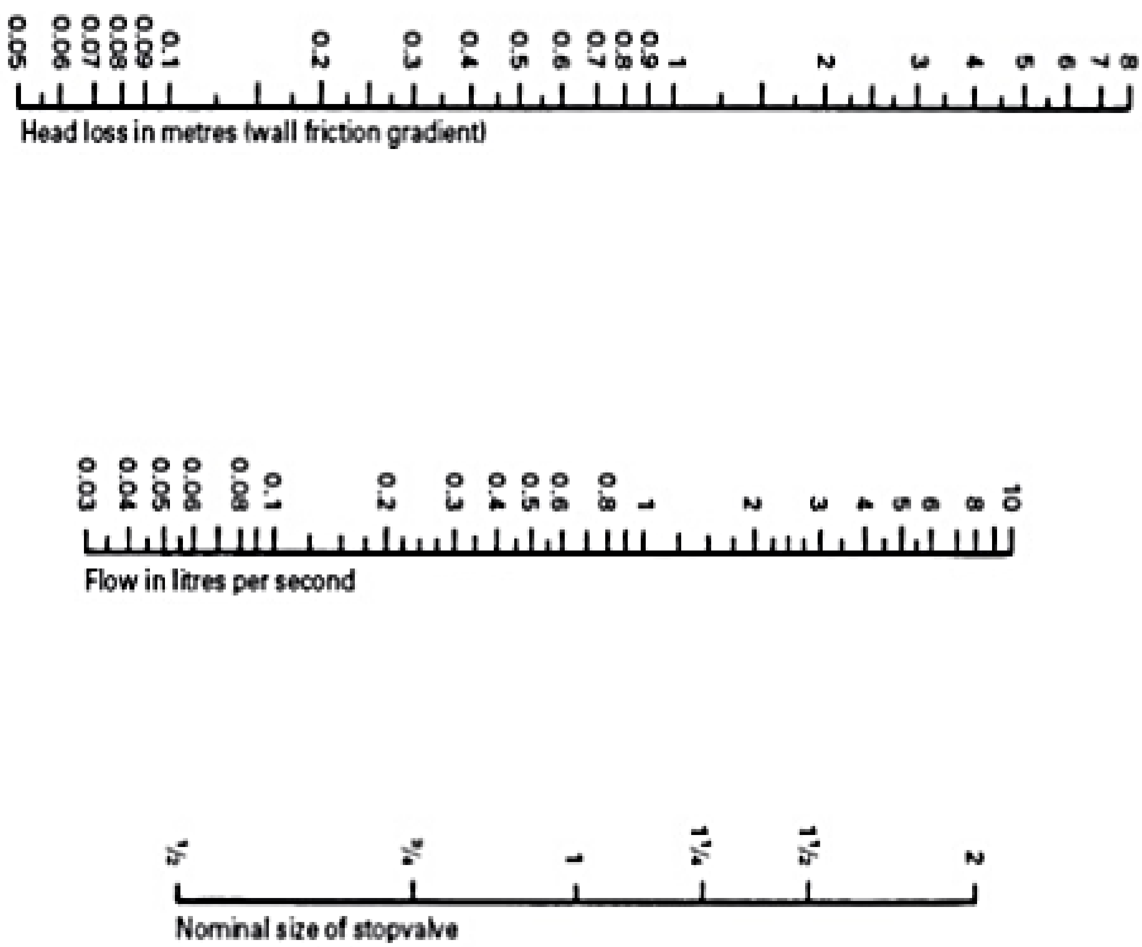
(Source: Garrett, R. H., 2008. *Hot and Cold Water Supply)*

Table 1.10 Typical head losses and equivalent pipe lengths for taps

Nominal size of tap	Flow rate (l/s)	Head loss (m)	Equiv. pipe length (m)
G1/2- DN 15	0.15	0.5	3.7
G1/2- DN 15	0.20	0.8	3.7
G3/4- DN 20	0.30	0.8	11.8
G1- DN 25	0.60	1.5	22.0

(Source: Garrett, R. H., 2008. *Hot and Cold Water Supply)*

Figure 1:12 Head loss through stop valves



Note Gate valves and spherical plug valves offer little or no resistance to flow provided they are fully open.

WATER FLOW RATES

- Cold water flow rates for sanitary appliances for small installations may be found from the table below.

Approximate hot or cold water demand	Flow rate (l/s)
Basin (spray tap)	0.05
Basin (tap)	0.15
Bath (private)	0.30
Bath (public)	0.60
Flushing cistern	0.10
Shower (nozzle)	0.15
Shower (100mm rose)	0.40
Sink (15mm tap)	0.20
Sink (20mm tap)	0.30
Wash fountain	0.40

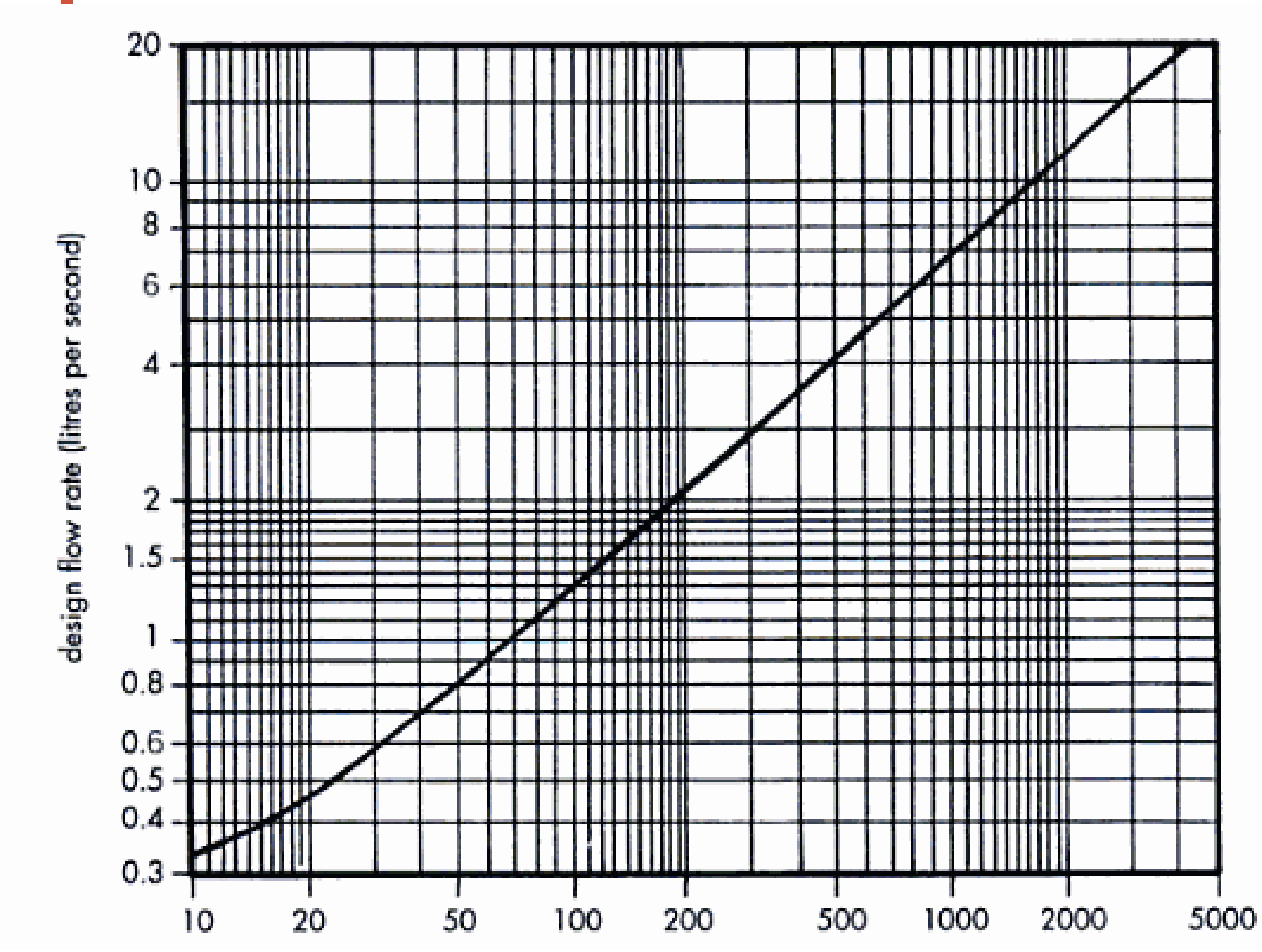
Pipe Size Procedure

- 1. Divide system into sections.
- 2. Calculate demand units if simultaneous demand is effective.
- 3. Estimate flow rates in each section.
- 4. Estimate pipe diameter.
- 5. Measure the pipe run for the section.
- 6. Calculate length of pipe equal to resistance of fittings.
- 7. Calculate effective pipe length.
- 8. Determine pressure loss due to friction for pipe
- 9. Calculate pressure consumed by friction.
- 10. Calculate cumulative pressure consumed.

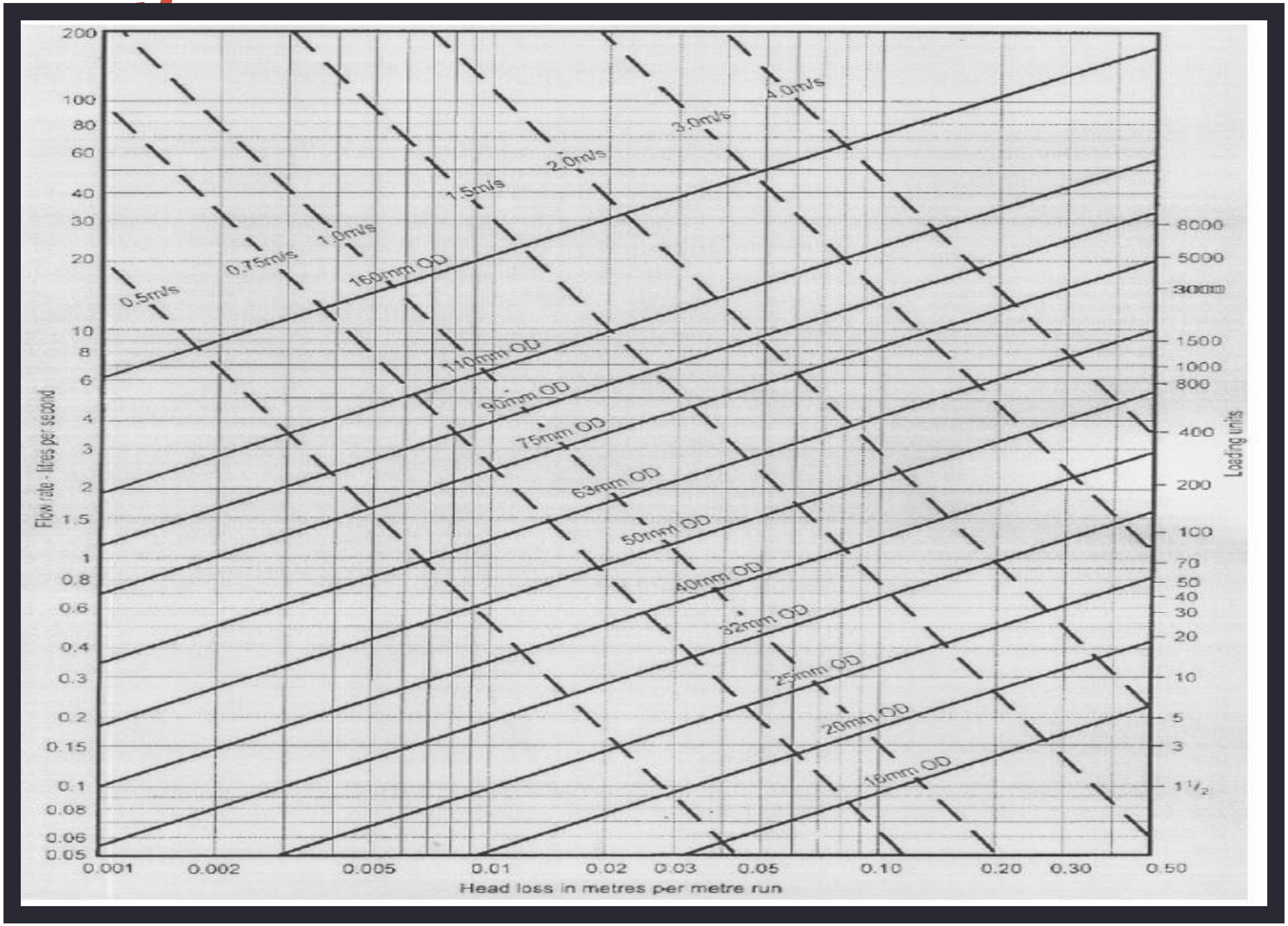
Below given table is to achieve loading units of appliances

S.NO	DWELLINGS AND FLATS	LOADING UNITS
1	WC FLUSHING CISTERN(TANK)	2
2	WASH BASIN	1 ½
3	BATH	10
4	SINK	5
5	SHOWER(WITH NOZZLE)	3
6	PUBLIC BATH	22
	OFFICES	
1	WC FLUSHING CISTERN	2
2	WASH BASIN	3
	SCHOOLS AND INDUSTRIAL BUILDINGS	
1	WC FLUSHING CISTERN	2
2	WASH BASIN	3
3	LAB SINK	1

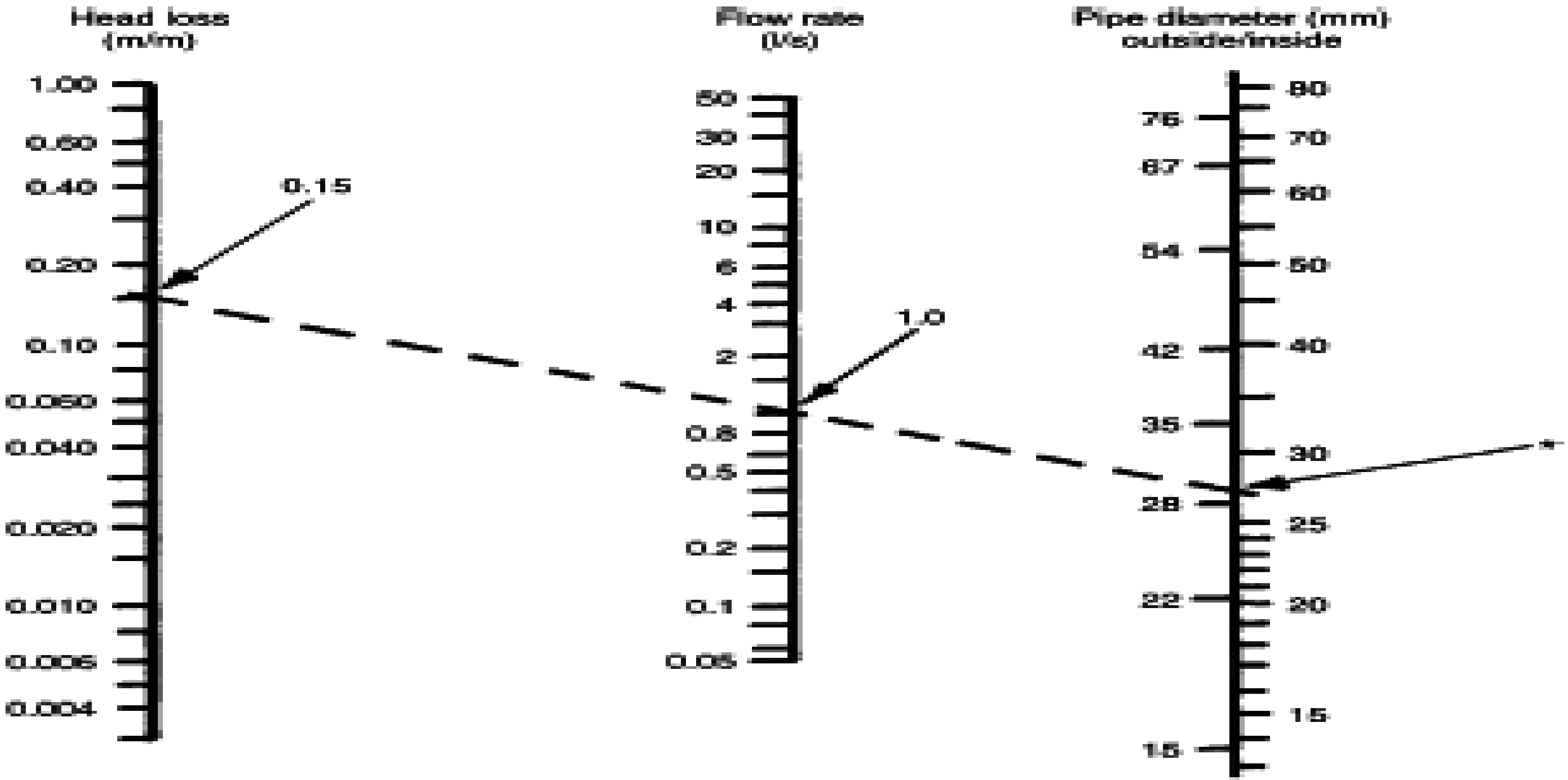
For calculating the flow rate of water liter per second refer to this chart



The chart given below is to select pipe sizing.



The chart given below is to select pipe sizing.



Pipe sizing-Introduction

Correct pipe sizes will ensure adequate flow rates at appliances and avoid problem caused by over sizing and under sizing;

Over sizing will mean:

- additional and unnecessary installation costs;
- delays in obtaining hot water at outlets;
- increased heat losses from hot water distributing pipes.

Under sizing may lead to:

- inadequate delivery from outlets and possibly no delivery at some outlets during simultaneous use;
- some variation in temperature and pressure at outlets, especially showers and other mixers;
- some increase in noise levels.

How to measure head loss

Pressure or head loss in pipework systems can be expressed as the relationship between available pressure (kPa) or head (m) and the effective length (m) of pipework

Length of pipe equal to Resistance

Equivalent pipe length

- **Equivalent pipe length** Is the expression of friction resistances to flow through valves and fittings in terms of pipe lengths having the same resistance to flow as the valve or fitting.

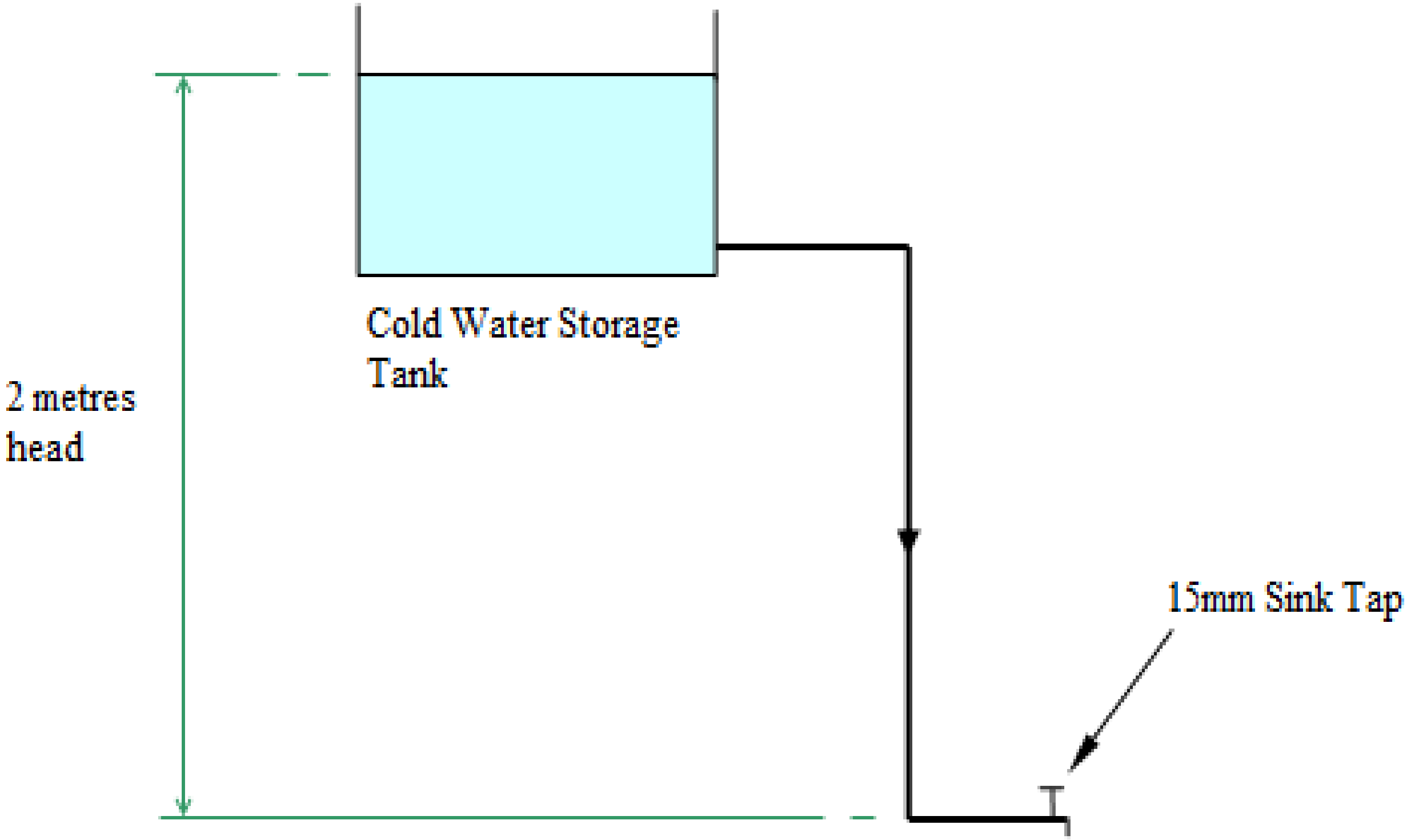
EXAMPLE 1

Determine a suitable pipe size for the system shown below.

DATA

Fittings include the following; exit from tank or large vessel, 3No. Bends, 1No. Gate valve, 1No. 15mm tap, Length of pipe run is 8 meters and copper pipe is to be used.

The flow rate for a 15mm Sink Tap from above Table is 0.2 l/s.


Cold Water Storage
Tank
2 metres
head
15mm Sink Tap

Example 1

- The pressure available to force the water through the pipe work and tap comes from the head of water above the tap. The formula below gives the relationship between pressure and head.
- $P = \rho x\ g\ x\ h$
- Where;
- P = pressure (N/m2)
- ρ= density (1000 kg/m3 for water)
- g = acceleration due to gravity (9.81 m/s2)
- h = head (m)
- Therefore: P = 1000 x 9.81 x 2.0 = 19,620 N/m2
- The resistance to flow is from the fittings and pipe work.

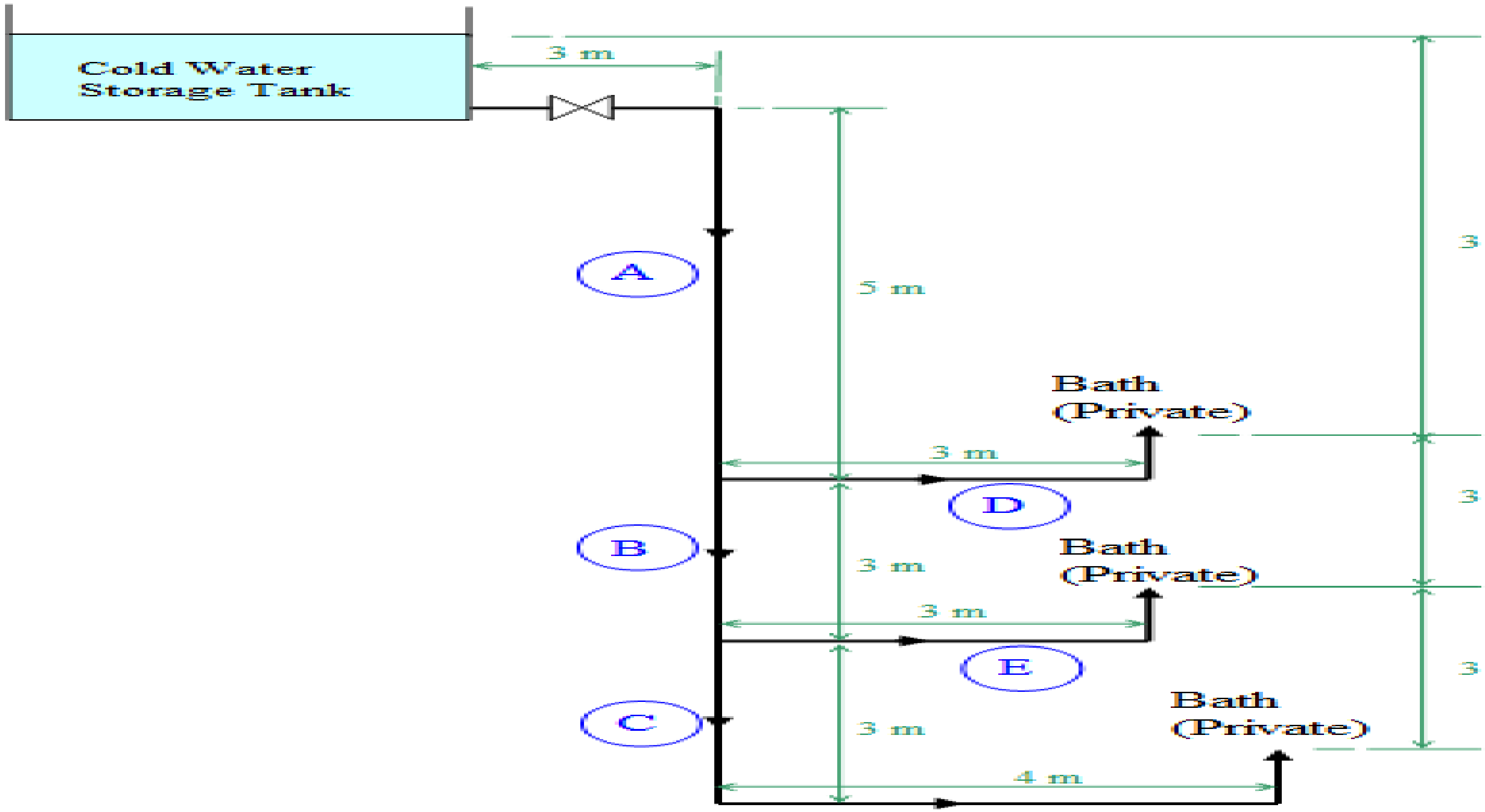
EXAMPLE 2

Determine suitable pipe sizes for the system shown below.

The building is a three-storey Nursing Home. Copper pipe is to be used. Flow rates are to be obtained from above Table?

EXAMPLE 2 (Cont)

Determine The pipe sizes, flow rates and pressures on the drawing below

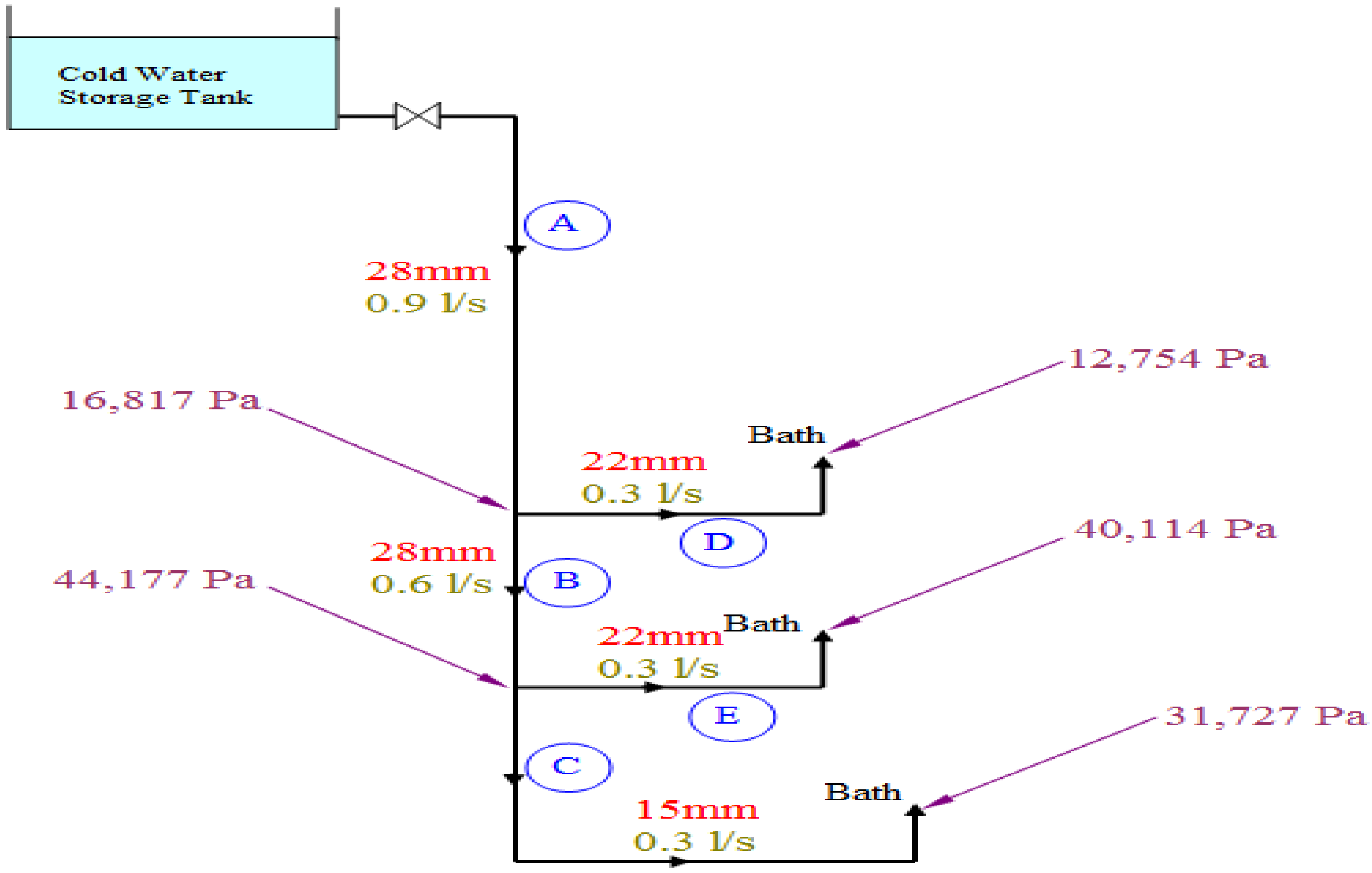


HOT AND COLD WATER PIPE SIZING TABLE

1	2	3	4	5	6	7	8	9	10	11	1
Ref	**Demand Units if required**	**Flow Rate** **(l/s)**	**Estimated Pipe Dia.** **(mm)**	**Measured Pipe Run** **(m)**	**Length of Pipe Equal to Resistance's** **(m)**	**Effective Pipe Length Col . 5 + 6** **(m)**	**Pipe Pressure Loss (Pa/m)**	**Pressure Consumed Col. 7 x 8 (Pa)**	**Total Pressure Consumed (Pa)**	**Pressure Available at End of Section (Pa)**	**Fi Pi Si** **(m**
A		0.9	28	8.0	ζ Factors for fittings: 1No.Exit large vessel = 0.4 1No.Gate Valve = 0.3 1 No. Bend = 1.0 1 No.28 x 28 x 22 tee = 0.2 ----------- Total 1.9 T.E.L. = Total ζ x le = 1.9 x 1.1 = 2.09 m	8 + 2.09 = 10.09 m	1250	12,613	12,613	Static pressure = 3m x 9810 = 29,430 Press. Available = 29,430 – 12,613 = **16,817 Pa**	2
B		0.6	28	3.0	1No.28 x 22 x 22 tee ζ = 0.20 with 28 x 22 reducer: $A_2 / A_1 = \pi \times 0.011^2 / \pi \times 0.014^2$. = 0.617 gives ζ = 0.25 ----------- Total 0.45 T.E.L. = Total ζ x le = 0.45 x 1.0 = 0.45m	3.0 + 0.45 = 3.45 m	600	2,070	12,613 + 2,070 = 14,683	Static pressure = 6m x 9810 = 58,860 Press. Available = 58,860 – 14,683 = **44,177 Pa**	2
C		0.3	22	7.0	1No.Bend = 1.0 1No. Angle valve bath tap = 5.0 ---------- - Total 6.0 T.E.L. = Total ζ x le = 6.0 x 0.7 = 4.2 m	7.0 + 4.2 = 11.2 m	625	7,000	14,683 + 7,000 = 21,683	Static pressure = 9 m x 9810 = 88,290 Press. Available = 88,290 – 21,683 = **66,607 Pa**	2

D		0.3	22	3.0	1No. Angle valve bath tap = 5.0 T.E.L. = Total ζ x le = 5.0 x 0.7 = 3.5 m	3.0 + 3.5 = 6.5 m	625	4,063	12,613 + 4,063 = 16,676	Static pressure = 3m x 9810 = 29,430 Press. Available = 29,430 – 16,676 = **12,754 Pa**	22
E		0.3	22	3.0	1No. Angle valve bath tap = 5.0 T.E.L. = Total ζ x le = 5.0 x 0.7 = 3.5 m	3.0 + 3.5 = 6.5 m	625	4,063	4,063	Static pressure = 6m x 9810 = 58,860 Press. Available = 58,860 – 14,683 = 44,177 Pa – 4,063 = **40,114 Pa**	22
Re-calculate pipe ref. C for 15mm pipe											
C		0.3	15	7.0	1No. 28 x 15 x 22 tee (already included) with 2 No.28 x 15 reducers: $A_2 / A_1 = \pi \times 0.0075^2 / \pi \times 0.014^2$. = 0.287 gives ζ = 0.47 2No. Reducers = 0.94 1No.Bend = 1.0 1No. Angle valve bath tap = 5.0 ----------- Total 6.94 T.E.L. = Total ζ x le = 6.94 x 0.5 = 3.47 m	7.0 + 3.47 = 10.47 m	4000 estimated	41,880	41,880 + 14,683 = 56,563	Static pressure = 9 m x 9810 = 88,290 Press. Available = 88,290 – 56,563 = **31,727 Pa**	15

The pipe sizes, flow rates and pressures are indicated on the drawing below.



- **PIPE SIZING PROCEDURE**
- 1. Reference the pipe section.
- 2. Calculate flow rates from Table below.
- 3. Estimate flow rates in each section.
- 4. Estimate pipe diameter from pipe sizing tables.
- 5. Measure the pipe run from drawings.
- 6. Calculate length of pipe equal to resistance of fittings.
- The Total equivalent length of a fitting = Equivalent Length x Pressure Loss factor z (Zeta).
- 7. Calculate effective pipe length.

- 8.Determine pressure loss due to friction from Tables.
- 9. Calculate pressure consumed due to friction (Pa) = effective pipe length (m) x pressure loss due to friction (Pa/m)
- 10. Calculate total pressure consumed = Friction loss + Static pressure loss
- 11. Determine pressure at start of section.
- 12. Calculate pressure available at end of section = Pressure at start of section - Total pressure consumed
- If pressure available at end of section is less than the maximum allowable pressure drop then we can accept this pipe size.

- 13. Determine pressure required at end of section, this can be the minimum pressure that is required for terminal equipment.
- 14. If the pressure available at the end of the section is more than or equal to the pressure required at the end of the section then the pipe size is correct.