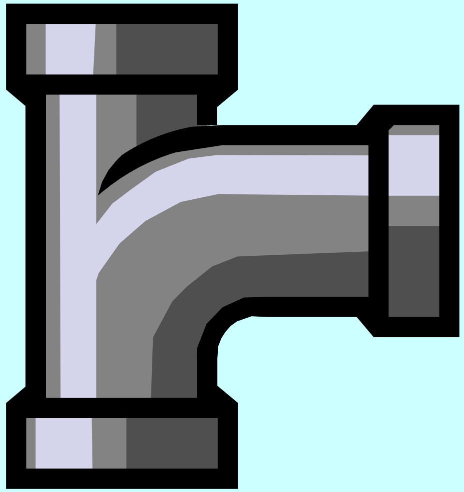
MEBS6000 Utility Services

http://www.hku.hk/mech/msc-courses/MEBS6000/index.html



Design of Cold and Hot Water Systems

Dr. Sam C M Hui

Department of Mechanical Engineering

The University of Hong Kong

E-mail: cmhui@hku.hk

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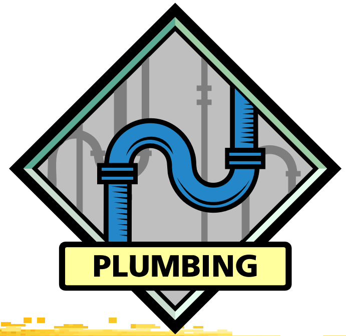
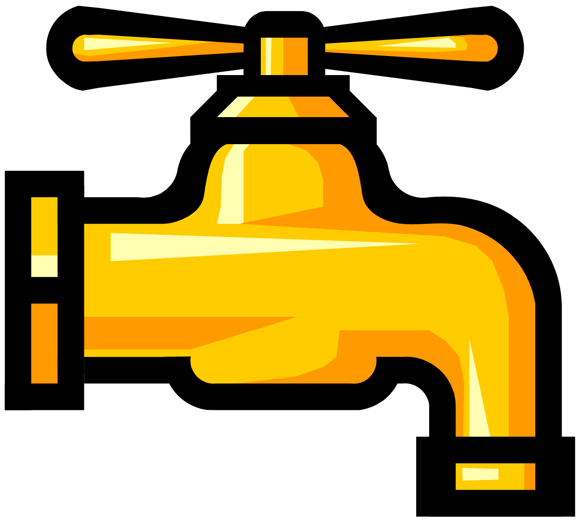
Design principles



- Common water supply systems
  - Cold water system
    - Potable/fresh water
    - Flushing (salt water in HK)
    - Cleansing water
    - Fire service
    - Swimming pool filtration
    - Irrigation (e.g. for landscape)
    - Fountain circulation
    - Air-conditioning water, etc.
  - Hot water system (e.g. in hotels & hospitals)

We will focus on these



Design principles

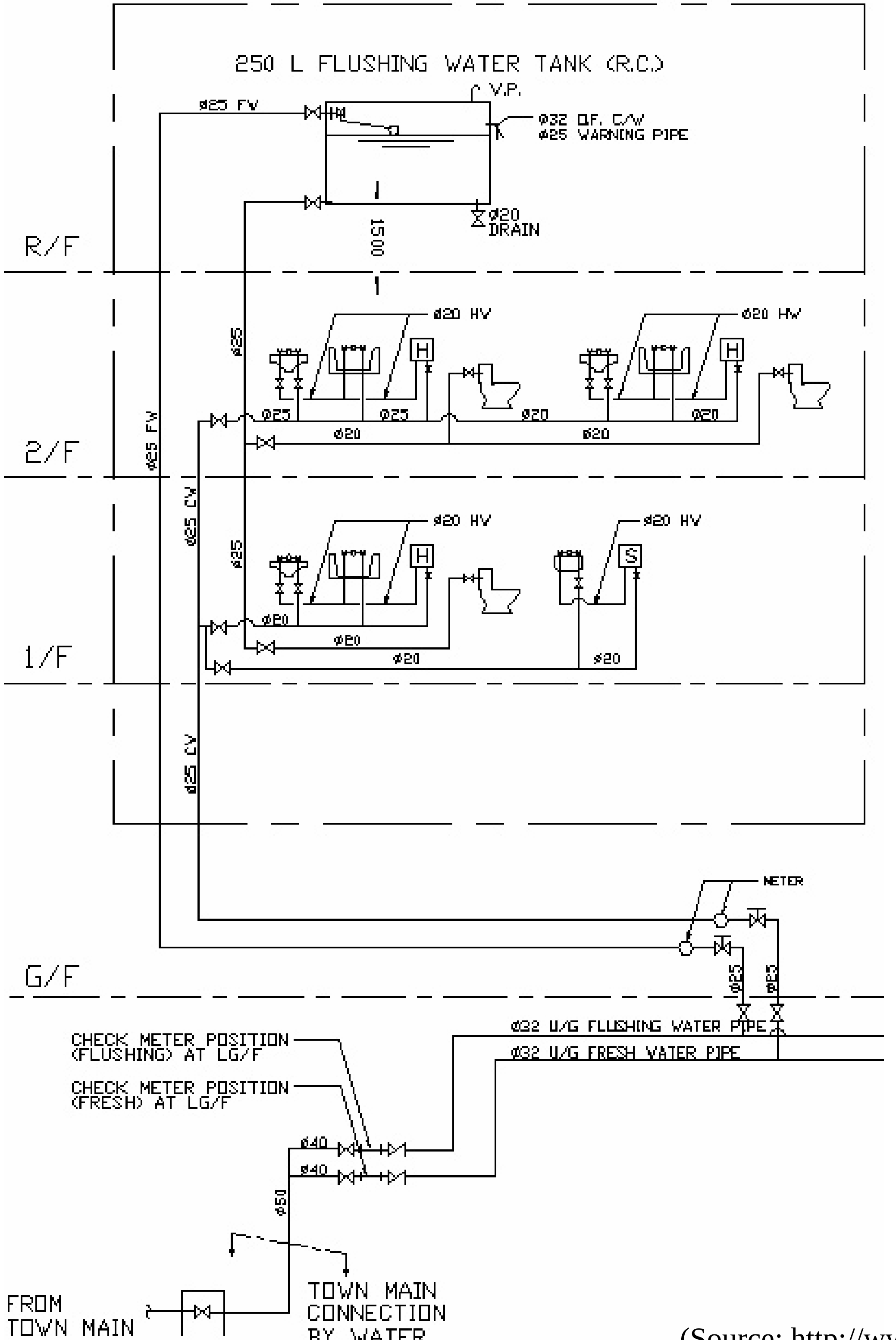
- Major tasks of water systems design:
  - 1. Assessment & estimation of demands
  - 2. Supply scheme & schematic
  - 3. Water storage requirements
  - 4. Piping layout
  - 5. Pipe sizing
  - 6. Pump system design
- The systems must comply with Water Authority (WSD) requirements

Design principles

- General principles for installing plumbing works (from *WSD Plumbing Installation Handbook*)
  - All water fittings and pipework shall comply with the relevant Waterworks Regulations
  - All plumbing works shall be carried out in accordance with the Hong Kong Waterworks Requirements
  - All plumbing works shall be carried out by a licensed plumber
  - System main pipes should preferably not be run through the individual premises
- Also, Building (Standards of Sanitary Fitments, Plumbing, Drainage Works and Latrine) Regulations

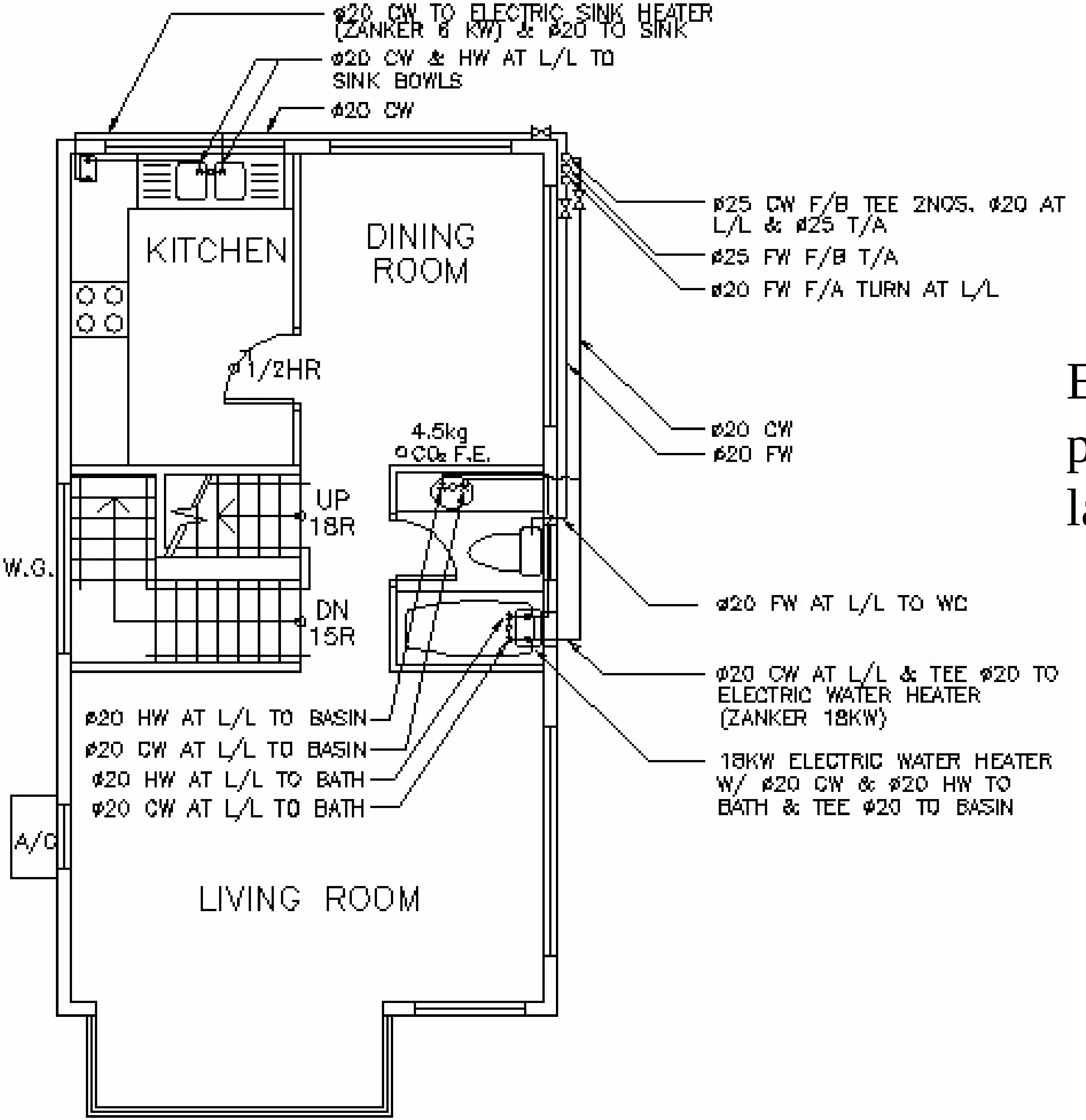
Design principles

- Plumbing proposal (vetted by WSD)
  - A block plan in a scale of 1:1000 showing the location and boundary of the development
  - The locations should be marked with datum level
  - A plan showing the alignment and size of the proposed connection pipes from the main to the development
  - A plan showing the proposed alignment and size of the internal underground water pipes to be laid in the development
  - Vertical plumbing line diagrams



Example of a plumbing system schematic (fresh & flushing water supplies)

(Source: http://www.arch.hku.hk/teaching/project/f-pl.htm)



Example of plumbing layout design

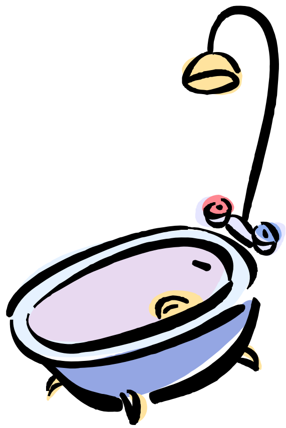
(Source: http://www.arch.hku.hk/teaching/project/f-pl.htm)

Design principles

- Plumbing proposal (cont'd)
  - A schedule containing the following items :-
    - (a) number of flats/units in each block of the building
    - (b) address of each premise needs individually metered water supply
    - (c) number of draw-off points and sanitary fittings in each unit
    - (d) estimated daily consumption for all trade purposes
  - Meters arranged in meter rooms & fittings at the meter positions
  - The relevant standards for the pipe materials to be used
  - Capacities of the water storage tanks e.g. roof storage tanks

Water demand

- Water demand depends on:
  - Type of building & its function
  - Number of occupants, permanent or transitional
  - Requirement for fire protection systems
  - Landscape & water features
- Typical appliances using the cold water
  - WC cistern, wash basin, bath, shower, sink
  - Washing machine, dishwasher
  - Urinal flushing cistern



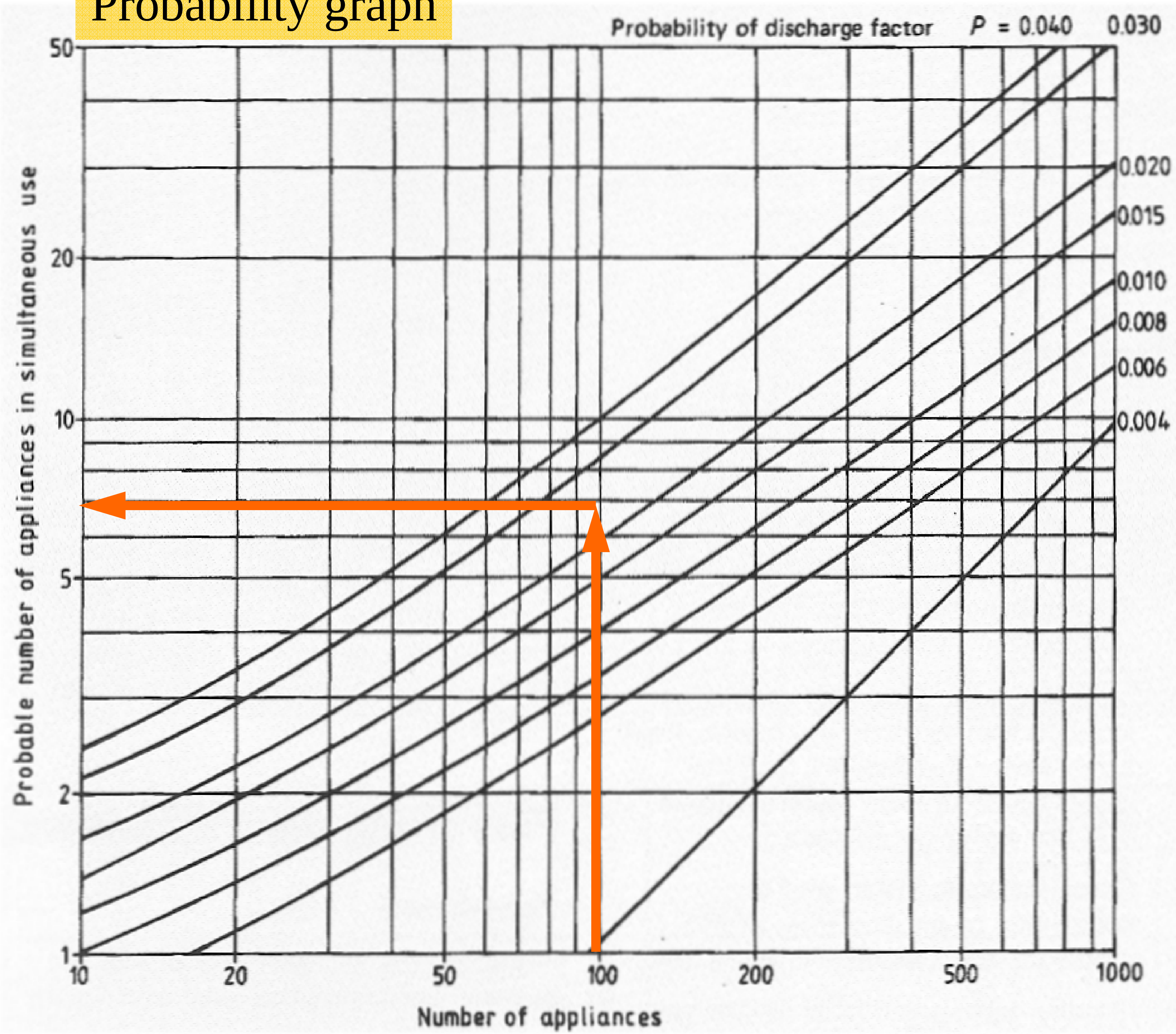
Water demand

- Theoretical framework: Probability Theory
  - Based on statistics & a binomial distribution

$$P_m = \left(\frac{n!}{m!(n-m)!} \right) \times P^m (1-P)^{n-m}$$

    - P_m = probability of occurrence; n is the total number of fittings having the same probability and m is number of fitting in use at any one time
  - Probability factor of a particular no. of draw off’s occurring at any one time is:
    - P = (t – time of appliance filling) / (T – time between successive usage of the appliance)

Probability graph



Example:
If 100 appliances each take 30 sec to be filled, and are used at 1200 sec (20 min) frequency interval, then:

P = t / T
= 30/1200
= 0.025

Using the graph, out of 100 appliances, only 7 would be in use at any one time.

(Source: IOP, 2002. *Plumbing Engineering Services Design Guide*)

Water demand

- Simultaneous demand
  - Most fittings are used only at irregular intervals
  - It is unlikely that all the appliances will be used simultaneously
  - No need to size pipework on continuous max.
  - Key factors to consider:
    - Capacity of appliance (litres)
    - Draw-off flow rate (l/s)
    - Draw-off period, or time taken to fill appliance (sec)
    - Use frequency, time between each use (sec)

Water demand

- Loading Unit (L.U.)
  - A factor given to an appliance relating the flow rate at its terminal fitting to
    - Length of time in use
    - Frequency of use for a particular type
    - Use of building
  - Evaluate the 'probable maximum'
  - Relates the flow rate to the probable usage
- Also, consider design & minimum flow rates

Design flow rates and loading units

Outlet fitting	Design flow rate (l/s)	Minimum flow rate (l/s)	Loading units
WC flushing cistern single or dual flush (to fill in 2 min.)	0.13	0.05	2
WC trough cistern	0.15 per WC	0.10	2
Wash basin tap size ½-DN 15	0.15 per tap	0.10	1.5-3.0
Spray tap or spray mixer	0.05 per tap	0.30	---
Bidet	0.2 per tap	0.10	1
Bath tap, ¾-DN 20	0.30	0.20	10
Bath tap, 1-DN 25	0.60	0.40	22
Shower head (will vary with type of head)	0.2 hot or cold	0.10	3
Sink tap, ½-DN 15	0.20	0.10	3
Sink tap, ¾-DN 20	0.30	0.20	5
Washing machine size – DN 15	0.2 hot or cold	0.15	---
Dishwasher size – DN 15	0.15	0.10	3
Urinal flushing cistern	0.004 per position	0.002	---

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

Water demand

- Apply probability theory, with caution
  - Assume random usage with fittings (is this true?)
  - Determine max. frequencies of use
  - Estimate average water usage rates & time
- The theory is valid with large nos. of fittings
  - Often expect to be exceeded at 1% time only
  - Reliability and risk management (what is the consequence)
- Need to understand the context/circumstance
  - Is it similar to average/typical? (* adjust data if needed)
  - Any foreseeable special requirements?

Water demand

- Design flow considerations
  - A small increase in demand over design level will cause a slight reduction in pressure/flow (unlikely to be noticed by users)
- Exceptional cases, such as:
  - Cleaners’ sinks (depends on one’s behaviour)
  - Urinal flushing cisterns (constant small flow)
  - Team changing rooms at sport clubs (high demand)
  - Special events (ad hoc demand)

Water storage

- Purposes of water storage
  - Provide for an interruption of supply
  - Accommodate peak demand
  - Provide a pressure (head) for gravity supplies
- Design factors
  - Type and number of fittings
  - Frequency and pattern of use
  - Likelihood and frequency of breakdown of supply (often design for 12- or 24-hour reserve capacity)

Recommended minimum storage of cold and hot water systems

Type of building	Minimum cold water storage (litres)	Minimum hot water storage (litres)
Hostel	90 per bed space	32 per bed space
Hotel	200 per bed space	45 per bed space
Office premises:		
- with canteen facilities	45 per employee	4.5 per employee
- without canteen facilities	40 per employee	4.0 per employee
Restaurant	7 per meal	3.5 per meal
Day school:		
- nursery or primary	15 per pupil	4.5 per pupil
- secondary or technical	20 per pupil	5.0 per pupil
Boarding school	90 per pupil	23 per pupil
Children's home or residential nursery	135 per bed space	25 per bed space
Nurses' home	120 per bed space	45 per bed space
Nursing or convalescent home	135 per bed space	45 per bed space

Note: Minimum cold water storage shown includes that used to supply hot water outlets.

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

Estimation of cold water storage per occupant

Type of building	Storage per occupant (litres)
Factories (no process)	10
Hospitals, per bed	135
Hospitals, per staff on duty	45
Hostels	90
Hotels	135
Houses and flats	135
Offices with canteens	45
Offices without canteens	35
Restaurant (* per meal)	7
Schools, boarding	90
Schools, day	30

(Source: www.engineeringtoolbox.com)

Estimation of hot water consumption

Type of building	Consumption per occupant (litres/day)	Peak demand per occupant (litres/hr)	Storage per occupant (litres)
Factories (no process)	22 – 45	9	5
Hospitals, general	160	30	27
Hospitals, mental	110	22	27
Hostels	90	45	30
Hotels	90 – 160	45	30
Houses and flats	90 – 160	45	30
Offices	22	9	5
Schools, boarding	115	20	25
Schools, day	15	9	5

(Source: www.engineeringtoolbox.com)

Fixtures water requirements (demand at individual water outlets)

Type of fixture	Flow rate (litres/min)	Minimum supply pressure (kPa)
Bathtub faucet	19	55
Bidet	7.5	28
Laundry machine	15	55
Lavatory faucet, ordinary	7.5	55
Lavatory faucet, self closing	10	55
Shower head	19	55
Shower, temperature controlled	10	138
Sink 3/8", 1/2"	17	55
Sink 3/4"	23	55
Urinal flush valve	56	110
Water closet with flush valve	132	170
Water closet with gravity tank	10	55

(Source: www.engineeringtoolbox.com)

Fixtures, cold water storage, hot water consumption & flow rate

Type of fixture	Cold water storage capacity (litres)	Hot water consumption (litre/hr)	Hot water flow rate (litre/s)
Basin (private)	90	14	0.08
Basin (public)	90	45	0.08
Bath	900	90 – 180	0.15
Garden water tap	180	---	---
Shower	450 – 900	180	0.5 – 0.6
Sink	90	45 – 90	0.15
Urinal	180	---	---
WC	180	---	---

(Source: www.engineeringtoolbox.com)

Quantity of flushing water required

User	Average demand
Domestic buildings	450 litres per number of required soil fitment per day
Offices, factories, department stores, shops, public buildings and other nondomestic buildings of a like nature	450 litres per number of required soil fitment per day
Restaurants	13.5 litres per seat per day
Cinemas	4.5 litres per seat per day
Schools	18 litres per head per day
Hotels and boarding houses	90 litres per room per day

(Source: Buildings Department HK, PNAP 17)

Water storage

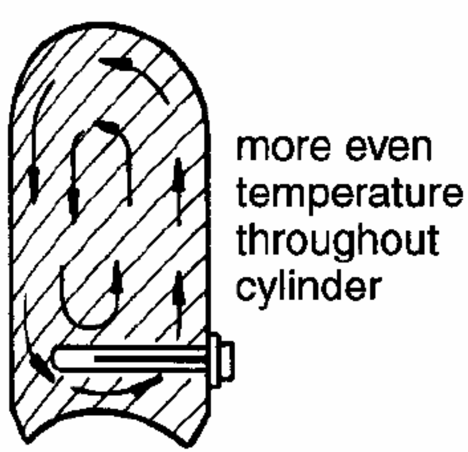
- Minimum hot water storage capacities for dwelling (from BS6700)
  - 35-45 litre per occupant (unless the heat source provides a quick recovery rate)
  - 100 litres for systems heated by solid fuel boilers
  - 100 litres for systems heated by off-peak electricity

Water storage

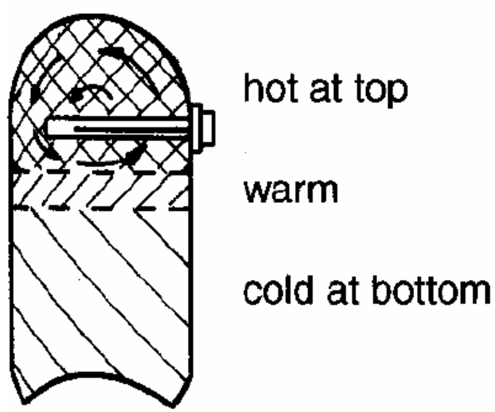
- Recovery rate and hot water storage
  - Recovery period = time to heat up the stored water
  - Too high a storage volume: unnecessary costs
  - Inadequate storage: loads not met
  - Need to consider the following factors:
    - Pattern of use
    - Rate of heat input to the stored water
    - Recovery period for the hot water storage vessel
    - Any stratification of the stored water

Typical heat input values

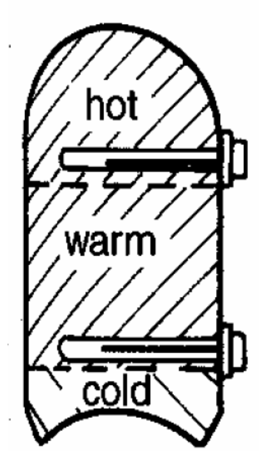
Appliance	**Heat input (kW)**
Electric immersion heater	3
Gas-fired circulator	3
Small boiler and direct cylinder	6
Medium boiler and indirect cylinder	10
Directly gas-fired storage hot water heater (domestic type)	10
Large domestic boiler and indirect cylinder	15



(a) Bottom entry heater



(b) Top entry heater



(c) Twin entry heater

Effects of stratification

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

Water storage

- Formula to calculate recovery period
  - $M = V\,T\,/\,(14.3\,P)$
    - M = time to heat the water (min.)
    - V = volume of water heated (litres)
    - T = temperature rise (^{o}C)
    - P = rate of heat input to the water (kW)
  - It can be applied to any pattern of use
  - It ignores heat losses from storage vessel

Example: A small dwelling with one bath. Maximum requirement: 1 bath (60 litre at 60ºC + 40 litre cold water) plus 10 litre hot water at 60ºC for kitchen use, followed by a second bath fill after 25 min. Thus, a draw-off of 70 litre at 60ºC is required, followed after 25 min by 100 litre at 40ºC, which may be achieved by mixing hot at 60ºC with cold at 10ºC.

Answer:

1) Assume good stratification (by heating w/ a top entry heater)

With 3kW heat input, the time to heat the 60 litre for the second bath from 10ºC to 60ºC:

$M = V\,T/(14.3\,P) = (60 \times 50)/(14.3 \times 3) = 70$ min.

The second bath is required after 25 min., thus it has to be form storage. But in the 25 min. the volume of water heated to 60ºC is:

$V = M\,(14.3)/\,T = (25 \times 14.3 \times 3)/50 = 21$ litre

Therefore, the minimum required storage capacity is:

70 + 60 – 21 = **109 litre**

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

Example: (Cont'd)

2) Assume good mixing of the stored water (by a primary coil in an indirect cylinder)

After the first bath & kitchen use, the heat energy in the 70 litre replacement at 10ºC equals the heat energy of the water in the full cylinder. If V is the min. size of the storage and T is the water temperature in the cylinder after refilling:

$(V – 70) \text{ x } 60 + (70 \text{ x } 10) = V\, T$

$T = (60\, V – 4200 + 700)/V$ *or* $T = 60 – 3500/V$

The second bath is required after 25 min. With 3 kW heat input:

$25 = V\, T\, /\, (14.3 \text{ x } 3)$

and temperature rise $T = (25 \text{ x } 14.3 \text{ x } 3)/\, V = 1072.5/V$

A temperature of at least 40ºC is required to run the second bath. Therefore the water temperature of the refilled cylinder after the first draw-off, plus the temperature rise after 25 min., must be at 40ºC, or:

$(60 – 3500/V) + (1072.5\, V) = 40$ (or more)

$60 – 2427.5/V = 40$

$V =$ **122 litre**

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

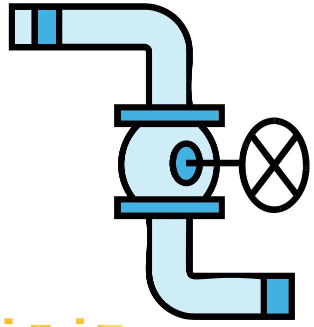
Hot water storage vessel – minimum capacities

Heat input for water (kW)	Dwelling with 1 bath		Dwelling with 2 baths*	
	With stratification litres	With mixing litres	With stratification litres	With mixing litres
3	109	122	165	260
6	88	88	140	200
10	70	70	130	130
15	70	70	120	130

Note: * Maximum requirement of 150 litre drawn off at 60ºC (2 baths plus 10 litre for kitchen use) followed by a further bath (100 litre at 40ºC) after 30 min.

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

Pipe sizing

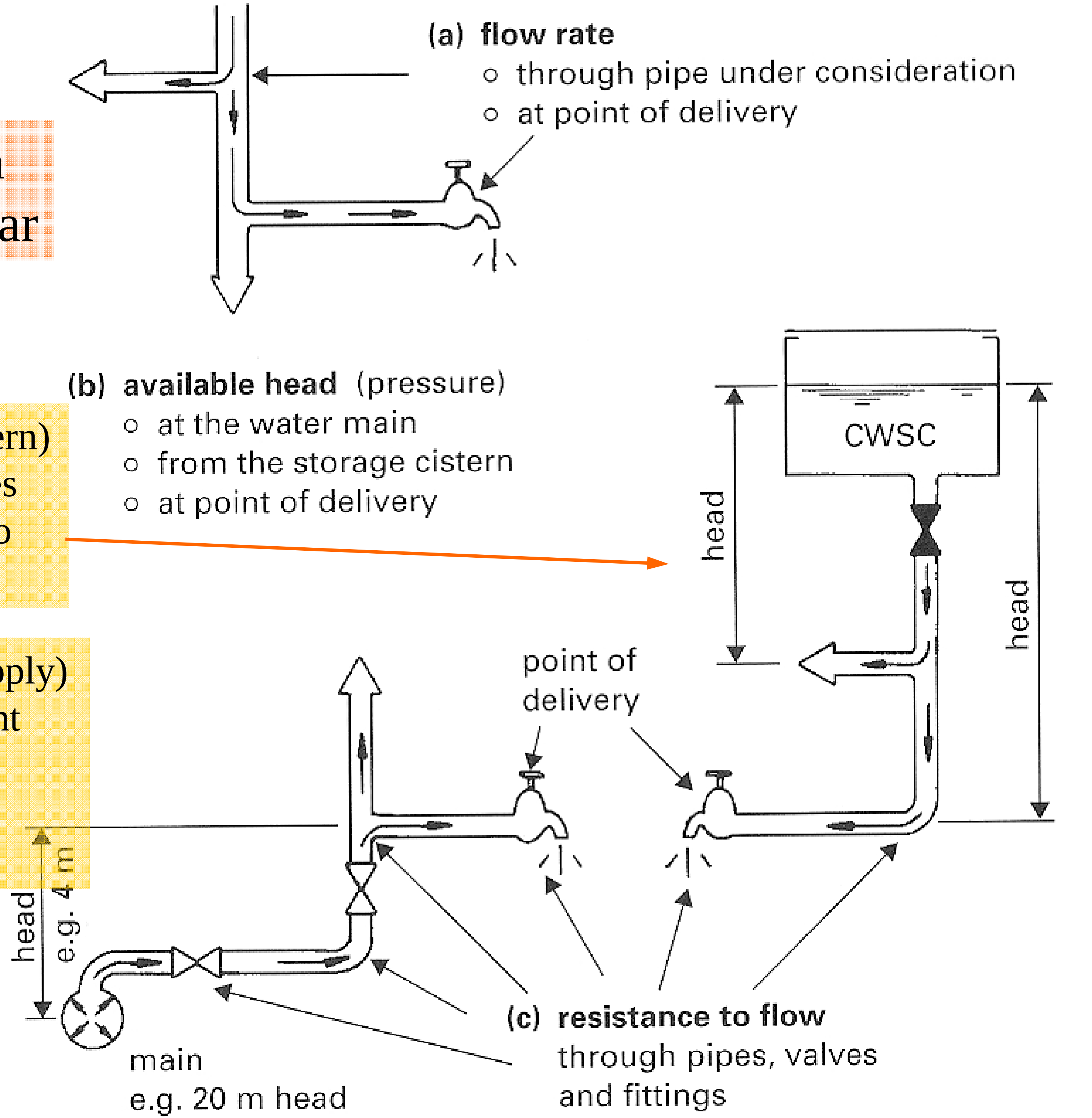


- Correct pipe sizes will ensure adequate flow rates at appliances and avoid problems, e.g.
  - Oversizing
    - Additional & unnecessary installation costs
    - Delays in obtaining hot water at outlets
    - Increased heat losses from hot water pipes
  - Undersizing
    - Inadequate delivery from outlets
    - Some variation in temperature & pressure at outlets (e.g. showers and other mixers)
    - Some increase in noise levels
- For small, simple installations, pipes are often sized based on experience & convention

1 m head = 9.81 kPa
= 98.1 mbar

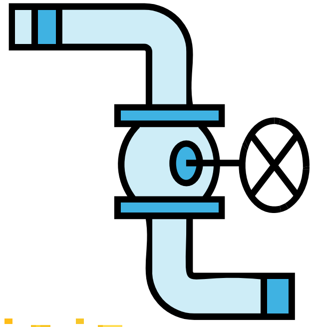
Available head (from cistern)
= vertical distance in metres from water line in cistern to point under consideration

Available head (mains supply)
= head at main minus height above main
= 20 m – 4 m
= 16 m head



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

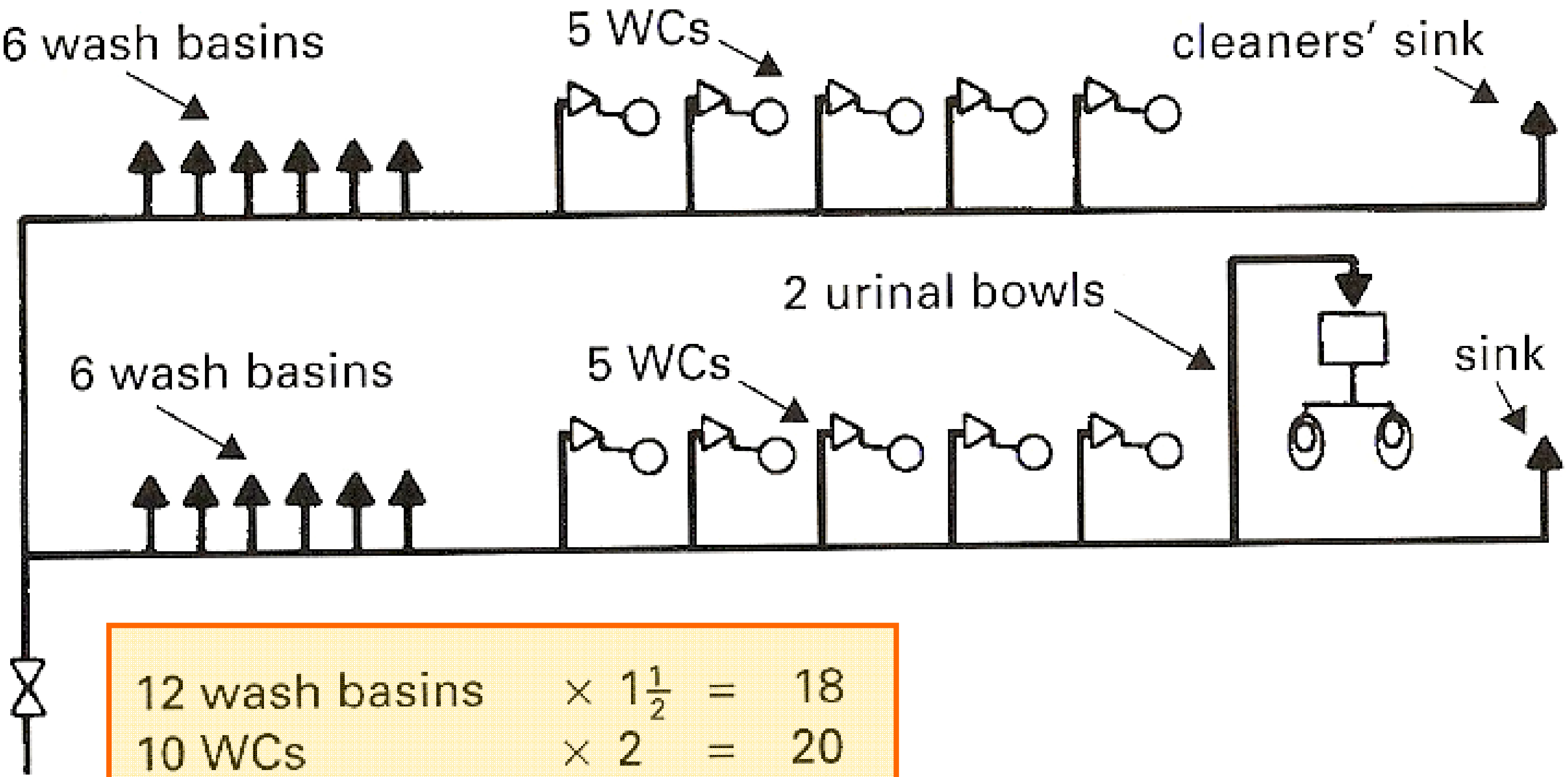
Pipe sizing



- Pipe sizing procedure
  - (a) Assume a pipe diameter
  - (b) Determine the flow rate:
    - 1) by using loading units
    - 2) for continuous flow
    - 3) obtain the design flow rate by adding 1) and 2)
  - (c) Determine the effective pipe length:
    - 4) work out the measured pipe length
    - 5) work out the equivalent pipe length for fittings
    - 6) work out the equivalent pipe length for draw-offs
    - 7) obtain the effective pipe length by adding 4), 5) & 6)

Pipe sizing

- Pipe sizing procedure (cont'd)
  - (d) Calculate the permissible loss of head:
    - 8) determine the available head
    - 9) determine the head loss per metre run through pipes
    - 10) determine the head loss through fittings
    - 11) calculate the permissible head loss
  - (e) Determine the pipe diameter:
    - 12) decide whether the assumed pipe size will give the design flow rate in 3) without exceeding the permissible head loss in 11)
  - Usually, flow velocities shall be < 3 m/s

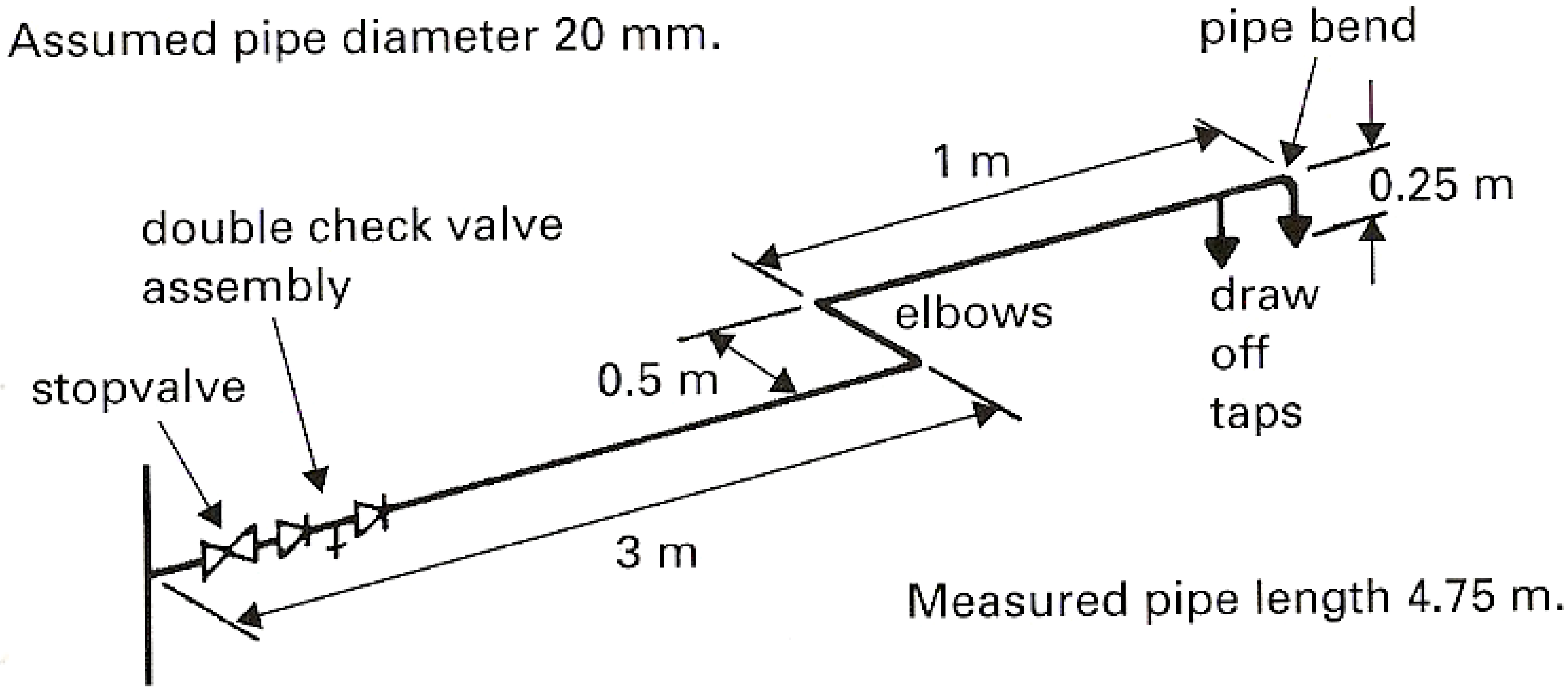


12 wash basins	× $1\frac{1}{2}$	=	18
10 WCs	× 2	=	20
2 urinal bowls	× —	=	—
2 cleaners' sinks	× 3	=	6
Total loading units			44

Required design flow (from graph) = 0.7 l/s

Example of use of loading units

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



Note There is no need to consider both branch pipes to taps.

Measured pipe length		=	4.75 m
Equivalent pipe lengths:			
elbows	2 x 0.8	=	1.6 m
tee	1 x 1.0	=	1.0 m
stopvalve	1 x 7.0	=	7.0 m
taps	2 x 3.7	=	7.4 m
check valves	2 x 4.3	=	8.6 m
Effective pipe length		=	**30.35 m**

Example of measured & effective pipe lengths

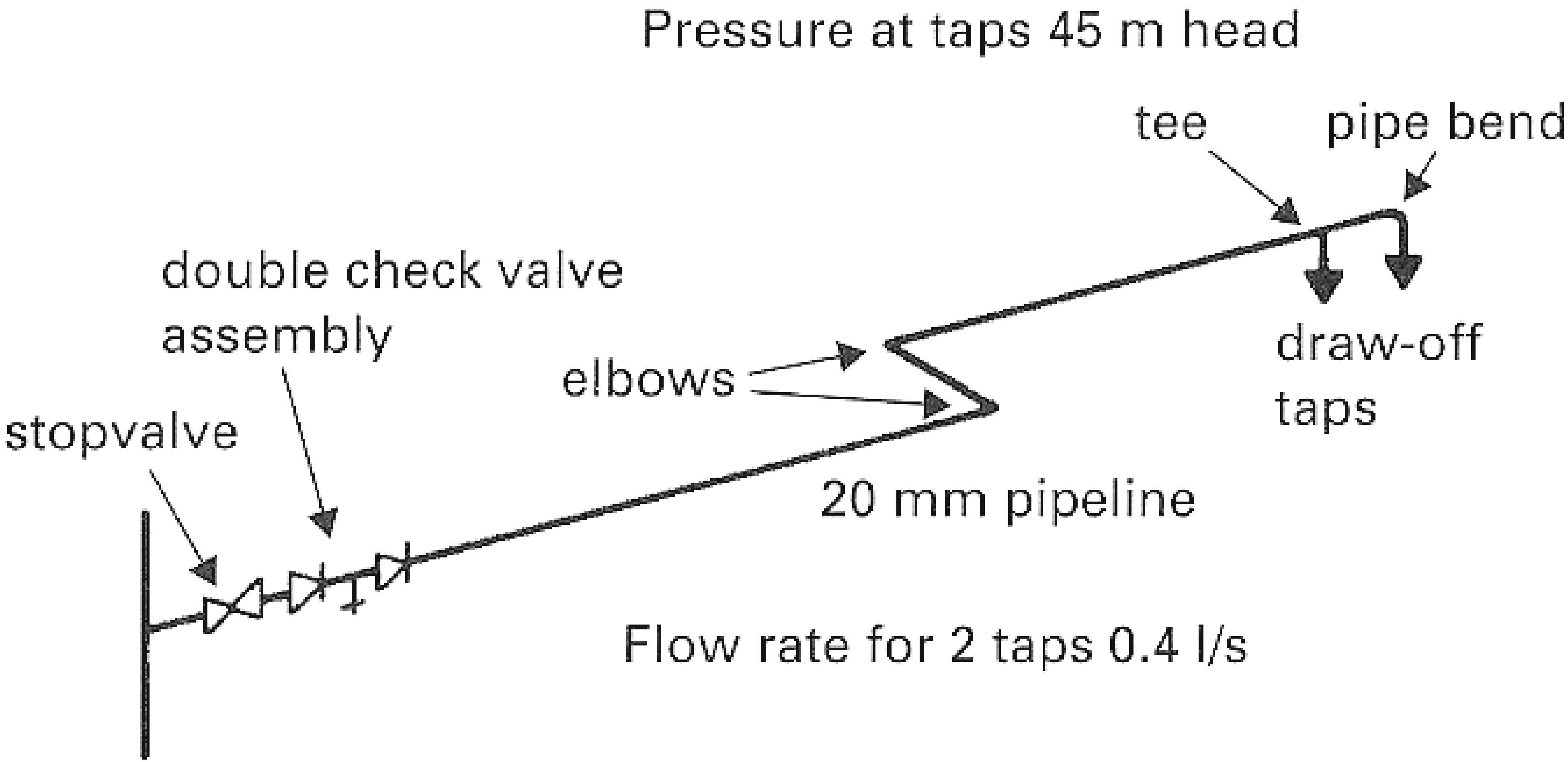
(Source: Garrett, R. H., 2008. *Hot and Cold Water Supply*)

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	---

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*)



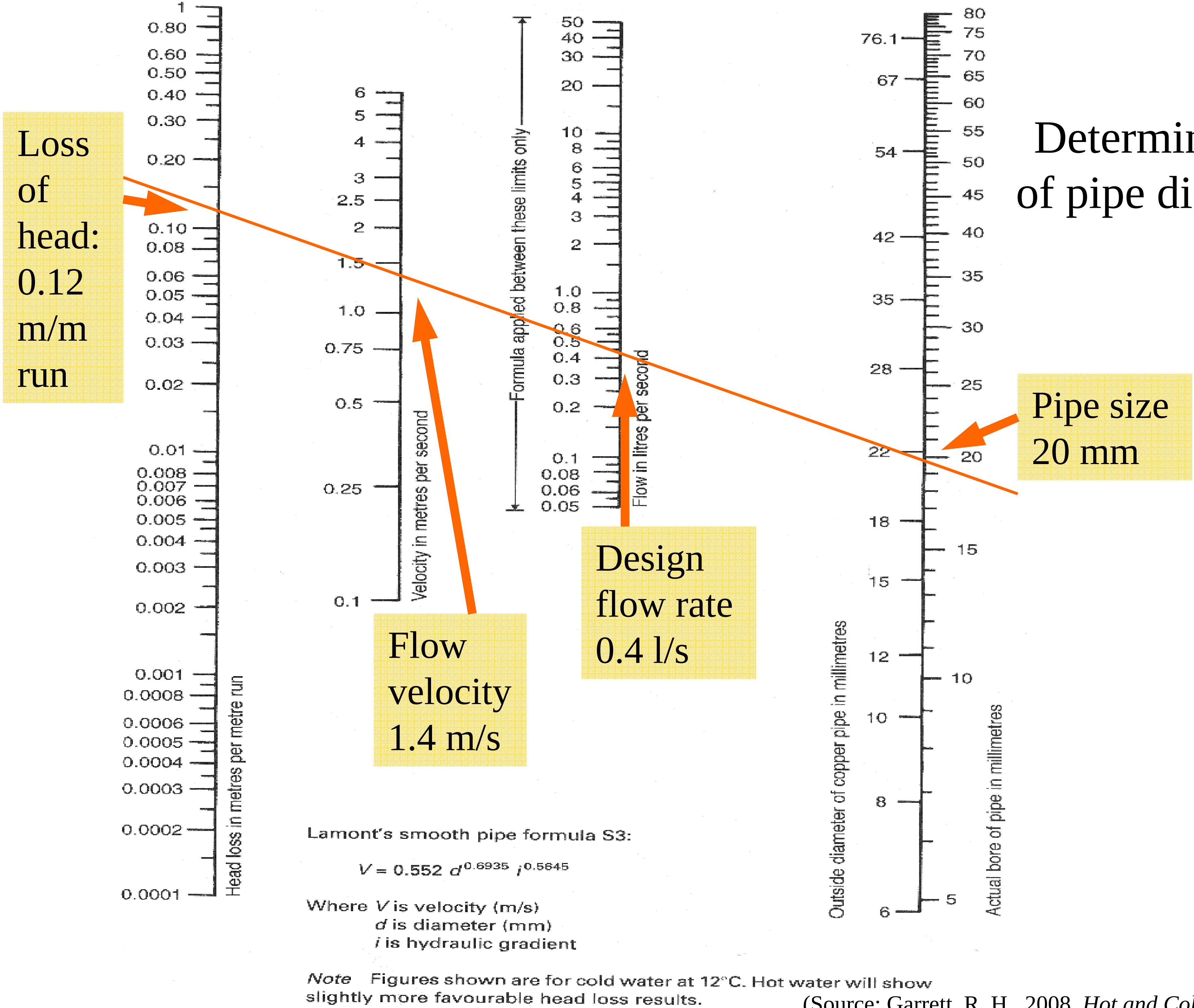
$$\text{Permissible head loss} = \frac{\text{available head (45 m)}}{\text{effective pipe length (30.55 m)}}$$

$$= 1.48 \text{ m/m run}$$

Example of permissible head loss

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

Determination of pipe diameter



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

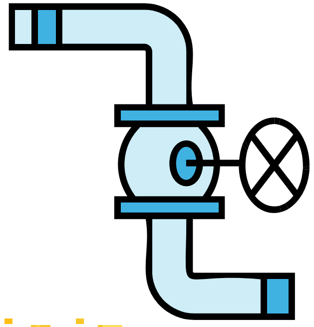
Maximum recommended flow velocities

Water temperature (^oC)	Flow velocity (m/s)	
	Pipes readily accessible	Pipes not readily accessible
10	3.0	2.0
50	3.0	1.5
70	2.5	1.3
90	2.0	1.0

Note: Flow velocities should be limited to reduce system noise.

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

Pipe sizing

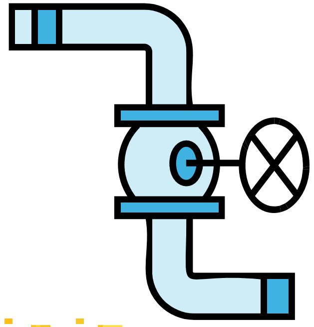


- Pipe sizing & design using tabular methods
  - Systematic way to design
  - Can also be done using spreadsheet or computer

Table D.4 **Example of pipe sizing calculations for cold water services**

Pipe reference	Flow rate		Pipe size	Velocity v	Head loss R	Drop + Rise −	Available head (7 + 14)	Pipe length		Head loss			Residual			
	Total	Design						Actual	Effective	Pipe (10 × 6)	Valves[A)]	Total (11 + 12)	Available (8 − 13)	Fitting type	Required	Surplus
m	LU	l/s	DN	m/s	kPa/m	kPa	kPa	m	m	kPa	kPa	kPa	kPa		kPa	kPa
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Main service pipe – for this example the minimum head in main = 300 kPa (3 bar)																
1 to 2	9 + list	0.6 + 0.3 0.9	28	1.7	1.4	−50	250	25	35	49	2 SV = 21	70	180			
2 to 3	6 + list	0.4 + 0.2 0.6	22	2.0	2.5	−30	150	3	4.2	11		11	139			
3 to 4	3 + list	0.2 + 0.1 0.3	15	2.2	5	−30	109	3	4.2	21		21	88			
4 to 5	3 + list	0.3	15	2.2	5	+10	98	1	1.4	7	SV = 18	25	73			
5 to 6		0.2	15	1.5	2.3	+10	83	6	8.4	20		20	63	sink float valve (5 mm ϕ)	5	58
5 to 7		0.1	15	0.75	0.6	−5	68	1	1.4	1		1	67		30	37

Pipe sizing



- Pipe sizing for hot water systems
  - The same as cold water, except cold feed pipe must also be considered

- Useful formulae for pipes:
  - Thomas Box formula

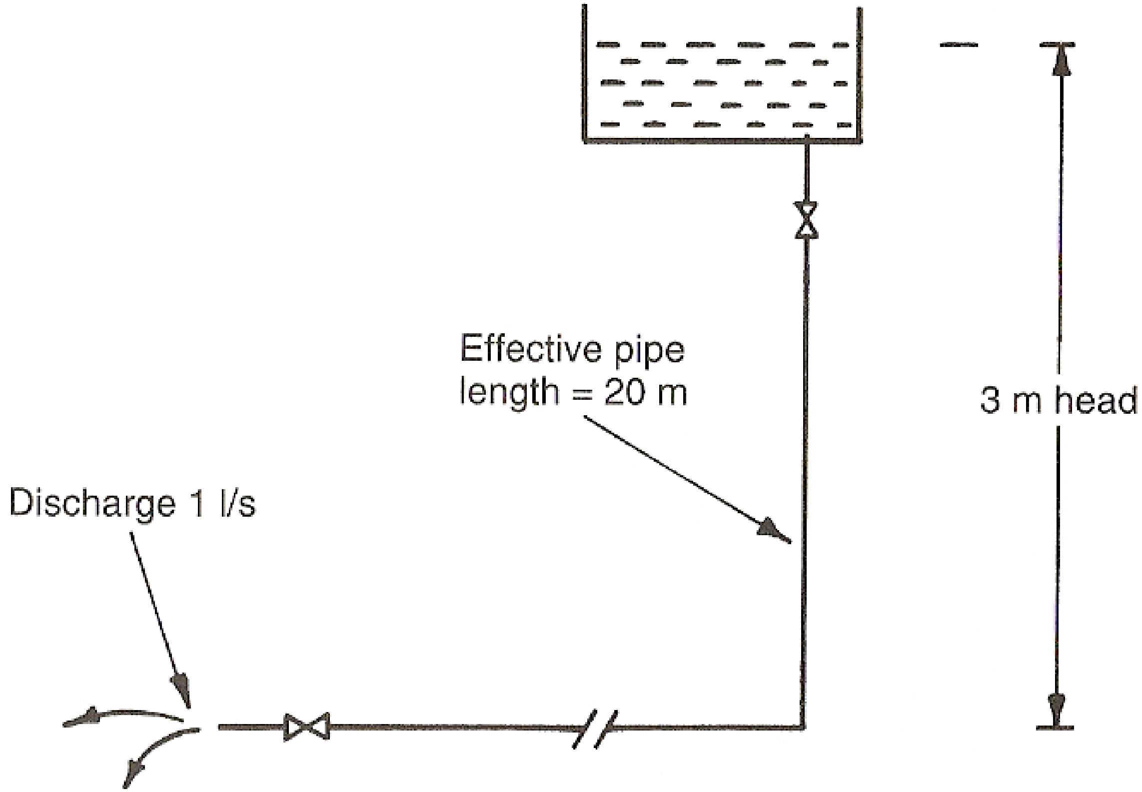
$$q = \sqrt{\frac{d^5 \times H}{25 \times L \times 10^5}}$$

    - See example
  - Relative discharging power

$$N = \sqrt{\left(\frac{D}{d}\right)^5}$$

    - See example

Example: Determine the pipe size using Thomas Box formula.



$$q = \sqrt{\frac{d^5 \times H}{25 \times L \times 10^5}}$$

where d = pipe diameter (mm)
q = flow rate (l/s)
H = head or pressure (m)
L = effective length of pipe (actual length + allowance for bends, tees, etc.)

Answer: Using Thomas Box formula,

$$d = \sqrt[5]{\frac{(1)^2 \times 25 \times 20 \times 10^5}{3}} \quad = \mathbf{27.83\ mm}$$

Hence, the nearest commercial size is 32 mm bore steel or 35 mm outside diameter copper.

(Source: Hall, F. and Greeno, R., 2008. *Building Services Handbook*)

Example: Relative discharge of pipes

$$N = \sqrt{\left(\frac{D}{d}\right)^5}$$

where N = number of short branch pipes
D = diameter of main pipe (mm)
d = diameter of short branch pipes (mm)

(a) The number of 32 mm short branch that can be served from 150 mm main.

Answer: $$N = \sqrt{\left(\frac{150}{32}\right)^5} = 47$$

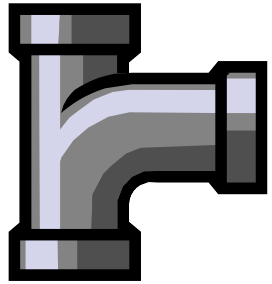
(b) The size of water main required to supply 15 nos. 20 mm short branch pipes.

Answer: $$D = d \times \sqrt[5]{N^2} = 20 \times \sqrt[5]{15^2} = 59$$

Hence, the nearest commercial size is 65 mm.

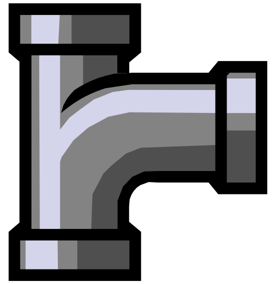
(Source: Hall, F. and Greeno, R., 2008. *Building Services Handbook*)

Pipe materials



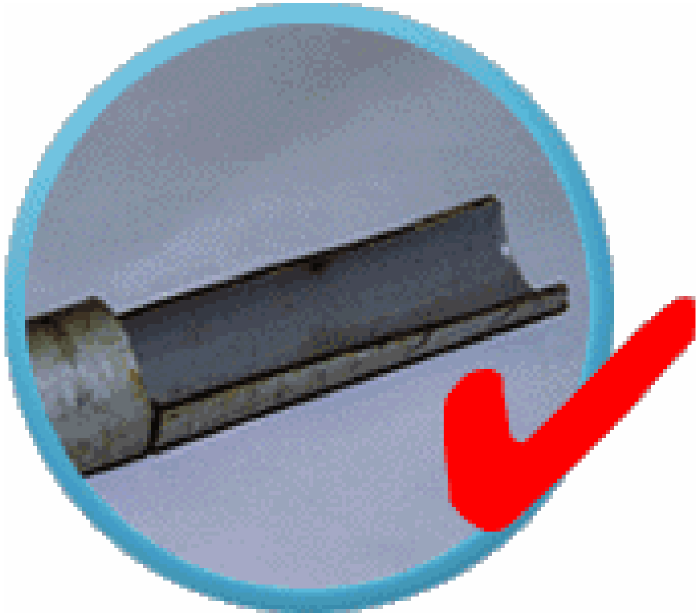
- Design & selection factors:
  - Effect on water quality
  - Cost, service life and maintenance needs
  - For metallic pipes, internal and external corrosion
  - Compatibility of materials
  - Ageing, fatigue and temperature effects, especially in plastics
  - Mechanical properties and durability
  - Vibration, stress or settlement
  - Internal water pressure

Pipe materials

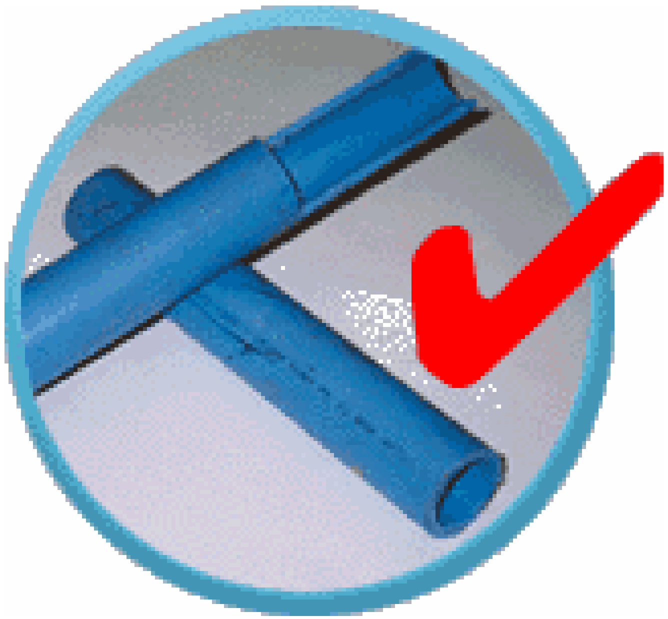


- Commonly used pipe materials, such as:
  - Copper (BS EN 1057)
  - Galvanised iron (GI) with PVC-C lining (BS 1387)
  - PVC, unplasticized PVC, PB, PE, PE-X
  - Stainless steel (BS 4127)
  - Ductile iron (BS EN 545) (for pipe dia. > 80 mm)
  - Mild steel (for pipe dia. > 600 mm)
- * Plastic material generally will degrade on prolonged exposure to ultra-voilet light

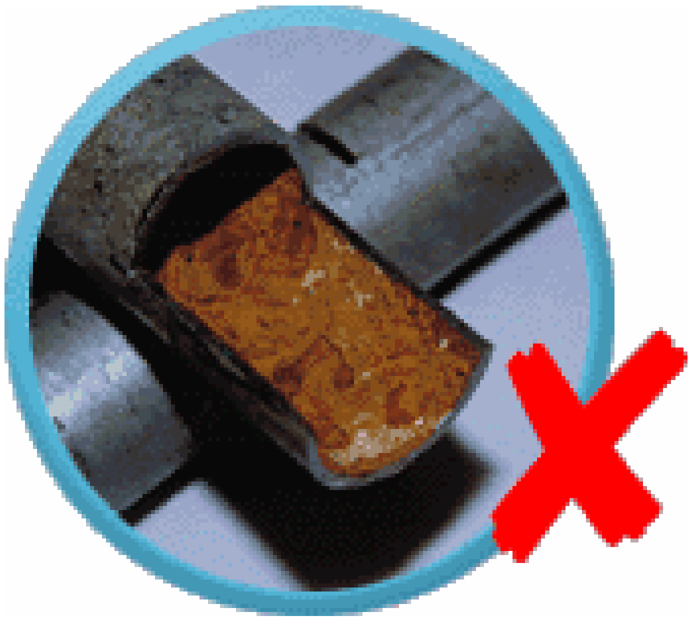
Copper pipe



Lined galvanized steel pipe



Polyethylene pipe



Rusty unlined galvanized steel pipe

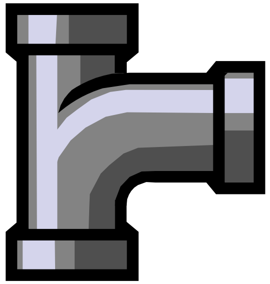
(Source: Water Supplies Department, www.wsd.gov.hk)

Common pipe materials in fresh water plumbing systems

Pipe Material	Cold Water	Hot Water	Standards
Copper	✓	✓	BS EN 1057
Ductile iron	✓	✓	BS EN 545
Galvanised iron (GI) with PVC-C lining	✓	✓	BS 1387
GI with PVC-U/PE lining	✓	X	BS 1387
Polybutylene (PB)*	✓	✓	BS 7291
Polyethylene (PE)*	✓	X	BS 6572 (below ground)
	✓	X	BS 6730 (above ground)
Chlorinated polyvinyl chloride (PVC-C)	✓	✓	BS 7291
Unplasticized polyvinyl chloride (PVC-U)	✓	X	BS 3505 Class D or above
Crosslinked polyethylene (PE-X)	✓	✓	BS 7291
Stainless steel	✓	✓	BS 4127

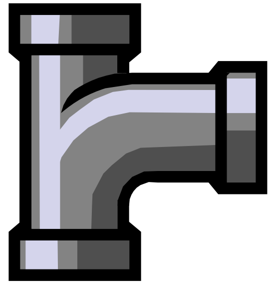
(Source: Water Supplies Department, www.wsd.gov.hk)

Pipe materials



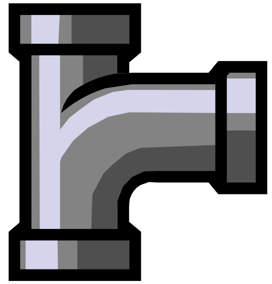
- Classification of pipe materials
  - Metallic
    - Copper
    - Stainless steel
  - Thermoplastics
    - PVC-U, PVC-C
    - Polyethylene (PE)
    - Medium Density Polyethylene (MDPE)
    - High Density Polyethylene (HDPE)
    - Crosslinked Polyethylene (PEX)

Pipe materials



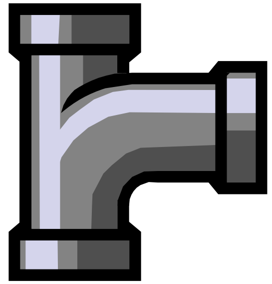
- Classification of pipe materials (cont'd)
  - Thermoplastics (cont'd)
    - Polybutylene (PB)
    - Acrylonitrile Butadiene Styrene (ABS)
  - Composite
    - Lined galvanised steel
    - Crosslinked Polyethylene/Aluminium/Crosslinked Polyethylene Composite Pressure Pipe (PEX-AL-PEX)
    - High Density Polyethylene/Alumnium/ High Density Polyethylene (HDPE-AL-HDPE)

Pipe materials



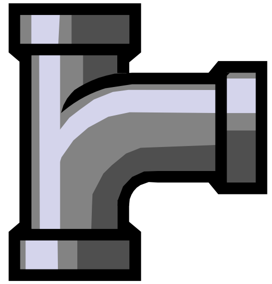
- Copper pipes (BS EN 1057)
  - Advantages:
    - High pressure capability
    - Good formability
    - Good corrosion resistance
    - High strength & durability to withstand external loading
    - Ease of jointing (compression & capillary joints)
    - Smooth surface: low resistance to water flow
    - Suitable for conveying hot water
  - Disadvantages:
    - Soft water can cause internal corrosion attack (give rise to ‘blue’ water)

Pipe materials



- Stainless steel (BS 4127)
  - Advantages:
    - High pressure capability
    - Good corrosion resistance
    - High strength & durability
    - Ease of jointing
    - Good resistance to accidental damage
    - Suitable for conveying hot water
  - Disadvantage:
    - More expensive than copper

Pipe materials

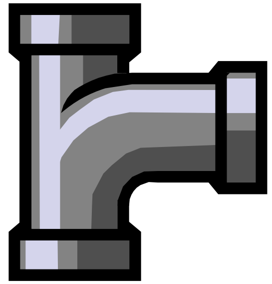


- Lined galvanised steel
  - PVC-U/PVC-C/Polyethylene or epoxy resin lined
  - Advantages:
    - Good resistance to internal corrosion & encrustation
    - Smooth surface: lower resistance to water flow
    - Can be used in vulnerable conditions e.g. exposure to direct sunlight & traffic loads
    - Readily compatible with existing commonly used unlined steel pipe
  - Disadvantages:
    - Heavy weight
    - Susceptible to impact damage (great care in handling)
    - Higher skills required for cutting, threading, jointing

Pipe materials

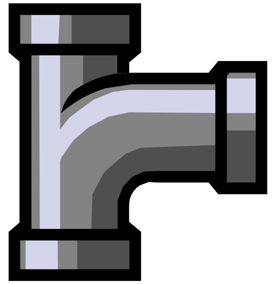
- PVC-U (BS 3505 Class D)
  - Advantages:
    - Good corrosion resistance
    - Light weight, low cost
    - Ease of jointing
    - Smooth surface: low resistance to water flow
    - Not a conductor of electricity (no galvanic/oxidative corrosion)
  - Disadvantages:
    - Brittle, susceptible to impact damage
    - Long drying time of solvent cement in jointing
    - Low abrasion resistance
    - Permeation/degradation by certain organic contaminants
    - UV degradation on prolonged exposure to sunlight
    - Not suitable for hot water supply

Pipe materials



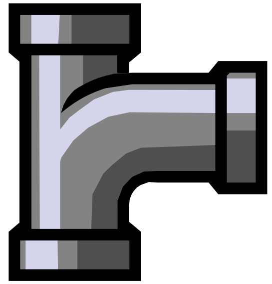
- PVC-C (BS 7291)
  - Advantages:
    - Suitable for conveying hot water
    - Good corrosion resistance & chemical resistance
    - Light weight
    - Smooth surface: low resistance to water flow
    - Not a conductor of electricity (no galvanic/oxidative corrosion)
    - Can be connected to other materials easily
  - Disadvantages:
    - Brittle, susceptible to impact damage
    - Long drying time of solvent cement in jointing
    - Can be flammable
    - Reduction in strength & rigidity with increase of temperature
    - Permeation/degradation by certain organic contaminants
    - Can be attacked by detergents & oxidizing agents
    - UV degradation on prolonged exposure to sunlight

Pipe materials



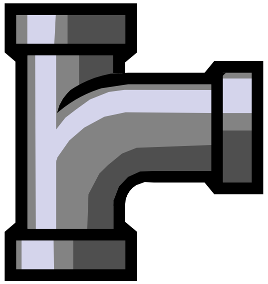
- MDPE (BS 7291)
  - Advantages:
    - Good corrosion resistance
    - Good formability
    - Light weight
    - Fusion & mechanical joint available
    - Smooth surface: low resistance to water flow
    - Strong & tough
    - Flexible & durable, light & easy to handle
    - Good resistance to impact
  - Disadvantages:
    - Fusion jointing requires skilled installers & special equipment
    - Subject to creep
    - Strength decrease with time (at a very slow rate)
    - UV degradation on prolonged exposure to sunlight
    - Permeation/degradation by certain inorganic & organic contaminants

Pipe materials



- Jointing of pipes
  - Copper pipes
    - Capillary solder or brazed joints
    - Autogenous welding
    - Compression, push, press/crimp fittings
  - Steel pipes
    - Screwed joints, with pipe threads
    - Flange joints (screwed or welded flanges)
  - Stainless steel pipes
    - Compression, capillary, push, press/crimp fittings (but not joined by soft soldering)

Pipe materials



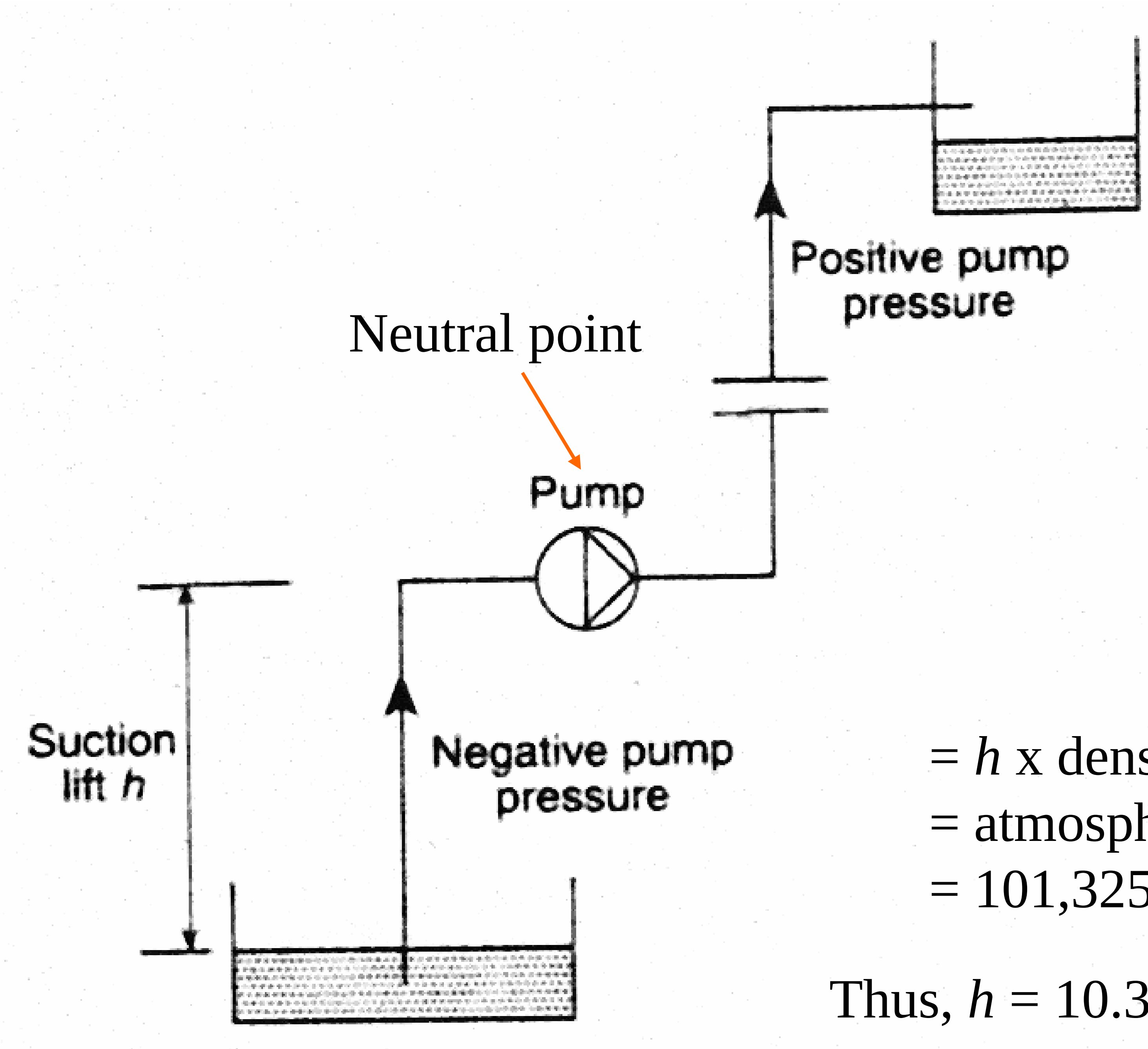
- Jointing of pipes (cont'd)
  - Unplasticized PVC pipes
    - Mechanical joints
    - Compression joints
    - Solvent cement welded joints
    - Flange joints
  - Polyethylene (PE) & polybutylene (PB) pipes
    - Mechanical joints (e.g. push-fit), thermal fusion
  - Acrylonitrile Butadiene Styrene (ABS) pipes
    - Similar to PVC-U pipes

Pump systems

- Centrifugal pumps are commonly used
  - Vertical and horizontal
  - Single & multiple stages
- Two types of systems:
  - Closed systems
    - Recirculation
  - Open systems
    - Open to atmosphere

Main characteristics of centrifugal & positive displacement pumps

Centrifugal pumps	**Positive displacement pumps**
- Capacity varies with head - Capacity proportional to pump speed - Head proportional to the square of pump speed - Non self-priming - Suitable for low-viscosity liquid	- Capacity substantially independent of head - Capacity proportional to speed - Self-priming - Suitable for various liquids (reduced speeds usually necessary for high viscosity



= h x density x 9.81
= atmospheric
= 101,325 Pa

Thus, h = 10.33 m

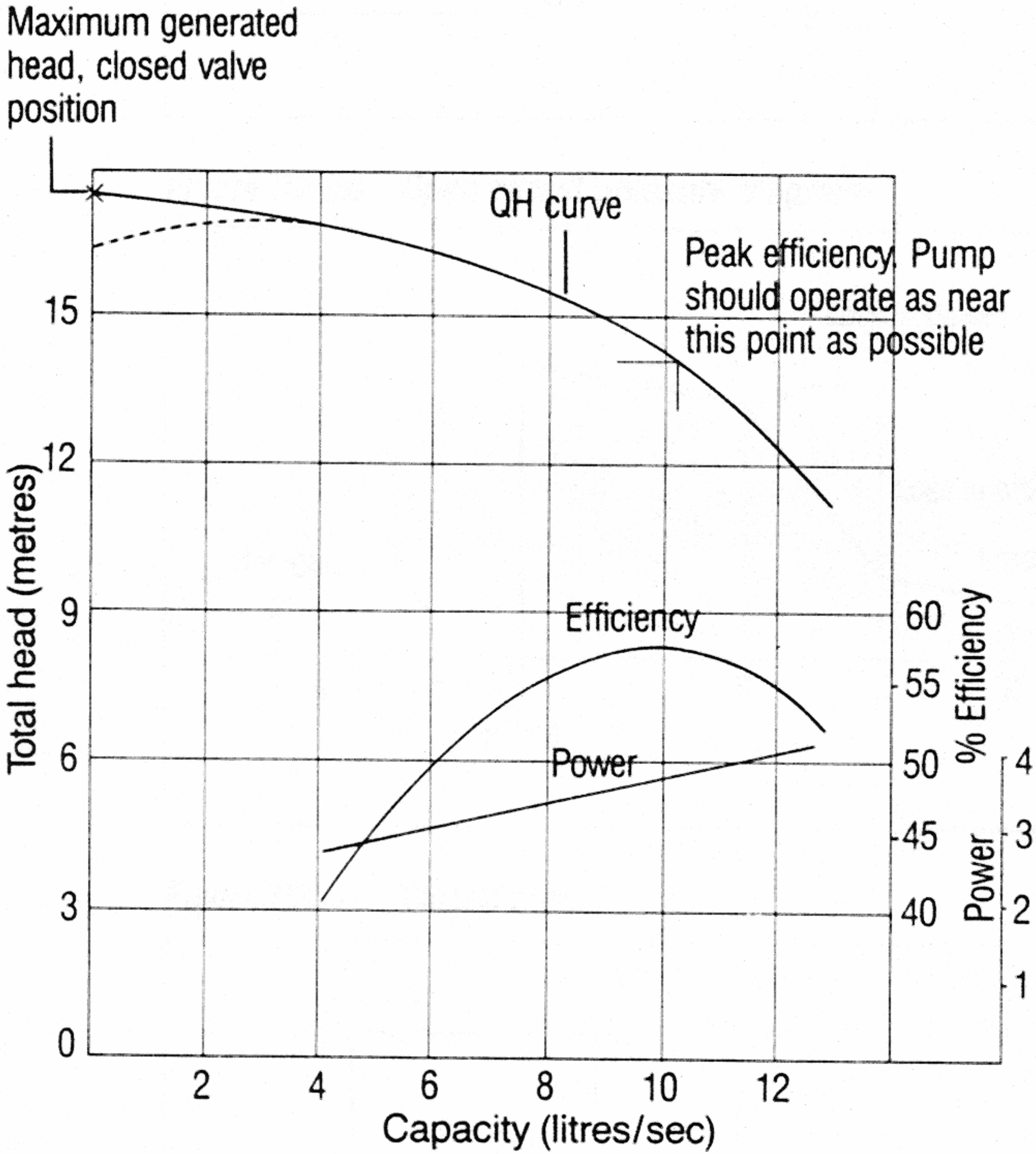
Pump pressure effects in an open system

Pump systems

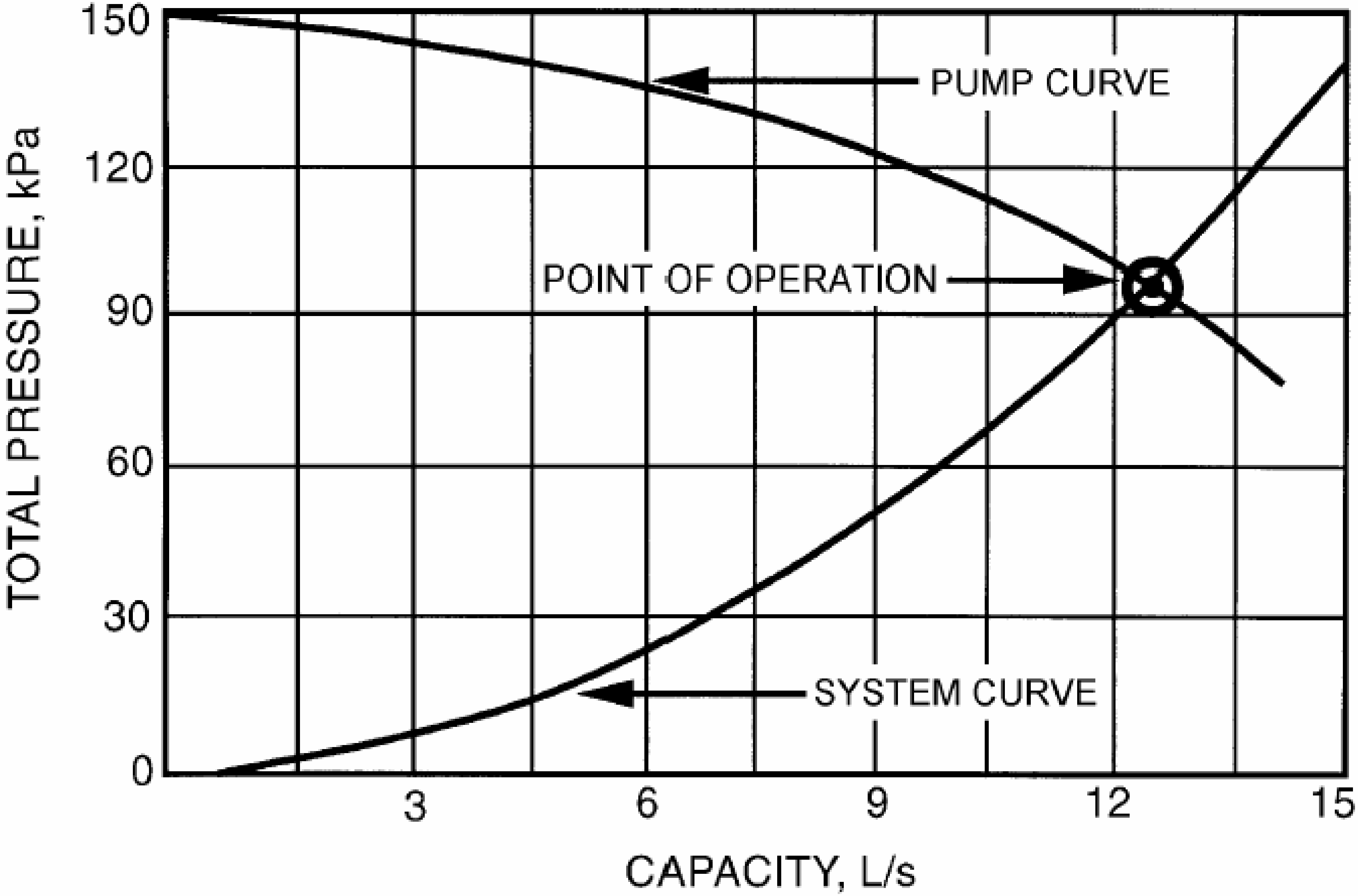
- Pump considerations
  - Practical suction lift is 5 m maximum
  - Also known as net positive suction head (NPSH)
- Pump location is important for both closed and open systems
  - Open system: not excessive to avoid cavitation
  - Close system: Influence water level of open vent pipe & the magnitude of antiflash margin (temp. difference between water & its saturation temp.)
  - ‘Self-priming’ to evacuate air from suction line

Pump systems

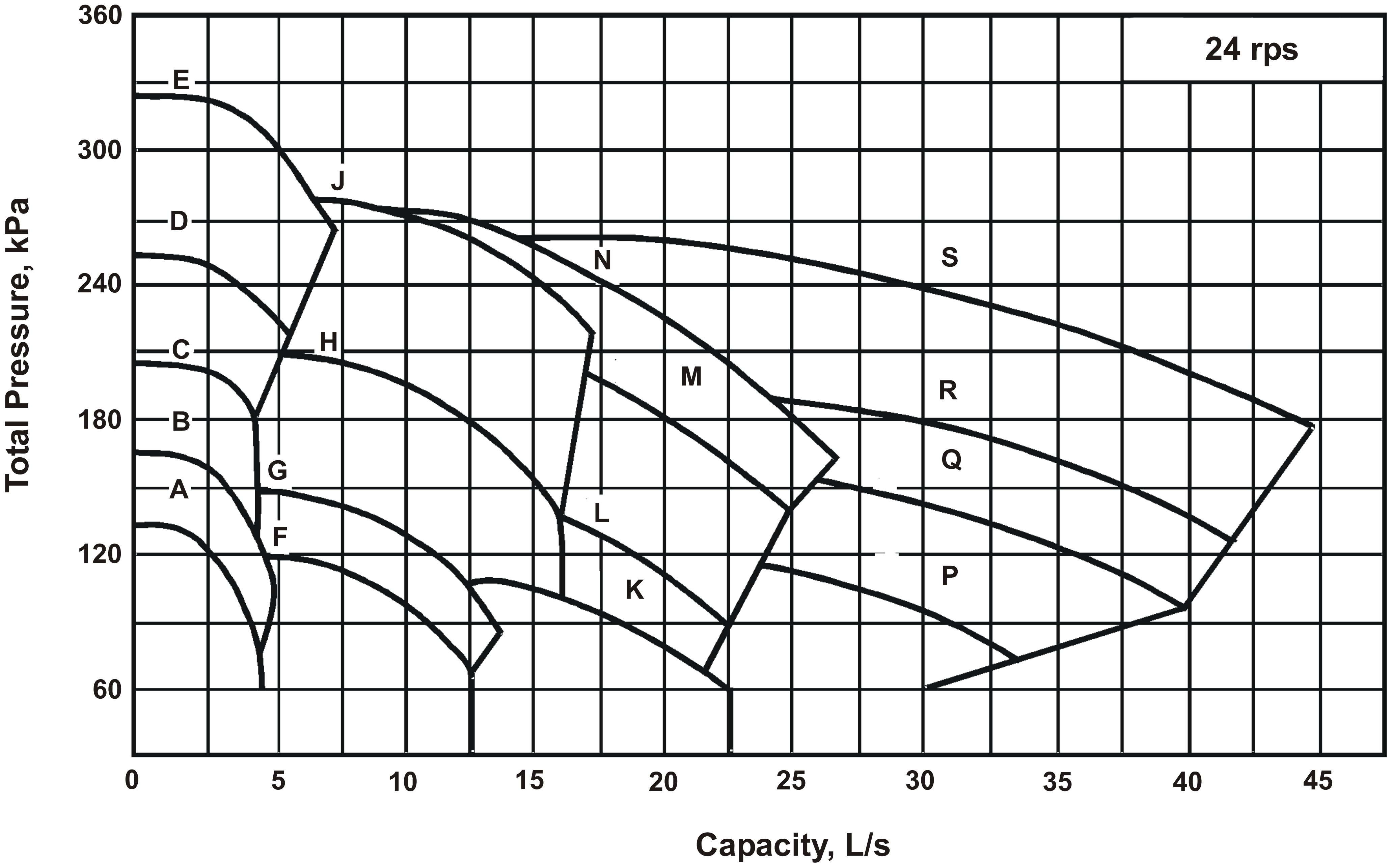
- Pump characteristics
  - Characteristics curves (e.g. from catalogue):
    - Total head
    - Power
    - efficiency
  - No-flow conditions (flow = zero)
    - Close valve pressure
    - Need to prevent over-heat
  - Pump power (W) = flow (L/s) x pressure (kPa)



Pump characteristics curves (centrifugal)

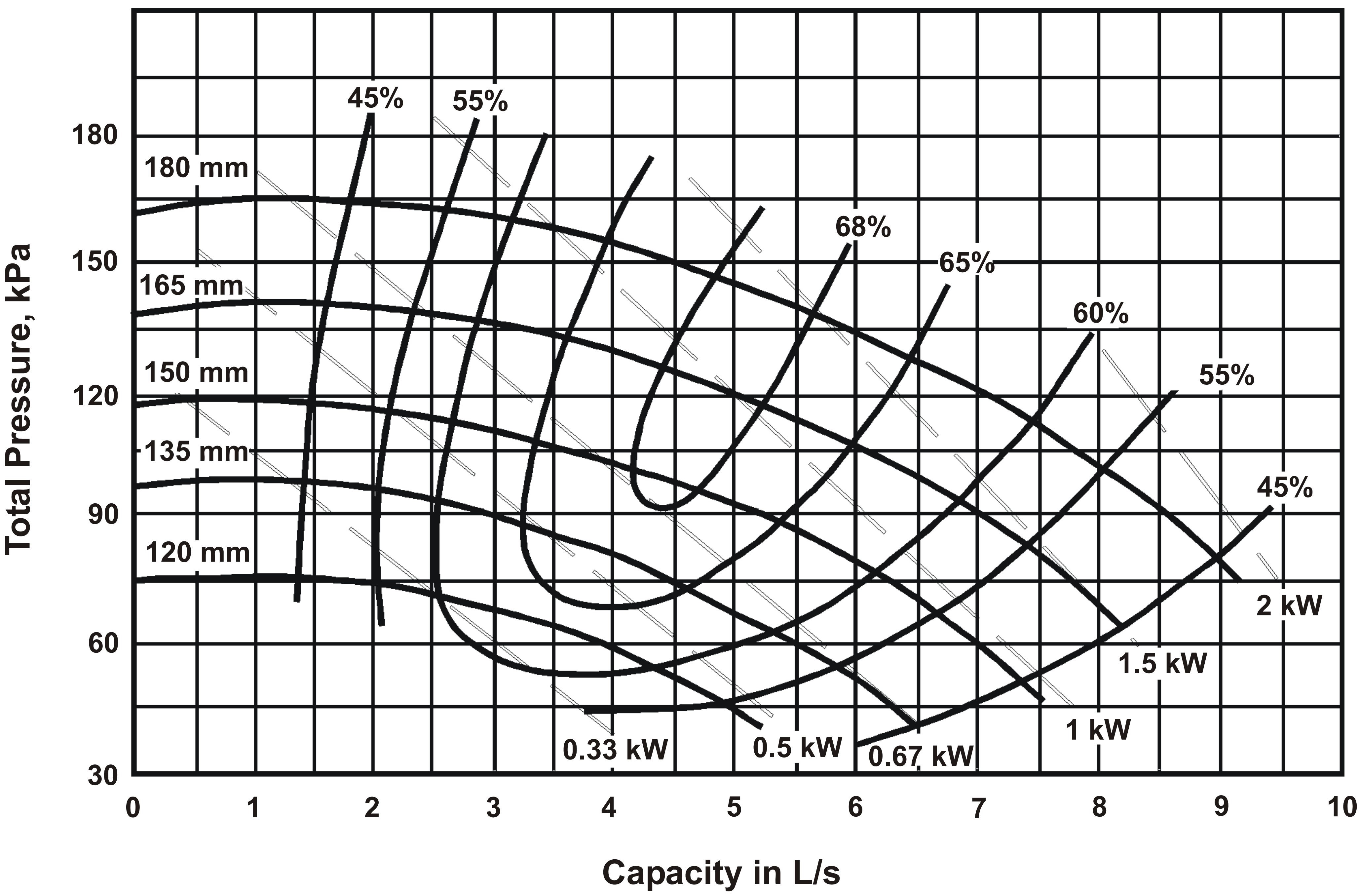


(Source: *ASHRAE HVAC Systems and Equipment Handbook 2004*)



Characteristic curves for pump models

(Source: *Fundamentals of Water System Design*)

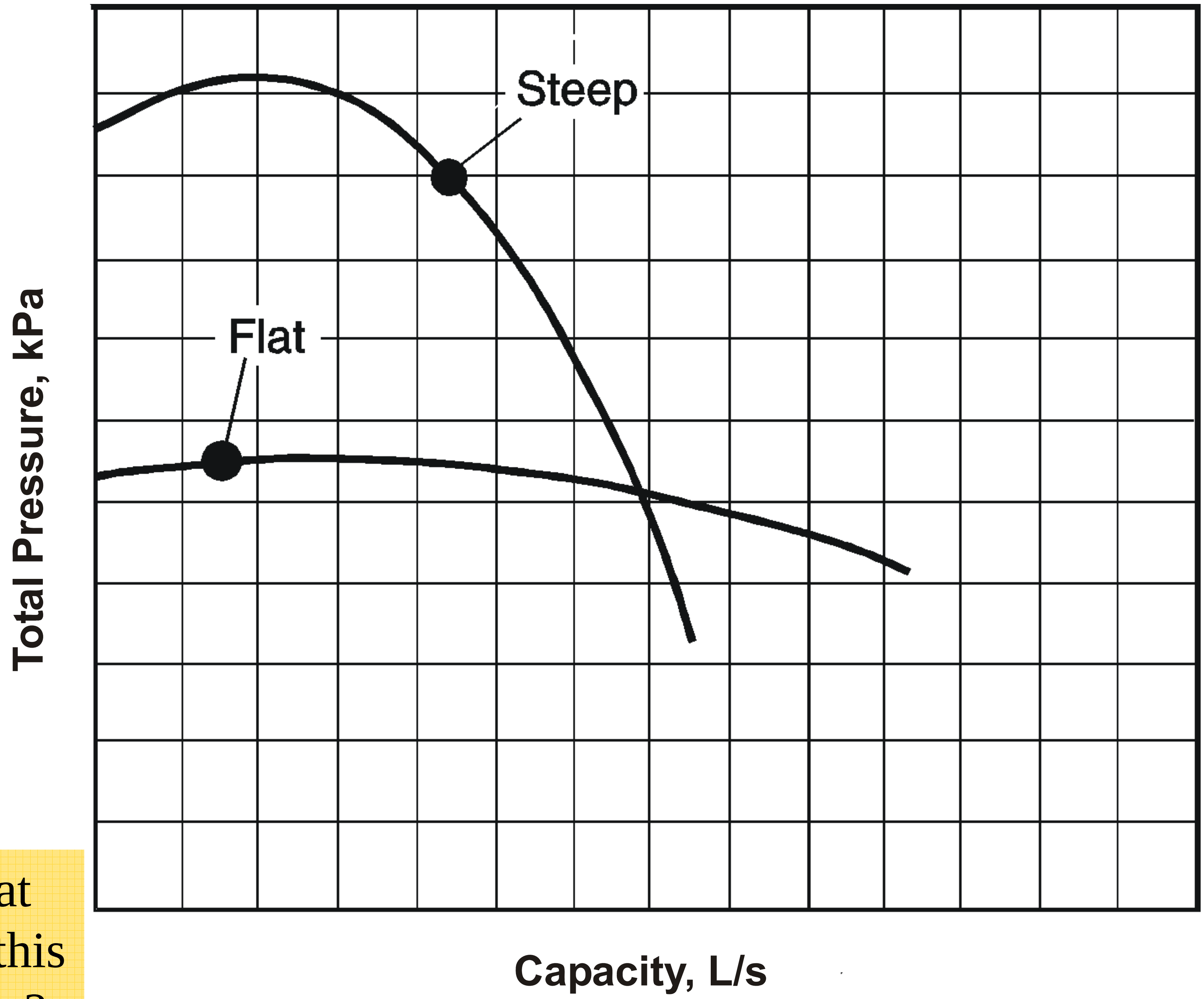


Selected pump pressure-capacity curve

(Source: *Fundamentals of Water System Design*)

Pump systems

- Pump characteristics (cont'd)
  - Pumps with steep characteristics
    - Change in pressure -> small change in flow rate
    - Useful where pipes tend to scale up
  - Pumps with flat characteristics
    - Change in flow -> small change in pressure
    - Useful where extensive hydraulic balancing is needed



What does this imply?

Flat versus steep pump curves

(Source: *Fundamentals of Water System Design*)

Pump systems

- Pump characteristics (cont'd)
  - Pumps with constant speed cannot respond to changes in load
    - Require a bypass to ensure constant flow
  - Variable speed pumps
    - Provides for savings in pumping costs during partial load
  - Pump materials to suit the environment, e.g. stainless steel pumps for salt water system

Other considerations

- Noise & vibration
  - Pipe noise
    - Pipe should not be fixed rigidly to lightweight panels
  - Flow noise
    - Keep velocities under control
  - Pump noise
    - Use rubber hose isolators, resilient inserts, acoustic filters

Other considerations

- Water hammer
  - Such as when a valve is closed rapidly
  - Pulsating type of noise by shock waves
  - Preventive measures:
    - Prevent sudden closing of the valve
    - Absorb pressure peaks (e.g. by pneumatic vessels)
    - Increase the attenuation of pressure waves when transmitted through the pipework
    - Design the pipework to avoid long straight pipe runs
    - Restrict water velocities (e.g. to a maximum of 3 m/s)

Other considerations

- Back siphonage
  - Occur when water mains pressure reduce greatly
  - Contamination of water may happen
  - Contamination might also occur due to gravity & backpressure backflow
  - Anti-siphonage device and design precautions

Other considerations

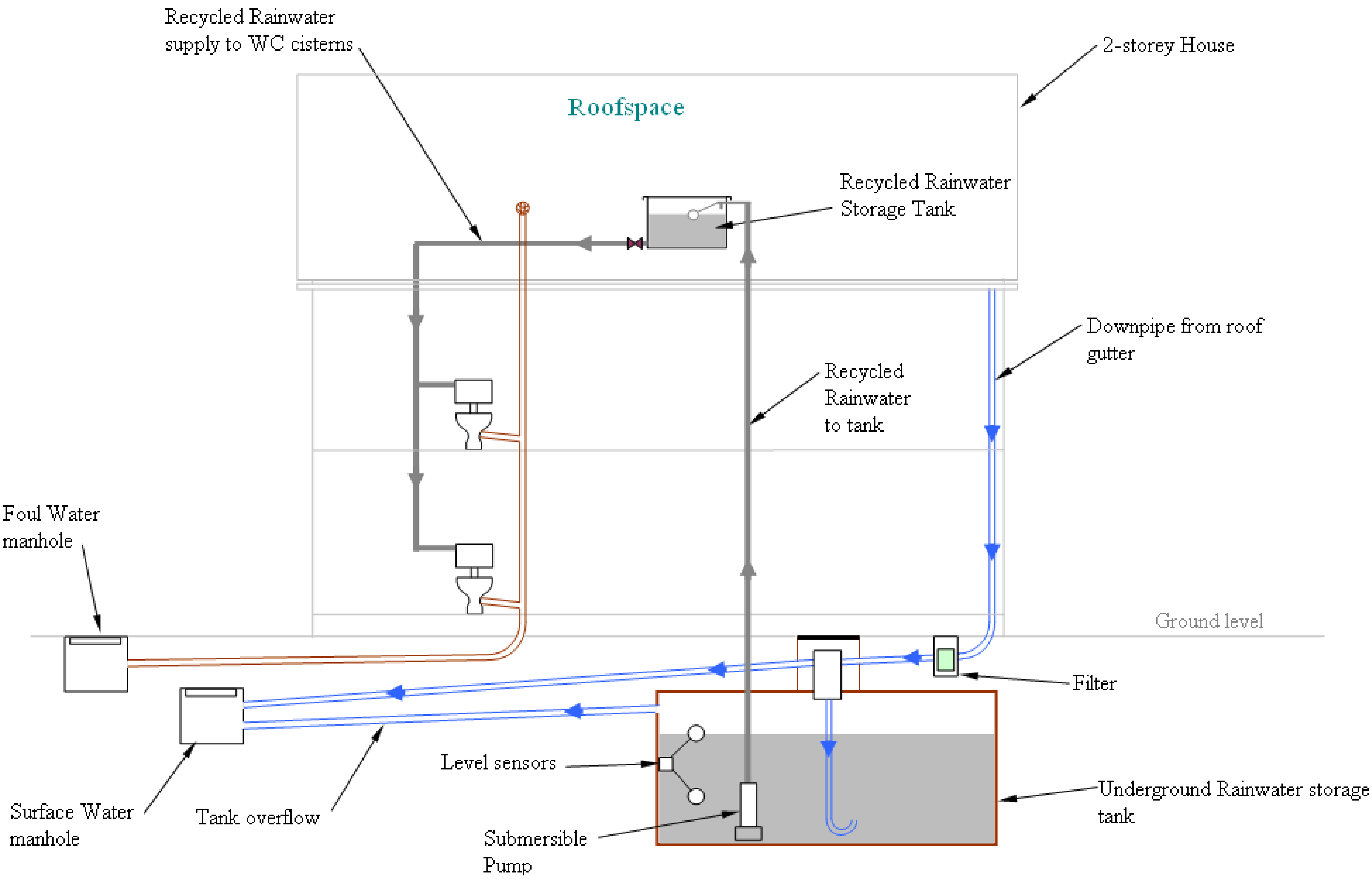
- Water economy & energy conservation
  - Economy of water
    - A key factor in the design (to conserve water)
    - Measures:
      - Detect water leakage
      - Reduce water consumption
      - Reuse or recycle water
  - Energy conservation
    - Insulation of hot water pipe, fittings & vessels
    - Use of fresh water for cooling tower make-up

Other considerations

- Water efficiency labelling scheme will be launched in HK soon
- Water saving devices
  - Low-flow showerheads
  - Taps with flow restrictors
  - Flow control valves
  - Washing machines & dish-washers with high water efficiency
  - Water plugs, self-closing taps, spray taps, aerators, etc.

Other considerations

- Water conservation (flushing water)
  - Low-water and pressure flushing cisterns
  - Dual-flush toilet cisterns
  - Urinal controls
- Water reuse and recycling
  - Rainwater reuse/recycling
  - Grey water recycling



Example: Rainwater recycling system for house

(Source: www.bsenotes.com)