

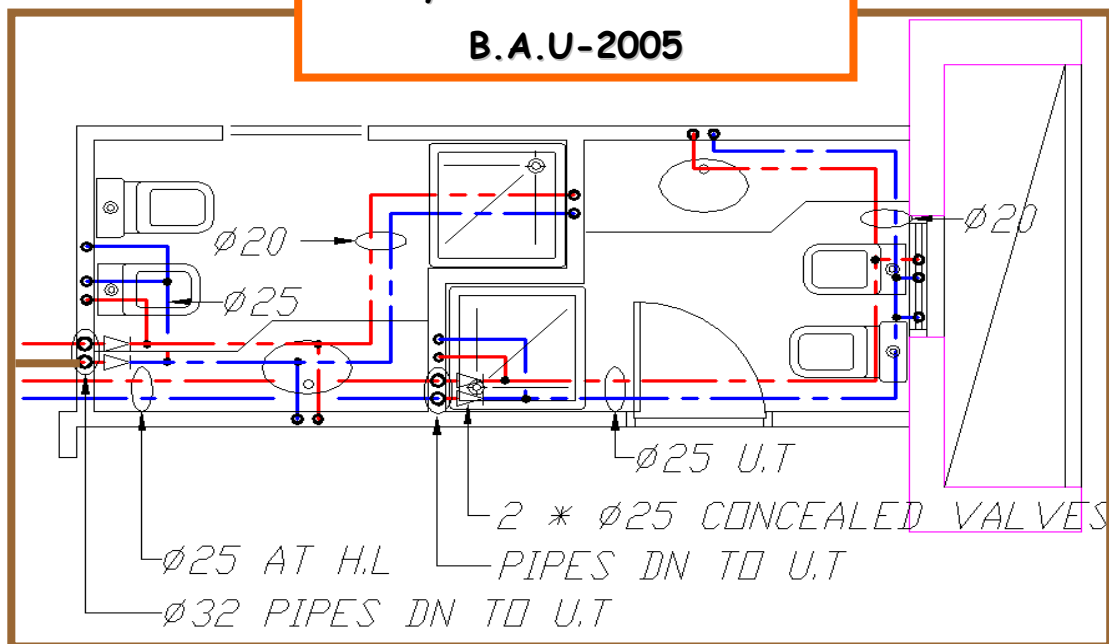
Part I

Plumbing Systems

Lecture Notes

By Dr. Ali Hammoud

B.A.U-2005



Mechanical Engineering short-course

This course is prepared for 3rd mechanical and civil engineering students, at Beirut Arab University.

This course concentrates on the design & calculations of Plumbing systems, used in building applications.

Course duration is 14 hours

7 hours for cold & hot water distribution systems in building.

7 hours for sanitary systems in building.

By Dr. Ali Hammoud

Associate professor in fluid mechanics
& hydraulic machines

OBJECTIVES

Before an engineer sets out to design the plumbing services of any project, it is necessary that he has well defined aims and objectives in order to install an efficient and economical plumbing systems.

These can be defined as follows:

1- Supply of Water

- a- Provide Safe Drinking-Water Supply
- b- Provide an Adequate Supply of Water

2- Fixtures units

- a- Minimum Number of Fixtures
- b- Quality Sanitary Fixtures
- c- Water Trap Seals
- d- Fixture spacing

DRAINAGE AND SEWERAGE SYSTEM

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a- Safe Drainage System

All sanitary drainage systems should be connected to the public sewer system (wherever available) at the nearest possible point. In case the public sewer system is not available, a safe and non-polluting drainage system must be ensured. The drainage system should be so designed as to guard against fouling, deposit of solids and clogging.

b- Vent Pipes

The drainage system should be designed to allow for adequate circulation of air within the system, thereby preventing the danger of siphonage or unsealing of trap seals under normal working conditions. The system should have access to atmospheric pressure and venting of foul gases by vent pipes.

c- Exclusion of Foreign Substances from the System

d- Ground and Surface Water Protection

e- Prevention of Contamination

f- Prevention of Sewage Flooding

Table of Contents part 1

Symbol & legend

Description of Architecture
drawings of the project

Cold water distribution system
"Calculation"

Hot water distribution system
"Calculation"

Drawing of water distribution
inside the flats

Questions

- Design of Risers
- Daily W. Requirement
- Load Values W.F.U.
- Pipe sizing
- Types of pumps

- Circulating Pump
- Pipe sizing
- Electrical W. heater
- Water storage heater
- Instantaneous or semi-inst. heaters

Dr. Hammoud

Symbols & legends

P I P E S	
SS	SOIL STACK
WS	WASTE STACK
VS	VENT STACK
V	VENT
SV	STACK VENT
RW	RAIN WATER
RWS	RAIN WATER STACK

S E R V I C E S	
CW	COLD WATER
SW	SOFT COLD WATER
PW	POTABLE WATER
HW	DOMESTIC HOT WATER
HWR	DOMESTIC HOT WATER RETURN
TS	TANK SUPPLY
WTR	WATER
DR	DRAINAGE
F.F	FIRE FIGHTING
G	GAS
A	COMPRESSED AIR
V	VACUUM
FOS	FUEL OIL SUPPLY

ABBREVIATION	DESIGNATION
P I P E M A T E R I A L	
CI	CAST IRON PIPE
GS	GALVANIZED STEEL PIPE (SEAMLESS & WELDED)
BS	BLACK STEEL PIPE (SEAMLESS)
PVC	POLYVINYLCHLORIDE PIPE
C-PVC	CHLORINATED POLYVINYLCHLORIDE PIPE
PVC-U	UNPLASTICIZED POLYVINYLCHLORIDE PIPE
P.P	POLYPROPYLENE PIPE (DRAINAGE)
P.P.R	POLYPROPYLENE RANDOM PIPE (WATER)
PE-X	CROSS-LINKED POLYETHYLENE PIPE
PE-X / AL / PE-X	PE-X , ALUMINUM , PE-X (TRIPLE LAYER) PIPE
CU	COPPER PIPE
P.E	POLYETHYLENE PIPE
H.D.P.E	HIGH DENSITY POLYETHYLENE PIPE

P L U M B I N G F I X T U R E S	
AWC	ASIATIC WATER CLOSET
EWC	EUROPEAN WATER CLOSET
B	BIDET
LAV	LAVATORY
S	SINK
SH	SHOWER
KS	KITCHEN SINK
BT	BATHTUB
DF	DRINKING FOUNTAIN
HB	HOSE BIB
FT	FLASH TANK
FV	FLASH VALVE 1

M I S C E L L A N E O U S	
CO	CLEANOUT
CCO	CEILING CLEANOUT
FCO	FLOOR CLEANOUT
J.B	JUNCTION BOX
RVC	ROOF VENT CAP
MH	MANHOLE
FHC	FIRE HOSE CABINET
WS	WATER SOFTNER
WH	WATER HEATER

D I R E C T I O N S	
FA	FROM ABOVE
TB	TO BELOW
IW	IN WALL
UT	UNDER TILE
UG	UNDER GROUND
UCL	UNDER CEILING LEVEL
I.F.S	IN FLOOR SLAB
B.F.S	BELOW FLOOR SLAB
LL	LOW LEVEL
HL	HIGH LEVEL
UP	UP
DN	DOWN
FM	FROM
NTS	NOT TO SCALE

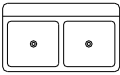
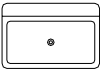
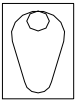
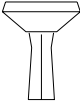
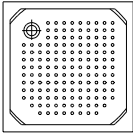
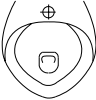
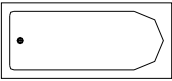
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HL	HIGH LEVEL
UP	UP
DN	DOWN
FM	FROM
NTS	NOT TO SCALE

S E R V I C E L I N E S	
—————	DRAIN,SOIL OR WASTE
———RW———	RAIN WATER
—————	VENT
———·———·———	DOMESTIC COLD WATER
———·———·———	DOMESTIC HOT WATER SUPPLY
———·———·———	DOMESTIC HOT WATER RETURN
———DW———	DRINKING WATER
———TS———	TANK SUPPLY
———FF———	FIRE FIGHTING WATER
———CD———	CONDENSATE DRAIN PIPE
———VAC———	VACUUM
———A———	COMPRESSED AIR

D R A I N S	
FDH	FLOOR DRAIN HORIZONTAL OUTLET
FDV	FLOOR DRAIN VERTICAL OUTLET
FD	FLOOR DRAIN
RD	ROOF DRAIN
GD	GARAGE DRAIN
AD	AREA DRAIN
FBD	FLOOR BED DRAIN
BD	BALCONY DRAIN
TD	TERRACE DRAIN

PLUMBING FIXTURES

 KITCHEN SINK DOUBLE BOWL	 KITCHEN SINK SINGLE BOWL	 ASIATIC WC AWC
 EWC FACE VIEW	 EWC TOP VIEW	 BIDET
 LAV FACE VIEW	 LAV TOP VIEW	 LAV TOP VIEW BUILT IN TYPE
 SHOWER	 URINAL	 BATHTUB

Project description

The project consist of two blocks A and Band a common Ground floor & One Basement
Block A consist of 18 floors and block B consist of 17 floors..

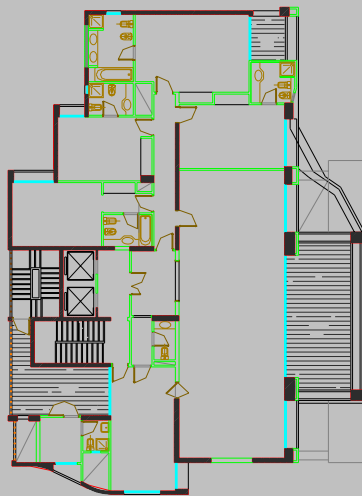
The design drawing of the two blocks are identical. Flat area is about 700 m².

Each flat consist of one master bedroom, three bedrooms, one living room, one dining room, one kitchen , maid room and six bathrooms.

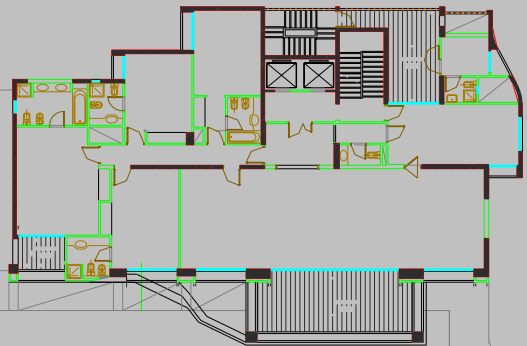
Floor to floor height is 3m

Water supply from city main is irregular and we have to rely on two well pumps for water domestic use which have a capacity of 5m³/hr each. However drinking water is supplied from city main water supply. The city water pressure is insufficient.

- (a) Work out daily water requirement, underground and overhead tank capacity
- (b) Assuming indirect water supply system .Calculate the size of the the main riser pipe from the underground reservoir up to overhead tank and the pump duty.
- (c) Assuming two downfeed risers from the overhead tank for each flat as indicated in the typical floor drawing. .Calculate the pipe diameters and branch lines for these risers.
- (d) Design the cold and hot water distribution system inside the flat.
- (e) size the pressure vessel of the top floors and the corresponding pump duty.



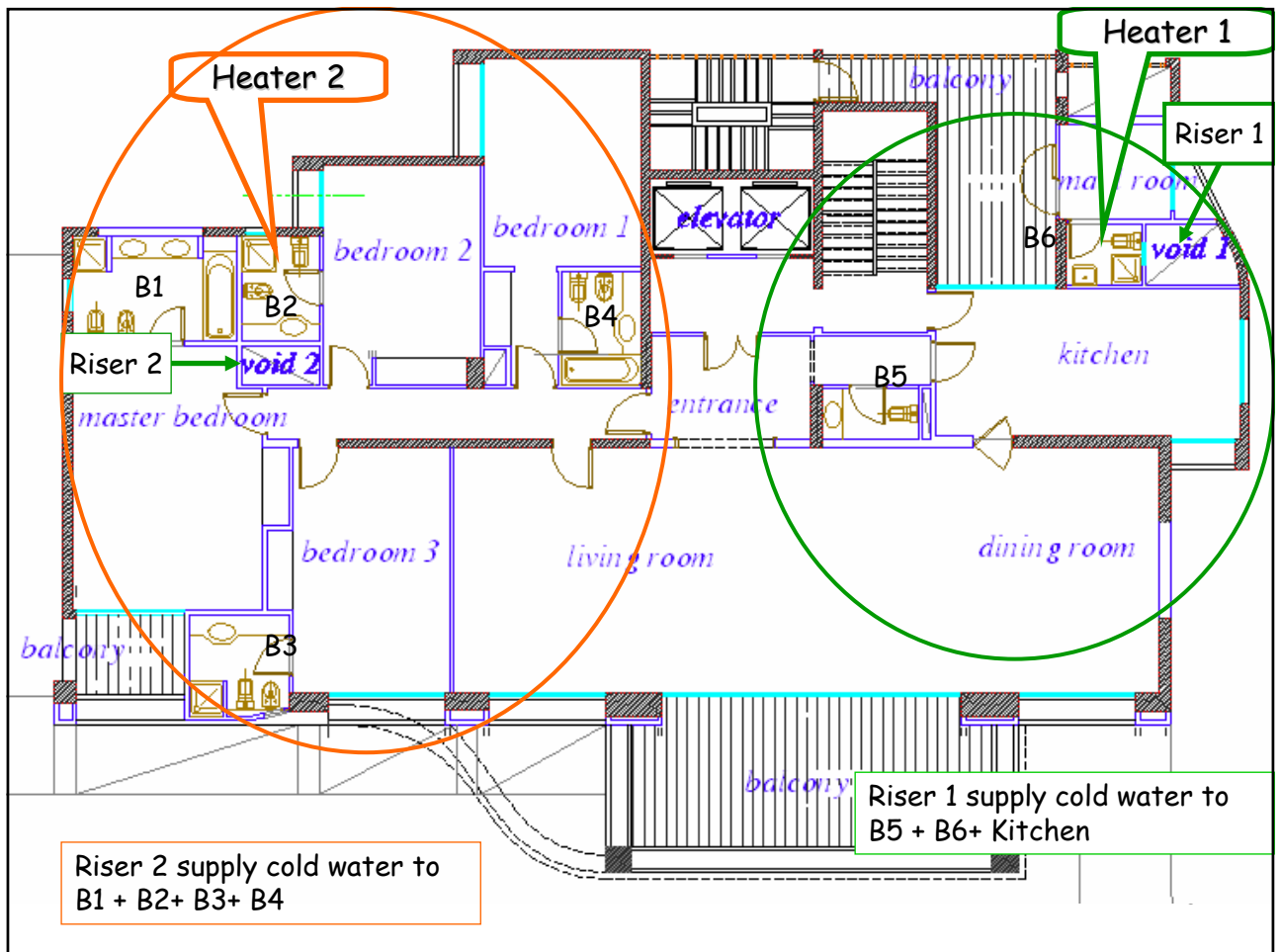
Block B 17 floors

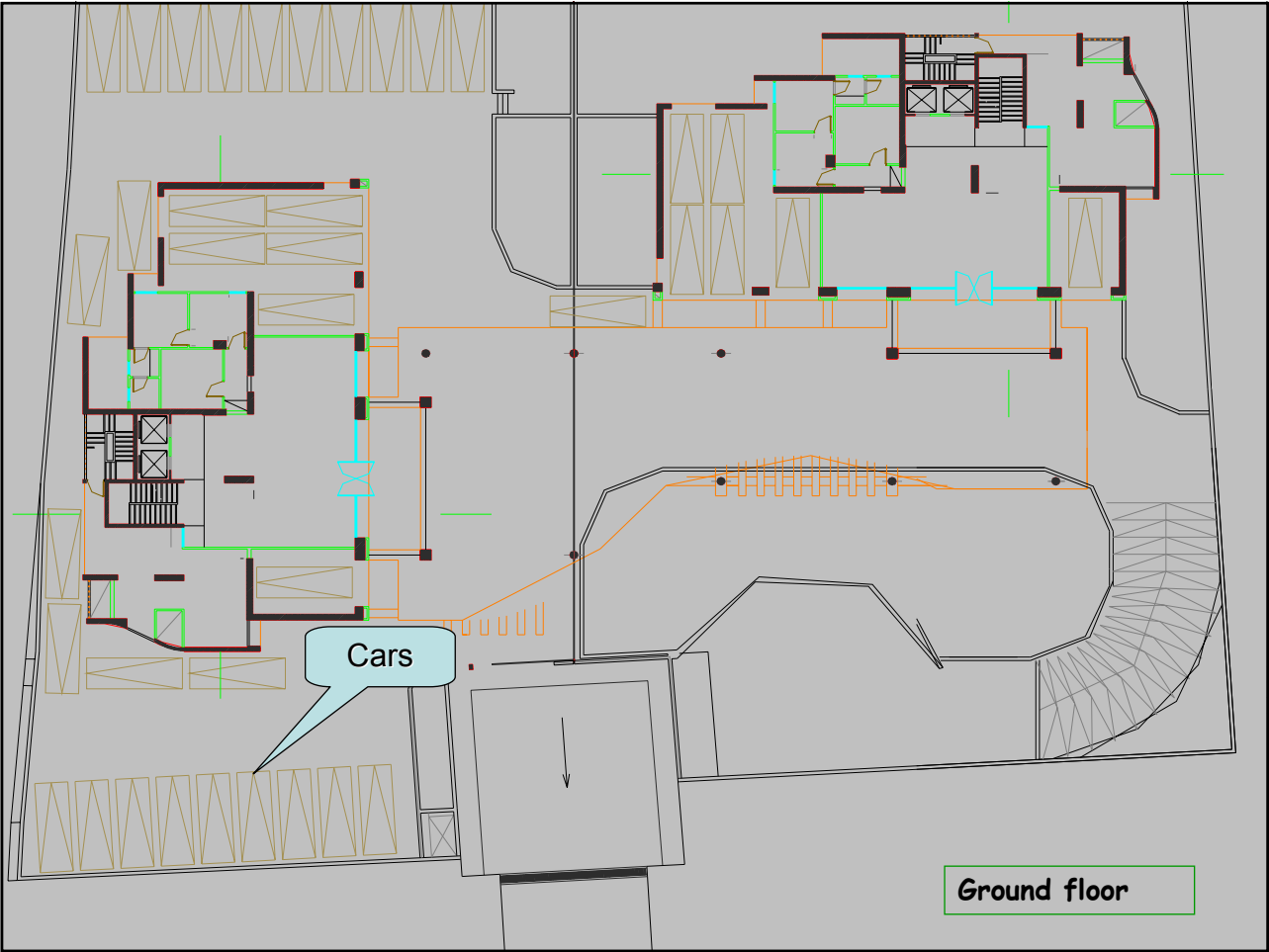


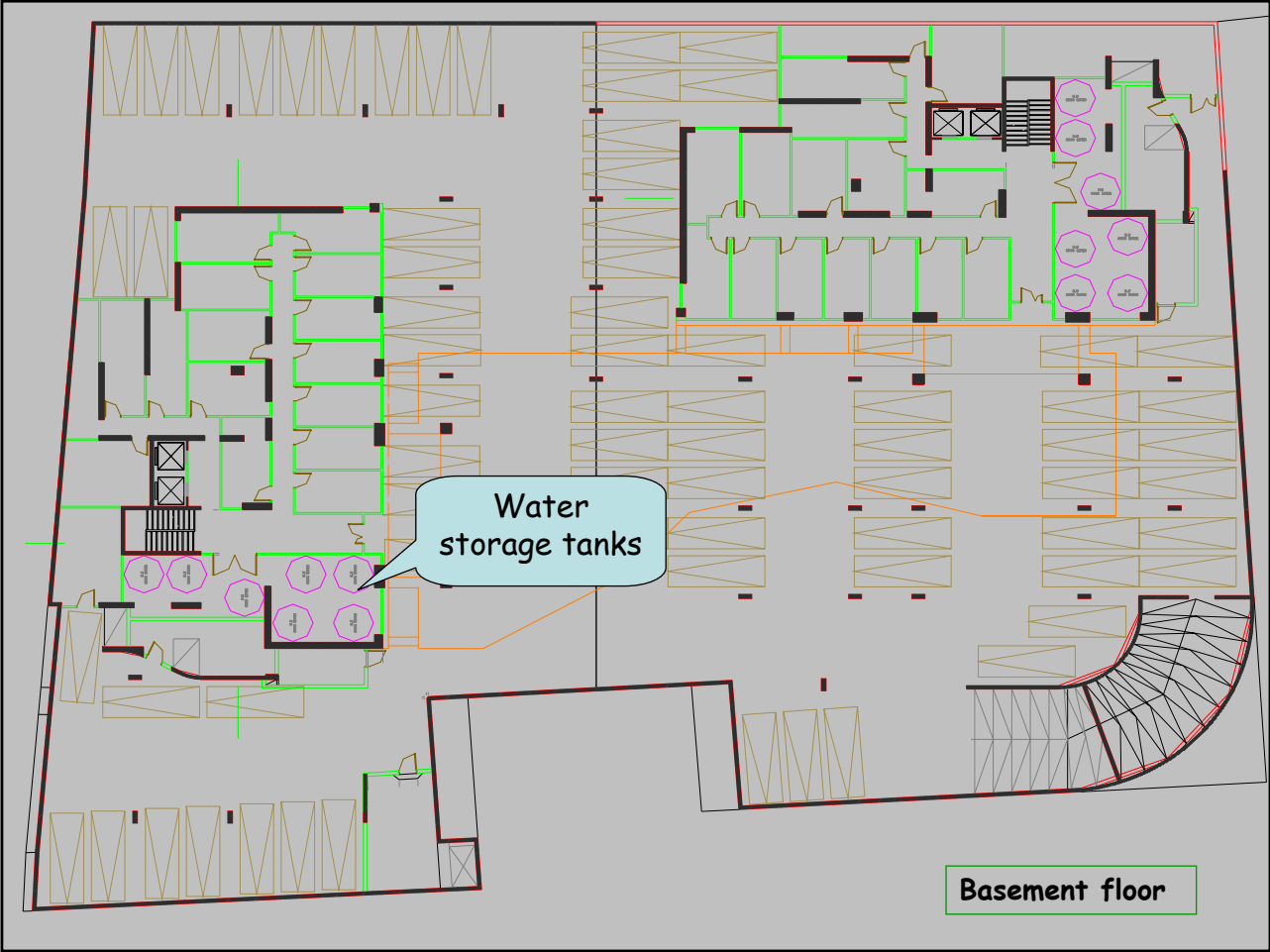
Block A 18 floors

Refer to your drawing & follow the lecture

Typical floor







HOW TO READ AND DRAW THE WATER DISTRIBUTION SYSTEM INSIDE THE FLAT .



90 DEGREE L



45 DEGREE L



T



REDUCING T



90 DEGREE STREET L



DROP-EAR L



90 DEGREE REDUCING L



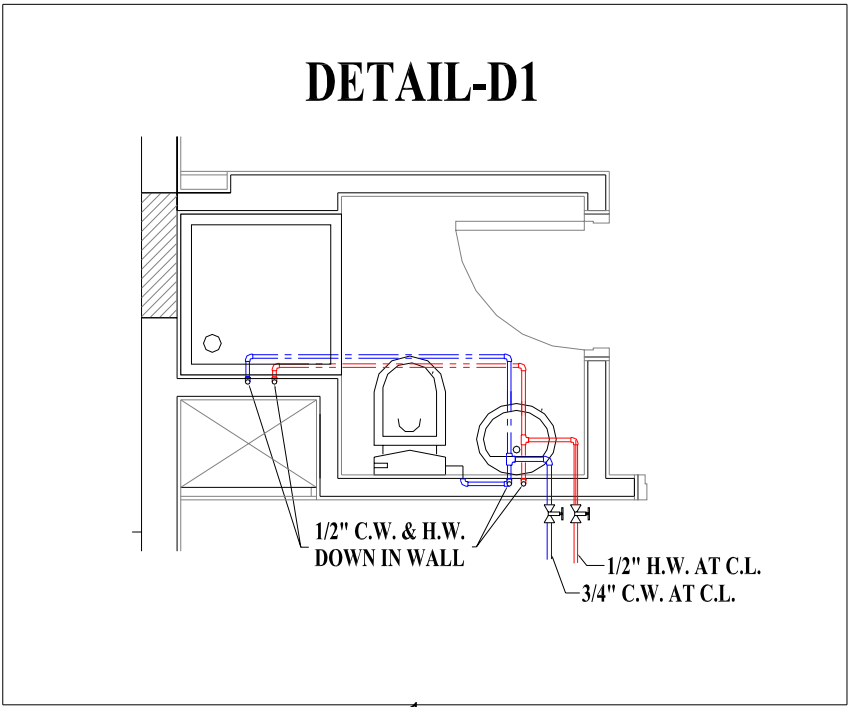
REDUCING T



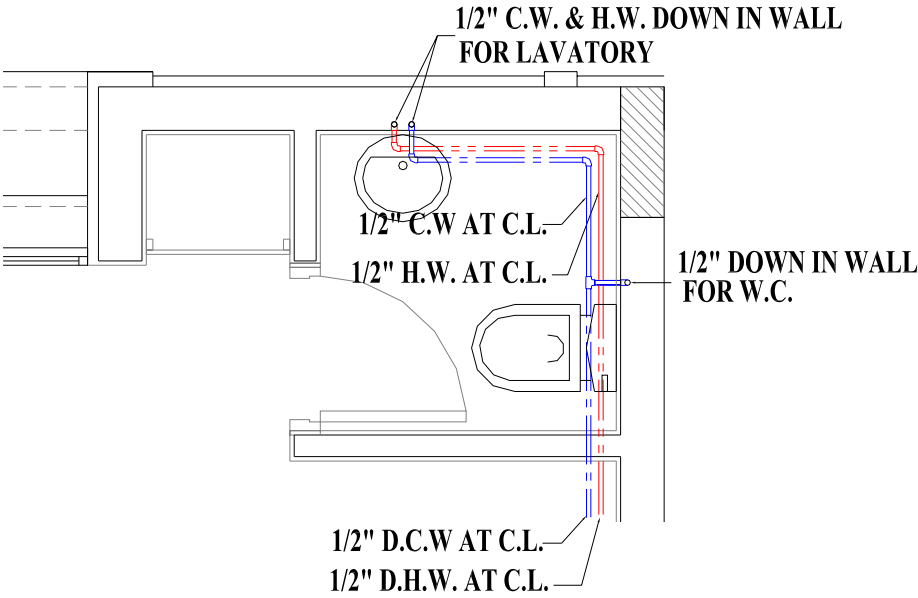
Example of some pipe accessories needed for water distribution system

EXAMPLE OF WATER DISTRIBUTION SYSTEM INSIDE
BATHROOM - GALV. STEEL PIPES

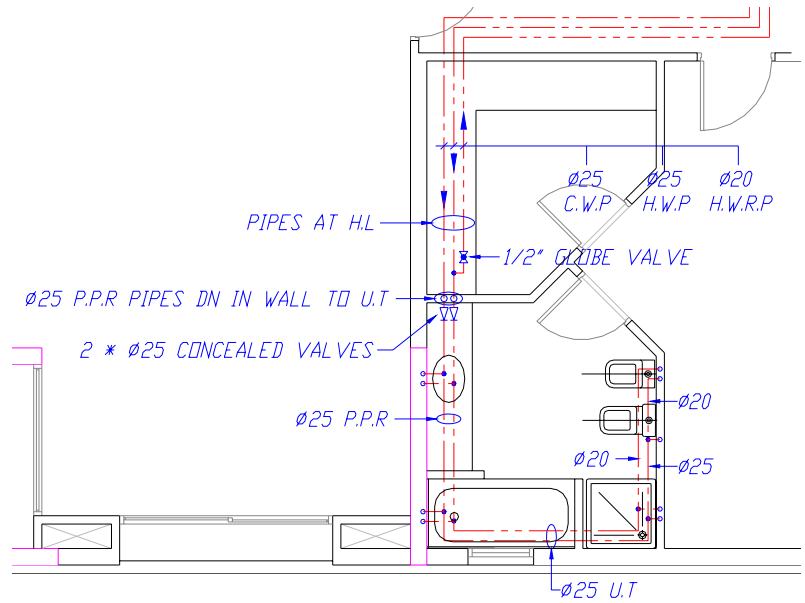
DETAIL-D1



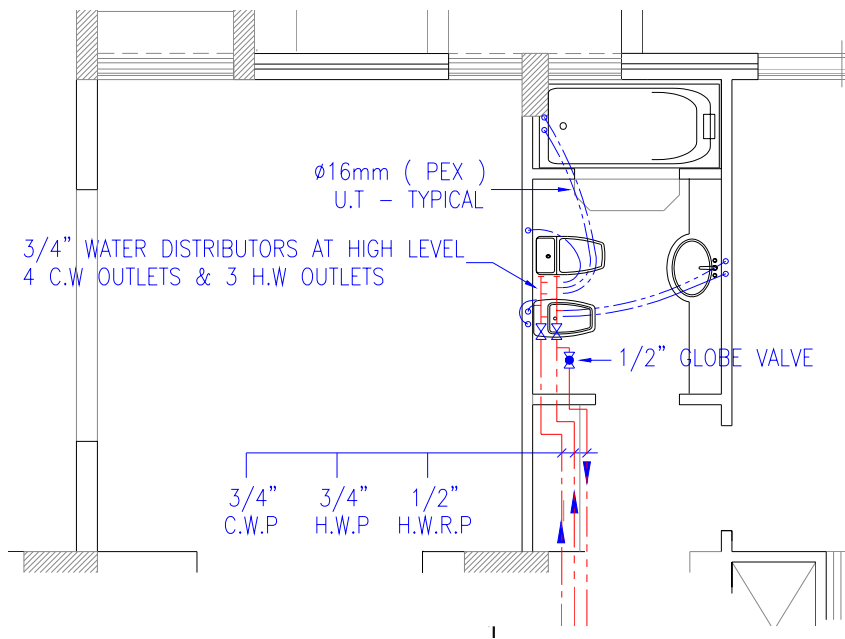
DETAIL-D2



DETAIL OF WATER DISTRIBUTION SYSTEM INSIDE BATHROOM – P.P.R PIPES



DETAIL OF WATER DISTRIBUTION SYSTEM INSIDE
BATHROOM - PEX OR PEX-AL-PEX PIPES

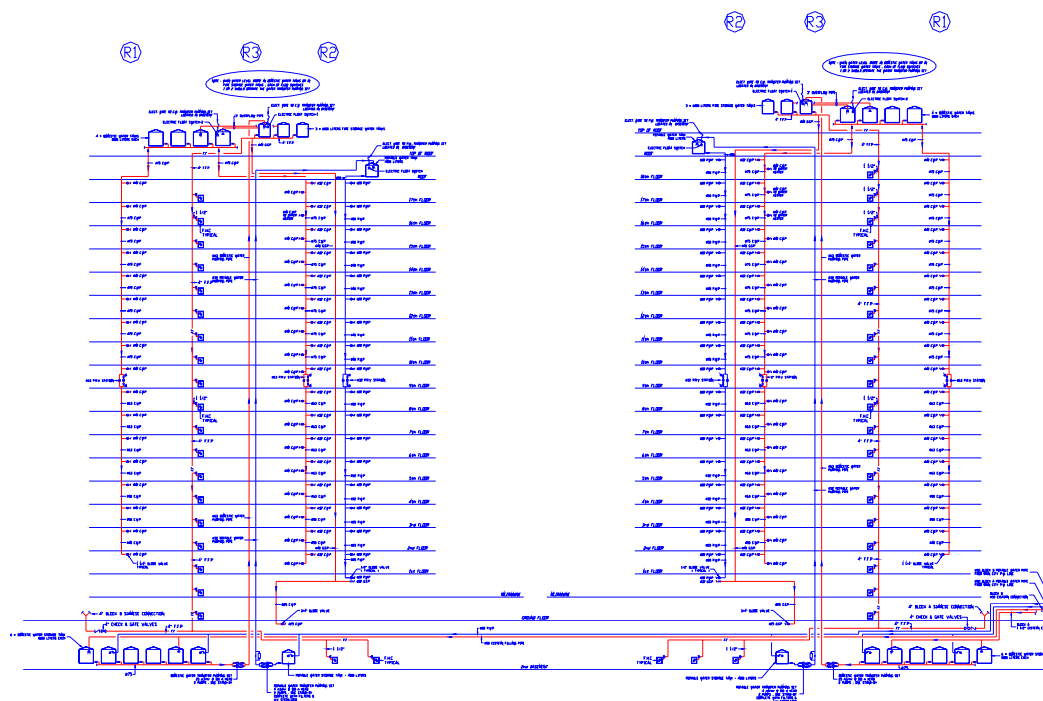


Solution of a ,b & c

Schematic water risers diagram for Madam Cury project

BLOCK (B)

BLOCK (A)

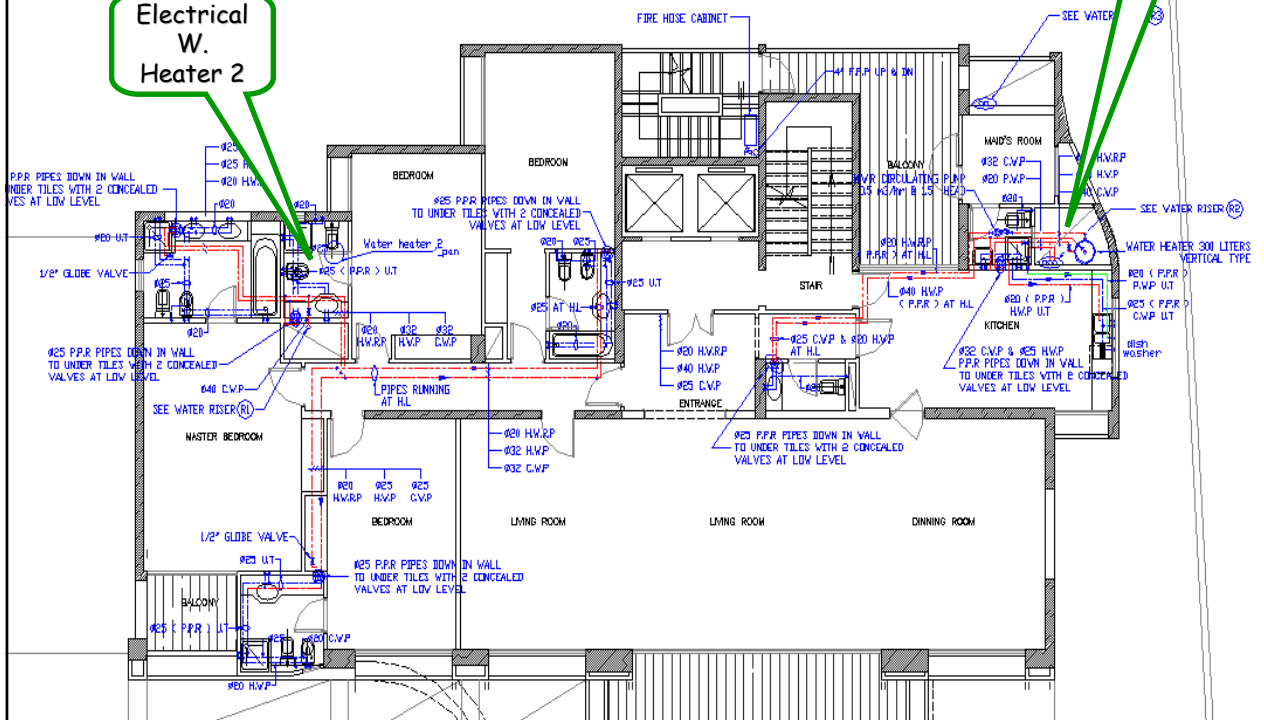


Madam Cury project - water distribution system for typical floor

Solution of (d) Two Electrical water
heaters & two water risers

Electrical
W.
Heater 2

E.W.
Heater
1



Solution of (d)

[illegible]

Up to now !!

Before starting the calculation of the plumbing project . Student should be able to read and understand all the Architecture drawings of the project entitled " Madam Curry ".

Chap.2

Cold & Hot water distribution systems

Calculation Of
W.D. Systems



Design Of W.D.
Systems



Daily Water requirement



Load Values



Pressure requirement



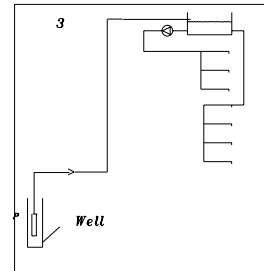
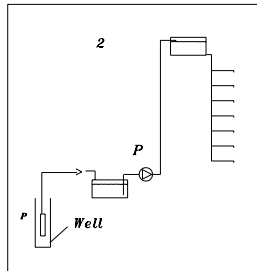
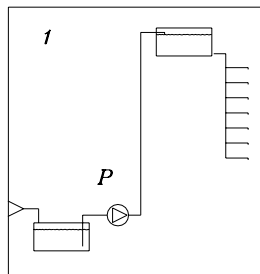
Pipe sizing



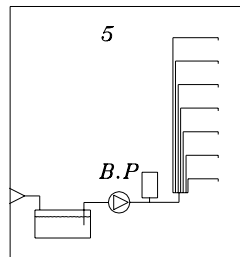
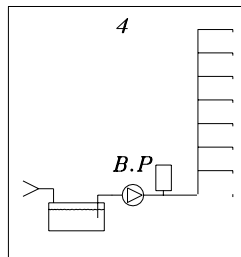
Pump selection

Water Distribution Systems Up to 10 floors Bldg

Indirect

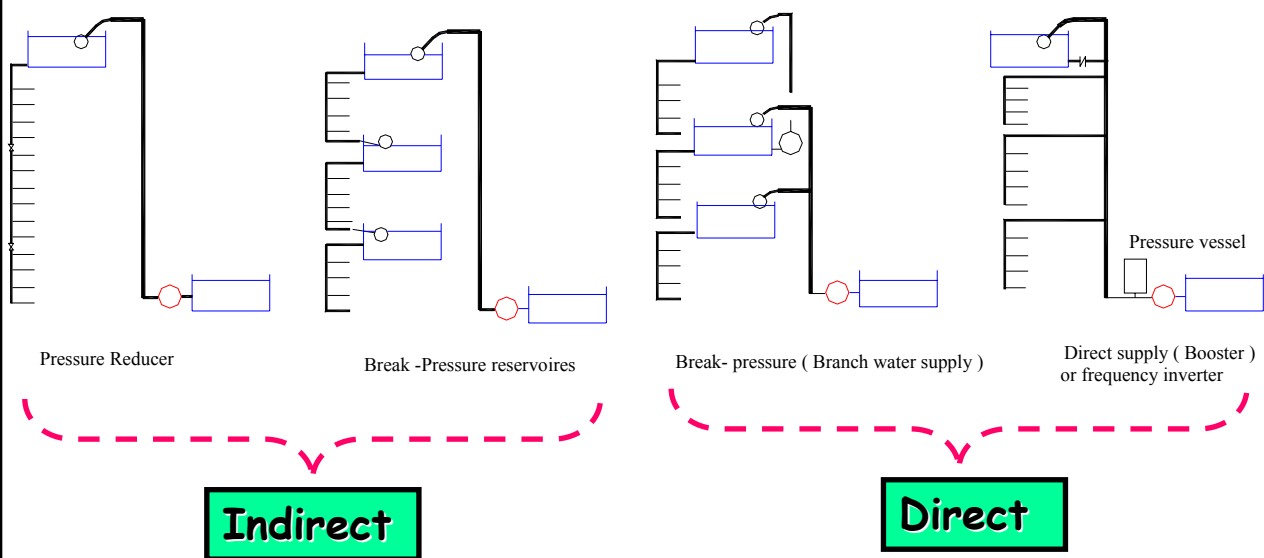


Direct

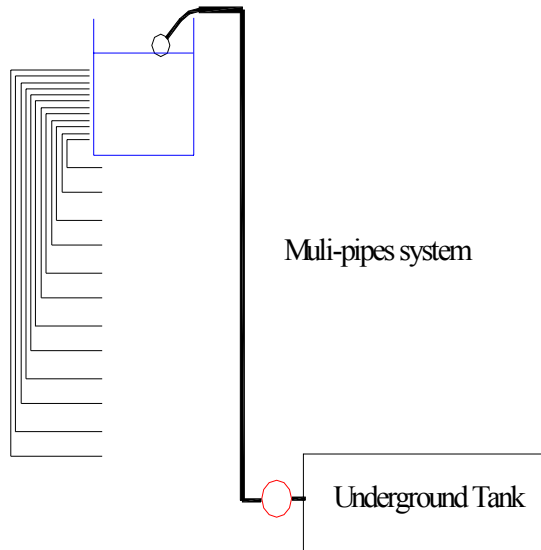


Distribution Systems

Buildings above 20 floors

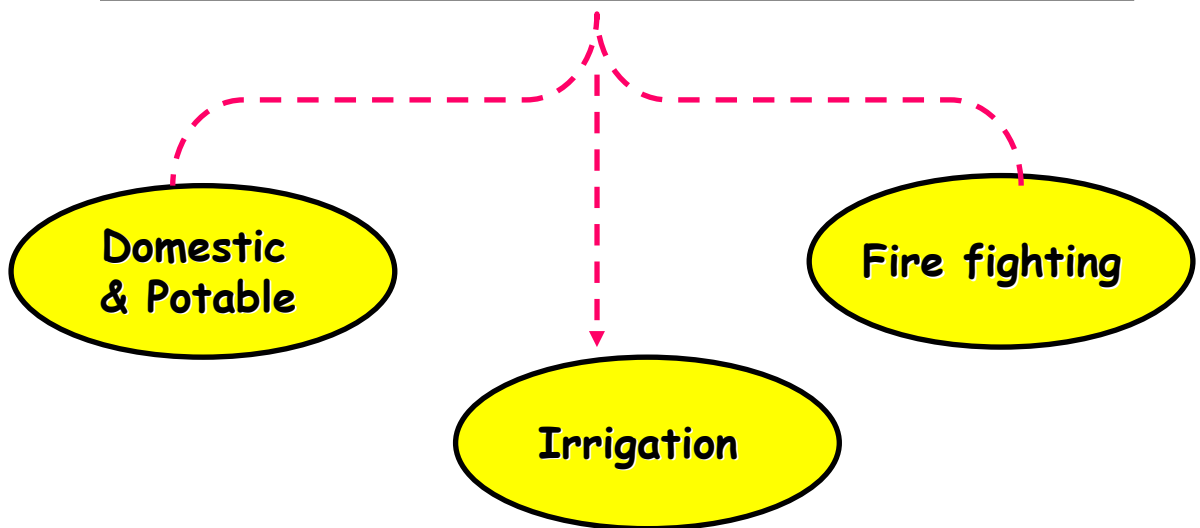


Multi-pipes system is always preferable



Each flat has its own inlet flow pipe

Water storage in buildings



Domestic water storage in buildings

Underground tanks

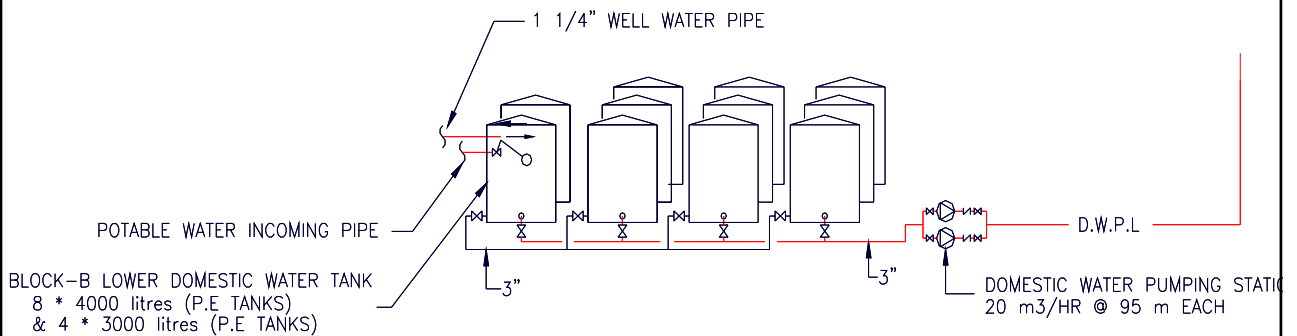
Roof tanks

Storage of water

Water is stored in buildings due to the irregular supply of city water. Normally water is stored in basement with pump transferring water to roof tanks. Roof tanks could be one single tank for the whole building or separate tanks for each flat.

As shown in the following pages, water tanks are provided normally with float valve, drain valve, discharge valve, overflow and vent pipe.

Underground water storage Pumps - Tanks Connections



Roof Tanks

Roof tanks should be elevated enough above roof level to have enough pressure for the upper apartment , otherwise booster pump is needed.

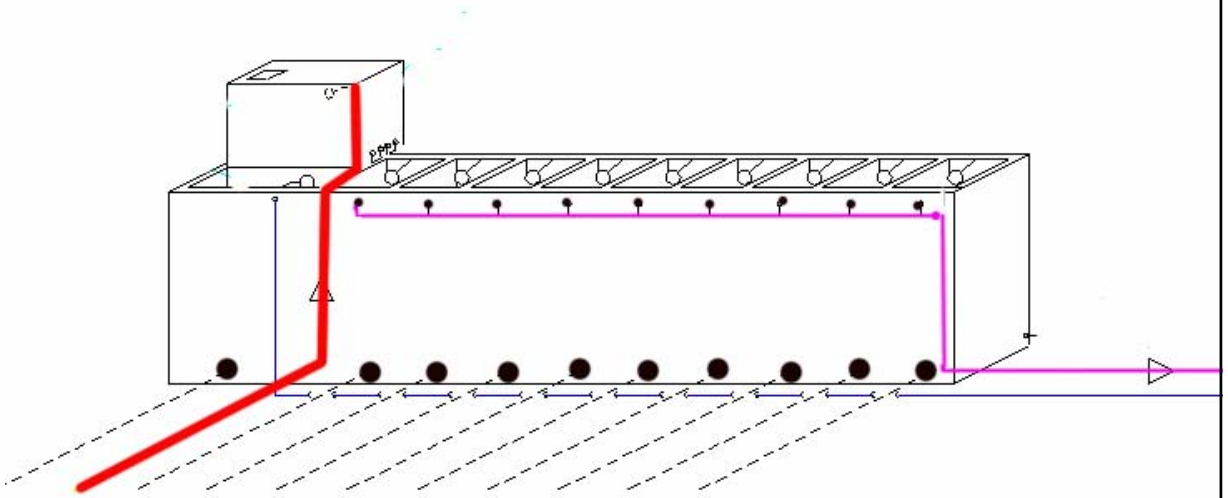
Material of roof tanks

1-Concrete tanks.

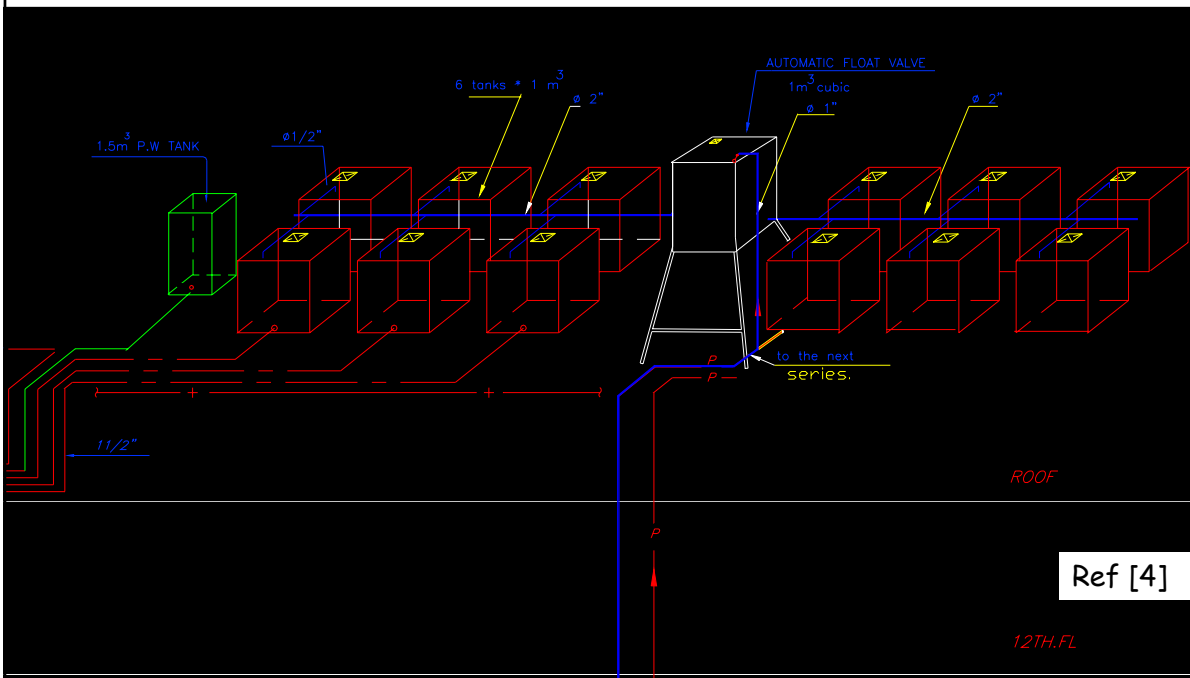
2-Galvanized tanks.

3- PPr tanks.

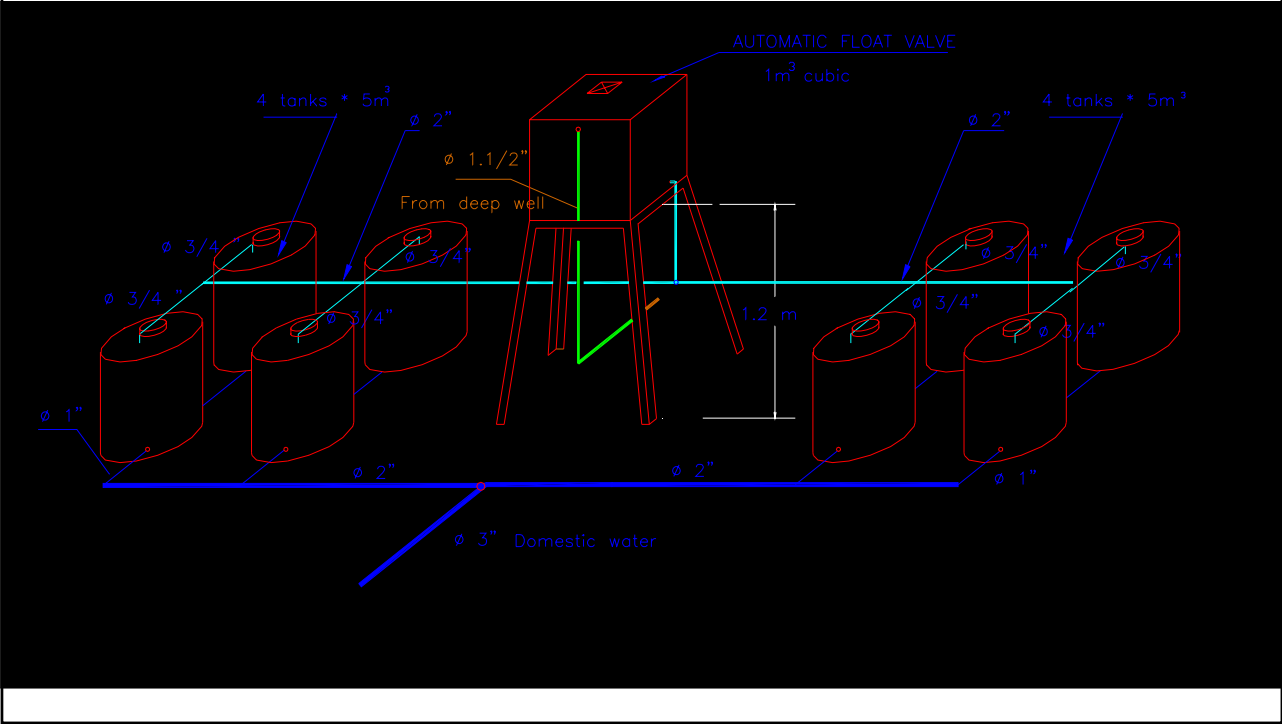
Concrete Roof tanks



Galvanized Roof tanks



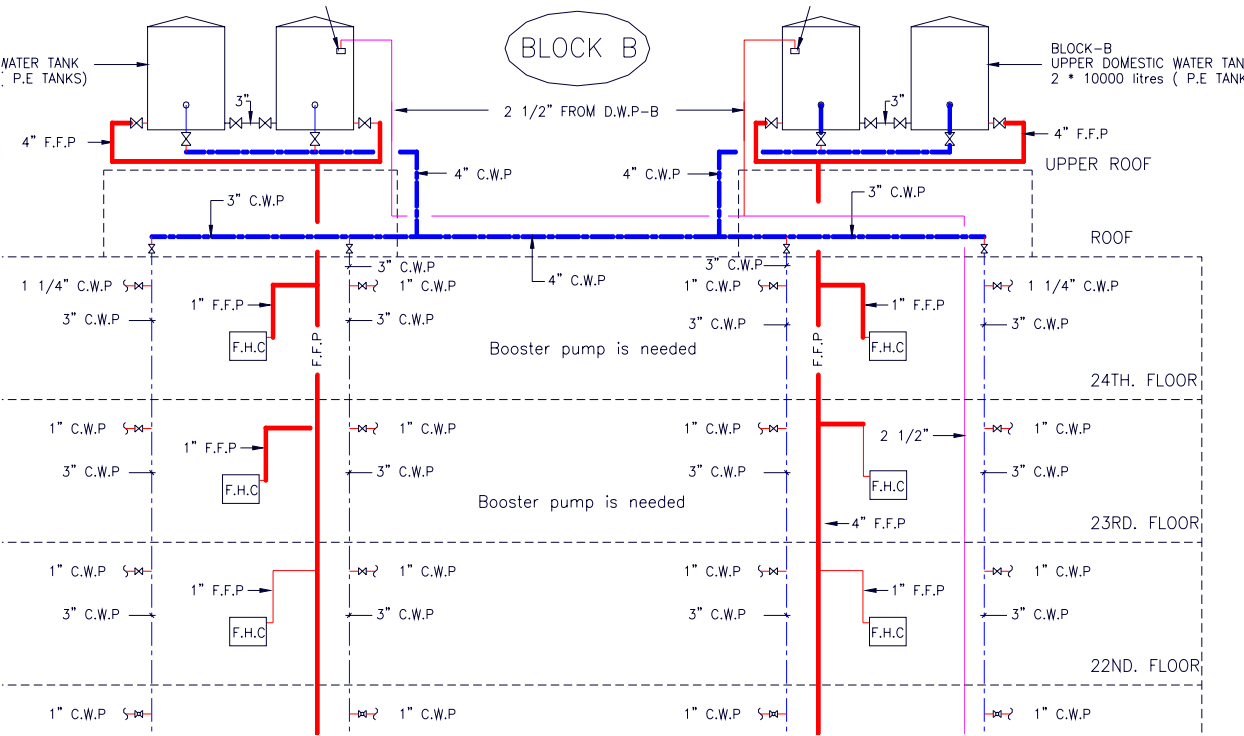
P.P.R. Roof tanks



Riser diagram

1

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Design recommendations & Calculations

Fixture-Unit Computations

Computing fixture units is a fundamental element of sizing piping systems for water distribution and drainage. Values assigned to specific types of fixtures are crucial in the sizing of a plumbing system. There are two types of ratings for fixture units:

- a) The first deals with drainage fixture units;
- b) and the second type has to do with the needs for potable / domestic water systems. Both types of ratings are needed when de-signing a plumbing system.

Ref [8] providing you with sample tables of fixture-unit ratings. The tables are based on actual code regulations, but always refer *to your local code for exact standards in your region*. As you look over the tables that will follow, pay attention to all details. It is not unusual for code requirements to have exceptions. When an exception is present, the tables in code books are marked to indicate a reference to the exclusion, exception, or alternative options. You must be aware of these notes if you wish to work within the code requirements. Computing fixture units is not a complicated procedure and all you really need to know is how to read and understand the tables that will give you ratings for fixture units.

Using fixture units to size plumbing systems is a standard procedure for many engineers. The task is not particularly difficult.

Drainage Fixture Units

1

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Pipes used to convey sanitary drainage are sized based on drainage fixture units. It is necessary to know how many fixture units are assigned to various types of plumbing fixture units. This information can be obtained, in most cases, from local code books. Not all plumbing codes assign the same fixture-unit ratings to fixtures, so make sure that you are working with the assigned ratings for your region. Let me give you some sample tables to review

Water Distribution Fixture units

Water distribution pipes are also sized by using assigned fixture-unit ratings. These ratings are different from drainage fixture units, but the concept is similar. As with drainage fixtures, water supply pipes can be sized by using tables that establish approved fixture-unit ratings. Most local codes provide tables of fixture-unit ratings.

Daily Water Requirement

1-Daily water requirement & Tanks capacities. (two methods are used to determine the daily water requirement ,the first is base on the number of occupants , the second is based on the load value).

2- Load value (W.f.u.)

Average Daily Water Requirement for Storage

Table W-1

Ref [2]

Type of Establishment	Gallons (per day per person)
Schools (toilets & lavatories only)	15
Schools (with above plus cafeteria)	25
Schools (with above plus cafeteria plus showers)	35
Day workers at schools and offices	15
Residences	35-50
Hotels (with connecting baths)	50
Hotels (with private baths, 2 persons per room)	100

Daily Water Requirement for Storage (Based on the number of occupants)

Example calculation of daily domestic water requirement

Suppose we have 24 floors & each floor consists of 4 flats,

2 of them having 3 bedrooms

2 of them having 2 bedrooms.

+1 Mad each flat.

As a rule of thumb we take 2 persons/bed room.

Total number/floor = $2 \times 3 \times 2 + 2 \times 2 \times 2 + 4 = 24$ Persons/floor.

Total number of occupants = $24 \times 24 + 5$ (labors+ concierges etc...) = 581 Persons.

From table W-1 the daily water requirement is between 35-50 gal/ day (Residential Building),

The daily water requirement for the whole building is:

=> $50 \times 581 = 29000$ gallons /day $\approx 110 \text{ m}^3/\text{day}$

Capacity of Underground & Roof Tanks:

Based on Plumbing code , the daily water requirement is divided between the roof & underground tanks as follows:

- 1 day's water requirement on the roof &
- 2 day's on the ground floor (standard).

As mentioned before the total amount of water needed for the 24 floors building is 110 m^3 , this equivalent to 110 tones additional weight on the roof. On the other hand $2 \times 110 = 220 \text{ m}^3$ must be stored in the basement floor, this may affect the number of cars in the basement.

As a general rules (**one day water storage** on the roof & basement may be satisfactory ,if **water flow** from well pump is guarantied).

N.B. Potable (drinking+ cooking) water tank capacity is calculated based on 10-12 L / person / day

Water storage for fire fighting

- For buildings , it is reliable that, water for fire fighting is provided by gravity storage wherever possible. Using elevation as the means for developing proper water pressure in water mains risers & FHCs, not dependent on pumps that could fail or be shut down as a result of an electrical outage. Storage can be provided through one or more large storage reservoirs or by multiple smaller reservoirs throughout the community that are linked together .A reasonable rule of thumb is that water storage for fire fighting should be sufficient to provide at least one hour .For example, in a typical residential building with an ordinary hazards, the storage for fire flow of 100 GPM for 30-60 min may be appropriate.

Hose reel installation should be designed so that no part of the floor is more than 6 m from the nozzle when the hose is fully extended. The water supply must be able to provide a discharge of not less than **33 gpm** through the nozzle and also designed to allow not less than three hose reels to be used simultaneously at the total flow of **100 gpm for one hour duration**.

The minimum required water pressure at the nozzle is **2 bar** where the maximum allowable pressure is **6.9 bar**. Adequate system pressures is about **4.5 bars**. Booster pump is used for top roof flats.

The rubber hose reel length is 32 m & could be 1" or $\frac{3}{4}$ " diameter (British standard), or 1.1/2"(US standard), and the jet should have a horizontal distance of 8 m and a height of about 5 m.

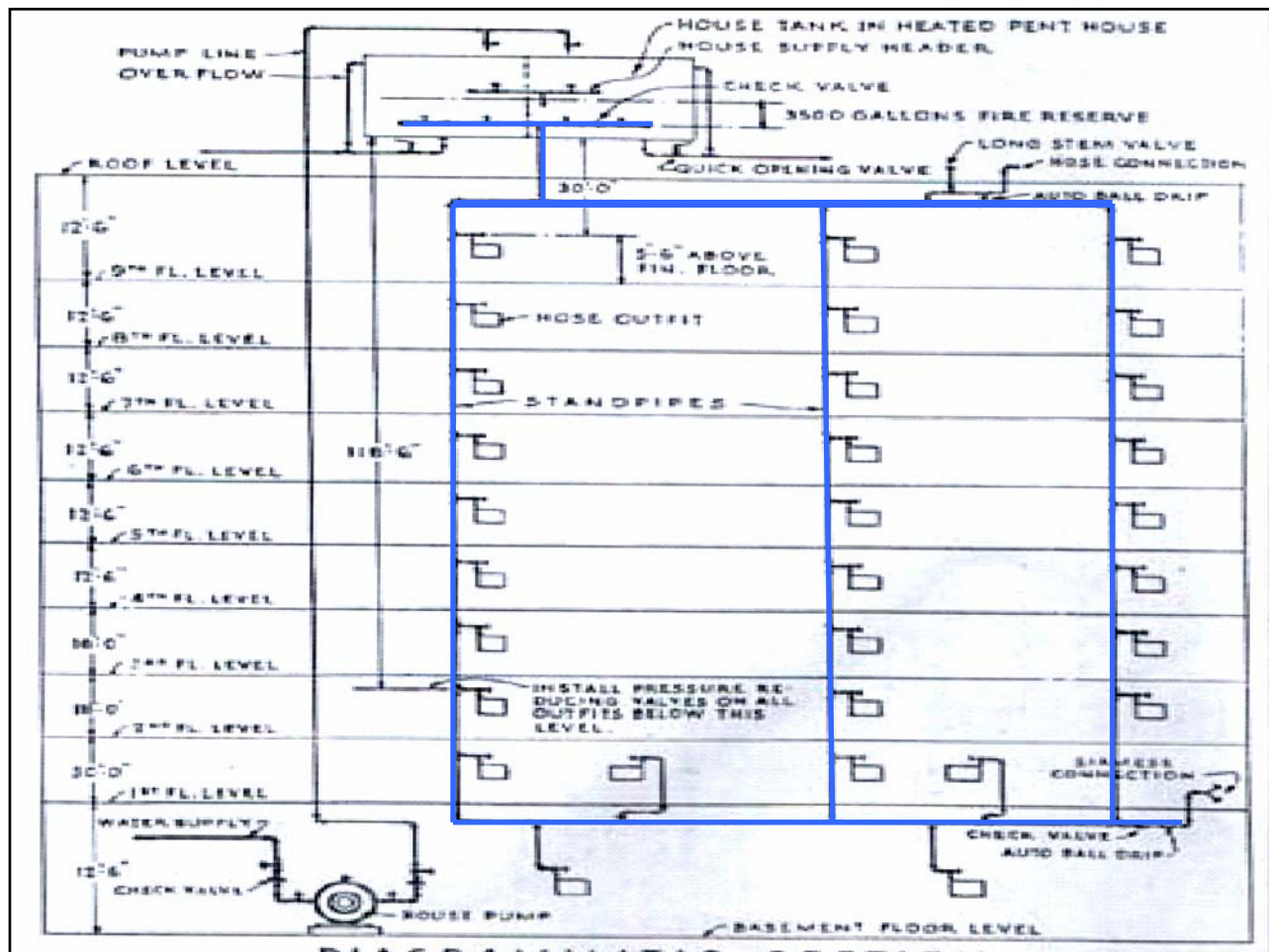
For commercial building:

Riser main pipe diameter $D = 2.1/2"$

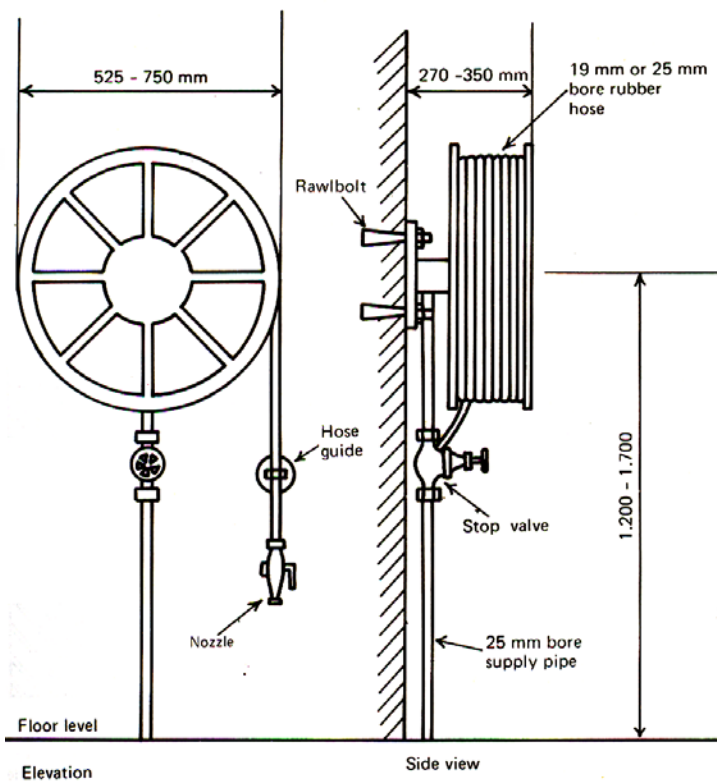
Branch pipe diameter = $1.1/2"$

Rubber hose reel diameter = $1"$.

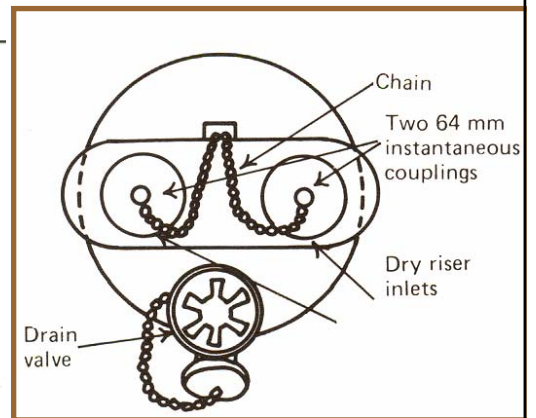




DIAGRAMMATIC SECTION



Siamese connection



Located next to fire escape

Water storage for irrigation

- Irrigation systems could be by hose or automatically using pump , electrical valves ,timers & sprinklers.
- As a rule of thumb ,the water consumption for irrigation is estimated as follows:

The green area $\times$ 0.02 m /day

For example :

Suppose we have a 500 m² green area to be irrigated. Calculate the water storage & the pumping rate per hour.

$500 \times 0.02 = 10 \text{ m}^3$. & the pumping rate is 10 m³/h.

Pipe sizing

Determine the number of FU's
From Table W-1

Determine the probable flow rate gpm
From Chart-1 or Table W-2

Determine the Pipe size
Pipe flow Chart-2

*N.B. Pipe material should be known in order to
use the corresponding pipe flow chart.*

Probable Water Demand F.U.'s (Cold + Hot)

Table W-2

Standard Plumbing Code of USA

Ref [2]

<u>Fixture Type</u>	<u>Use</u>	<u>F.U.s</u>
Water closet - Flush tank	(Private)	3
Water closet - Flush valve	(Public)	10
Bidet	(Private)	2
Bath tub	(Private)	2
Lavatory	(Private)	1
Lavatory	(Public)	2
Shower	(Private)	2
Shower	(Public)	3
Urinal - Flush tank	(Public)	5
Kitchen sink	--	2
Restaurant sink	--	4
Mop sink	--	3
Drinking fountain	--	1/2
Dish washer, washing mach.	(Private)	2

The value for separate hot and cold water demands should be taken as $\frac{3}{4}$ of the total value

Table W-2
Ref [2]

Fixture	Occupancy	Type of supply control	Load values, in water supply fixture units		
			Cold	Hot	Total
Bathroom group	Private	Flush tank	4.5	3.0	6.0
Bathroom group	Private	Flush valve	6.0	3.0	8.0
Bathtub	Private	Faucet	1.5	1.5	2.0
Bathtub	Public	Faucet	3.0	3.0	4.0
Bidet	Private	Faucet	1.5	1.5	2.0
Combination fixture	Private	Faucet	2.25	2.25	3.0
Dishwashing machine	Private	Automatic		1.0	1.0
Drinking fountain	Offices, etc.	¾" valve	0.25		0.25
Kitchen sink	Private	Faucet	1.5	1.5	2.0
Kitchen sink	Hotel, Restaurant	Faucet	3.0	3.0	4.0
Laundry trays (1 to 3)	Private	Faucet	2.25	2.25	3.0
Lavatory	Private	Faucet	0.75	0.75	1.0
Lavatory	Public	Faucet	1.5	1.5	2.0
Service sink	Offices, etc.	Faucet	2.25	2.25	3.0
Shower head	Public	Mixing valve	3.0	3.0	4.0
Shower stall	Private	Mixing valve	1.5	1.5	2.0
Urinal	Public	1" flush valve	10.0		10.0
Urinal	Public	¾" flush valve	5.0		5.0
Urinal	Public	Flush tank	3.0		3.0
Washing machine (8 lb)	Private	Automatic	1.5	1.5	2.0
Washing machine (8 lb)	Public	Automatic	2.25	2.25	3.0
Washing machine (16 lb)	Public	Automatic	3.0	3.0	4.0
Water closet	Private	Flush valve	6.0		6.0
Water closet	Private	Flush tank	3.0		3.0
Water closet	Public	Flush valve	10.0		10.0
Water closet	Public	Flush tank	5.0		5.0
Water closet	Public or Private	Flushometer Tank	2.0		2.0

NOTE: For fixtures not listed, loads should be assumed by comparing the fixture to one listed using water in similar quantities and at similar rates. The assigned loads for fixtures with both hot and cold water supplies are given for separate hot and cold water loads, the separate hot and cold water loads being three-fourths of the total load in each case.

Figure 12.3 Load values assigned to fixtures, Table F101 of the 1991 edition of The Standard Plumbing Code* with permission from the International Association of Plumbing and Mechanical Officials.

Sizing the indoor cold water pipe

The value for separate hot and cold water demands should be taken as $\frac{3}{4}$ of the

SIMULTANEOUS DEMAND

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Probability of Use:

(a) The probability that all the taps in a commercial building or a section of the piping system will be in use at the same moment is **quite remote**. If pipe sizes are calculated assuming that all taps are open simultaneously, the pipe diameters arrived at will be prohibitively large, economically unviable and unnecessary.

(b) A 100% simultaneous draw-off may, however, occur if the water supply hours are severely restricted in the building. It also occurs in buildings, such as factory wash-rooms, hostel toilets, **showers in sports facilities**, places of worship and the like, In these , cases, all fixtures are likely to be open at the same time during entry, exit and recess. The pipe sizes must be determined for 100% demand.

(c) In buildings with normal usage, the probability of simultaneous flow is based on statistical methods derived from the total number of draw-off points , average times between draw-offs on each occasion and the time interval between occasion of use . There is complex formula to get the probable water demand, however a simple chart & table are used to determine the probable water demand which are presented below in chart 1 & table W-3.

Remark Chart 1 & Table W-3 cover both **flash tank** and **Flash valve** data.

Ref [2]

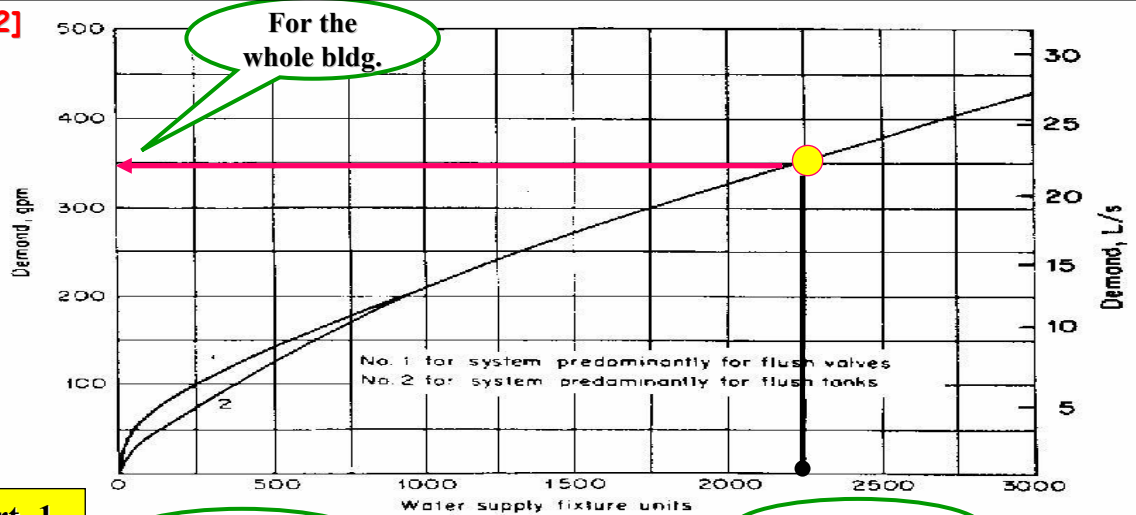
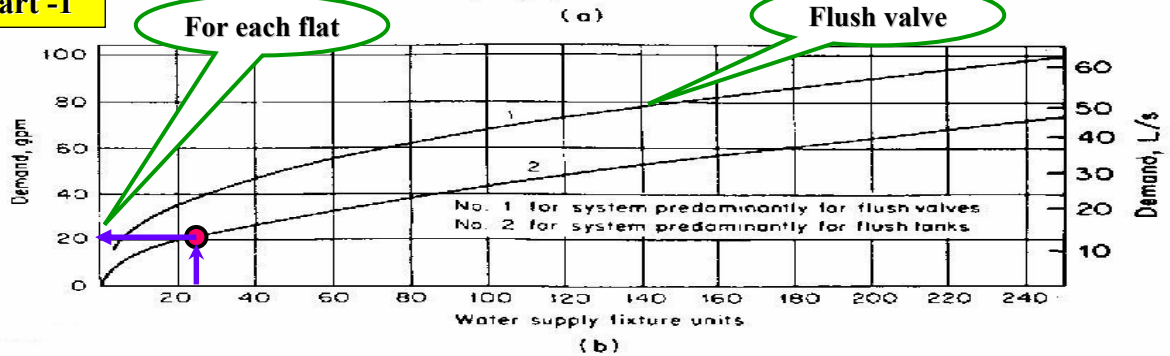


Chart -1



(a) The estimated demand in gallons per minute or liters per second corresponding to a given load expressed in fixture units. (b) A detail of Fig. 2.1a for small demand.

Table W-3 Ref [2]

Fixture Units equivalent to water flow in gpm

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Supply systems predominantly for flush tanks			Supply systems predominantly for flush valves		
Load	Demand		Load	Demand	
(Water supply fixture units)	(Gallons per minute)	(Cubic feet per minute)	(Water supply fixture units)	(Gallons per minute)	(Cubic feet per minute)
1	3.0	0.04104			
2	5.0	0.0684			
3	6.5	0.86892			
4	8.0	1.06944			
5	9.4	1.256592	5	15.0	2.0052
6	10.7	1.430376	6	17.4	2.326032
7	11.8	1.577424	7	19.8	2.646364
8	12.8	1.711104	8	22.2	2.967696
9	13.7	1.831416	9	24.6	3.288528
10	14.6	1.951728	10	27.0	3.60936
11	15.4	2.058672	11	27.8	3.716304
12	16.0	2.13888	12	28.6	3.823248
13	16.5	2.20572	13	29.4	3.930192
14	17.0	2.27256	14	30.2	4.037136
15	17.5	2.3394	15	31.0	4.14408
16	18.0	2.40624	16	31.8	4.241024
17	18.4	2.459712	17	32.6	4.357968
18	18.8	2.513184	18	33.4	4.464912
19	19.2	2.566656	19	34.2	4.571856
20	19.6	2.620128	20	35.0	4.6788
25	21.5	2.87412	25	38.0	5.07984
30	23.3	3.114744	30	42.0	5.61356
35	24.9	3.328632	35	44.0	5.88192
40	26.3	3.515784	40	46.0	6.14928
45	27.7	3.702936	45	48.0	6.41664

Volume Flow Rate (Cold+Hot) at The Inlet of Flat.

Pipe size at inlet of the flat is determined based on FU's. For example suppose it is require to determine the inlet flow rate (gpm) of an apartment having the following fixtures:

3 W.C(flash tank) + 2 bidet + 3 lavatory + 1 shower + 2 bath tube + 1 sink + 1 Dish washer.

From table W-1 we get :

$(3 \times 3 \text{ F.U} + 2 \times 2 \text{ F.U} + 3 \times 1 \text{ F.U} + 2 \times 1 \text{ F.U} + 2 \times 2 \text{ F.U} + 1 \times 2 \text{ F.U} + 1 \times 2 \text{ F.U}) \cong 26 \text{ F.U}$

From Graph-1 or table-2 we select the probable water demand for each identical flat : is 20 gpm (1.24 L/s).

Volume Flow Rate (Cold+Hot) for the whole building.

If two risers pipe are used to supply water for the whole building The probable flow rate is determined as follows:

Assuming 24 floors each floor has 4 identical apartments
As calculated before the probable water demand for each apartment is 26 F.U'S , therefore $24 \times 26 \times 4 = 2496$ F.U'S let say 2500 FU's.

Inter Graph-1 with a value of 2500 FU and read the corresponding probable water demand for whole building which is $\cong 3000$ gpm . Since we have four risers the total gpm is divided by 4 , that will be 750 gpm.

Each riser will be sized based on this value i.e. 750 gpm.

Without question the plumbing fixture in this blg.will not operate simultaneously , the diversity factor is included in Chart -1

Sizing a Water supply system

The most important design objective in sizing the water supply system is the satisfactory supply of potable water to all fixtures, at all times, and a proper pressure and flow rate for normal fixture operation. This may be achieved only if adequate sizing of pipes are provided.

The sizes established must be large enough to prevent occurrence of negative pressure in any part of the system during periods of peak demand in order to avoid the hazard of water supply , contamination due to back flow and back flow and back siphonage from potential sources of pollution.

Main objectives in designing a water supply system are:

- a) To achieve economical size of piping and eliminate over design.
- b) To avoid corrosion-erosion effects and potential pipe failure or leakage conditions owing to corrosive characteristic of the water.
- c) To eliminate water hammering damage and objectionable whistling noise effects in piping due to excess design velocities of flow .

Pipe sizing

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Pipe flow charts are available which shows the relation between the water flow in gpm or L/s , pressure drop in Psi or ft / 100 ft , pipe diameter in mm or inches and the corresponding flow velocity in m/s or ft/s.

The acceptable pressure drop per 100 ft is around **2-5 Psi/100ft** ,that, in order to avoid excessive pressure loss and the need for higher pressure to maintain the flow rate.

Low velocity pipe less than 0.5 m/s can cause precipitation of sand and others in the pipe .

Pipe flow charts are available for different pipes material such as copper water tube, galvanized iron, & plastic pipes.

Sizing based on Velocity limitation

In accordance with good engineering practice, it is recommended that maximum velocity in water supply piping to be limited to no more than 8 ft/sec (2.4m/sec), this is a deemed essential in order to avoid such objectionable effects as the production of whistling line sound noise, the occurrence of cavitation, and associated excessive noise in fittings and valves.

It is recommended that maximum velocity be limited no more than 4ft/sec (1.2m/sec) in branch piping from mains, headers, and risers outlets at which supply is controlled by means of quick-closing devices such as an automatic flush valve, solenoid valve, or pneumatic valve, or quick closing valve or faucet of self closing, push-pull, or other similar type. This limitation is deemed necessary in order to avoid development of excessive and damaging shock pressures in piping equipment when flow is suddenly shut off. But any other kind of pipe branch supply to water closet (tank type) and non-quick closing valves is limited to 4 ft/sec(1.2 m/sec). Ref [2]

Recommendation for minimizing cost of pumping

Velocity limitation is generally advisable and recommended in the sizing of inlet and outlet piping for water supply pumps . Friction losses in such piping affect the cost of pumping and should be reduced to a reasonable minimum .the general recommendation in this instance is to limit velocity in both inlet and outlet piping for water supply pumps to no more than 4ft/sec (**1.2 m/sec**),_this may also be applied for constant-pressure booster-pump water supply system

SIMPLIFIED STEP BY STEP PROCEDURE FOR SIZING PIPING (Based on Velocity limitation) Ref [2]

The procedure consists of the following steps:

1-Obtain the following information:

- (a) Design bases for sizing
- (b) Materials for system
- (c) Characteristics of the water supply
- (d) Location and size of water supply source
- (e) Developed length of system (straight length + equivalent length of fittings)
- (f) Pressure data relative to source of supply
- (g) Elevation
- (h) Minimum pressure required at highest water outlet

2-Provide a schematic elevation of the complete water supply system. Show all piping connection in proper sequence and all fixture supplies. Identify all fixture and risers by means of appropriate letters numbers or combinations .Specially identify all piping conveying water at a temperature above 150F(66 C), ,and all branch piping to such water outlets as automatic flush valves, solenoid valves, quick-closing valves.

Provide on the schematic elevation all the necessary information obtained as per step1

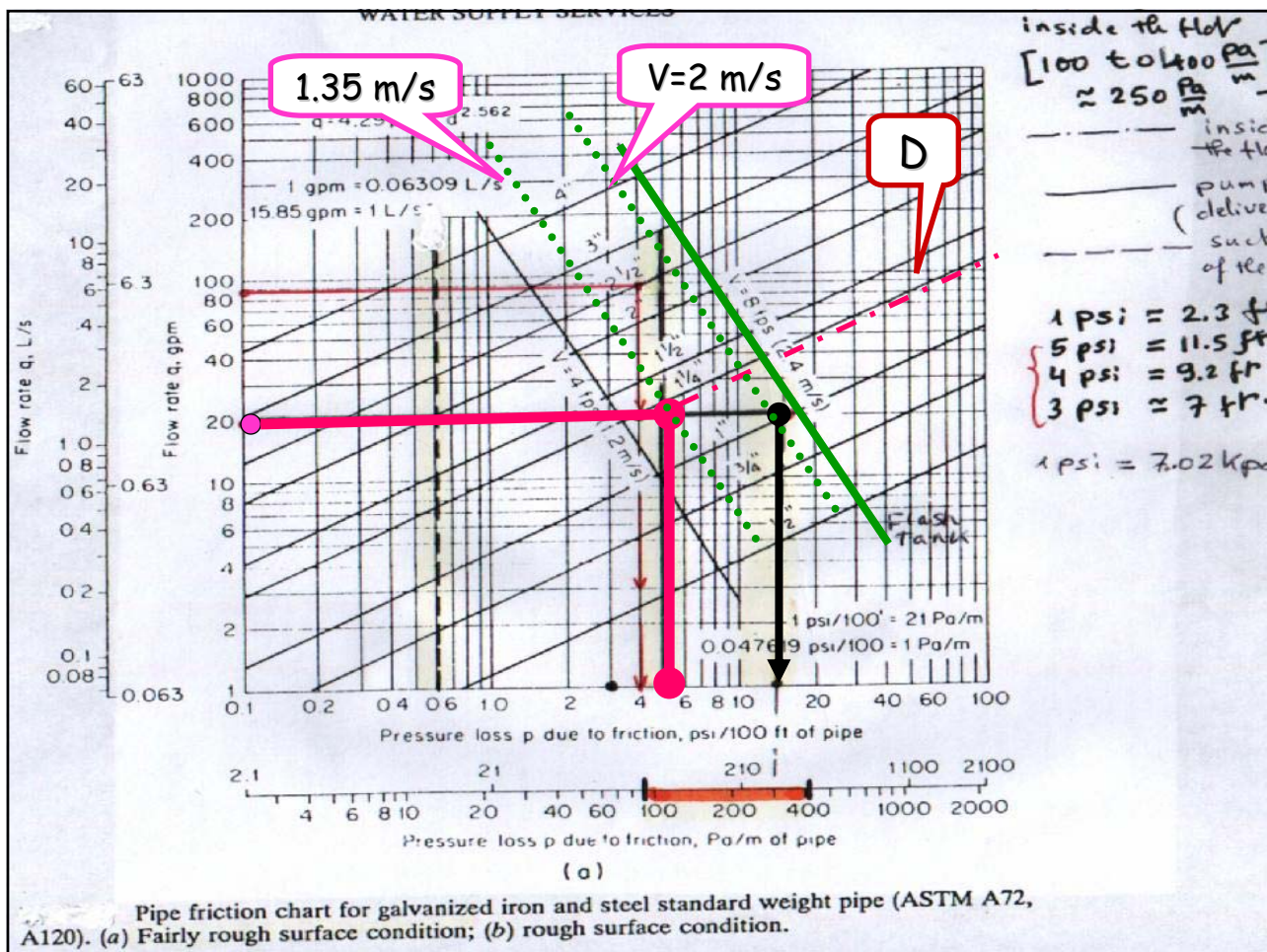
3-Mark on the schematic elevation for each section of the complete system, the hot- and cold water loads conveyed thereby in terms of water supply fixture units in accordance with table (wsfu -gpm).

4-mark on the schematic elevation adjacent to all fixture unit notations, the demand in gallons/min or liter/sec, corresponding to the various fixture unit loads in accordance with table (wsfu-gpm).

5-Mark on the schematic elevation for appropriate sections of the system, the demand in gallons /min or liter/sec for outlets at which demand is deemed continuous, such as outlets for watering gardens irrigating lawn ,air-conditioning apparatus refrigeration machines, and other using continuously water. Add the continuous demand to the demand for intermittently used fixtures and show the total demand at those sections where both types of demand occur

6-size all individual fixture supply pipes to water outlets in accordance with the minimum sizes permitted by regulations. Minimum supply pipe size is given in table (1).

7-Size all parts of the water supply system in accordance with velocity limitation recognized as good engineering practice, with velocity limitation for proper basis of design, 2.4 m /sec for all piping, except 1.2 m /sec for branches to quick closing valves .



How to use the pipe flow-chart

The use of the pipe flow chart is best presented by an **example** : A fairly rough steel pipe is used to deliver **20 gpm** of water at ordinary temperature with a **maximum** allowed pressure drop of **5Psi/100 ft** .**What is the recommended pipe size that can be used ?**

Solution : Enter the Figure along the abscissa with the value of **5 Psi/100 ft** , move upward to the ordinate where Q_v is **20 gpm** .From the intersection ; read the values of (**D**)and the corresponding flow velocity (**V**) .

Now it is clear that the intersection lies between **1.1/4"** and **1"** diameter . If the **1 in** pipe is used , the pressure drop will be **15 Psi/100 ft** which is greater than the given value . This **is unacceptable** . If the **1.1/4"** pipe is used , the pressure drop will be **4 Psi/100 ft** which is less than the maximum allowed pressure drop .I would recommend **D=1.1/4"** with a flow velocity less than **3 m/s** .**The flow velocity is about 1.35 m/s** .

Size of Principal Branches and Risers

- The required size of branches and risers may be obtained in the same manner as the building supply by obtaining the demand load on each branch or riser and using the permissible friction loss described before.
- Fixture branches to the building supply, if they are sized for them same permissible friction loss per one hundred (100 feet) of pipe as the branches and risers to the highest level in the building, **may lead to inadequate water supply to the upper floor of a building (case of upfeed water supply) .** This may be controlled by:
 - (1) Selecting the sizes of pipe for the different branches so that the total friction loss in each lower branch is approximately equal to the total loss in the riser, including both friction loss and loss in static Pressure;

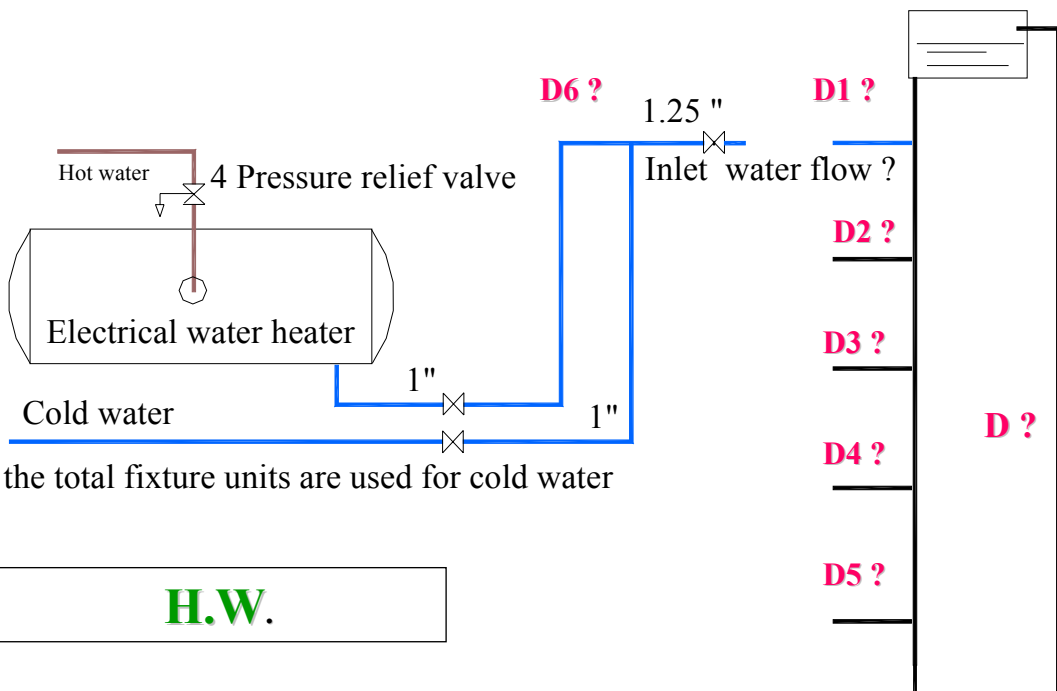
(2) throttling each such branch by means of a valve until the preceding balance is obtained;

(3) increasing the size of the building supply and risers above the minimum required to meet the maximum permissible friction loss.

Refer to Upfeed & down feed system .

- The size of branches and mains serving flush tanks shall be consistent with sizing procedures for flush tank water closets. *(Courtesy of The Uniform Plumbing Code).*

Sizing the riser diagram



Equal friction loss

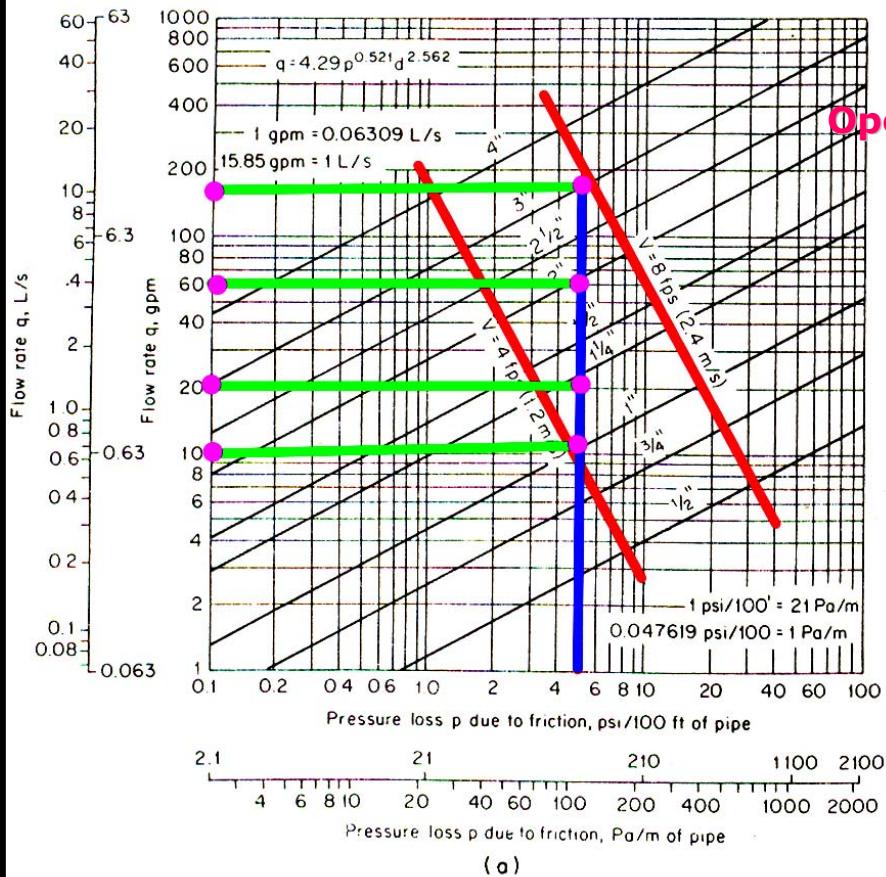
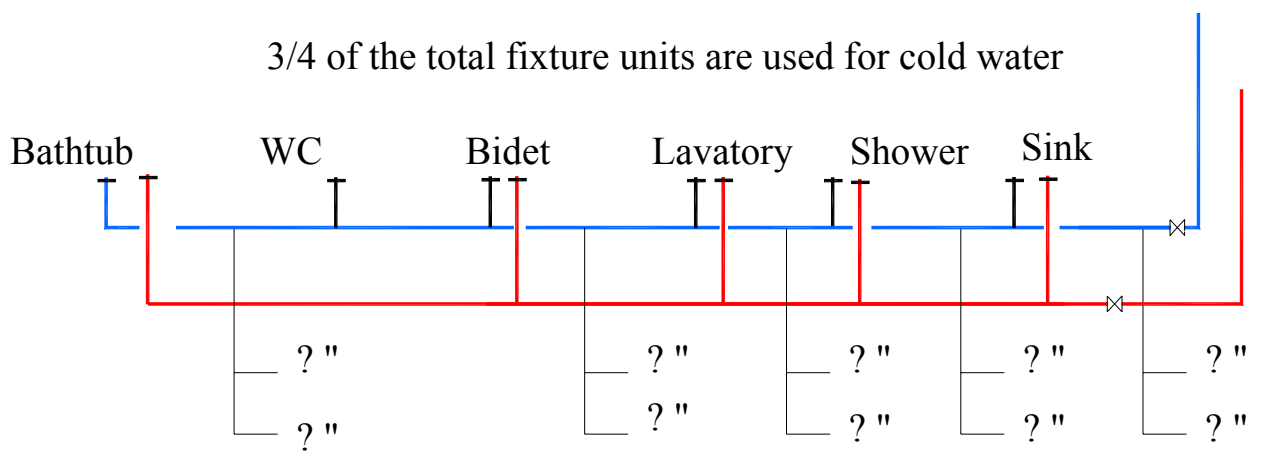


FIG. 7.6 Pipe friction chart for galvanized iron and steel standard weight pipe (ASTM A72, A120). (a) Fairly rough surface condition; (b) rough surface condition.

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3/4 of the total fixture units are used for cold water



Determine the pipe sizes of the present drawing

H.W.

Minimum size of fixture supply pipe

The diameters of fixture supply pipes should not be less than sizes in table below . The fixture supply pipe should terminate not more than 30 inch (0.762 m), from the point of connection to the fixture.

Fixture	Minimum size of pipe
Bathtub	" $\frac{1}{2}$
Drinking fountain	" $\frac{8}{3}$
Dishwashing machine	" $\frac{1}{2}$
Lavatory	" $\frac{8}{3}$
single head-Shower	" $\frac{1}{2}$
flushing rim-Shower	" $\frac{3}{4}$
flush tank-Urinal	" $\frac{1}{2}$
in flush valve1-Urinal	" $\frac{3}{4}$
flush valve-Water closet	"1
flush tank-Water closet	" $\frac{1}{2}$

TABLE 7.2 Minimum Size of Fixture Supply Pipes

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Fixture or device	Size	
	in	cm
Bathtub	½	1.27
Combination sink and laundry tray	½	1.27
Drinking fountain	¾	0.95
Dishwashing machine (domestic)	½	1.27
Kitchen sink (domestic)	½	1.27
Kitchen sink (commercial)	¾	1.90
Lavatory	¾	0.95
Laundry tray (1, 2, or 3 compartments)	½	1.27
Shower (single head)	½	1.27
Sink (service, slop)	½	1.27
Sink (flushing rim)	¾	1.90
Urinal [1 in (2.54 cm) flush valve]	1	2.54
Urinal [¾ in (1.9 cm) flush valve]	¾	1.90
Urinal (flush tank)	½	1.27
Water closet (flush tank)	¾	0.95
Water closet (flush valve)	1	2.54
Hose bib	½	1.27
Wall hydrant or sill cock	½	1.27

Note: For fixtures not listed in the above table, the minimum size of fixture supply pipes shall be the same as given in the table for comparable fixtures.

Ref [2]

General remarks on the installation of water pipes

- 1- Every apartment should have a valve on the main cold water pipe feeding this apartment. Every bathroom should have two valves one for cold and the second for hot water pipe.
- 2- Each plumbing Fixture should have an angle valve for maintenance reason.
- 3- Exposed pipes are installed approximately 3 cm from wall with hangers and supports.
- 4- Antirust paint is recommended for all exposed steel pipes.
- 5- Pipes under tiles or in walls are PPR if however steel pipes are used, the pipes are wrapped with jute and asphalt.
- 6- Pipes crossing walls should be through pipe sleeves

A rule of thumb is that not more than two fixtures should be served by a single $\frac{1}{2}$ " branch

Pressure Requirements

- 1- Pressure required during flow for different fixtures.
- 2- Pressure required at the inlet of the flat.
- 3- The hydrostatic pressure available at each shut-off valve.
- 4- Pressure reducer valve PRV

Pressure Required During Flow for Different Fixtures

Rate of Flow and Required Pressure during Flow for Different Fixtures

Fixture	Flow pressure ¹ (psi)	Flow rate (gpm)
Ordinary basin faucet.....	8	3.0
Self-closing basin faucet.....	12	2.5
Sink faucet, $\frac{3}{8}$ in.....	10	4.5
Sink faucet, $\frac{1}{2}$ in.....	5	4.5
Bathtub faucet.....	5	6.0
Laundry tub cock, $\frac{1}{2}$ in.....	5	5.0
Shower.....	12	5.0
Ball cock for closet.....	15	3.0
Flush valve for closet.....	10-20	15-40 ²
Flush valve for urinal.....	15	15.0
Garden hose, 50 ft, and sill cock.....	30	5.0

N.P.Code USA

Ref [8]

¹ Flow pressure is the pressure in the pipe at the entrance to the particular fixture considered.

² Wide range due to variation in design and type of flush-valve closets.

Pressure Required At The Inlet Of each Flat

As it well known the Hydrostatic pressure @ shut-off valve is given by :

$$P = \gamma \times h$$

Where γ is the specific weight kN/m^3 & h is the pressure head in m

The maximum pressure at the inlet of the flat is Limited to 30 m which is about 2.9 bar , that , avoid excessive pressures

If the pressure is more than 2.9 Bar :

You may need break-pressure tank or pressure reducing valve.

The available pressure at the inlet of the flat, has to overcome the pressure loss due to pipe friction and fittings of the longest branch and have a surplus pressure to operates the most critical fixture (for example Dish washer or shower).

Pressure Drop, $P = \gamma \times h_L + \text{Surplus pressure}$ (h_L is the head loss due to pipe friction)

Allowing additional pressure drop around 25-30% for fittings on straight pipe or calculate the effective length for minor losses as described in Fluid Mechanics Lecture notes. **It is always recommended to use the K value for the calculation of the pressure drop.**

Example of high riser
Building

24
floors

Ref [4]



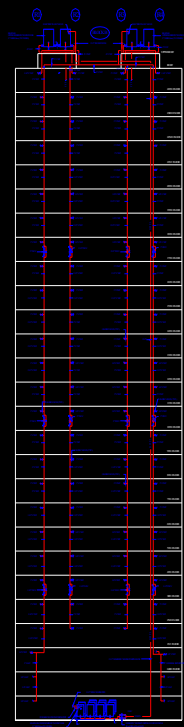
The hydrostatic pressure available at each shut-off valve.

The value of the static pressure (at shut off valve) at inlet of each floor:

Floor	h (m)	Pst (bar)
24	6	0.588 Critical
23	9	0.882 Critical
22	12	1.174 just about
21	15	1.47
20	18	1.764
19	21	2.058
18	24	2.352
17	27	2.646
16	30	2.94 max. limit
15	33	3.234
14	36	3.528
13	39	3.822
12	42	4.116
11	45	4.41
10	48	4.704
9	51	4.998
8	54	5.292
7	57	5.586
6	60	5.880
5	63	6.174
4	66	6.468
3	69	6.762
2	72	7.056
1	75	7.350
Ground	78	7.644
Basement 1	81	7.938
Basement 2	84	8.232

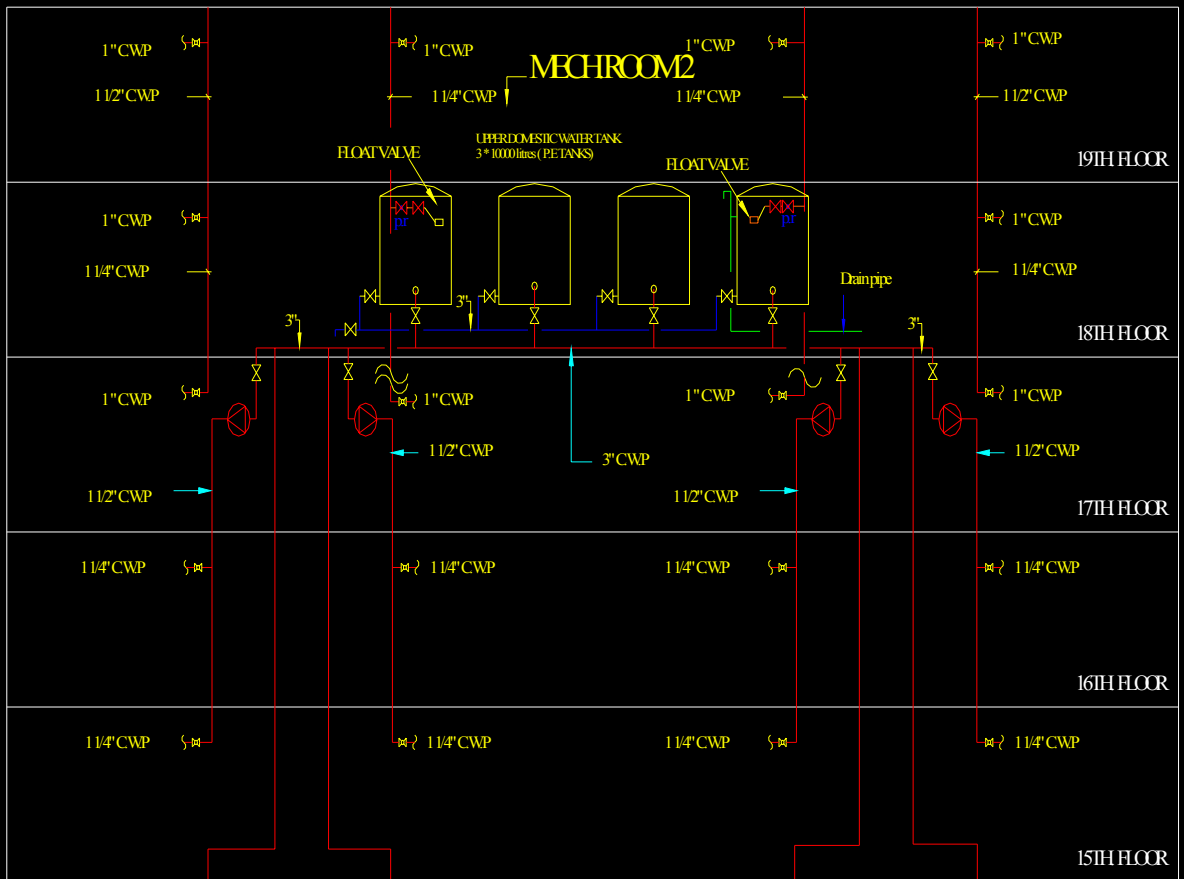
From the above table it is clear that, floors 24, 23 and 22 need additional small booster pumps to compensate the lack of hydrostatic pressure. On the other hand, floor 16 and the floors below it, have the value of the static head reaching more than 2.92 bars, which is not allowable. To avoid this high pressure, two methods are presented: The former is to

*Riser diagram
(pressure reducers)*

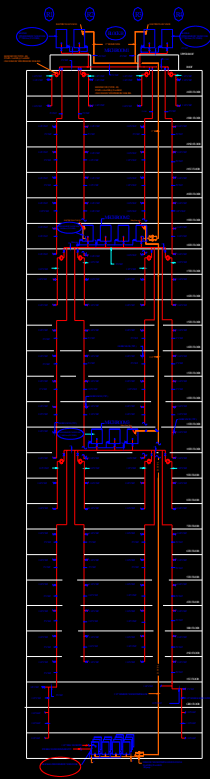


Indirect pumping system

Ref [4]



*Riser diagram
(Break pressure tanks II)*



Indirect pumping system Case study (II)

Ref [4]

The tables below present the new pressure distribution and location of brake pressure tanks. Operating pressure $P = 1.17$ bar (gage).

Zone 3 (Location:Roof) Tank capacity = 30,000 liters

Floor	Height (m)	Pst (bar)	Pipe diam.(in)	Situation
24	6	0.588	1.25"	Critical
23	9	0.882	1.25"	Critical
22	12	1.176	1.25"	Just about
21	15	1.47	1.25"	Acceptable
20	18	1.764	1"	Acceptable use Control valve
19	21	2.058	1"	Acceptable use Control valve
18	24	2.352	1"	Acceptable use Control valve
17	27	2.646	1"	Acceptable use Control valve

Zone 2 (Location:18th floor) Tank capacity = 35,000 liters

Floor	Height (m)	Pst (bar)	Pipe diam.(in)	Situation
16	6	0.588	1.25"	Critical
15	9	0.882	1.25"	Critical
14	12	1.176	1.25"	Just about
13	15	1.47	1.25"	Acceptable
12	18	1.764	1"	Acceptable use Control valve
11	21	2.058	1"	Acceptable use Control valve
10	24	2.352	1"	Acceptable use Control valve
9	27	2.646	1"	Acceptable use Control valve

Zone 1(Location:10th floor) Tank capacities = 30,000 liters

Floor	Height (m)	Pst (bar)	Pipe diam.(in)	Spare pressure
8	6	0.588	1.25"	Critical
7	9	0.882	1.25"	Critical
6	12	1.176	1.25"	Just about
5	15	1.47	1.25"	Acceptable
4	18	1.764	1"	Acceptable use Control valve
3	21	2.058	1"	Acceptable use Control valve
2	24	2.352	1"	Acceptable use Control valve
1	27	2.646	1"	Acceptable use Control valve
Ground	30	2.94	0.75"	smaller pipe size and control valve
Base 1	33	3.234	0.75"	Service
Base 2	36	3.528	0.75"	Service

1

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19TH. FLOOR



18TH. FLOOR



17TH. FLOOR



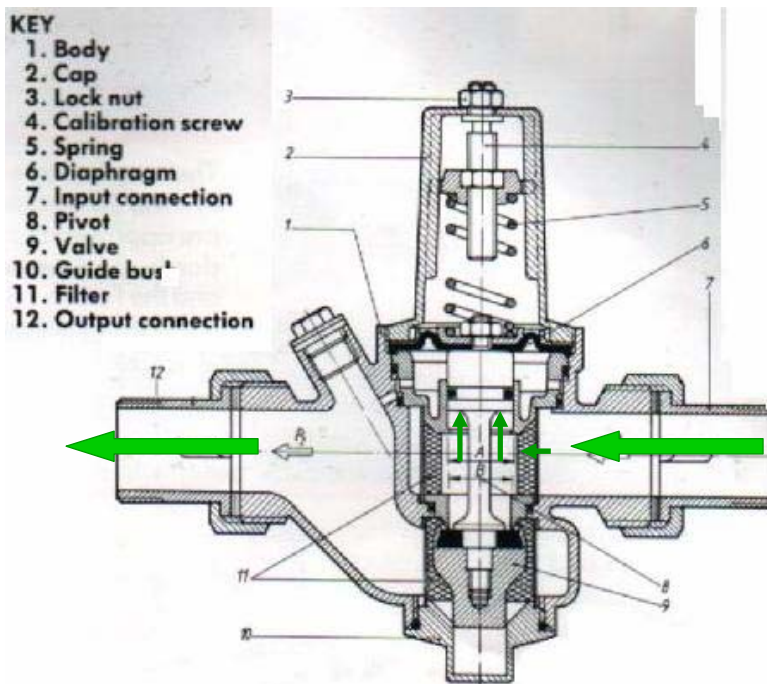
16TH. FLOOR



15TH. FLOOR



Pressure Reducer Valve PRV



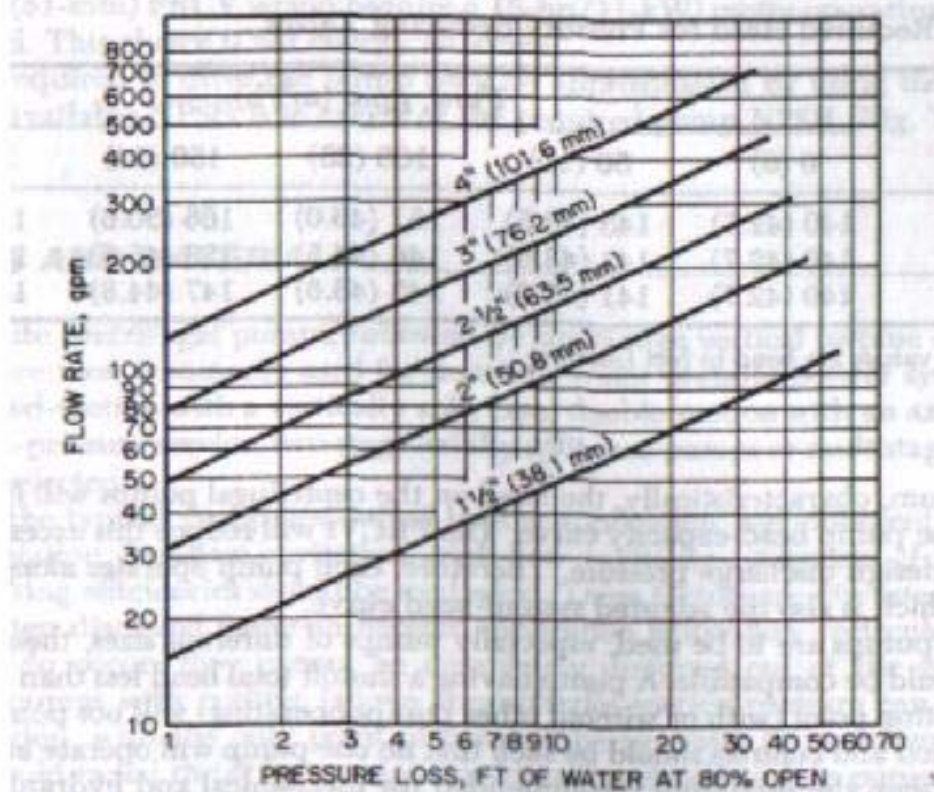


FIG. 6 Typical PRV or PRCV flow chart. (ft $\times$ 0.3048 = m; gpm $\times$ 0.2271 = m³/h; in $\times$ 25.4 = mm) (Cla-Val)

The head loss due to pipe friction & fittings

Review your "lecture notes" .Ref [5] Chap.9-10

Or refer to [10]

Now !!

After completing the above chapters you should be able to :

- 1- Calculate the daily water requirement for the given project & the capacity of the overhead & underground tanks.**
- 2- Recognize the drawing of water distribution system inside the flat.**
- 3- Selecting the type of the riser diagram i.e. Direct or indirect water supply. Sizing the riser diagram. Sizing the pipes inside the bathrooms etc..**
- 4- Justified if the hydrostatic pressure at the inlet of the flat is enough to overcome losses + the surplus pressure to operates the most critical fixture .**
- 5- Do we need a booster pump for top roof?**
- 6-Do we need a break -pressure tank or pressure reducing valve ?**

Now move on to the next part

"Pump selection"

Design of pumping supply system to a building

In engineering practice, the process of pipe sizing and component selection is an *iterative* one , requiring the design engineer to first assume initial values :(the velocity , pressure and allowable pressure loss) and recalculate if necessary using new values if the initial assumption was proved wrong .

The pipe sizing is estimated easily using the pipe flow charts followed by a simple calculation to determine the pumps power. Usually, the equal friction loss method is the simplest method used which gives acceptable results.

The following procedure is used when estimating the pipe size and pumps duty (based on equal friction loss rate)

- 1) Prepare the drawing of the piping /pumping system, measure the length of the pipe connecting the **underground tank** to the **overhead (delivery) tank** and count all fittings along the way .
- 2) Find the required volume flow rate for each flat. Then, add them up to obtain the total flow rate at the peak demand . The probable water demand for each flat is determined based on the number of occupants or based on the total fixture units. (It is not always easy to know the number of occupants in the early stage , so the second method using the T.F.U.s becomes more reliable) .
- 3) Since the equal friction loss method is used , choose a value of friction loss rate for the main riser pipe based on the following limits :
 - a) The recommended friction loss rate is between length or (2 -5 Psi per 100 ft) .
 - b) The velocity in the main should not exceed **1.2-1.8 m / s (say 1.5 m/s)** in small systems , or **2.4- 3 m / s** in larger systems . The velocity in occupied areas should not exceed **2.4 m/s**, so as to prevent noise.

Design of pumping supply system to a building (con't)

4) Select a *pipe size* from the pipe flowcharts based on the above limits . We could also prepare tables which present the pipe diameters , friction factor and flow rate . The tables are regarded as more accurate but the pipe flowcharts are more convenient.

5) Continuing along the circuit chosen , select the succeeding pipe sizes . This should be done according to the following guides:

Determine by inspection which branch will be the longest, or have the greatest equivalent length . Calculate the pressure drop in the longest circuit.

Design of pumping supply system to a building (con't)

6-Calculate :

a) The total effective length **E.L** which is:
The actual pipe length + Equivalent length (due to fittings and valves etc.).

$$L_{\text{eff.}} = L + \sum L_e$$

b) The total head loss or pressure drop **h_L** is :
The head loss per unit of length is about (**5 ft w./100 ft**) multiplied by the effective length .

$$h_L = h_1 \times L_{\text{eff.}}$$

Design of pumping supply system to a building (con't)

7) The approximated pump s power is then calculated as follows :

The head delivered by the pump or the total head of the pump: which is equal to the static head + the total head loss (case of open tanks).

$$h_A = h_{st} + h_L$$

The theoretical power requirement (Water power) is

$$P = \gamma \times h_A \times Q_V .$$

(Where γ is the specific weight of water, h_A is the pump head in m and Q_V is the operating discharge m^3/s). The operating discharge is taken from the intersection of the pump characteristic curve with the pipe system curve.

Safety Margin

To avoid any miscalculation during pump selection, it is recommended to apply a safety margin of around 5% for the estimated flow rate & 10 % for the estimated head.

For example :

Estimated Flow rate $Q = 30 \text{ L/s}$ & Head 25 m

The recommended flow & head will be :

$Q = 30 \text{ L/s} + 5\%$, & $H = 25 \text{ m} + 10\%$

Design of pumping supply system to a building (con't)

8- The shaft power of the pump can be determined by dividing water power by the pump efficiency.

$$\text{Pump Power} = \frac{\gamma \times h_A \times Q_V}{\eta}$$

The motor power of the pump can be determined by dividing water power by the **overall pump** efficiency.

$$\text{Pump Motor Power} = \frac{\gamma \times h_A \times Q_V}{\eta_0}$$

The most popular types of centrifugal pump used for cold water supply systems in buildings are:

For further details Refer to Ref [10]

Vertical Multistage Pumps



Horizontal multistage pump



Vertical - Line shaft submerged-pumps

The usual pumping depth is about **120 m**. Nowadays, a depth of **250 m** can be obtained with multistage turbines.

- This kind of pumps is used for clean water, sewage irrigation and fire fittings, etc.
- A broad selection of driver heads is available to drive the pumps by most common prime movers.
- High performance and low maintenance.



TURBINE, VERTICAL TYPE, MULTISTAGE, DEEP WELL, SUBMERSIBLE

These pumps develop high head by using a series of small impellers rather than a large single one. The characteristic curves for such pumps depend upon the number of stages or impellers. Each impeller has the same characteristic curve and the final curve is obtained by adding them up. The total head at a given discharge is the sum of individual heads (case of series pumps). This kind of pumps may deliver the liquid up from **400 to 500 m** depth.

These pumps are commonly used in tube wells, deep open wells, etc.

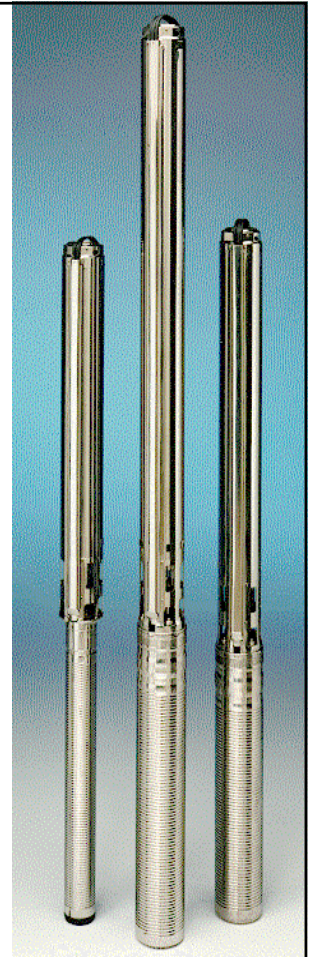


SUBMERSIBLE PUMP



For high heads and low flow.

DEEP WELL



Booster pump Packages

(Auto-pneumatic, pressurized system)

Boosted water directly to each floor.

This method of providing high rise buildings with water supplies is more common, as it does not require electrical wiring from ground/basement where the booster pump is situated to the high level tank room where the float switches are located in the storage tank and drinking water header.

There are a number of specialist pump manufacturers who offer water pressurization plant similar to that shown in the pressurization unit drawing. The cold water down service will require pressure reduction at intervals of five storeys to avoid excessive pressures at the draw off points. The pressure vessel is sized to hold the calculated quantity of water, as a rule of thumb the vessel capacity is about **15 minutes** the actual discharge.

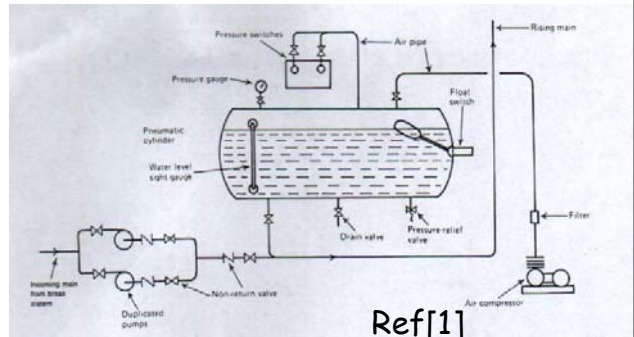
As water is drawn off through the high level fittings, the water level in the vessel falls. At a predetermined low level a pressure switch activates the booster pump.

The capacity of the pneumatic pressure tank :

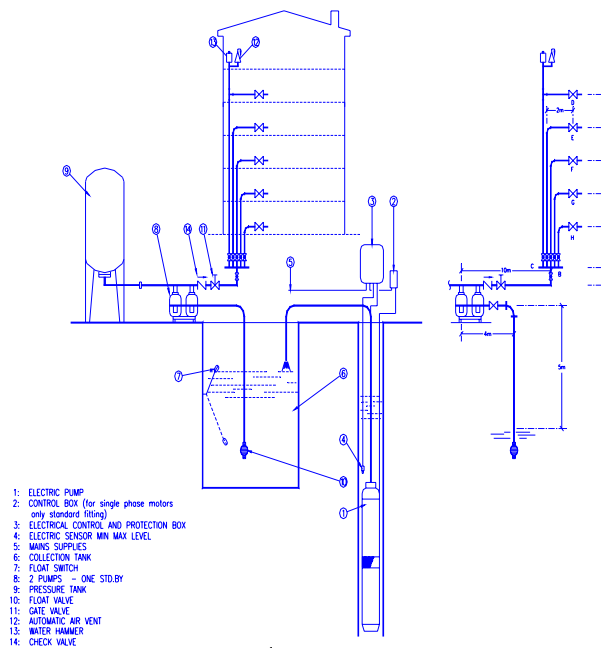
$$V_{\min} = \frac{\text{net volume}}{\text{Degree of admission}}$$

The net volume = $Q_{\max} \times T$, where $Q_{\max}$ = Peak water demand ,
 T = 15 minutes storage of $Q_{\max}$
 , where P_2 and P_1 are the Maximum and minimum allowable operating pressure in absolute values.

$$\text{Degree of admission} = \frac{P_2 - P_1}{P_2}$$



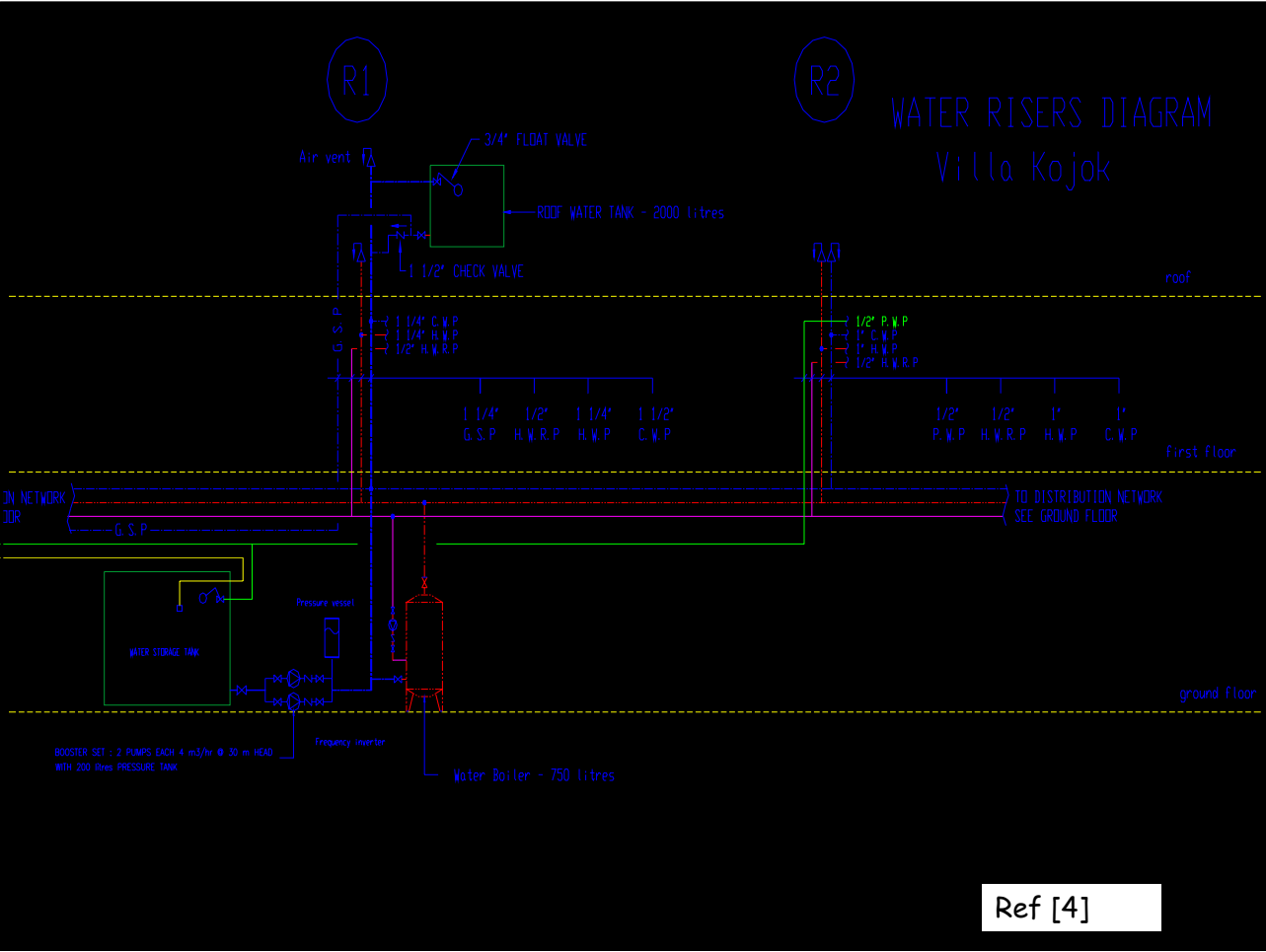
Booster pump, pressurized system "balloon" type



Booster Pump, Pressurized System "Balloon" Type

Used for direct supply system, e.g. Villa etc..





Sphere booster Units

Is used for boosting the water to top floors, when the hydrostatic pressure at the inlet of the flat is less than the recommended pressure requirement .

Location : In the attic or on the roof.

As a rule of thumb the vessel capacity is about **2 minutes** the actual pump discharge.



Domino booster

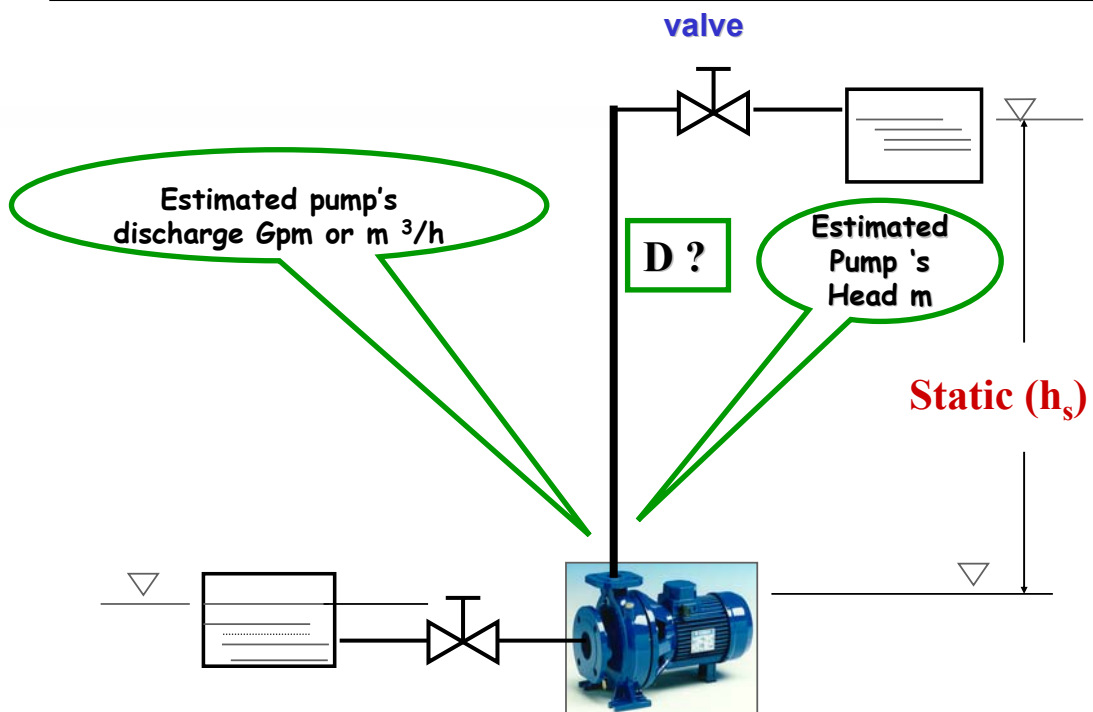
Is used for boosting the water to top floors, when the hydrostatic pressure at the inlet of the flat is less than the recommended pressure requirement .

Location : In the attic or on the roof.



Ref [7]

Discharge & pressure head

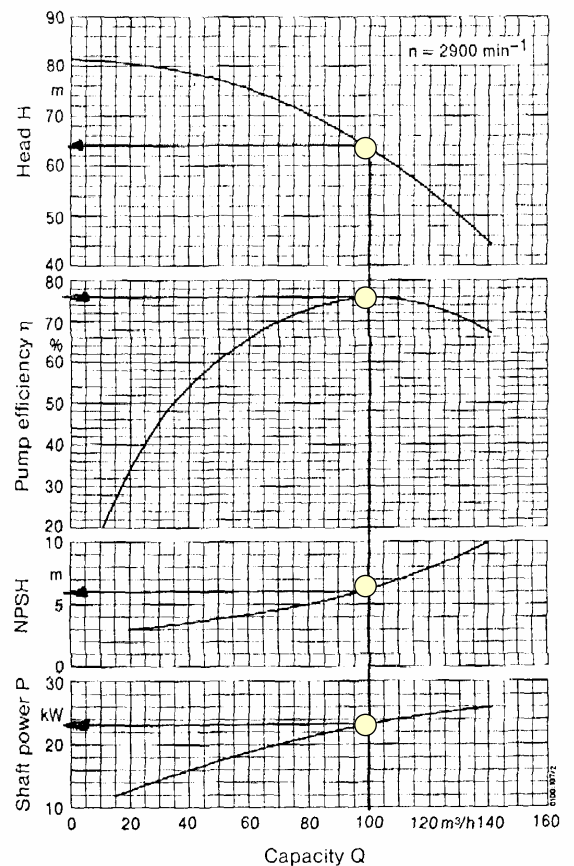


Each pump drawing should have the value of H & Q .

Review of the Performance Characteristics curves of a water centrifugal pump

- Q-H curve
- Efficiency curve
- Shaft power curve
- NPSH

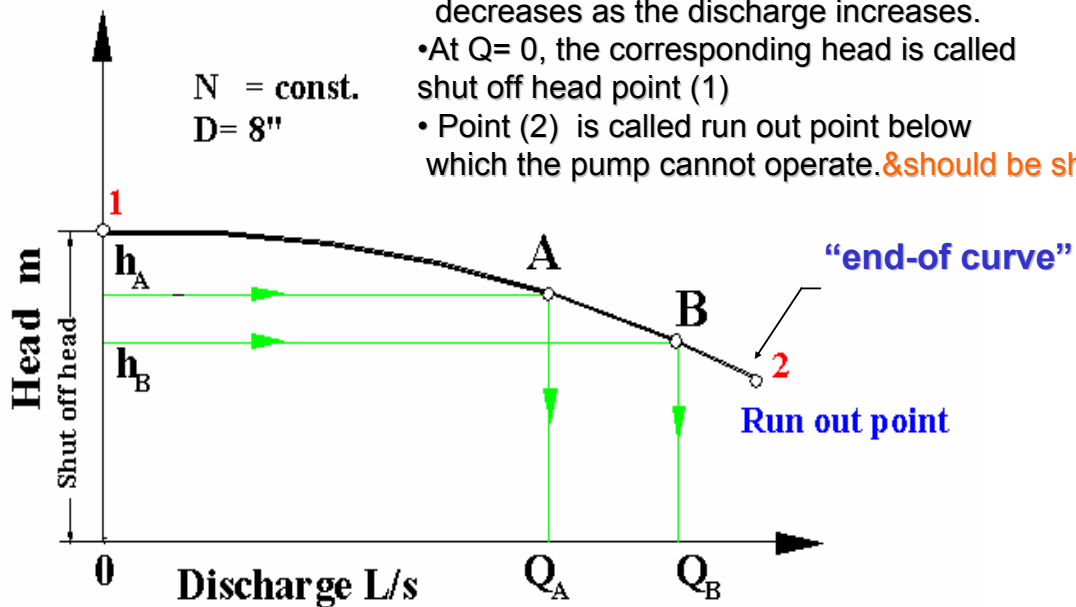
Review



Characteristic curves of a radial centrifugal pump.

1- Head capacity curve

- The available head produced by the pump decreases as the discharge increases.
- At $Q=0$, the corresponding head is called shut off head point (1)
- Point (2) is called run out point below which the pump cannot operate. **& should be shut down**

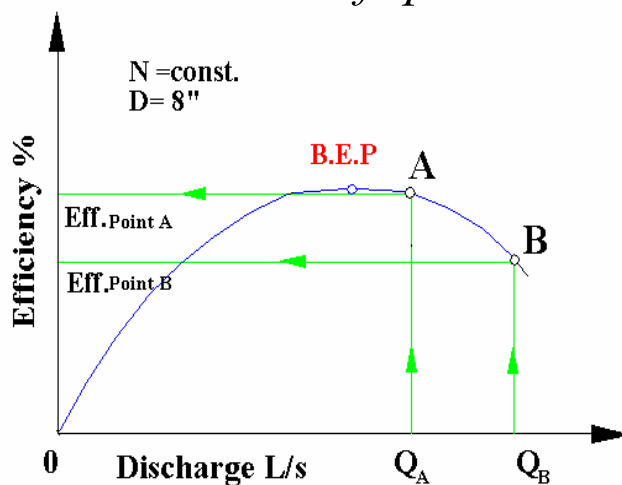


Head capacity curve

2- Efficiency curve

The efficiency of a centrifugal pump is the ratio of water power to brake power.

$$\eta_P = \frac{\text{Water power}}{\text{Shaft power}}$$



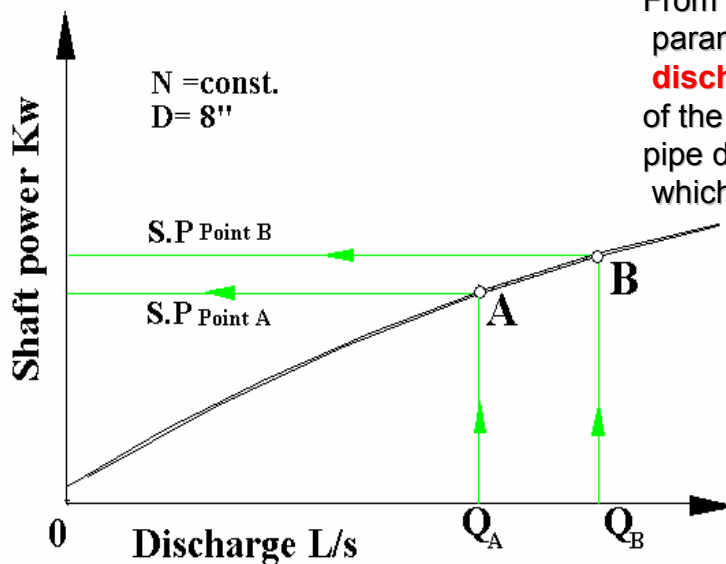
The **highest efficiency of a pump** occurs at the flow where the incidence angle of the fluid entering the hydraulic passages best matches with the blade angle. The operating condition where a pump design has its highest efficiency is referred to as the best efficiency point **B.E.P.**

3- Power curve

The shaft power is determined in order to select a motor for the pump.
The shaft power can be determined directly from the manufacturer's catalogue plot or calculated from the following formula :

$$\text{shaftPower} = \gamma \times H \times Q / \eta$$

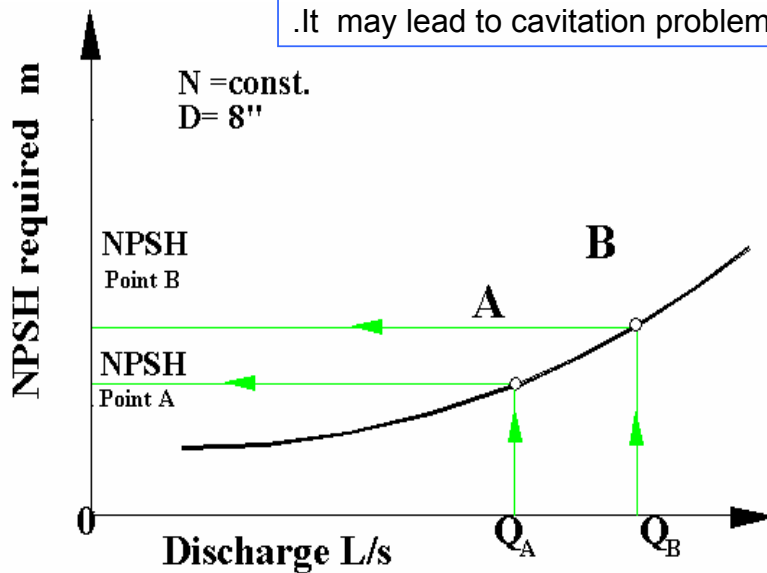
From the equation, it is clear that the main parameter affecting the shaft power is the **discharge and not the head**. This is because of the increase in the discharge for the same pipe diameter leading to additional losses which need more power to drive the pump.



4- NPSH required curve

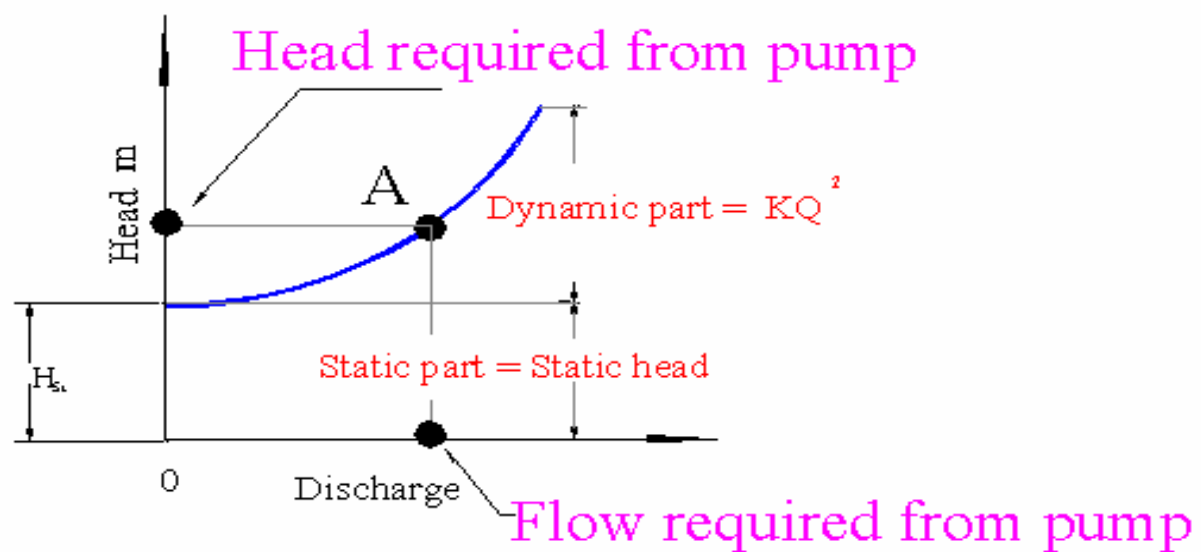
The Net Positive Suction Head Required is the minimum energy required at the suction flange for the pump to operate satisfactorily away from **cavitation** problem .

The NPSHR required increases with an increase in discharge. , Operating the pump near the **run-out** point should be avoided .It may lead to cavitation problem as the NPSHR value is high



How to draw the pipe system resistance curves?

$$h_A = h_{St} + K \times Q^2$$



Sizing the discharge pipe of the pump & the Pumping Rate

In order to size the discharge pipe which feed the roof tanks , the following data are needed:

- 1- The capacity of the roof tanks
- 2- The pumping rate.

N.B. To avoid disturbance & noise the Pumping time is limited to 4 hours /day (CIBSE B4).

If for example , the Pump has to refill the empty overhead tank in 4 hours ,the pumping rate becomes $40 \text{ m}^3 / 4 \text{ h} = 10 \text{ m}^3 / \text{h}$.

If however ,the Pump has to refill the empty overhead tank in 2 hours
The pumping rate becomes $20 \text{ m}^3 / \text{h}$.

Decision has to be made by the consultant engineer to determine the pumping time ,for example one or two hours .

The pumping rate is not the operating point or duty point of the pump.

It is an estimated value used to estimate the flow rate in the pipe. The actual pump discharge is obtained from =>Intersection of the pipe system curve and pump performance curve.

Refer to your " Lecture notes " [Ref [6]] .

The estimated pump' s head

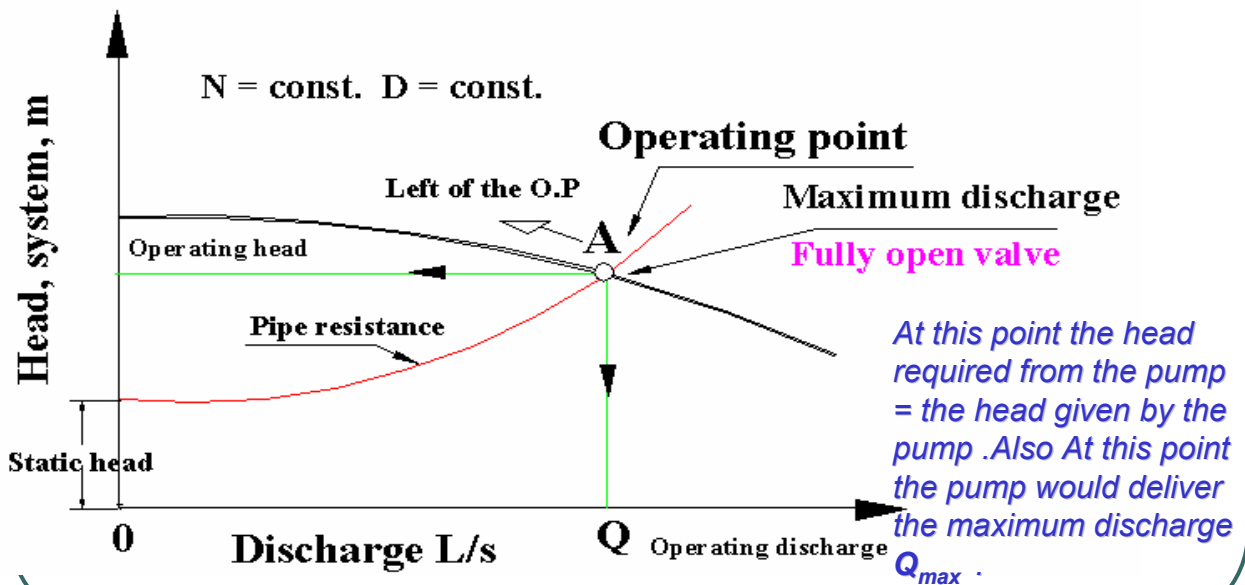
As it is known that , the role of the pump is to overcome loss + elevation difference + dynamic head.

$$h_A = h_L + Z_2 - Z_1 + \frac{V^2}{2 \cdot g}$$

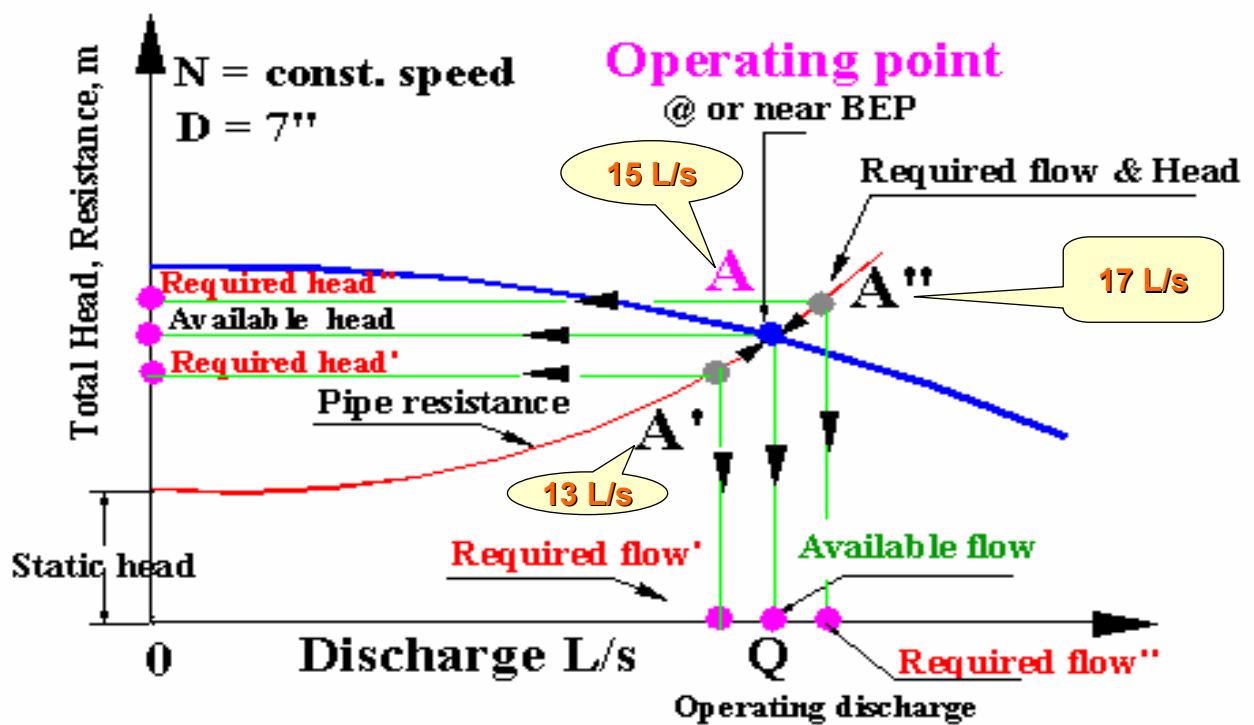
- The elevation difference represents the total static head which is the vertical distance between the water surface level of the suction and discharge tanks.
- The dynamic head is too small, practically it can be neglected.

“Operating point or duty point “

A centrifugal pump operating in a given system will deliver a flow rate corresponding to the intersection of its head-capacity curve with the pipe system curve. The intersection point is called “ **Duty point or operating point** ”



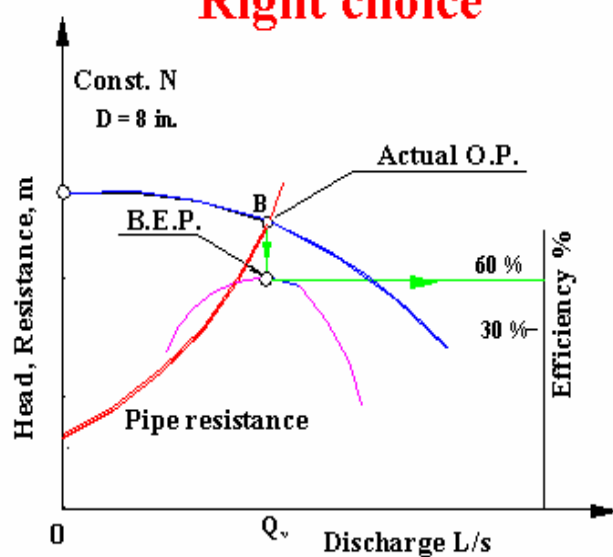
Pump selection limitations



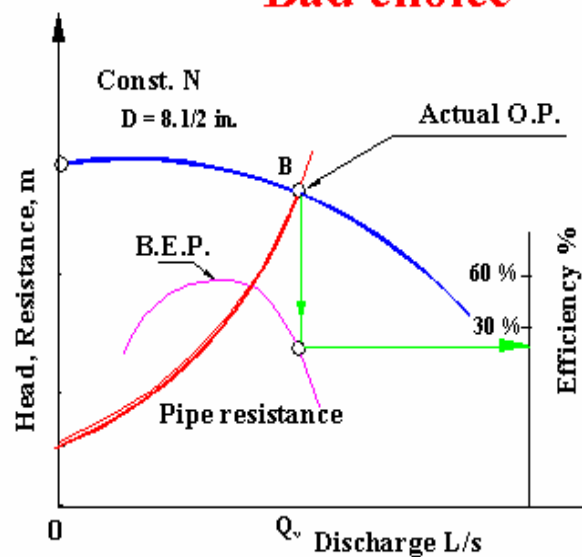
"Pump selection "

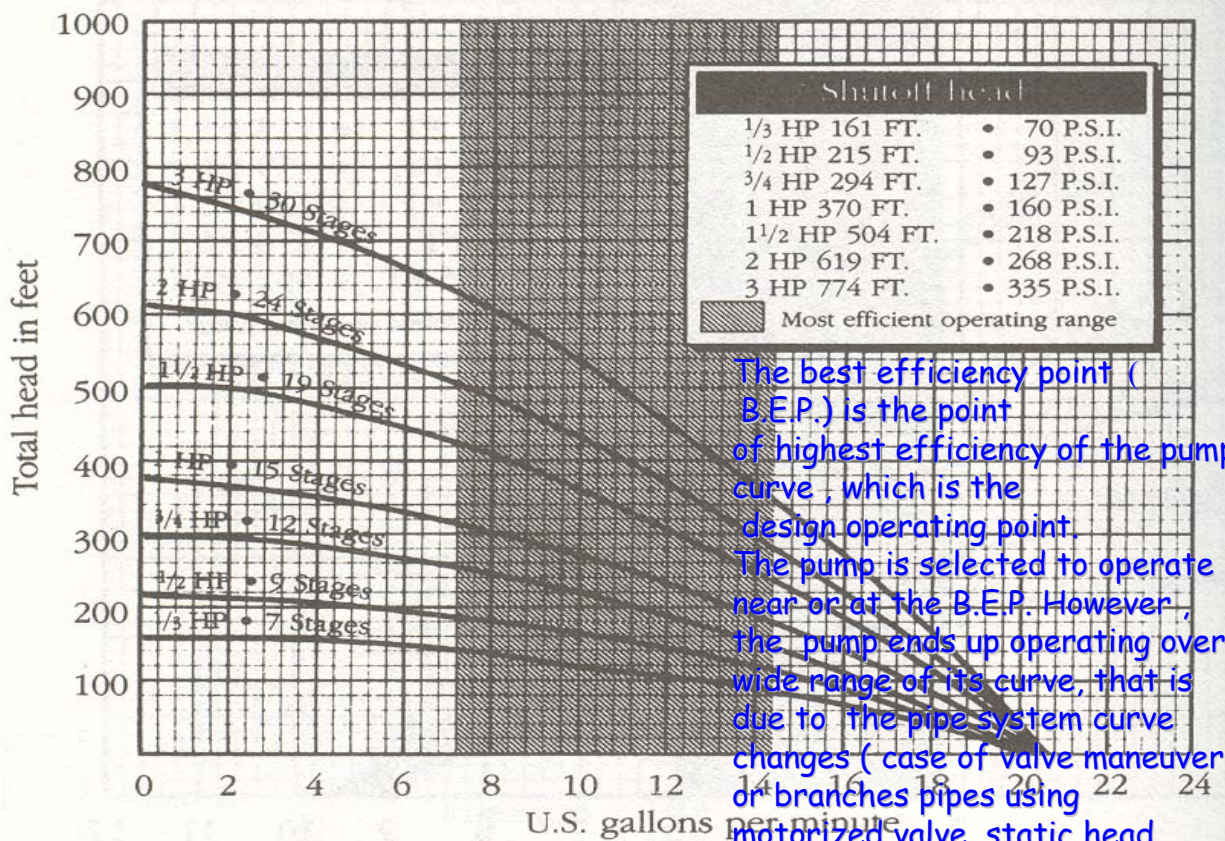
Pump is selected based on the B.E.P. or nearly so .

Right choice



Bad choice





The best efficiency point (B.E.P.) is the point of highest efficiency of the pump curve, which is the design operating point. The pump is selected to operate near or at the B.E.P. However, the pump ends up operating over wide range of its curve, that is due to the pipe system curve changes (case of valve maneuver or branches pipes using motorized valve, static head deviation etc.

Performance rating chart for pump with 15 gallon-per-minute output. (Courtesy of McGraw-Hill)

Pump's power

Mono-block



The hydraulic power or water power is given by:

$$\underline{\text{water power} = F \times V = P \times A \times V = \gamma \times Q_V \times h_m}$$

$$S.P = \frac{\text{water power}}{\eta_P}$$

$$\text{Input power} = \frac{\text{Water power}}{\text{Pump efficiency} \times \text{Transmission efficiency} \times \text{Motor efficiency}}$$

Pump efficiency & motor power is selected from the **manufacturer catalogues**.

For Example ; The Transmission efficiency is taken as follows:

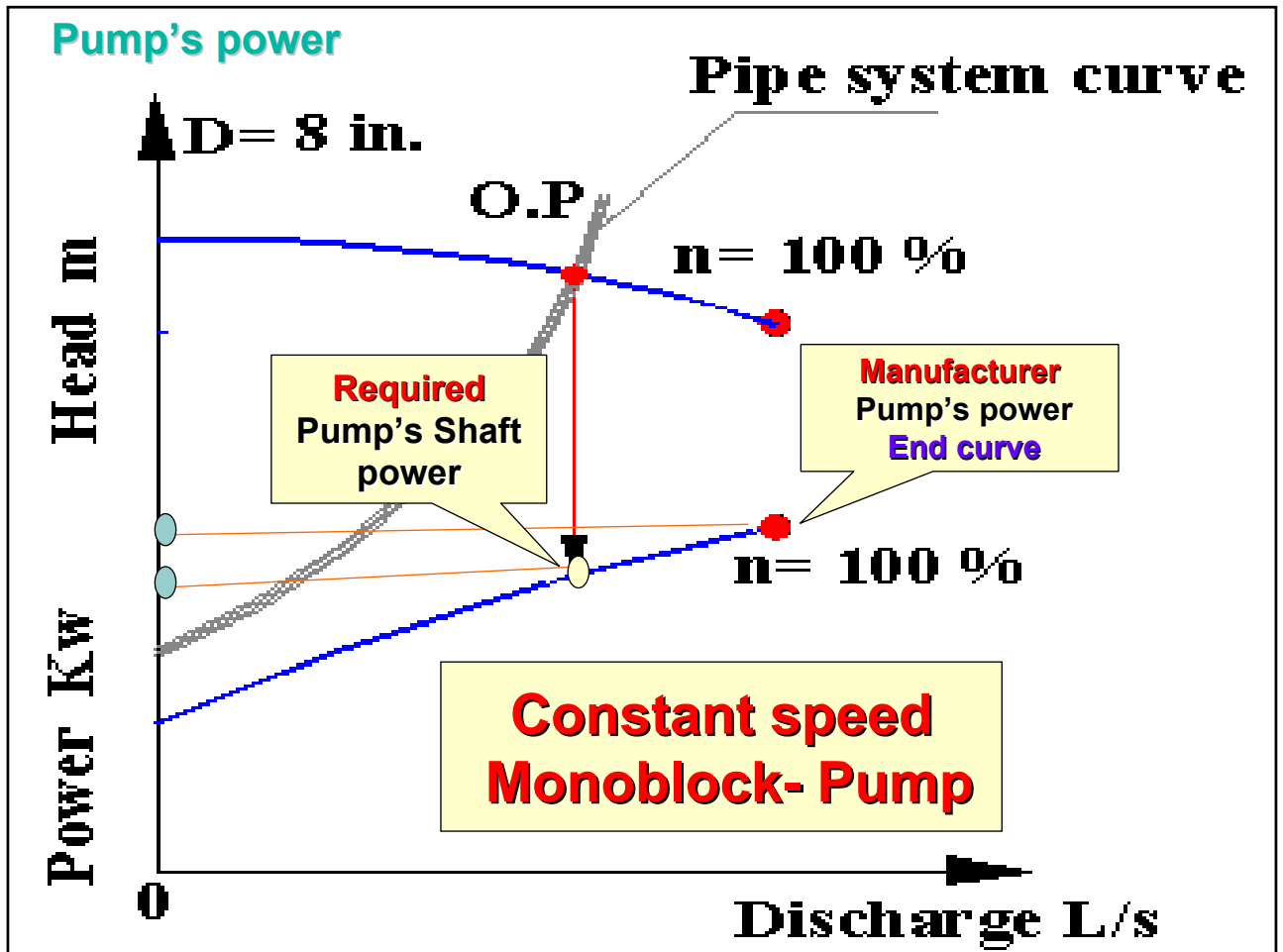
- 1- Case of shaft coupling = **1** ,
- 2- Case of flat belt Transmission = **0.9 to 0.93**
- 3- Case of V-belt Transmission = **0.93- 0.95.**

Motor Power selection

There is no simple rule of thumb in motor selection.. Each manufacturer suggest a safety margent for their motor selection.

Example: KSB pump catalogue presents the follows estimation values :

- Example:
- UP to 7.5 kW add 20%
- From 7.5 - 40 kW add approximately 15%
- From 40 kW and above add approximately 10%.



Class exercise

Select the size of the pump from the coverage chart shown in the accompanied figure, assuming that the estimated head and discharge are $h = 30 \text{ m}$ & $Q = 30 \text{ m}^3/\text{h}$ respectively.

Solution:

Enter the chart at $Q = 30 \text{ m}^3/\text{h}$ and move vertically up to the line of intersection with

$h = 30 \text{ m}$. The selection charts give the following pump selections for the present data:

CN 40-160 or CN40-200 at $n = 2900 \text{ rpm}$. The CN40-160 is selected for the reason of economy.

After this preliminary selection, you will be able to analyze the performance characteristic curve CN40-160

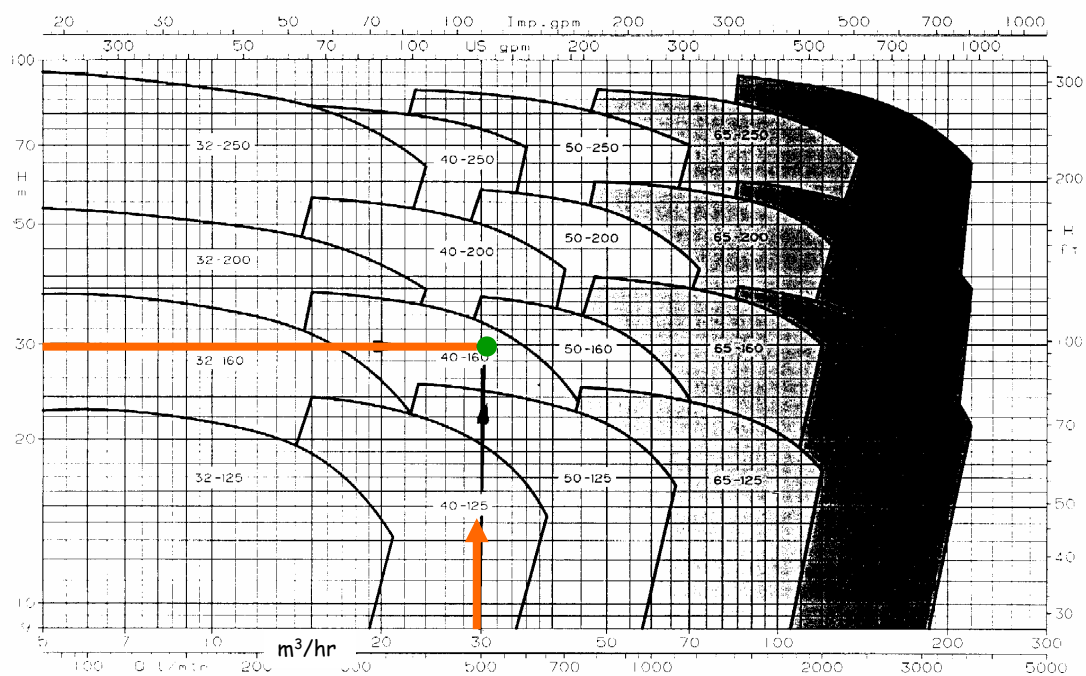
CN: Standard motor

40 mm delivery output

160 mm impeller diameter

PERFORMANCE RANGE 2900 rpm

CN series
Closed-coupled



Class exercise

A centrifugal pump is used to supply water to the overhead tank located at the top of a 10- floor building . The capacity of the overhead tank is 30 m³.

- 1- Estimate the size of the rising main to overhead tank.
- 2- Select the most suitable pump from the Lawora- pump catalogues.
- 3- Estimate the power required which fits the water pipe system.
- 4- Discuss the results.

Assuming that:

The total length of the pipe is 50 m.

The elevation difference is 31 m. (from minimum water level of the underground level up to the top Float switch of the overhead tank)

2 gate valves full open and 6 (90 standard elbows) and one check valve swing type. **Other losses are neglected.**

The maximum running time of the pump is about 2 hours /day.

The pumping of water is controlled automatically using automatic water level switches.

Class exercise

A centrifugal pump is used to supply water to a 10- floor building, which consists of 35 flats. Each flat is occupied by 6 persons.

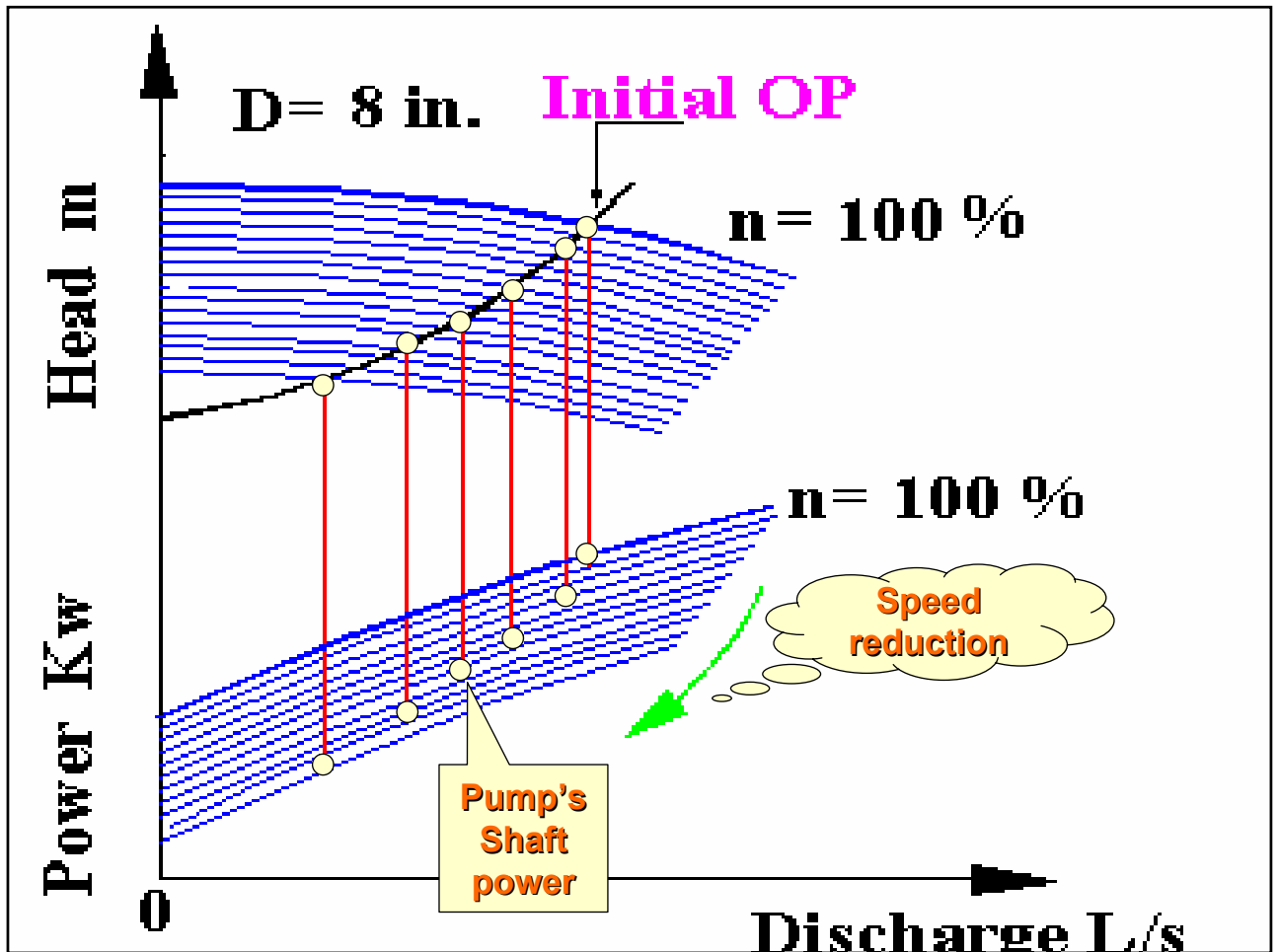
**1-Work out the daily water requirement, the underground and overhead tank capacity.
Assuming that, each person requires 35 gal of water / per day.**

2- Estimate the pumping rate of the pump.

The pumping of water is controlled automatically using automatic water level switches.

**Variable Speed Pumps
Driven by Frequency
Converters .
Direct supply system . Used
In Hotels , villas , Hospital
etc..**





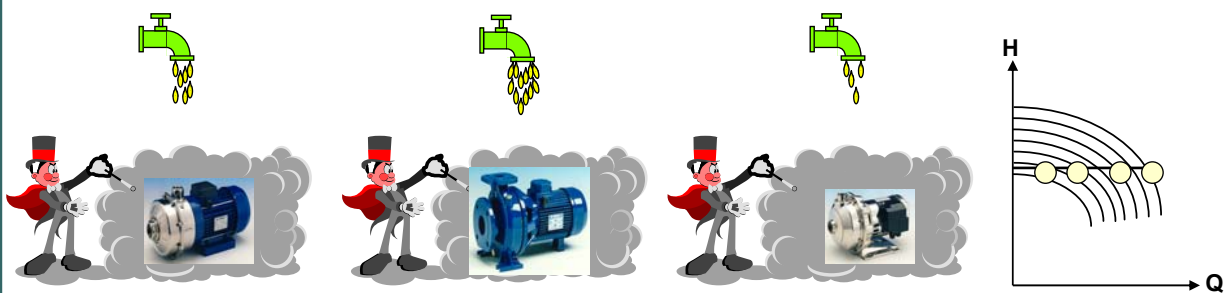
Summary

- Using constant speed centrifugal pump ,it is not possible to get **a const flow rate** under variable pressure condition. (@BEP)
- Using constant speed centrifugal pump ,it is not possible to get a **const pressure** under variable flow. (@BEP)

Variable speed pump accompanied with frequency inverter (VFD) can do So!

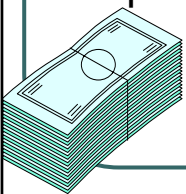
VFD-pump can maintaining **a constant pressure at variable flow**

- ◆ It can generate a **constant** pressure at variable flow



- ◆ It can avoid **water-hammer** due to pump stopping gradually

The RPM increases or decreases automatically to keep the pressure constant

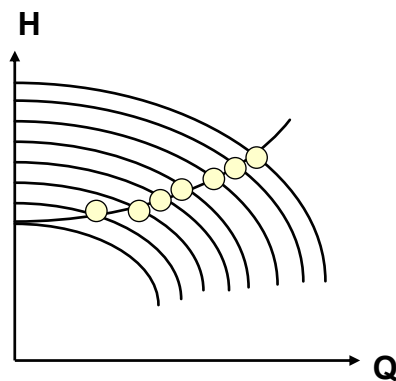


- ◆ It can **save energy**

Ref [7]

Compensation for system losses (according system curve)

- ◆ Using a differential pressure transmitter, the pump is **balancing** the friction losses of system curve.



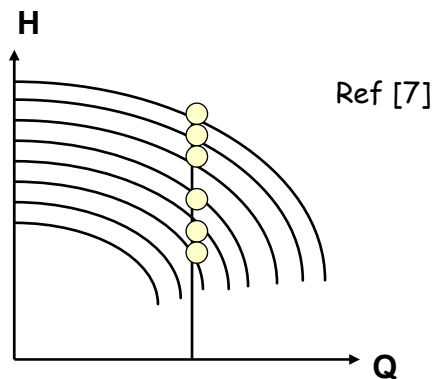
- ◆ It can **save energy** up to **60 %** versus a full speed pump.

As the discharge increases the pressure increases to compensate for the added friction losses in the system.

Ref [7]

Maintaining a constant flow rate

- ◆ It can guarantee a **constant flow** at variable head
- ◆ It can avoid to **run out** of the curve when the system needs low head
- ◆ It can **save energy**



As the discharge changes .The VFD increase the rpm i.e. the pressure to maintain a constant discharge.

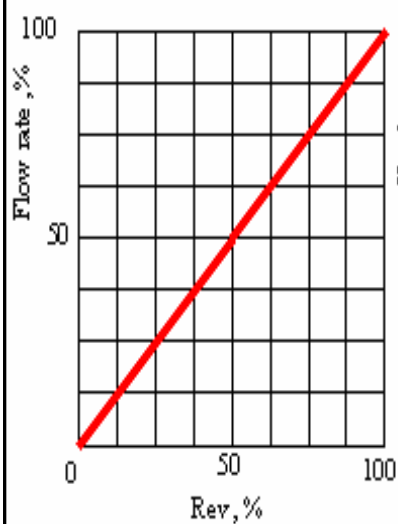
What happens to Flow, Head and Power with Speed?

$$Q \sim \text{RPM}$$

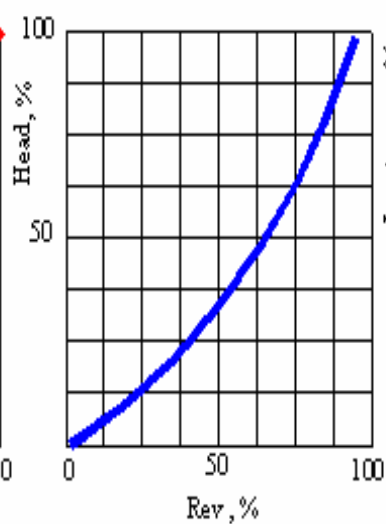
$$H \sim \text{RPM}^2$$

$$SP \sim \text{RPM}^3$$

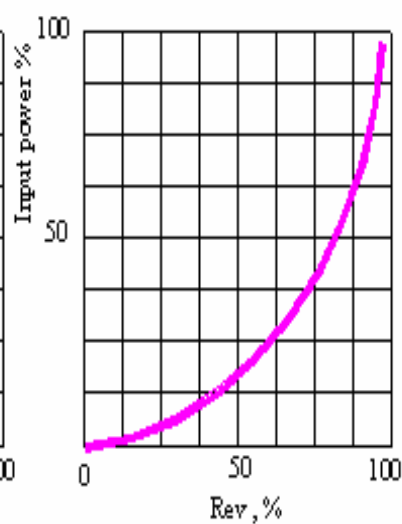
Rotational Speed = flow



Head = flow²



Input power = flow³



Graphic presentation of the relation between speed, flow and input power

The pump efficiency will remain the same

Affinity laws (For the same pump)

- 1- Volume flow rate varies in direct proportion to the speed;

$$\frac{Q_1}{Q_2} = \frac{N_1}{N_2}$$

$$Q_2 = Q_1 \left(\frac{N_2}{N_1} \right)$$

- 2- The head varies in direct proportion to the square of the speed;

$$\frac{h_{a1}}{h_{a2}} = \left(\frac{N_1}{N_2} \right)^2$$

$$h_{a2} = h_{a1} \left(\frac{N_2}{N_1} \right)^2$$

- 3- The power required by the pump varies with the cube of the speed:

$$\frac{P_1}{P_2} = \left(\frac{N_1}{N_2} \right)^3$$

$\Rightarrow$

$$P_2 = P_1 \times \left(\frac{Q_2}{Q_1} \right)^3$$

Affinity laws

Doubling the pump rotational speed leads to:

- 1- Double the discharge.
- 2- Increase the total head value by a factor of 4.
- 3- Increase the power by a factor of 8.

Class Exercise

A pump delivers **2000 L /min.** of water against a head of **20m** at a efficiency of **70 %** and running at shaft rotational speed of **3000 rpm**. Estimate the new pump characteristics if the rotational speed of the shaft is changed to **4000 rpm**. Assume the pump efficiency is constant .

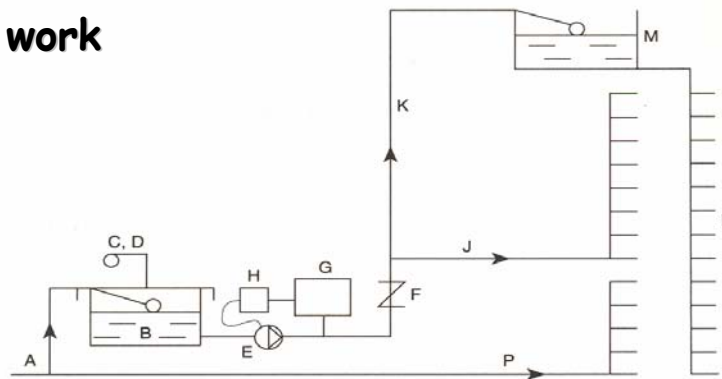
Summary of Exercise :

When decreasing the speed (from 4000 to 3000)

RPM	4000	3000	25 %
Flow rate L/min	2666	2000	25 %
Pressure Head m	35.6	20	44 %
Shaft Power Kw	22.1	9.34	58 %

Consider a 15-floor building with four flats (three bedroom) each floor. Each flat having one drinking water point. Minimum mains water pressure is 2 bar (gauge) and floor heights are 3 m. Calculate 1) Cold water storage tank capacity 2) booster pump head & flow 3) Select a pump from Lawora catalogue (using 4psi/100 ft) . Assuming 5 standard elbow , 2 gate valves , one check valve (swing type) . Other losses are neglected. Pipe material is galvanized steel.

Home work



Assume that,
the Pumping
time is 4 hours

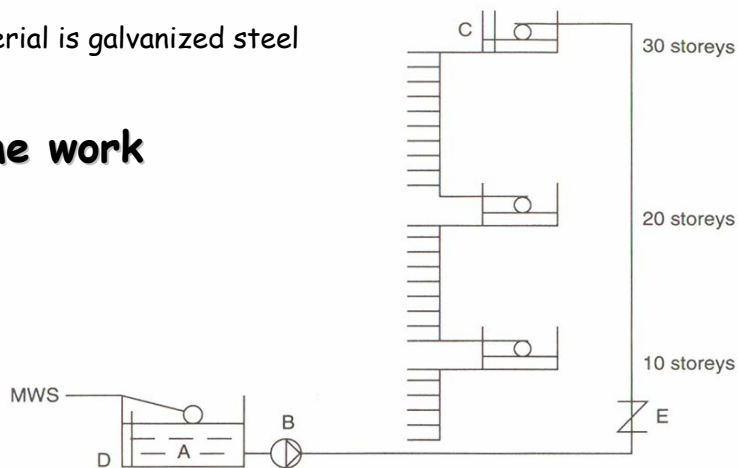
Assume missing
data if any.

Boosted cold water, control by water pressure, valves omitted: A, mains water service; B, ground storage tank; C, D, filtered open vent and overflow; E, booster pump; F, recoil valve; G, pressure vessel; H, pressure switch; J, drinking water header to upper floors; K, boosted water to CWS tank; M, high-level cold water storage tank; N, cold water down-service serving urinals, WCs, basins, sinks etc.; P, mains drinking water to lower floors. E, G and H form the pressurization unit, which is supplied complete.

A 30-storey office block having a central toilet accommodation . Each floor occupied by 100 person . Floor to floor height is 3 m. Select a pump for this configuration using the velocity limitation method. Assuming 5 standard elbow , 2 gate valves , one check valve (swing type) . Other losses are neglected.

Pipe material is galvanized steel

Home work



Assume that,
the Pumping
time is 3 hours

Assume missing
data if any.

Boosted cold water above 20 storeys: A, ground storage tank; B, booster pump; C, float switch pump control; D, low-level float switch pump control; E, recoil valve.

Next lecture

- Hot water distribution system in building