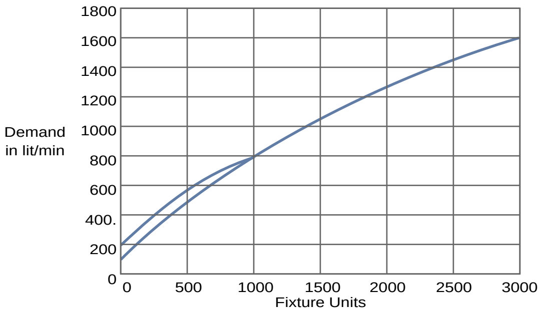
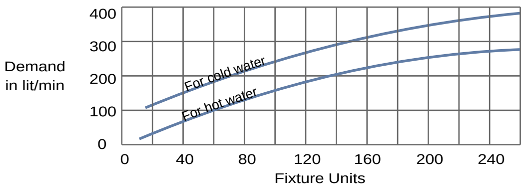
Booster Pump and Inverter Selection

General Data

Calculation using Fixture water supply load unit (FU)

This method was developed by Roy B. Hunter and is also used in America. Appropriate FU values are selected as per the type and service of fixtures, and the sum of FU values for all installed fixtures is selected as the total FU value. And then, instantaneous maximum flow rate is determined on the flow curve (Hunter curve) as below.





Various hygiene fixtures and their FU value

Fixture name	Water tap	Fixture water supply load unit (FU)	
		Public use	Individual use
Faeces bowl	Flushing valve	10	5
	Flushing tank	5	3
Wash bowl	Water tap	2	1
Flushing bowl	Water tap	1	0.5
Wash bowl for medical use	Water tap	3	-
Office sink	Water tap	3	-
Kitchen sink	Water tap	-	3
Cockery sink	Water tap	4	2
	Mixing valve	3	-
Food washing sink	Water tap	5	-
Common Sink	Water tap	-	3
Sink for cleaning	Water tap	4	3
Bathtub	Water tap	4	2
Shower	Mixing valve	4	2
Bath set	Feces bowl-Flushing valve	-	8
	Feces bowl-Flushing valve	-	6
Drinking bowl	Drinking water tap	2	1
Kitchen set	Ball tower	2	-
Sprinkling, Garage	Water tap	5	-

Calculation using the number of fixtures and simultaneous service rate

(Installed quantity x Service volume per time x Service times per hour) are calculated and multiplied by the appropriate simultaneous service rate as per the number of installed fixtures and type of building service. And then, the instantaneous maximum flow is determined by the sum of these values.

Various hygiene fixtures Water supply flow rate and connection pipe diameter

Type of fixture	Service Volume per time (l)	Service times per hour	Instantaneous Max. flow(l / min)	Pipe diameter (mm)	Remark
Faeces bowl (Flushing valve)	13.5 ~ 16.5	6 ~ 12	110 ~ 180	25	Average 15L / time / 10 sec
Faeces bowl (Flushing tank)	15	6 ~ 12	11	13	-
Urinal (Flushing valve)	4 ~ 6	12 ~ 20	30 ~ 60	20	Average 15L / time / 10 sec
Flushing bowl	3	12 ~ 20	8	13	-
Wash bowl	10	6 ~ 12	10	13	-
Sink (13mm water tap)	15	6 ~ 12	15	13	-
Sink (20mm water tap)	25	6 ~ 12	15 ~ 25	20	-
Drinking bowl	-	-	3	13	-
Sprinkling tap	-	20 ~ 50	13 ~ 20	-	-
Bath	As per size	2	25 ~ 30	20	Large sized bath : Diameter 25 ~ 32A
Western Bath tub	125	4 ~ 12	25 ~ 30	20	-
Shower	24 ~ 60	3	12 ~ 20	13 ~ 20	Varies seriously as per the type

Simultaneous service rate of fixtures

House Type / No. of House	1	2	4	8	12	16	24	32	40	50	70	100	101 ~ 200	201 ~ 500
Faeces Bowl (Flushing valve)	100	20	20	40	30	27	23	19	17	15	12	10	30 ~ 20	20
Faeces Bowl (Flushing tank)	100	100	70	55	48	45	42	40	39	38	35	33		

Calculation method of Water supply load in common housing

In accordance with the formula to be applied for the quality criteria (BL) of housing facility, Which was established by the Japanese Construction Ministry,

Below 10 houses $Q = 42 \times N \times 0.33$

10 houses - 600 houses $Q = 19 \times N \times 0.67$

Above 600 houses $Q = 2.8 \times N \times 0.97$

Average service rate per personnel per day : 250 L

Average personnel per house : 4 personnel

Q : Instantaneous maximum flow (L/min)

N : Number of houses

Number of Houses (N)	Instantaneous Max. Water Supply (L/min)	Number of Houses (N)	Instantaneous Max. Water Supply (L/min)	Number of Houses (N)	Instantaneous Max. Water Supply (L/min)
5	72	200	662	700	1,611
10	89	250	768	800	1,833
20	142	300	868	1,000	2,276
40	225	350	963	1,500	3,373
60	296	400	1,053	2,000	4,459
80	358	450	1,139	2,500	5,536
100	416	500	1,222	3,000	6,607
150	546	600	1,387	4,000	8,733

Booster Pump and Inverter Selection

General Data

Calculation using No. Of water supplied-personnel

To select the size of fixture and piping in the water supply facility, the way of water service should be fully understood for the fixture. Methods such as the Estimated average water supply per hour (Qh) which is the value of Average water supply divided by Average service hours per day, estimated maximum water supply per hour when water consumption is the greatest volume during a day (Qm) and estimated instantaneous water supply (Qp) are mostly used.

① Estimated total water supply per day : Qd (lit / day)
Qd = [Average service rate per day] x [Water supplied-personnel]
② Estimated average water supply per hour : Qh (lit / hr)
Qh = Qd / T (where T = Average service hours per day)
② Estimated maximum water supply per hour : Qm (lit / hr)
Qm = k1 x Qh (where k1 = 1.5 ~ 2)
② Estimated maximum instantaneous water supply : Qp (l / min)
Qp=2 x (Qm / 60) = k2 x (Qh / 60) (where k2 = 3~4)

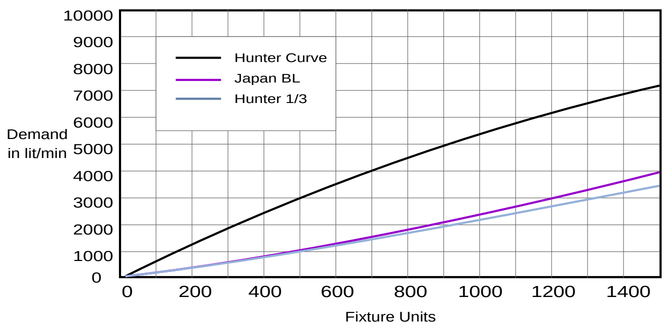
For buildings such as school, factory and theater where the water service rate is concentrated during a short time, k1 and k2 values shall be determined as larger than those for normal buildings.

Design criteria of pumps

Items to be reviewed	Subjects to be designed
Estimated maximum water supply per hour (Qm)	Reservoir, water tank on the roof, storage basin, lifting pump, reuse equipment, treatment facility
Estimated maximum instantaneous water supply (Qp)	Booster pump, piping size, various fixtures and water tap
Budgeting and city water plan (price, etc)	Age variation, based on annual (average total) and monthly (peak month) consumption
Water saving strategy, Leakage check	Daily, based on every week / night (total volume)

Calculation using Pig coefficient

Q = kp x N (250~300) x (3-5 personnel) H x 60
Kp : Pig coefficient as per the number of household
N : Number of household
H : Average service hour (10~18 hours per day)



Calculation using Type of equipment

Water supply for Cooling tower (open type)
Water supply (LPM) = Supply coefficient (0.02) x Refrigerator capacity x Cooling water volume (13~19 LPM/RT)
Compression type : 13 LPM
Absorption type : 18 LPM (Multiple use)

Cooling water supply for engine (Emergency diesel generator)
Cooling water supply (L/h) = 30~40 /hour x Generator capacity (KVA) x Generating hour

Water supply calculation for bathhouse and sauna facilities
Water supply (LPM) = No. of showers x 15 LPM / EA x Simultaneous service rate (1.0)

Example of pump quantity determination as per flow rate

Range of flow rate	Example of pump quantity determination
300 LPM	2 EA ~ 3 EA
300 – 1000 LPM	2 EA ~ 4 EA
1000 2000 LPM	3 EA ~ 5 EA

Personnel water supply quantity by type of building

Type of Building	Average service Quantity (L)	Average service time per day (H)	Service personnel	Personnel per Effective area	Effective area/Gross area (%)
Office	100 – 120	8	Per men in service	0.2 personnel / m^2	Rent : 60
Government Office, Bank	100 – 120	8	Per staff	0.2 personnel / m^2	General 55-57
Hospital	High cl.≥1000 Middle cl.≥500 Others≥250	10	Per stickbed Outpatient : 8 Staff : 120 Others : 250	3.5 personnel /stickbed	45~48
Temple Church	10	2	Per visiting devotee		
Theater	30	5	Per seat	53~55	
Cinema	10	3	Extended personnel	1.5 personnel / seat	
Department store	3	8	Per guest	1.0 personnel / m^2	55~60
Store	100	7	Residential : 160L	0.16 personnel/m^2	
Market	40	6	Per personnel	1.0 personnel/m^2	
Public Restaurant	15	7	Per personnel	1.0 personnel/m^2	
Private Restaurant	30	5	Per personnel	1.0 personnel/m^2	
Bar	30	6	Per personnel		
Socializing Club	30		Per personnel		
Night Club	120~350		Per seat		
House	160~200	8~10	Per resident	0.16 personnel/m^2	50~53
Mansion	250	8~10	Per resident	0.16 personnel/m^2	42~45
Apartment	160~250	8~10	Per resident	0.16 personnel/m^2	45~50
Apartment (w/o kitchen)	100	8~10	Per resident		
Dormitory	120	8	Per resident	0.2 personnel/m^2	
Hotel	250~300	10	Per seat	0.17 personnel/m^2	
Inn	200	10	Per seat	0.24 personnel/m^2	
Club House	150~200		Per visitor	15 hole 150 personnel	
Primary school, Middle school	40~50	5~6	Per student	0.25-0.1 personnel/m^2	58~60
Above High School	80	6	Per student	0.1 personnel/m^2	
Laboratory	100~200	8	Per labman	0.06 personnel/ m^2	
Library	25	6	Per user	0.06 personnel/ m^2	
Factory	60~140	8	Per worker (shift)	0.3 personnel/ m^2	
Station	3	15	Per passenger		

Various supply pressures for type of fixtures

Fixture name	Min. required pressure (Kg/cm^2)	Fixture name	Min. required pressure (Kg/cm^2)
General water tap	0.3	Shower (Temperature control type)	0.7~1.2
Maxing water tap	0.5	Shower (General type)	0.5
Feces bowl (Flushing valve)	0.7	Instantaneous Water heater No.4~5	0.4
Faces bowl (Flushing valve)	0.4	Instantaneous Water heater No.7~16	0.5
Urinal (Flushing valve)	0.3~0.5	Instantaneous Water heater No.22~30	0.8
Shower (Mixing type)	0.7~0.9	Fixed level valve	0.3~0.5

Maximum Service pressure for types of buildings

Building Service	Max. service pressure (Kg/cm^2)	Building Service	Max. service pressure (Kg/cm^2)
Individual house	Below 2	Hospital, Hotel	3 ~ 4
Communal house (Apartment)	3 ~ 4 (8 ~ 10 floors)	Communal house (Apartment)	4 ~ 5

When the maximum service pressure by building service is higher than the value shown above, the pressure reducing valve or the interim tank is installed to control the supply pressure and to stabilize the supply pressure between floors for lower floors.

Booster Pump and Inverter Selection

Technical Data

Purchasing method of pump

Service
Should indicate the purpose of service such as general pumping, circulation, hydrant, boiler feed water supply, etc.

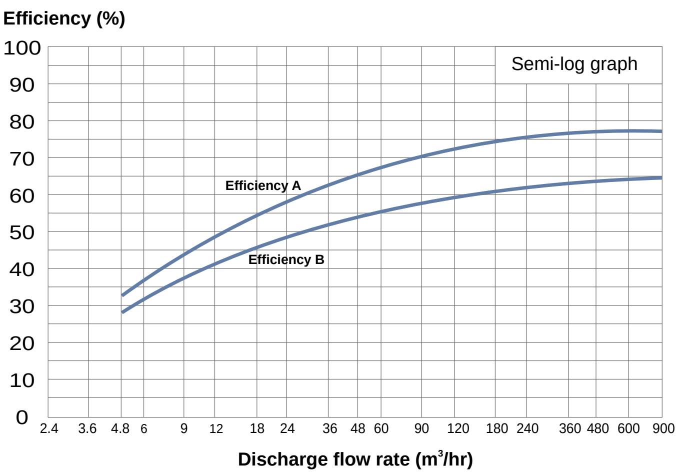
Total Head (m)
Should indicate the suction head, discharge head, friction loss due to pipe length and flow velocity, and head loss of other fixtures, etc.
If the friction head loss is not known, following should be checked:
1) The vertical height from the suction water level to pump, length and pipe diameter.
2) The vertical height from pump to the discharge water level, length and pipe diameter.
3) Types and quantity of various pipe fittings.

Flow Rate
Should indicate the required flow rate per hour, per minute, per second etc. (in m^3/hr, m^3/min, m^3/sec, m^3/day, LPM, etc)

Fluid Characteristics
It is recommended to indicate the following, since the fluid characteristics may affect the driving power, pump performance, pump material and shaft sealing method.
1) Type of fluid (clean water, sea water, acid and alkali, etc)
2) Density of fluid (kg/m^3)
3) Temperature
4) Viscosity (Poise, Centi-poise, kg/m.s; 1 Poise = 0.1 kg/m.s; for water = 1.002 cP)

Prime Mover
1) Kind and type of prime mover such as motor or engine.
2) In case of motor, indicate the voltage, number of pole, frequency, etc.
3) Type of shaft connection (direct, belt, etc)

Method determining Pump Total Head



Important Terminologies

Cavitation
In case the fluid is water, boiling temperature is 100°C, but this is the phenomenon is only in atmospheric pressure. If the pressure falls down, boiling temperature falls below 100°C. And, if the pressure falls down furthermore, water boils in the normal temperature. And, if this phenomenon is growing more serious, bubbles may be generated. Inside the pump, high suction head, sudden change in the fluid velocity and obstacles in the fluid flow causes sudden localized decrease in pressure and bubbles can be generated. This phenomenon is called as cavitation. In the pump, this phenomenon tends to occur at the impeller inlet where there is sudden collapse of the bubbles at high pressure zones. If this repeats, the pump performance falls down, noise and vibration occurs, and finally the pumping reduces in volume and may be impossible. Further more, if the cavitation continues for long term, materials can be damaged due to the impact generated when the bubbles collapse. Therefore, special attention should be made in deciding the proper suction condition that does not allow cavitation to occur.

Net Positive Suction head (NPSH)
The way to protect the pump from the cavitation, which occurs when the fluid pressure falls below the saturated vapor pressure, is by not generating the parts in the pump where pressure falls below the saturated vapor pressure. To do this, it is essential to consider the available net positive suction head (NPSHav) that is to be decided in accordance with the suction condition and the required net positive suction head (NPSHre) that indicates the suction capability of the pump.

NPSH = $h_s - h_v$
Wherein, h_s = suction head = $p_s - \rho + v_s^2 / 2g$ & h_v = liquid vapor head = p_v / ρ
p = pressure(kg/m^2); ρ = density(kg/m^3); v = velocity(m/s); g = gravity acceleration(m/s^2)

Available Net Positive Suction Head (NPSHav)
NPSHav is the value to be determined in accordance with the status in piping and system regardless of pump itself when the pump is operated after installation. This value is the pressure acting on the fluid flowing into the center of the suction nozzle indicated in absolute pressure minus the saturated vapor pressure at the actual temperature of the fluid.

NPSH av = $p_{atm} / \rho - h_e - h_i - p_v / \rho$
Wherein, h_e = Height from the suction water level to the pump (m)
(+ ve) if pump is above the tank; (- ve) if pump is below the tank
h_i = Head loss from the surface of water to the impeller due to friction (m)
p_v = vapor pressure (kg/m^2) which depends on temperature; p_{atm} = 10000 kg/m^2
ρ = density of fluid (for water = 1000 kg/m^3)

Total Pump Head
Pump head is the vertical height to which pump can take up water. Users must convert pressure and flow measurements at the pump into head before comparisons may be made to performance data supplied by the pump manufacturer. Total head is calculated by adding converted vertical height of the losses to the actual vertical height. However, it is not so easy to convert the head into vertical height, because it changes according to the length, caliber, quantity, condition of pipe and water temperature. In case the loss head is calculated too much, the unnecessary high pressure pump may risk overloading system, despite more water comes out, it runs in low pressure. In case the loss head is calculated too less, water actually does not come out and comes out less with higher pressure. Therefore, it is very important to calculate loss head properly.

Total head (H) = A. Actual Suction Head (m)
+ B. Actual Delivery Head (m)
+ C. Head of Flow Velocity (m)
+ D. Head of Friction Loss (m)

Pump Efficiency v/s Discharge Flow Rate

Discharge flow rate (m^3/min)	4.8	6	9	12	18	24	30	36	48	60	90	120	180	240	300	360	480	600	900
Efficiency A (%)	37	37	44	48	53.5	57	59	60.5	63.5	65.5	68.5	70.5	73	74	74.5	75	75.5	76	76.5
Efficiency B (%)	26	30.5	36	39.5	44	46.5	48.5	49.5	52.0	53.5	56	58	60	60.5	61	61.5	62	62.5	63

Note : 1. Maximum value of pump efficiency shall be higher than efficiency A at the discharge flow rate.
2. Pump efficiency at the rate discharge flow rate shall be higher than B efficiency.

Efficiency, nominal diameter and discharge rate of Single suction volute pump

Pump Nominal Diameter v/s Discharge Flow Rate

Standard discharge flow rate as per pump nominal diameter is specified in KS B 7501 as below.

Unit : m^3 / hr

Suction diameter (mm)		40	50	65	80	100	125	150	200
Range of discharge flow rate (50 Hz)	4 pole	Below 12	7.2 ~ 24	15 ~ 48	30 ~ 96	48 ~ 150	60 ~ 240	120 ~ 380	190 ~ 750
	2 pole	-				60 ~ 190	96 ~ 480	-	-

Unit : m^3 / hr

Suction diameter (mm)	40	50	65	80	100	125	150
Range of discharge flow rate (50 Hz)	Below 13.2	10.8 ~ 21.6	16.8 ~ 33.6	27 ` 54	42 ~ 84	67 ~ 134	108 ~ 216

Booster Pump and Inverter Selection

Technical Data

Frictional loss of various pipe fittings (Indicated as an equivalent horizontal pipe length in metres)

Fittings in mm	15	20	25	32	40	50	65	80	100	125	150
90° elbow	0.60	0.75	0.90	1.20	1.50	2.10	2.40	3.00	4.20	5.10	6.00
45° elbow	0.36	0.45	0.54	0.72	0.90	1.20	1.50	1.80	2.40	3.00	3.60
90° Tee	0.90	1.20	1.50	1.80	2.10	3.00	3.60	4.50	6.30	7.90	9.90
90° Tee	0.18	0.24	0.27	0.36	0.45	6.00	0.75	0.90	1.20	1.50	1.80
Gate valve	0.12	0.15	0.18	0.24	0.30	0.39	0.48	0.63	0.81	0.99	1.20
Globe valve	4.50	8.00	7.50	10.50	13.50	16.50	19.50	24.00	37.50	42.00	49.50

Pumping flow rate, pump capacity & pump quantity

Pump for city water

Intake pump and Conveyance pump
(in case of full load operation without sudden change in flow)

Planned intake flow (m^3/day) = Planned maximum water supply per day x (1.1~1.51)
Planned conveyance flow (m^3/day) = Planned maximum water supply per day
Planned maximum water supply per day= Planned maximum water supply per day and per personnel x planned water supply

Planned maximum water supply per day and per personnel

Planned water supply population	Planned maximum water supply per day and per personnel (L)
Below 10,000 personnel	150 ~ 300
10,000 ~ 50,000	200 ~ 350
50,000 ~ 100,000	250 ~ 400
100,000 ~ 300,000	275 ~ 425

Planned water supply and Pump Quantity

Planned water supply (m^3/day)	Quantity
Below 2,800	2 (1 preliminary)
2,500 ~ 12,000	3 (1 preliminary)
Above 9,000	4 (1 preliminary)

Drainage pump

Planned drainage flow rate (m^3/hr) = Planned maximum water supply per hour
= planned maximum water supply and drainage per day / 24 x 1.3 (large size city)
OR x 1.5 (small and medium size city)

Pump Quantity

Planned water supply (m3/day)	Quantity
Below 125	3 (1 preliminary)
125 ~ 450	Large size 2 (1 preliminary) + small size 1
Above 400	Large size 4-6 (1 preliminary) + small size 1

Standard of pump for simple tap type pump

At the branch point of each supply piping from drainage pipe for pressure, the pressure is normally 1.5 kg/cm²

Service rate per day per personnel by business type

Business type	Planned maximum water supply per day and per personnel (L)	Remark
General housing	100 ~ 200	
Officetel	150 ~ 300	
Apartment	80 ~ 160	
Restaurant	70 ~ 140	Including staffs
Inn	70 ~ 140	Including staffs
Theater	8 ~ 15	Including staffs and visitors
School	30 ~ 60	

Average flow velocity in conveyance pipe

Service	City Water	Irrigation & Drainage	Indutrial Water piping	Water supply	Condenser cooling
Average flow Velocity (m/sec)	0.5 ~ 1.5	1.5 ~ 3.0	1.5 ~ 2.0	1.5 ~ 2.5	2.0 ~ 3.0

Formula for flow rate, capacity and pump quantity

$$P_{bhp} = \frac{Q \times H \times \gamma}{367.2 \times \eta}$$

Wherein, P_{bhp} = Shaft horsepower (kW)
Q = Flow rate (m^3 / hr)
η = Efficiency (in case of the efficiency higher than 75%, 0.75)
γ = Specific gravity (kg/L)
(in case of water at normal temperature, 1)

Note :

1. HP = kW x 1.34
2. Shaft horsepower should be decided considering the specific gravity, in case that the specific gravity is not equal to 1
(ie., the fluid is not clean water at normal temperature).
3. In case of viscosity higher than 10 cs, the performance (flow rate, total head and efficiency) should be compensated in accordance with the viscosity. It should be noted that when the pump is used for the fluid with the viscosity, the performance may be declined and, especially, the shaft horsepower may be increased seriously.

Decision criteria for shaft and motor power

$$P_W > P_{BHP} \times \alpha$$

Wherein, P_W = Motor horsepower (kW)
P_{bhp} = Shaft horsepower (kW)
α = Allowance (%)

Since the proper allowance may not be satisfied around the range of maximum flow when motor horsepower selected in the catalogue is applied actually, motor horsepower should be decided after checking whether the flow rate and total head could be satisfied on the standard performance curve which has been distributed already and the efficiency in the purchasing specification.
Voltage, variation in frequency, allowance in design and manufacturing and pump efficiency drop due to pump use for the long term should be considered and motor horsepower should be determined by adding the allowance to the horsepower calculated by the formula above.