Information for selecting a pump

1-1. Piping by application

(1) For pumping

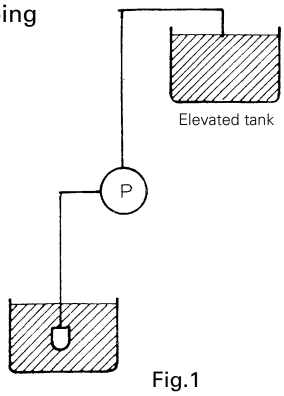

Fig.1

Used for pumping water from the receiving tank to the elevated tank.

(2) For cooling water and cold water

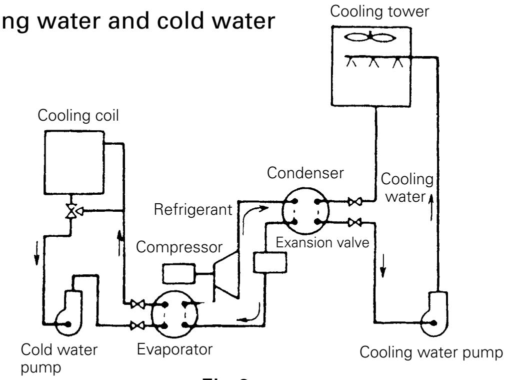

Fig.2

1) Cooling water pump
   Used to circulate cooling water between the condenser and cooling tower of a refrigerator.
2) Cold water pump
   Used for circulating cold water between the evaporator of the refrigerator and the heat exchanger.

(3) For hot water

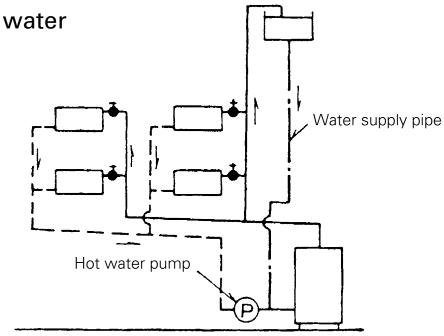

Fig.3

Used for circulating hot water between a heat source such as a boiler and a radiator.

(4) For hot water circulation

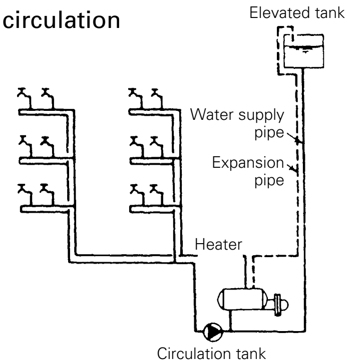

Fig.4

In large-scale hot water supply system, the piping is long and complicated, so the piping resistance increases and the natural circulation of hot water becomes impossible.
Therefore, it is necessary to forcibly circulate the hot water with a pump.
It is used for its forced circulation purpose.

1-2. Pump performance

(1) Discharge rate

The discharge rate is usually expressed in m^3/min, L/min. This refers to the amount of water the pump discharges per minute. Discharge rate is also called pump discharge or flow rate.
1m^3/min=1000L/min
In other cases, units called m^3/h, L/s are used. Since h is the time and s is the second, it needs to be converted accordingly.
Example :0.1 m^3/min=6 m^3/h

6m^3/min＝100L/s

(2) Total head

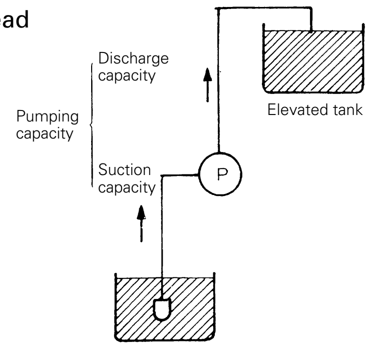

Fig.5

The pump must be capable of sucking water and discharging it, i.e. suction and discharge. The sum of the suction capacity and discharge capacity is defined as the pump's pumping capacity (pumping capacity), and is expressed as the total pump head in meters.

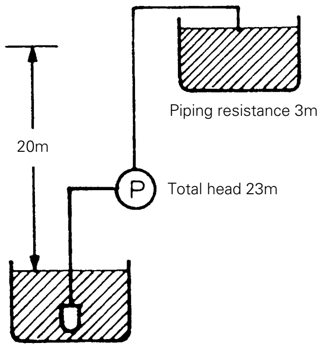

Fig.6

When 3m piping resistance occurs, the pump with a total head estimated at 3m excess can be used, i.e. pumps with a total head of 20+3=23m can be pumped up to a height of 20m.
CAUTION: In calculating the total head, it may be necessary to take into account the pressure of water discharged from the piping.

(3) Shaft power

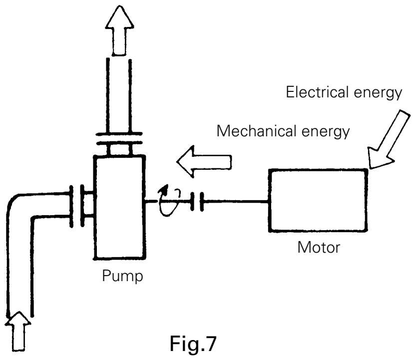

Fig.7

The energy that the motor rotates is called output or shaft power, and the energy causes the impeller to rotate and the pump to pump up water.

(4) Efficiency

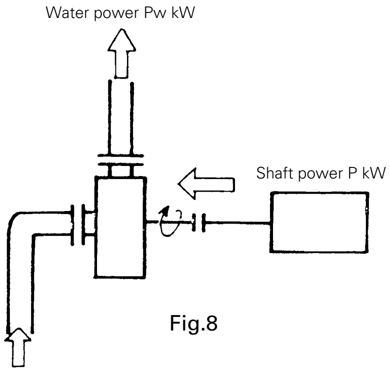

Fig.8

$$\text{Pump Efficiency } \eta = \frac{Pw}{P} \times 100\ (\%)$$

Pump efficiency is the rate at which mechanical energy, or shaft power, P, can be converted to water power, Pw. The higher this value, the better the efficiency.
For example, if the shaft power P=10kW and the water power Pw=6kW, the pump efficiency η (%)
is as follows;

$$\eta = \frac{Pw}{P} \times 100 = \frac{6}{10} \times 100 = 60\%$$

Pump efficiency varies depending on the pump type, and even one pump varies depending on the operating conditions.

(5) Power and efficiency

The shaft power S required for the pump to pump the discharge volume Q to the height of the total pump head H is determined by the water power W and the pump efficiency η that are effectively used for pumping. The capacity M of the motor that drives the pump is determined by giving some margin to the shaft power S.

The above relations are summarized as follows:

$$W = 0.163\gamma QH\ [kW] \qquad S = \frac{W}{\eta}\ [kW]$$

$$M = S \cdot \frac{e}{\eta b}\ [kW]$$

Meaning of each symbol:
γ = density of pumped liquid (kg/L) (γ = 1 for fresh water at room temperature),
Q = discharge rate (m^3/min), H = total head (m), η = pump efficiency, e = margin factor, ηb=1
Refer to the figure on the right for pump efficiency η.
The values in the A and B curves are excerpts from JIS (Japanese Industrial Standards) related to pumps. They are called A efficiency and B efficiency, respectively.
JIS indicates that the maximum efficiency of the pump characteristics curves is equal to or greater than A efficiency and that the pump efficiency at the specified discharge rate is equal to or greater than B efficiency.
It is recommended to use the B efficiency value when determining the pump specifications.

● Efficiency of small centrifugal pump

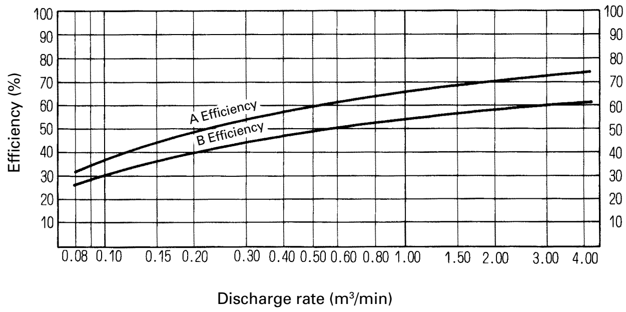

Fig.9

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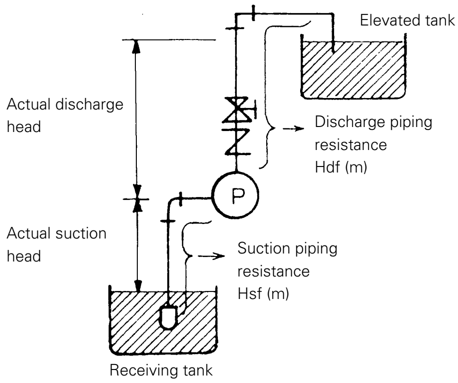
1-3. Calculation of pump head and piping resistance

(1) Basic equation for head calculation



Total head H = Hsa + Hsf + Hda + Hdf

Fig.10

The pump head can be considered as follows.

1) Actual suction head = Height from the receiving tank surface to the pump center
2) Discharge actual head = Height from pump center to elevated tank surface
3) Suction piping resistance = piping resistance generated between the suction port of the suction piping and the suction port of the pump
4) Discharge piping resistance = piping resistance generated between the discharge port of the pump and the discharge port of the discharge piping
5) Total head = (actual suction head + suction piping resistance) + (Actual discharge head + Discharge piping resistance)

Total suction head is defined as actual suction head plus suction piping resistance.

Total discharge head is defined as actual discharge head plus discharge piping resistance.

Example

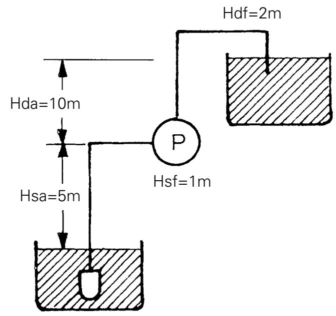
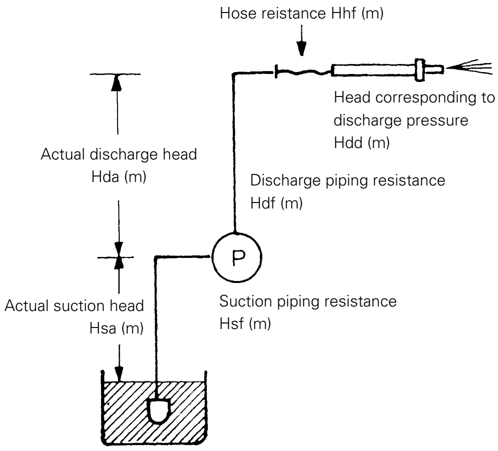


Fig.11

In case of example,
H = Hsa + Hsf + Hda + Hdf
= 5+1+10+2 = 18 (m)

(2) When considering discharge pressure and suction pressure

1) Total pump head of hydrant pump



Total head H = Hsa + Hsf + Hda + Hdf + Hhf + Hdd

Fig.12

The nozzle discharge pressure of the indoor hydrant is determined by the Fire Service Law to be 0.17MPa or more and 0.7MPa or less. When calculating the total head, it is necessary to add the head corresponding to the discharge pressure.
The discharge pressure of 0.17MPa is directly converted to a head of approximately 17.3m by a factor of 102. However, the Fire Defense Law stipulates that a head of 17m should be added to the discharge pressure as the right figure.

Discharge pressure of fire extinguishing equipment Indoor hydrant pumps (for No.1)
Pd = 0.17MPa - 0.7MPa
Outdoor hydrant pumps
Pd = 0.25MPa to 0. 6MPa
Sprinkler
Pd = 0. 1MPa to 1.0MPa

Example.

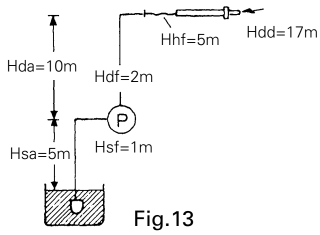
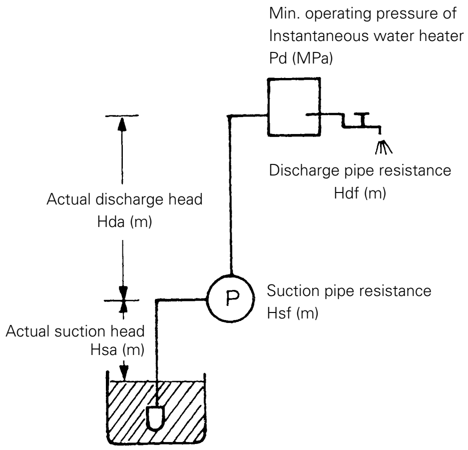


Fig.13

In case of example,
H = Hsa + Hsf + Hda + Hdf + Hhf + Hdd
= 5+1+10+2+5+17
= 23+17 = 40 (m)

2) When the working pressure of the hot water supply equipment becomes a problem



Total head H = Hsa + Hsf + Hda + Hdf + Pd ×102

Fig.14

When the minimum operating pressure of the instantaneous water heater is 0.04MPa as shown in the figure, this value must be added to the total head calculation.
The min. working pressure Pd(MPa) is converted to meter (m) by a factor of 102.

Minimum pressure of the instrument (MPa)

Cleaning valve		0.07MPa
Ordinary faucet		0.03MPa
Self-closing faucet		0.07MPa
Shower		0.07MPa
Instantaneous water heater	(large)	0.05MPa
〃	(Middle)	0.04MPa
〃	(small)	0.01MPa

Note) The desirable max. pressure is:

Cleaning valve	0.4MPa
Ordinary faucet	0.5MPa

Example.

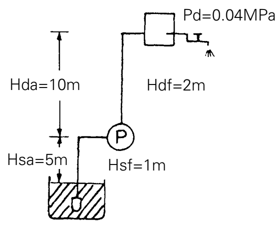


Fig.15

In case of example
H = Hsa + Hsf + Hda + Hdf + Pd ×102
= 5+1+10+2+0.04×102
= 18+4.08
≒ 22.1 (m)

3) Circulation pump

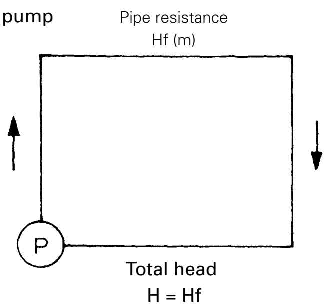


Fig.16

The pumps used for air conditioning and other purposes do not need to consider the actual pump head because the pumped water falls naturally and returns to the pump.
The piping resistance is the total pump head required.

Example

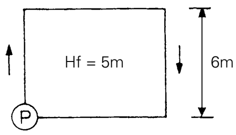
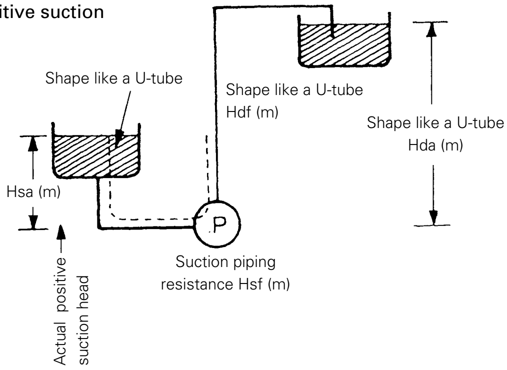


Fig.17

In case of the example, :
H = Hf = 5 (m)

4) Positive suction



Total head H = (Hda-Hsa) + Hdf + Hsf

Fig.18

In the case of positive suction, the capacity of the pump can be reduced by the actual positive suction head.

Principle of a U-tube

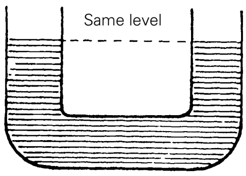


Fig.19

Example

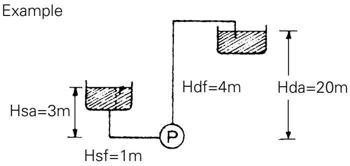


Fig.20

In case of the example,
H = (Hda - Hsa) + Hdf + Hsf
= (20-3)+4+1
= 22 (m)

(3) Calculation example of piping resistance

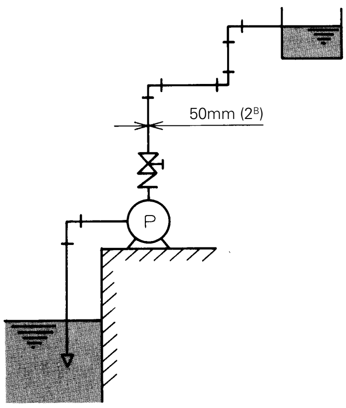


Fig.21

In the piping system shown on the left, the total frictional loss is calculated for a total length of 120m straight pipes with a pipe diameter of 50mm, one foot valve, four elbows, one check valve, and one gate valve. The volume of water conveyed shall be 0.2m³/min, and the pipes shall be carbon-steel pipes for pipes.
Length of the straight tube... 120m

Equivalent length of the piped element
Equivalent length of the foot valve: 8.4m/pc. (See to the table below)
Equivalent length of the check valve: 4. 0m/pc. (See to the table below)
Equivalent length of the gate valve: 0.39m/pc. (See to the table below)
Equivalent length of the elbow: 2.1m /pc.(See to the table below)
In case of 4 pcs 2.1×4 = 8.4m
Total equivalent length of piping elements 21.19m

Total pipe length 141.19m

In other words, the loss head including the piping element can be obtained by determining the loss head of a straight pipe with a pipe length of 141.19m in this pipe diameter.
From Fig. 22 on the next page, friction loss head of 9m / 100m (90mmAq/m) is obtained from the intersection of flow rate of 0.2m³/min (200L/min) and pipe diameter of 50mm (2B).
Therefore, the water head loss at a pipe length of 141.19m is
hf = 9m×1.4119 = 12.707m, that is, about 12.7m.
In practice, this value is assumed to have some margin in consideration of aging and other factors.

(4) Material for calculating piping resistance

1) Equivalent pipe lengths of fittings and valves

Table 1

Nominal diameter / Type	15 (½)	20 (¾)	25 (1)	32 (1¼)	40 (1½)	50 (2)	65 (2½)	80 (3)	100 (4)	125 (5)	150 (6)	200 (8)	250 (10)
90° elbow	0.6	0.75	0.9	1.2	1.5	2.1	2.4	3.0	4.2	5.1	6.0	6.5	8.0
45° elbow	0.36	0.45	0.54	0.72	0.9	1.2	1.5	1.8	2.4	3.0	3.6	3.7	4.2
90°T (diversion)	0.9	1.2	1.5	1.8	2.1	3.0	3.6	4.5	6.3	7.5	9.0	14	20
90°T (direct current)	0.18	0.24	0.27	0.36	0.45	0.6	0.75	0.9	1.2	1.5	1.8	4.0	5.0
Gate valve	0.12	0.15	0.18	0.24	0.3	0.39	0.48	0.63	0.81	0.99	1.2	1.4	1.7
Ball valve	4.5	6.0	7.5	10.5	13.5	16.5	19.5	24	37.5	42	49.5	70	90
Angle valve	2.4	3.6	4.5	5.4	6.6	8.4	10.2	12	16.5	21	24	33	43
Check valve	1.2	1.6	2.0	2.5	3.1	4.0	4.6	5.7	7.6	10	12	15	19

NOTE) Refer to the angle valve for the foot valve. Check valve is of the swing type.

2) Friction loss head of various pipes

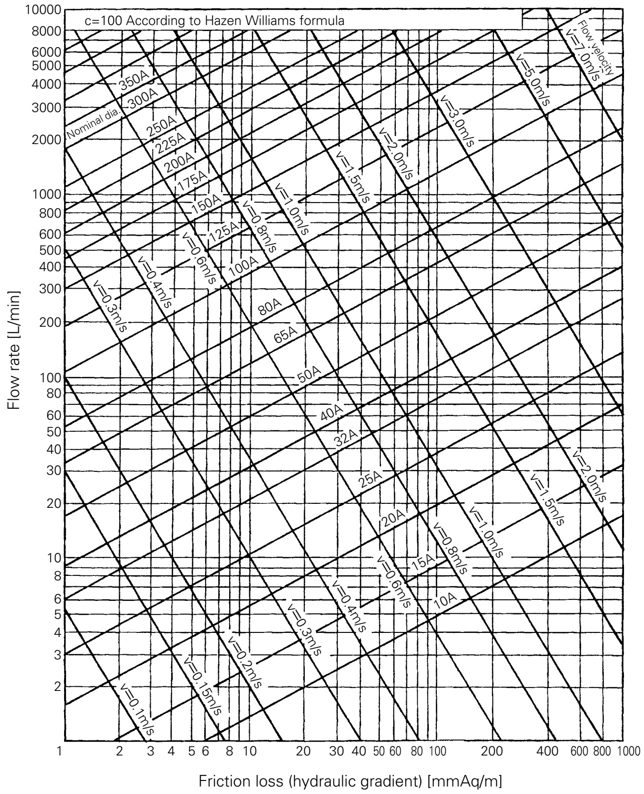


Fig. 22. Carbon steel pipes for ordinary piping (JIS G 3452)flow rate diagram (HAS-S 206-1982)

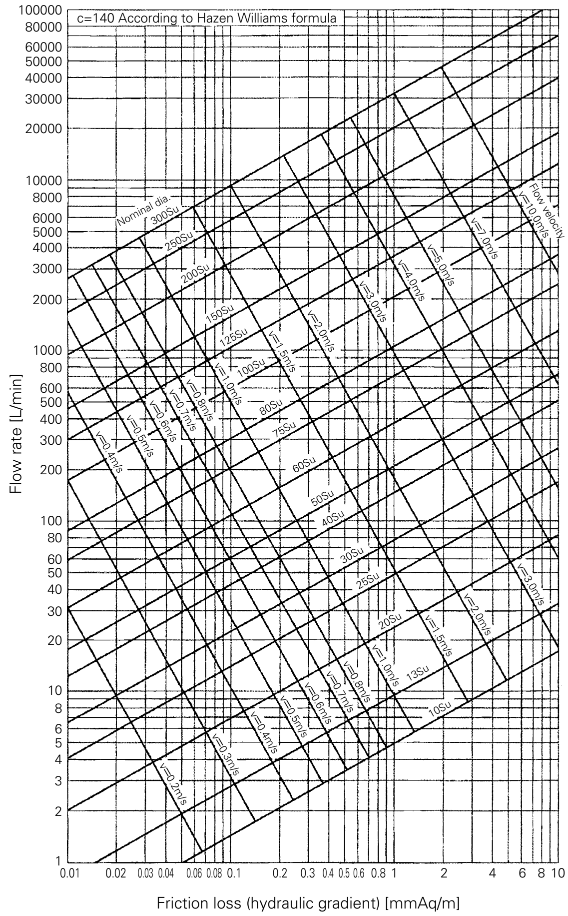


Fig. 23. Stainless steel pipes for ordinary piping flow rate diagram (SHASE-S 206-2009)

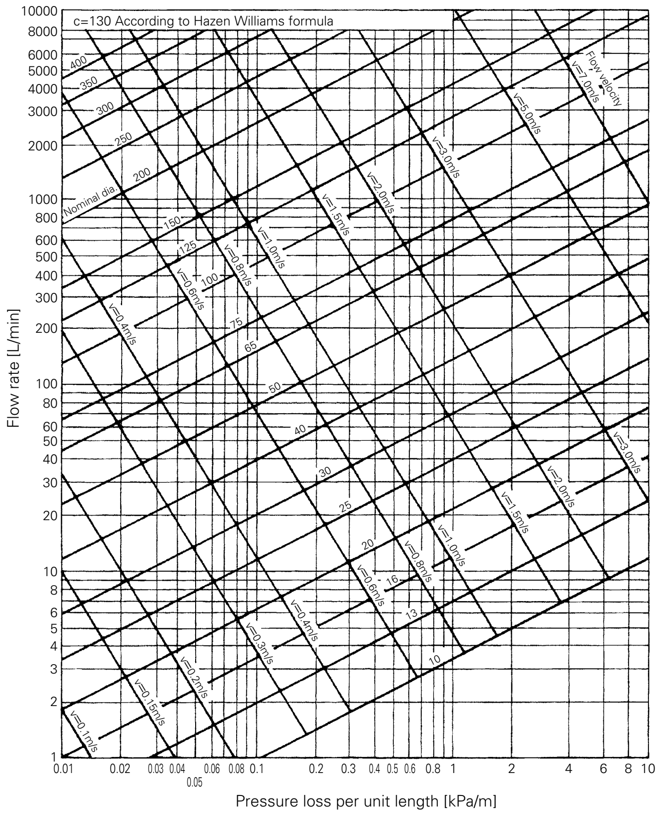


Fig. 24. Rigid vinyl chloride pipe flow rate diagram (SHASE-S 206-2009)

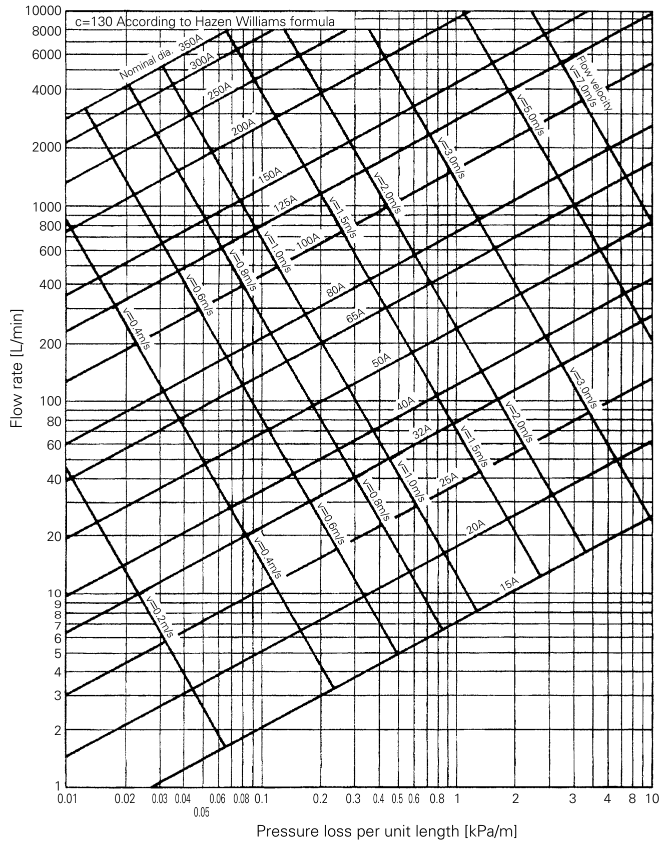


Fig. 25. Rigid vinyl chloride lined steel pipe flow rate diagram (SHASE-S 206-2009)

(5) Determination of the diameter of the water supply pipe

There are various methods for determining the diameter of the water supply pipe. The methods shown in the table below are used as a simplified method for determining the diameter of the water supply pipe of a small-scale building or branch pipe section. This table shows that a 25mm tube flows 4.1 pieces of water in a 15mm tube, that is, a 15mm tube 4.1 pieces and a 25mm tube are equal in flow rate relationship.

Table 2. Equivalent Table of Carbon Steel Pipes for Piping

Main pipe \ Branch pipe	15	20	25	32	40	50	65	80	100	125	150
15	1										
20	2.2	1.9									
25	4.1	3.7	1								
32	8.1	5.6	2.0	1							
40	12.1	12.1	2.9	1.5	1						
50	22.8	10.6	5.5	2.8	1.9	1					
65	44.0	20.3	10.7	5.4	3.6	1.9	1				
80	69.4	32.0	16.8	8.5	5.7	3.0	1.6	1			
100	140.0	64.5	33.8	17.2	11.5	6.1	3.2	2.0	1		
125	247	114	60.0	30.4	20.4	10.8	5.6	3.6	1.8	1	
150	387	179	93.9	47.7	31.9	17.0	8.8	5.6	2.8	1.6	1

References: From the Air Conditioning / Hygiene Engineering Handbook

(6) Relationship between water temperature and suction height

The suction height of a small pump is usually set to 6m. However, it is particularly problematic when using hot water. The table below shows the maximum actual suction height for a single suction spiral pump.

Table 3

Temperature of water (˚C)	0	20	50	60	70	80	90	100
Theoretical suction height (m)	10.336	9.685	9.042	7.894	7.208	5.562	2.926	0
Actual suction height (m)	7.0	6.5	4.0	2.5	0.5	0	–3	–7

1-4. Measuring the total head using a measuring instrument

The total head of the pump operating at the site can be measured with a vacuum gauge, a pressure gauge, or a compound gauge.

1) Vacuum gauge → Indicates the sum of actual suction head and suction pipe resistance. The unit of the vacuum gauge is MPa and converted to meter as follows.
χMPa→χ×102→102χm

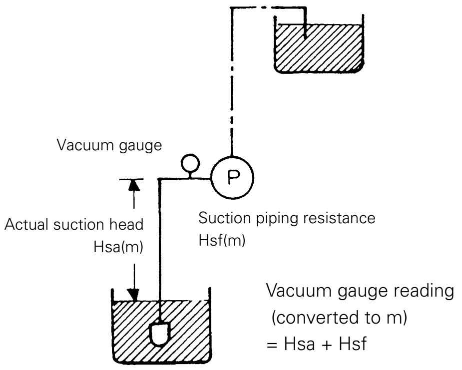


Fig.26

2) Pressure gauge → Pressure gauge Indicates the value obtained by adding the actual discharge head and discharge pipe resistance after the mounting position.
The unit of the pressure gauge is MPa and the conversion to m is as follows.
χMPa→χ×102→102χm

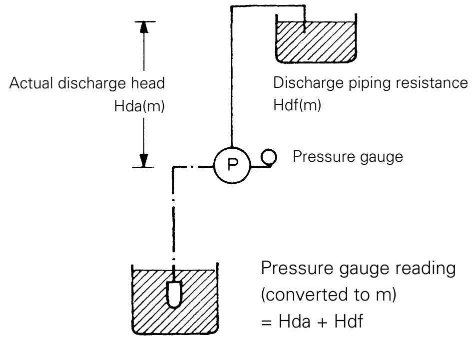
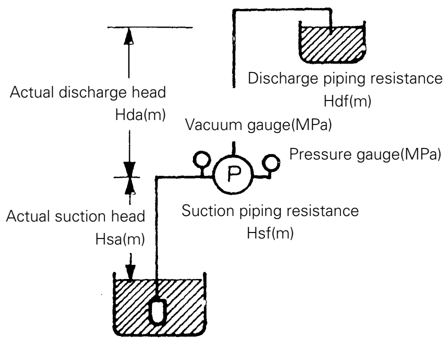


Fig.27

3) The compound gauge is a gauge that has both functions of a vacuum gauge and a pressure gauge.

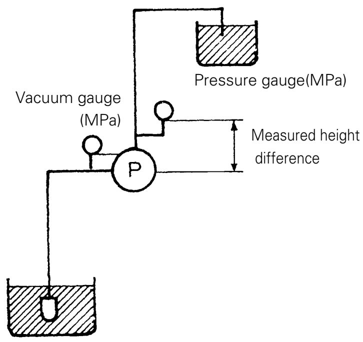
4) The total pump head for the piping shown in Fig. 28 is expressed by H = (Hsa + Hsf) + (Hda + Hdf). Vacuum gauge reading (converted value in m) = Hsa + Hsf
Pressure gauge reading (converted value in m) = Hda + Hdf. The result is as follows.
Total head H (m) = vacuum gauge reading (converted value in m) + pressure gauge reading (converted value in m)

5) Calculated value correction by measurement height difference
As shown in Fig. 29, the pressure gauge is usually mounted at a higher position than the vacuum gauge. Therefore, it is necessary to compensate for this. The height difference of the mounting position is called the measurement height difference, and the total head is calculated as shown below.
Total head H (m) = vacuum gauge reading (converted value in m) + pressure gauge reading
(Converted value in m) + Measuring height difference (m)



Total Head H(m)
= Vacuum gauge reading (converted value in m)
+ Pressure gauge reading (converted value in m)

Fig.28



Total Head H(m)
= Vacuum gauge reading (converted value in m)
+ Pressure gauge reading (converted value in m)
+ Measuring height difference

Fig.29

1-5. How to read pump performance

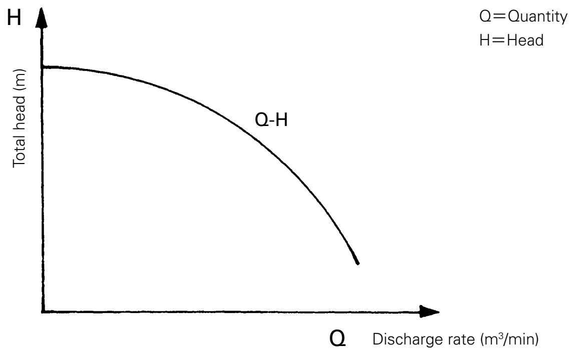


Fig.30

Characteristic curves are used to represent pump performance.
Of these, the curve showing the relationship between the discharge rate and the total head is shown in the figure.
If the discharge quantity is represented by Q and the total head is represented by H, and the curve in Fig. 30 is called the Q-H curve, it can be said that the Q-H curve is the downward curve.

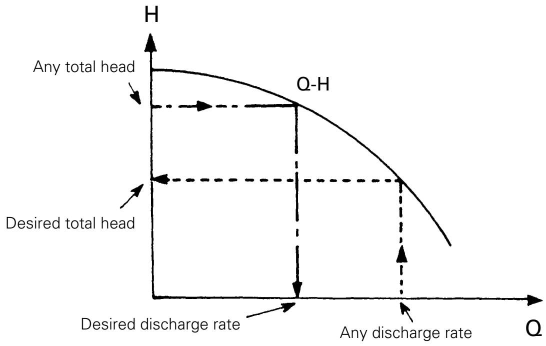


Fig.31

If there is a Q-H curve representing the characteristics of the pump, it is possible to know the total pump head at any discharge rate and conversely the discharge rate at any total pump head.

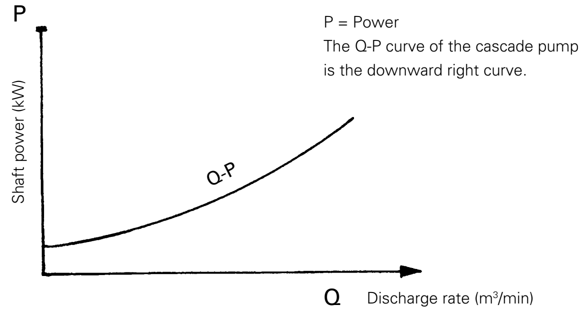


Fig.32

Fig. 32 shows the relationship between the pump discharge rate Q and the shaft power P required by the pump.
This Q-P curve is the upward right curve.

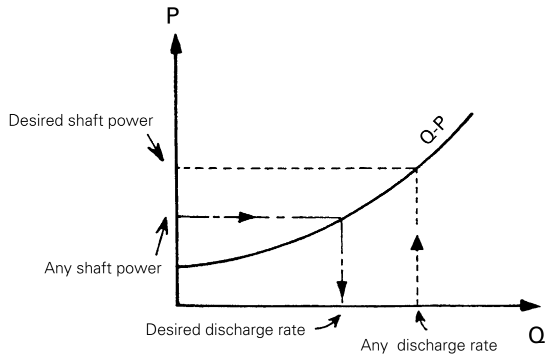


Fig.33

If there is a Q-P curve representing the characteristics of certain pump, it is possible to know the shaft power at any discharge rate and the discharge rate at any shaft power.

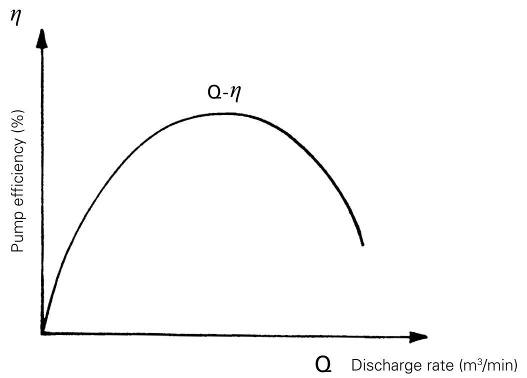
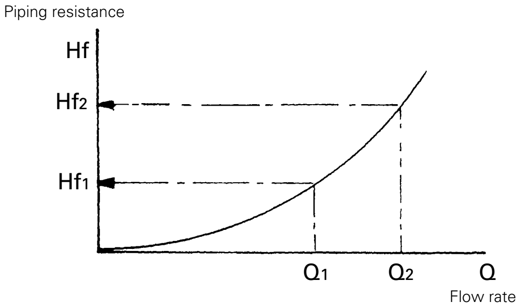


Fig.34

Fig. 34 shows the relationship between the discharge rate Q and the pump efficiency η at that time.
The Q-η curve is a crest curve, and the pump efficiency η is maximized. at a given discharge rate.
Like the Q-H curve and the Q-P curve, the Q-η curve also shows the relationship between any Q and η.
Ideally, the pump should be operated close to the discharge rate that achieves the maximum efficiency.

1-6. Resistance curve

Piping resistance $Hf = KQ^2$



$Q_1 < Q_2 \rightarrow Hf_1 < Hf_2$

Fig.35

The piping resistance is proportional to the square of the flow rate. This is illustrated in Fig. 35
This curve is called the resistance curve. Equation or Fig. 35 shows that the greater the flow rate, the greater the piping resistance.

K is a coefficient and it decreases as the pipe diameter increases.

Darcy's formula

$$Hf = \lambda \cdot \frac{L}{D} \cdot \frac{v^2}{2g}$$

$$v = \frac{Q}{\frac{\pi}{4} D^2 \times 60}$$

Hf : Piping resistance (m)
λ : Coefficient
L : Pipe length (m)
D : Pipe diameter (m)
v : Flow velocity (m/s)
g : Acceleration of gravity (approx. 9. 8m/s^2)
Q : Flow rate (m^3/min)

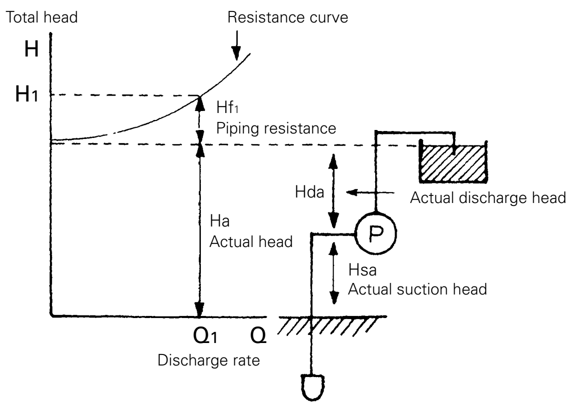


Fig.36

As mentioned above, the total pump head H_1 required when operating a pump at discharge amount Q_1 at a given site is the sum of the actual pump head Ha, which is obtained by adding the actual suction head Hsa and actual discharge head Hda, and the pipe resistance Hf_1, which is generated when discharge amount Q_1 flows through the pipe.
This relationship is shown in Fig. 36

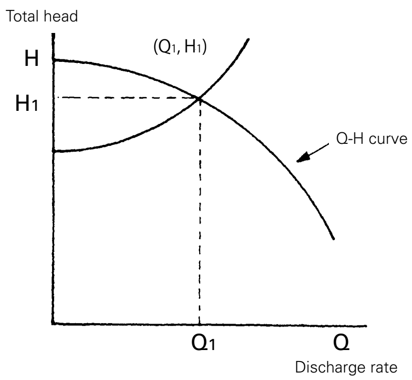


Fig.37

If the total pump head required to deliver the discharge rate Q_1 at the site is H_1, it is necessary to select the pump whose Q-H curves passes this (Q_1, H_1).

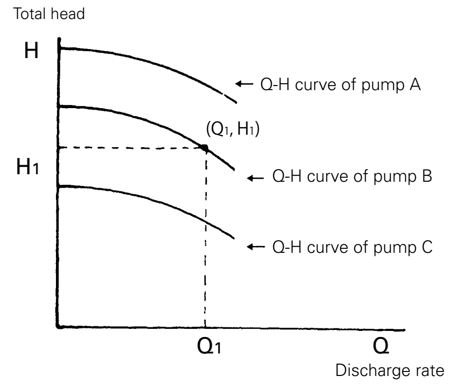


Fig.38

Selection of a pump in the selection diagram is just to find a pump with a Q-H curve through a single point (Q_1, H_1) determined by the pump discharge rate Q_1 and total head H_1 required at the calculated site.
In Fig. 38, a pump B with a Q-H curve passing through the point (Q_1, H_1) must be selected.

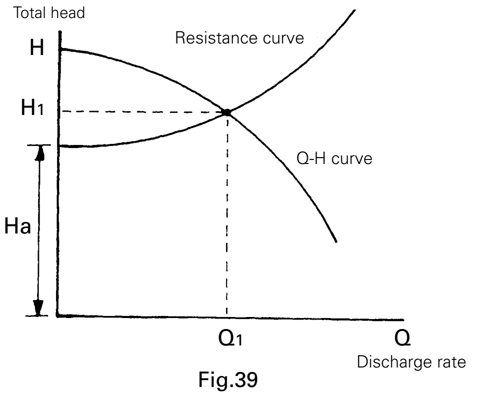


Fig.39

Expressing the above in another way, it can be said that the pump operates with the discharge rate Q_1 and total head H_1 at the intersection of the Q-H curve of one pump and the resistance curve of the site where the pump is used.

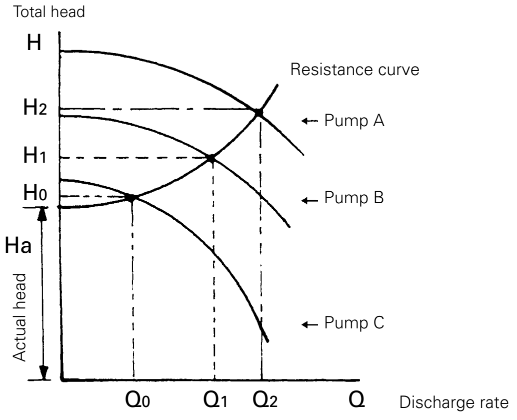


Fig.40

For example, if pump B is operated at an actual head as shown in Fig. 40 and at a resistive curved site with a discharge rate of Q_1 and a total head of H_1, this site will have a pump with a performance greater than that of pump B.
When A is used, the pump operates at the discharge rate Q_2 and total head H_2. That is, the discharge rate increases.
If a pump with a performance smaller than B is used, the pump operates at a discharge rate of Q_0 and a total head of H_0. In other words, the discharge rate decreases.

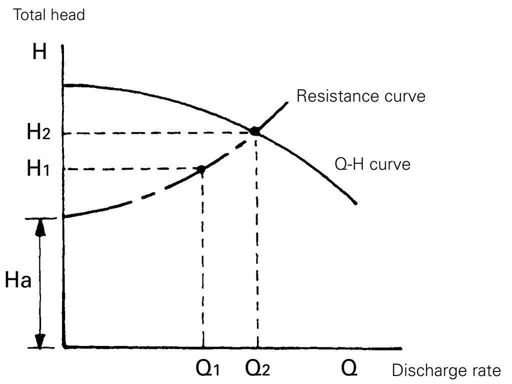


Fig.41

If a pump with a Q-H curve as shown in Fig. 41 is selected with a margin when a pump with a total head H_1 is required at the discharge quantity Q_1, the actual operating point will be the discharge quantity Q_2 and the total head H_2, so the pump will operate at a larger discharge quantity than planned.

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1-7. Water Volume Adjustment

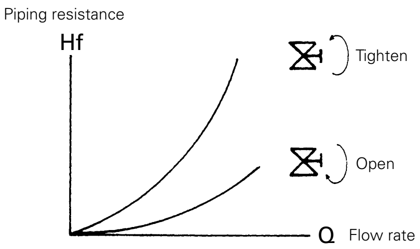


Fig.42

The resistance curve of the valve can be expressed in the same way.
Fig. 42 shows the resistance curve when a valve is tightened and the resistance curve when it is opened. At any flow rate, the piping resistance increases when the flow rate is reduced.

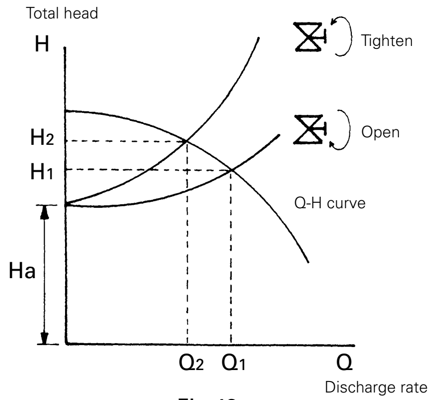


Fig.43

Using this principle, the water volume of the pump is controlled by a valve. As described above, the pump operating point is determined by the intersection of the Q-H curve and the resistance curve. However, by changing the resistance curve by valve operation, the operating point can be changed to obtain the required discharge amount.

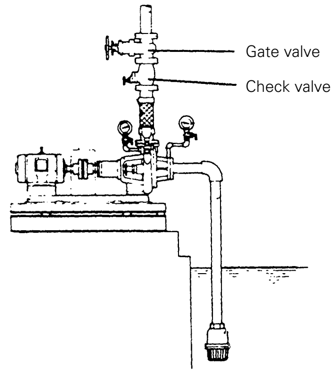


Fig.44 Piping example

1-8. Relationship between pump performance and impeller

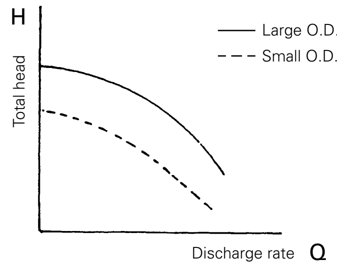


Fig.45

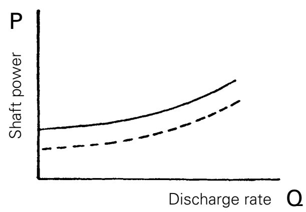


Fig.46

(1) Impeller outside diameter
When the outer diameter of the impeller increases the discharge rate, total head, and shaft power of the pump will also increase accordingly.

Calculation example

$$\frac{Q_1}{Q_2} = \frac{D_1}{D_2}$$

$$\frac{H_1}{H_2} = \left(\frac{D_1}{D_2}\right)^2$$

$$\frac{P_1}{P_2} = \left(\frac{D_1}{D_2}\right)^3$$

D_1 D_2 : Impeller O.D.
Q_1 Q_2 : Discharge rate
H_1 H_2 : Total head
P_1 P_2 : Shaft power

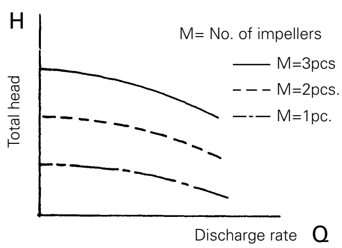


Fig.47

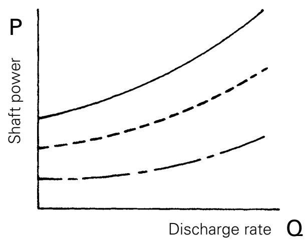


Fig.48

(2) Number of impellers
The combination of two or more impellers in series is called a multi-stage pump. The total pump head and shaft power also increase in proportion to the number of impellers.

$Q_1 = Q_2$

$$\frac{H_1}{H_2} = \frac{M_1}{M_2}$$

$$\frac{P_1}{P_2} = \frac{M_1}{M_2}$$

M_1 M_2 : No. of impellers
Q_1 Q_2 : Discharge rate
H_1 H_2 : Total head
P_1 P_2 : Shaft power

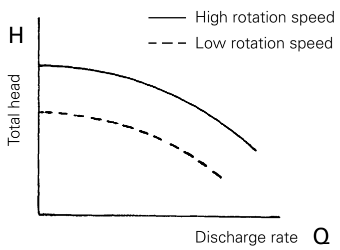


Fig.49

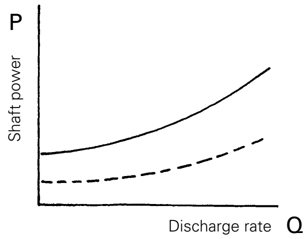


Fig.50

(3) Rotation speed of the impeller
When the rotation speed of the impeller increases the discharge rate, total head, and shaft power of the pump will also increase accordingly.
The variable speed pump utilizes this property to keep the discharge rate constant while increasing or decreasing the rotation speed.
Using a 60Hz pump in the 50Hz area results in insufficient performance, and using a 50 Hz pump in the 60Hz area will also result in the motor' s overpowering.

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

$$\frac{H_1}{H_2} = \left(\frac{N_1}{N_2}\right)^2$$

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

N_1 N_2 : RPM
Q_1 Q_2 : Discharge rate
H_1 H_2 : Total head
P_1 P_2 : Shaft power

1-9. Parallel and series operation of the pump

1) Parallel operation

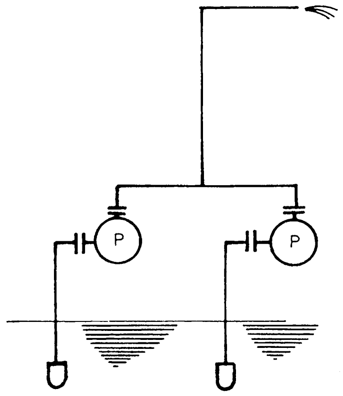
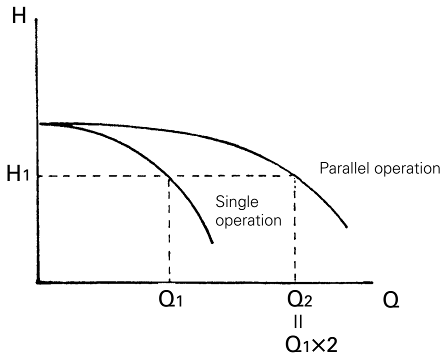


Fig.51

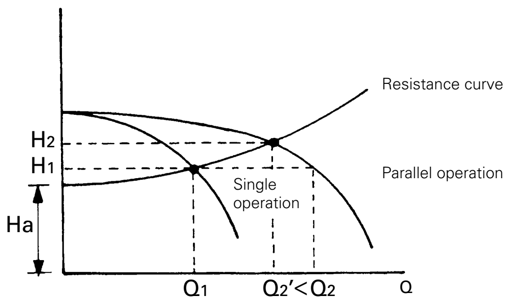
Parallel operation refers to the method in which two pumps are operated simultaneously by arranging them as shown in Fig. 51.
On the other hand, the operation of one pump is called single operation. The relationship between the Q-H curve for single operation and the Q-H curve for the combined performance of the two pumps in parallel operation is shown in Fig. 52. In other words, when the discharge amounts Q_1 and Q_2 are compared for the same total head H_1, it can be said that Q_2 in parallel operation is twice as large as Q_1 in single operation.

In practice, the pump operating point is determined by the intersection of the resistance curve and the Q-H curve. Therefore, when the pump is operated alone as shown in Fig. 53 and the discharge is Q_1, the discharge is Q_2' in parallel operation.
As can be seen from the diagram, there is a relation to $Q_2' < Q_2$, and it does not mean that twice the amount of water in single operation is discharged. Actually, the discharge amount in parallel operation is less than twice.



The performance of the two pumps shall be the same.

Fig.52



(Refer to Fig. for Q2)

Fig.53

2) Series operation

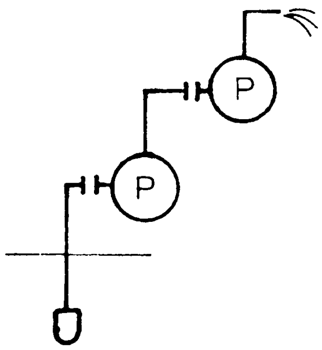


Fig.54

When the pump is arranged as shown in Fig. 54, comparing the total heads H_1 and H_2 at the same discharge quantity Q_1, H_2 in series operation is twice as large as H_1 in independent operation.

In practice, the pump operating point is determined by the intersection of the resistance curve and the Q-H curve. Therefore, when the pump is in single operation as shown in Fig. 56 and the discharge is Q_1, the discharge is Q_2 in the series operation.

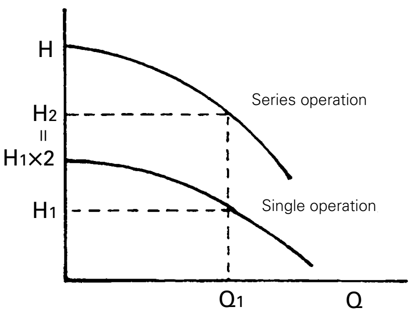


Fig.55

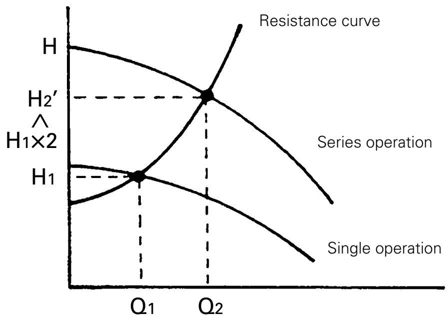


Fig.56