HYDRAULICS - PUMPING | GE 13

A) General notions

The hydraulics principles reminded herein are voluntarily reduced to simplified expressions that are most often effectively used in the water treatment industry.

Displacing a fluid in a pipe is bound to three interlinked items of data:

Q = Flow-rate in m^3/h

D = Rated diameter in mm

V = Velocity in m/s

$$D = 18{,}8\sqrt[2]{\frac{Q}{V}}$$

for a velocity of 1.5 m/s (value frequently retained in calculations)

$$D = 15\sqrt[2]{Q}$$

PIPE DIAMETER

Flow-rate		Velocity in m/s								
m3/h	l/s	1	1.1	1.2	13	1.4	1.5	1.7	2	2.5
1	0.277	18.5	18	17	16.5	16	15	14.5	13	12
2	0.555	26.5	25	24	23.5	22.5	22	20	19	17
3	0.833	32.5	31	30	28.5	27.5	26.5	25	23	20
4	1.111	37.5	36	34	33	32	30	29	26.5	24
5	1.388	42	40	38	37	35	34	32	30	26
6	1.666	46	44	42	40	39	37.5	35	33	29
7	1.944	50	47	45	43.5	42	40	38	35	31.5
8	2.222	53	51	48	46	45	43	41	38	34
9	2.500	56	54	51	50	48	46	43	40	36
10	2.777	60	57	54	52	50	48	45	42	37.5
12	3.333	65	62	60	57	55	53	50	46	41
14	3.888	70	67	64	62	60	57	54	50	45
16	4.444	75	72	69	66	63	61	58	53	48
18	5.000	80	76	73	70	67	65	61	56	50
20	5.555	84	80	77	74	71	69	64	60	53
22	6.111	89	84	80	77	75	72	68	63	56
24	6.666	92	88	84	81	78	75	70	65	58
25	6.944	94	90	86	83	80	77	72	67	60
27	7.500	98	93	89	86	83	80	75	69	62
30	8.330	103	98	94	90	87	84	79	73	65
35	9.720	111	106	102	97	94	91	85	79	70
40	11.111	120	114	109	104	100	97	91	84	75
45	12.500	126	120	115	111	107	103	97	89	80
50	13.888	133	127	122	117	113	109	102	94	84
60	16.666	146	139	133	128	123	119	112	103	93
70	19.444	158	150	144	138	133	129	121	111	100
80	22.222	168	160	154	148	142	137	129	119	107
90	25.000	179	170	163	157	151	146	137	126	113
100	27.777	188	179	172	165	159	154	144	133	119

Load losses are represented by the pressure required to overcome fluid resistance to viscosity in pipe system achievement conditions in order to obtain a predetermined flow. Practically, one should be concerned by the following load losses:

1°/ friction of fluids against pipe walls,

2°/ changes in pipe cross-sections and direction, such as widened sections, restricted sections, elbows, tees, cocks, valves, etc. ...

The load loss resulting from a fluid flow in a straight pipe section is:

a/ independent from internal pressure,

b/ in direct ratio of pipe length and fluid density,

c/ in inverse ratio of pipe diameter,

d/ a function of flow velocity (in standard pipes, it may be admitted that the load loss is proportional to the square of the flow velocity),

e/ a function of fluid viscosity and pipe wall roughness.

For example, the nomogram given in page 5 shows load losses given in water head metres per linear metre in a plastic pipe (PVC, ...).

B) Pumping

To move a fluid from one point to another, different types of pumps are used.

A pump is selected by comparing its characteristics with the operating requirements.

The overall pressure head HMT

The overall pressure head (HMT) of a pump is the pressure difference in metres of fluid head (mCL) between the suction and delivery ports.

When pumping a liquid, the pump must not only deliver a pressure equalling the pressure corresponding to the level difference between suction and delivery (overall head geometric height), but also the pressure required to overcome the load losses in suction and delivery pipes (J asp. and J ref. respectively).

If both suction and delivery levels are at the same pressure, say the atmospheric pressure, we have:

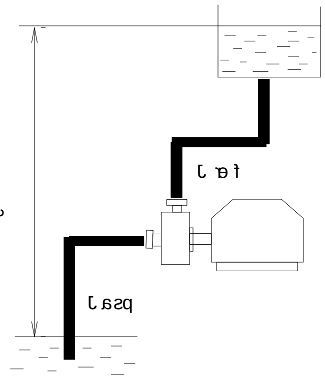
HMT in mCL = H geom + J asp + J ref

If both suction and delivery levels are at different pressures, e.g.: p1 and p2 kg/cm^2, the formula becomes:

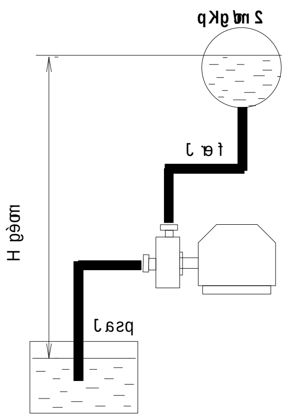
$$\text{HMT in mCL} = \text{H geom} + \text{J asp} + \text{J ref} + \frac{p2 - p1}{\gamma} \times 10$$

where γ is the specific weight of the pumped liquid in kg/dm^3 .

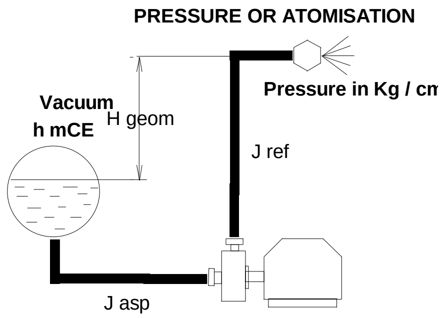
The following diagrams show a few examples of overall pressure head calculations.



HmT = H geom + J asp + J rep



HmT = H geom + J asp +J ref + P/γ x 10



HmT = H geom + J asp +J ref + h/γ + P/γ x 10

The maximum suction head NPSH

Most pumping difficulties originate from too high a suction head. The suction head of a pump is limited because it is in fact the pressure prevailing at the surface of the liquid at the suction level which delivers this liquid into the suction pipe.

If during the suction phase, the level of the liquid to be pumped, water for instance, is at the 760 mm Hg atmospheric pressure, the suction pressure head shall counterbalance this atmospheric pressure, i.e. reach a 10.33 m water head.

Actually, this head is significantly lower because the available pressure is partly necessary to overcome load losses in the suction line on the one hand, and for bringing the liquid to the desired velocity on the other hand.

Further, the absolute pressure at pump inlet should not drop below a determined value because the vapour pressure corresponding to the temperature of the liquid to be pumped should in no case be reached.

If this happened, vapour bubbles might form in the liquid which, when entering the turbine at a higher pressure point, would strongly hit each other and locally cause very high specific pressures likely to fully destroy materials at said points (this phenomenon is called **cavitation**).

In such a case, pump flow-rate would be unfavourably influenced and when reaching the vapour pressure value of the liquid, the inlet pressure would cause the pump to unprime.

The suction capability of a pump is also expressed by the NPSH (Net Positive Suction Head). Currently, using this very usual notation makes it possible to define a pump suction capabilities as a function of its characteristics and operating conditions.

The NPSH is a specific pump characteristic which is fully independent from the carried liquid, making its use very convenient. For each type of apparatus and for a given rotational speed, each manufacturer provides a chart showing the NPSH value as a function of the considered pump flow-rate.

- Static NPSH available (NPSH d)

This represents the power available at the suction tank outlet and is computed as follows:

$$\text{NPSH d} = \frac{10,2}{W}(P - Tv) \pm H$$

NPSH d expressed in metres of liquid head (m.c.l.) where:

W: fluid density at metering temperature

P: pressure (bar absolute) in the suction tank

Tv: vapour pressure (bar absolute) of the fluid at metering temperature

H: geometric suction head (m). The H value is measured between the lowest level of the suction tank and the location of pump suction head.

We use the +H term when the pump is in the so-called "on-load" configuration and the -H term when the pump is in the so-called "suction" configuration.

- Required NPSH (NPSH r)

It is usually admitted to add on-line load losses to the internal pump NPSH required. On-line load losses of the static NPSH available may also be deduced.

- NPSH check

A system is deemed satisfactory in relation to the NPSH criterion if the NPSHd is higher than the NPSHr.

Appropriate installation procedure

Precautions to be taken

A well-performing pumping installation will make it possible to override the problems relating to inertia effects and their consequences in order to yield the desired flow-rate and service pressure.

- **Cavitation**

It may appear at the beginning of the suction phase when the negative pressure required to start moving the fluid head is too high. Any cavitation level will affect pumping accuracy and may lead to damages, vibrations or unacceptable noises. Cavitation hazards are evidenced by NPSH calculations.

- **Excessive flow-rates**

They may appear during suction and delivery due to the inertia of fluid heads.

- On completion of the suction phase:
When the dynamic pressure at pump inlet exceeds the outlet static pressure.

- On completion of the delivery phase:
When the dynamic pressure at pump outlet is lower than the inlet static pressure.

- **Overload**

This may appear at the beginning of the delivery phase when the pump must produce an overpressure to "push" the fluid head. The overpressure must be compatible with the maximum permitted pressure or a breakage (pump, pipes, accessories), motor seizure, pressure relief valve opening, might occur ...

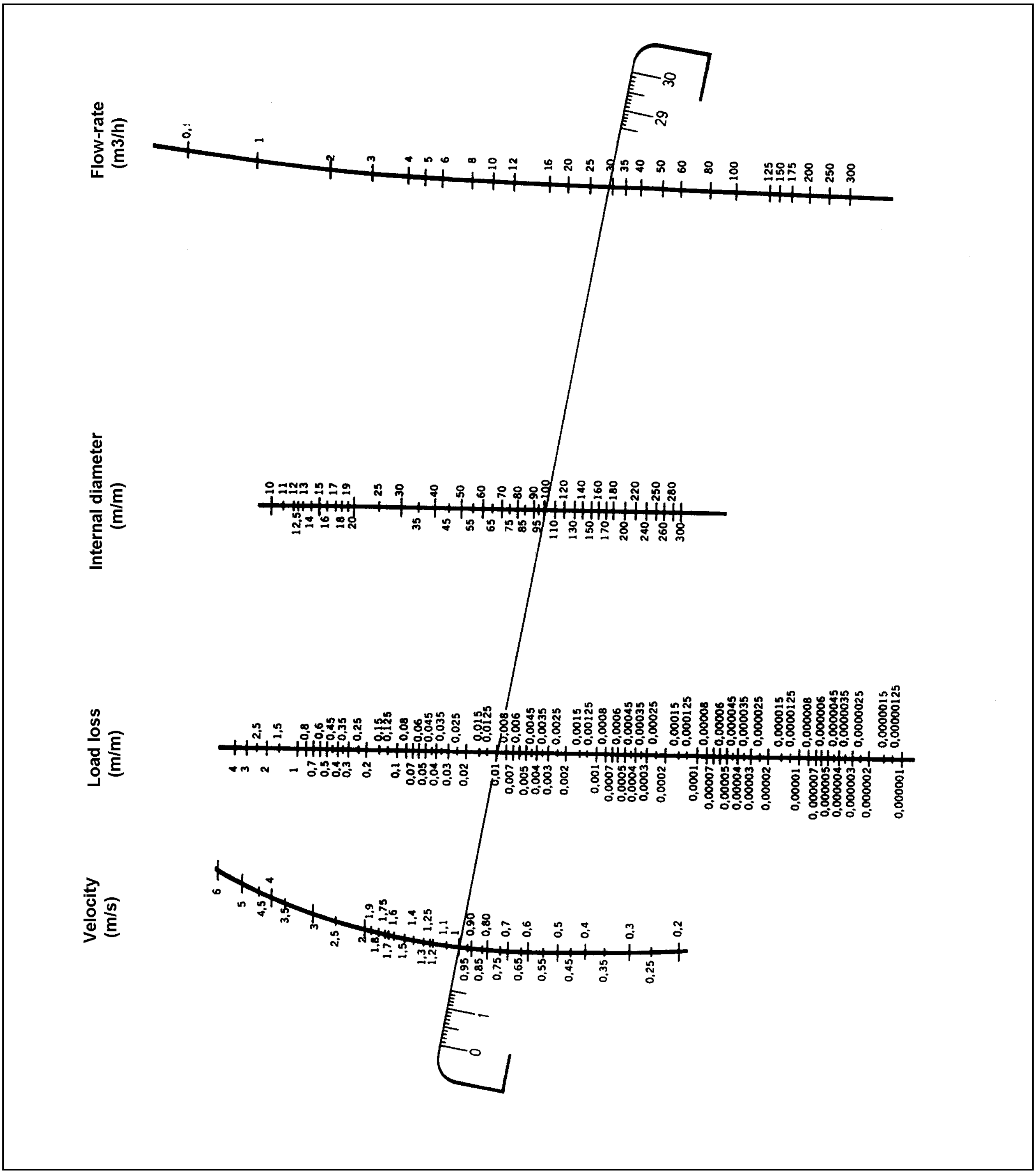
- **Other possible discrepancies**

In addition, a good installation is also the one which provides for reliable pumping and extended equipment lifetime. It should therefore take into account any unpriming or siphoning risks, during shut-down for instance, and include all the necessary washing, discharging and prefiltering devices.

BWT BEST WATER TECHNOLOGY | For You and Planet Blue.

Nomogram

PLASTIC PIPES LOAD LOSSES



LOAD LOSS PER METER IN PLASTIC PIPES

(Water at 20°C)

Example above : FLOW-RATE = about 30 m3/h
Tube dia. = 100 mm
Load loss = 0.01 m per m