PVC-U PRESSURE PIPE

iPLEX Pipelines

PIPELINE DESIGN - HYDRAULIC

FLOW CAPACITY DETERMINATION

The hydraulic capacity of a pipeline can vary due to various factors, which include:

- Growth of slime, which will vary with the age of the pipeline and available nutrient in the water.
- Roughening, due to wear by abrasive solids.
- Siltation or settlement of suspended particulate matter.
- Joint imperfections and fittings

Flow resistance charts relate friction loss to discharge and velocity for pipes running full and have been calculated using the Colebrook-White transition equation in the form:

$$V = -2\sqrt{2gdS}\,\log\left(\frac{k}{3.7d} + \frac{2.51\nu}{d\sqrt{2gdS}}\right)$$

Where:

V = Mean velocity (m/s)

g = Acceleration due to gravity (m/s²)

d = Pipe internal diameter (m)

S = Hydraulic gradient (m/m)

k – Equivalent hydraulic roughness (m)

ν = Kinematic viscosity (m²/s)

The Colebrook-White transition equation takes into account the variation in viscosity with temperature and pipe roughness and is recognised as being one of the most accurate in general use but requires an iterative solution.

The flow resistance charts shown have been prepared based on a temperature of 20°C which corresponds to a kinematic viscosity for water V = 1.01 x 10-6 m^2/s and equivalent pipe wall roughness co-efficient, k = 0.003 mm. These can be downloaded from the Iplex website www.iplex.com.au.

This value of the equivalent roughness coefficient "k" assumes the PVC-U pipeline is straight, clean and concentrically jointed without fittings. Possible values ranging between 0.003 to 0.015 mm are given in AS 2200 “Design Charts for Water Supply and Sewerage" for PVC. An approximate allowance for the effect of variation in water temperature can be made by increasing the chart value of the head loss by 1 % for each 3°C below 20°C and decreasing it by 1% for each 3°C in excess of 20°C.

The hydraulic performance of a pipeline may be adversely affected if combined air release and anti-vacuum valves are not installed at local high points in each section of a pipeline, with a maximum spacing not exceeding 500m. These are required to maintain full bore flow and limit the occurrence of sub atmospheric conditions.

AUSTRALIA'S PIPELINE SPECIALISTS EST. 1938

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PRESSURE CLASS SELECTION

The nominal pressure rating in kilopascals of a PVC pressure pipe is equal to PN multiplied by 100. This rated pressure should not be exceeded at any location in the pipeline by the maximum operating pressure including water hammer pressure surcharges.

When designing a pipeline, Class PN6 should not be used for vacuum conditions unless pipes have been embedded and surrounded in very good, well-compacted non-cohesive material (such as sand or gravel). Above ground pipelines subject to full vacuum should be a minimum of PN9.

Where the pipeline will be operating at elevated temperatures, for example greater than 20°C, the nominal rating should be multiplied by the re-rating factor given in the flow resistence chart. This can be downloaded from the PVC-U pressure pipe pipeline design section of the Iplex website.

Fatigue and structural considerations should also be considered when selecting the pipe class. For example surge pressures commonly known as 'water hammer' must be considered when selecting the pipe class.

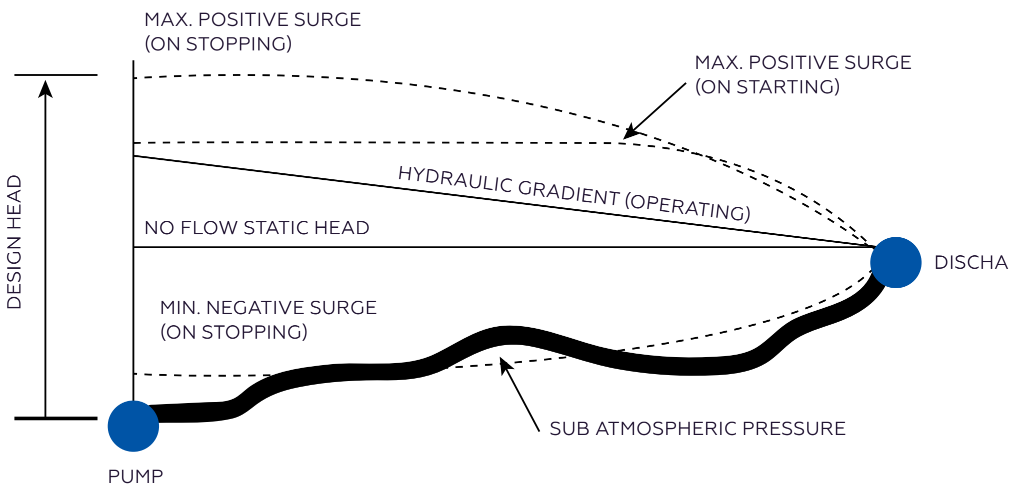

Figure 1.0 Typical hydraulic grades and surge envelopes required for design

WATER HAMMER SURGES AND CYCLICAL EFFECTS

Water hammer effects in thermoplastic materials are considerably reduced compared with ductile iron, steel and concrete due to the much lower modulus of elasticity.

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Typical values for celerity for PVC-U pipes of various pressure classes are provided in Table 1.0.

Where repeated pressure variations occur in PVC-U pipeline, (a pump switching on and off in a rising main) it may be necessary to consider the effect of fatigue over the life of the pipeline.

The designer should take into account the frequency of the cyclic pressure fluctuations during the life of the pipeline. The amplitude of the pressure change between the maximum and minimum operating pressures, including all transients when divided by the load factor given in Table 2.0 should not exceed the nominal pressure class rating of the pipeline.

TABLE 1.0 - WATER HAMMER CELERITY

MATERIAL	APPROXIMATE CELERITY (M/SJ)
4.5	253
6	293
9	362
12	421
15	446
16	495
18	528
20	561

In practice the pressure changes in water reticulation systems are seldom of sufficient amplitude and frequency for fatigue to affect pipe class selection, but they can be an important consideration for sewer rising mains.

TABLE 2.0 - PVC-U FATIGUE LOAD FACTORS

TOTAL CYCLES	APPROXIMATE NO. OF CYCLES / DAY FOR 100 YEAR LIFE	FATIGUE FACTOR F
26, 400	1	1
100, 000	3	1
200, 000	5.5	0.81
500, 000	14	0.62
1,000,000	27	0.50
2,500,000	68	0.38
5,000,000	137	0.38
10,000,000	274	0.38

Reference: PIPA Industry Guidelines "PVC Pressure Pipes, Design for Dynamic Stresses" Issue 1.2 POP101

The frequency is defined as the number of combined pump start and stop cycles. If an allowance is considered necessary to allow for attenuation of water hammer oscillations, the frequency can then be taken as being twice the number of start/ stop cycles. (It can be shown mathematically that this is appropriate for the exponential decay typical of pressure surge oscillations).

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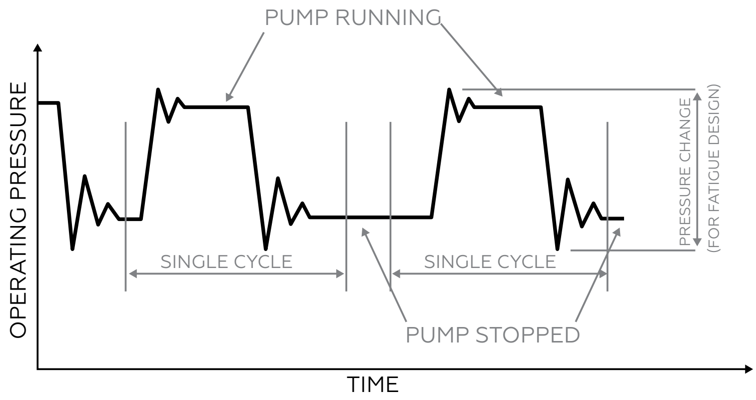

Figure 4.0 - Inputs for fatigue design - pressure amplitude and frequency

The dynamic fatigue consideration requires a pipe to be selected with a pressure rating which, when multiplied by the fatigue factor, will give a value (Maximum Cyclic Pressure Range) greater than the pressure range or amplitude.

Examples:

1) Question A water main will for most of its lifetime experience diurnal operating pressures of 55 metres and 85 metres, that is a pressure change amplitude of 30 metres with a total number of cycles over 50 years of 18250 fluctuations.

Solution: Since the maximum operating pressure is 85 metres and from Table 2.0, the fatigue load factor is 1, a PN 9 pipe would be suitable. No de-rating is needed for cycling.

2) Question A sewer pump station has a wet well capacity which will require a pump start (and stop) 3 times per hour on average over a 40 year design life (for the rising main). The static head on the main without pump operation is 12 metres and with a maximum pump station operating of 29 metres. A surge analysis shows the normal shut down phase generates a (maximum) hammer effect of 32 metre maximum head and (minimum) minus 8 metre head at shut down.

Solution: Steady state operating conditions would suggest that a Class 6 pipe might be selected. However the amplitude of the maximum pressure transient during the pumping cycle is 32-(-8)= 40 metres and this must be checked for fatigue effect.

The number of cycles used for this check is usually the number of pump stop/start operations. But in this case the number of cycles is to be multiplied by 2, i.e. 1,051,200 x 2 = 2,102,400 to allow for surge wave attenuation.

The dynamic fatigue consideration requires a pipe to be selected, which will give a maximum cyclic pressure range greater than the pressure fluctuation amplitude of 40 metres. Therefore the class rating can be obtained by dividing the pressure amplitude by the fatigue factor obtained from Table 2.0 for a frequency of 2.1 million pressure fluctuations. (It should be noted that pressure amplitude of 0.38 times the rated pressure is the threshold value below which fatigue will not occur irrespective of frequency.) Here 40 / 0.38 = 105.3m. Therefore the appropriate pipe class selection would be PN12 rated to 120 metres.