Internal Training

Training Course:	**Water Distribution Management**
Training Module P-5:	**Water Pressure Control**
Version:	**01 July 2022**

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Training Course: **Water Distribution Management**

Training Module P5: **Water Pressure Control**

1. Outline of the training module

1.1 Background of the training

[Controlling and regulating the pressure in the water supply network can provide savings on resources as well as reduce the level of non-revenue water.]

Pressure management is the single most beneficial and cost-effective leakage management activity. Most pipe bursts are not caused solely by high pressure, but by continuous pressure fluctuations that force the pipe to continuously expand and contract, causing stress fractures.

However, there is a close relationship between leakage and pressure. The higher the water pressure, the greater the risk of leakage. Therefore, pressure should be kept to a minimum to the extent that it does not affect the needs of consumers.

The water utility's responsibility is to provide consumers with sufficient quantities of water at the correct water pressure. Therefore, water utilities often use a constant inlet pressure if not a fixed inlet pressure for individual zones/districts to ensure that consumers have sufficient pressure at all times of the day.

[Pressure level at the consumers]

The pressure at the consumer depends on the friction losses in the distribution pipe and the difference in height from the reservoir. To compensate for friction, the inlet pressure is usually set higher than the minimum required pressure.

However, friction losses depend on the flow rate and therefore vary with consumption. If the inlet pressure (water level in the reservoir) is constant, the pressure at the consumer varies with consumption during the day.

In practice, this means that the pressure at the consumer will be highest at times when water is least needed and lowest at times when it is actually used a lot, e.g. in the morning or in the evening.

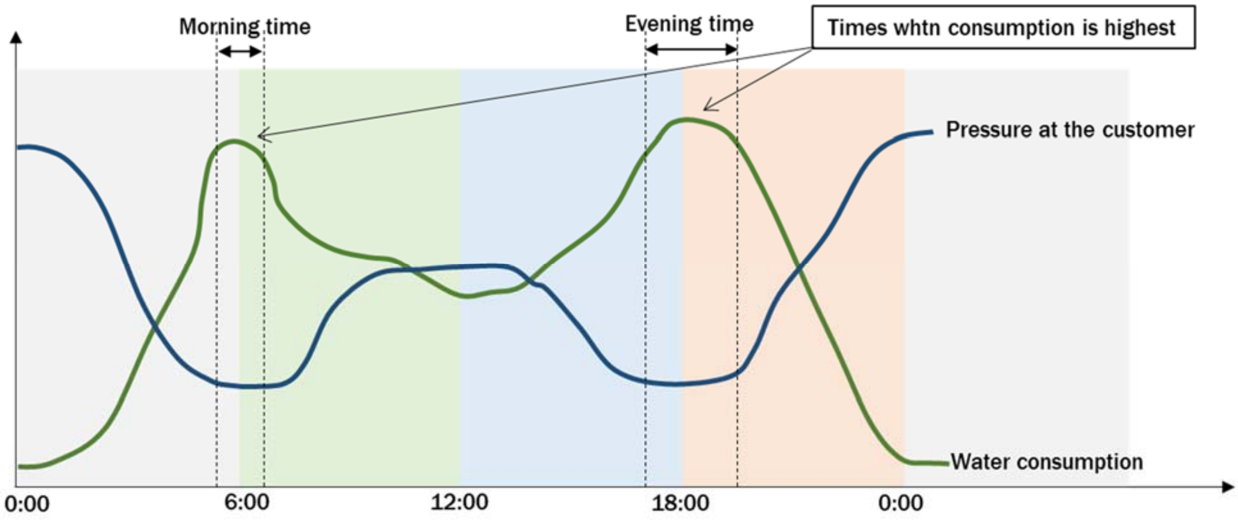


Figure 1.1 Relation between Consumption and Pressure

[Keeping the pressure level at customer]

To ensure that consumers do not experience pressure that is too low, the inlet pressure is generally usually determined based on peak consumption. For this purpose, a hydraulic analysis of the pipe network is carried out.

Typical consumption patterns for water supply show a rapid increase in consumption only for short periods in the morning and evening during the day. Industries that consume large amounts of water are an exception, but in a normal household, the time of high consumption is considered to be around two hours a day.

A high pressure has a huge impact on the distribution network. This applies to the overall service life of the components and to the number of fractures and pipe bursts.

[A lower pressure reduces pipe bursts and leakage – and thus also non-revenue water]

There is a direct correlation between water pressure and the number of pipe bursts. A international study has shown that a 37% reduction in the average pressure resulted in a 51% reduction in the number of bursts[1].

In addition, high water pressure also increases the risk of water loss due to leakage, as leakage through a hole in a pipe is highly pressure-dependent.

If, for example, there is a 5 mm hole at a pressure of 5 bar, it will result in a water loss of 11,520 m^3 per year. If, on the other hand, the pressure is lowered to 4 bar, the annual water loss will be reduced by 11%, corresponding to 1,267 m^3 [2](source (Danish)).

[Effective pressure management based on time or flow]

Maintaining the pressure in the distribution network within the correct range is essential for the efficient use of water, but can be easily achieved without compromising quality.

Reducing the inlet pressure during periods of low consumption helps consumers maintain an acceptable minimum pressure and reduces the risk of water cuts due to burst or broken pipes. Consumers will also generally experience more uniform pressure throughout the day.

1.2 Purpose of this training

The training aims to provide staff who will be working in water supply service by KUKL with the basic knowledge required for water pressure control in the distribution networks, as well as to understand the practicalities of water pressure measurement and analysis of the results, and the negative effects of water pressure fluctuations on the distribution pipe network.

1.3 Target person

- Persons newly appointed Level 5 Senior Assistant (Technical)
- Persons newly appointed Level 6 Assistant Officer (Technical)

[1] https://www.waternz.org.nz/Attachment?Action=Download&Attachment_id=3683

[2] http://www.kildekrogvand.dk/SPAR-P%C3%85-VANDET/Vandspild.aspx

1.4 Timetable

[Session 1: Lecture]

- Definition of Pressure
- Understanding of Water Pressure
- Control of Water Supply Pressure
- Protection of Water Hammer

[Session 2: Practice of Water Pressure Measurement]

- Setting and Installation of Datalogger
- Pressure measurement with Datalogger
- Pressure measurement with Bourdon Tube Pressure Gauge

[Session 3: Achievement test]

Table 1.1 Training Timetable

Session	Activity	Estimated time	Venue
1	Lecture	90 min	Mahankalchaur Seminar Room
	Q&A	10 min	
	Lunch break	60 min	
2	Practice & Data analysis	90 min	Mahankalchaur Training Yard
	Coffee Break	20 min	
3	Achievement test	30 min	Mahankalchaur Seminar Room
	Total	300 min	

2. Definition of Pressure

2.1 How to express the water pressure

2.1.1 Understanding of SI units

There are a number of ways of expressing units related to force, but in addition to the International System of Units (SI) units, which are the international standard, there are other ways of expressing force as an engineering system of units.

Table 2.1 Pressure Unit

Unit	Symbol	Conversion	Meaning
SI Unit			
Mass	kg		
Newton	N	1N = 1kg･1m/s^2	Magnitude of force required to produce an acceleration of 1 m/s^2 when a force acts on an object with a mass of 1 kg.
Pascal	Pa	1Pa = 1N/m^2	Force (N) applied per unit area (m^2)
Mega Pascal	MPa	1MPa = 10^{6}Pa	
Non-SI Unit			
Bar	Bar	1bar = 10^{5}Pa	Pressure
Standard Atmospheric Pressure	Atm	1atm = 101.325MPa	Pressure
Engineering Unit			
Kilogram-force	Kgf	1kgf = 9.8N	The magnitude of the gravitational force that a 1 kg mass is subjected to under standard gravitational acceleration (9.8 m/s^2).
Kilogram-force per square meter	kgf/m^2	1kgf/m^2 = 9.8Pa	Force applied per unit area (kgf)
Weight kilograms per square centimeter	kgf/cm^2	1kgf/cm^2 = 98.067Pa	Force applied per unit area (kgf)
Pound per square inch	psi	1psi = 9.8Lb/in^2	Force applied per unit area (Lb.)

The terms that should be distinguished when referring to Newton are the terms “mass” and “gravity”.

When describing the computer at hand as weighing 3 kg, it is accurate to say that it has a “mass of 3 kg”.

When you lift a computer with a mass of 3 kg, you naturally feel its weight because of gravity. This is because of the force generated by the earth pulling on the computer, and the magnitude of this pulling force is called “Weight”, or “Gravity”, and is expressed in units of “Newton”.

To convert “Weight” into “Newtons (N)”, multiply the mass (kg) by the standard acceleration of gravity (9.8 m/s^2).

Weight (N) = Mass (kg) × 9.8 (m/s^2)*1

Note*1: The standard acceleration of gravity is 9.8 m/s2 for the Earth, but about 1.6 m/s^2

for the Moon.

For example, the weight of an object with a mass of 1 kg on the earth is:

$1\ \text{kg} \times 9.8\ \text{m/s}^2 = 9.8\ \text{kg}\cdot\text{m/s}^2 = 9.8\ \text{N}$

2.1.2 Understanding of Pressure

Pressure is a force acting perpendicularly to a unit area.

The pressure exerted by an object placed on a table is determined by dividing the 'force applied' by the area subjected to it.

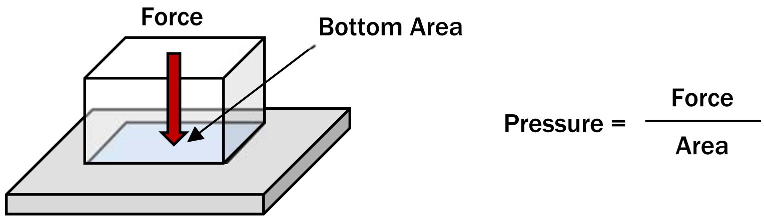


Figure 2.1 Meaning of pressure

For example, even if the following objects had the same mass, they would receive different pressures in different areas.

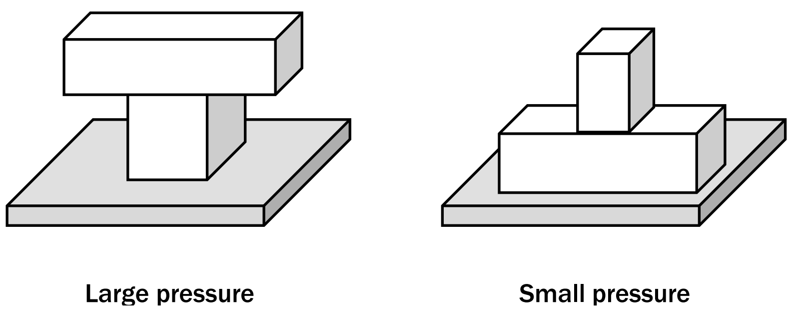


Figure 2.2 Difference of pressure

Although SI units exist as an international unit arrangement, gravity units are still widely used as a way of expressing pressure. Furthermore, in the field of water supply, pressure is often expressed in terms of the height of the water column (m-H_2O).

The relationship between the units is shown in the conversion table below.

Table 2.2 Conversion of pressure unit

	MPa	kgf/cm^2	bar	atm	psi	$m\text{-}H_2O$
MPa	1	10.197	10	9.869	145.03	101.974
kgf/cm^2	0.0981	1	0.9807	0.9678	14.223	10
bar	0.1	1.0197	1	0.9869	14.503	10.197
atm	0.10132	1.0332	1.0133	1	14.7	10.332
psi	0.06894	0.0703	0.0689	0.068	1	0.703

[Example]

Try filling one empty rectangle box with water as follows:

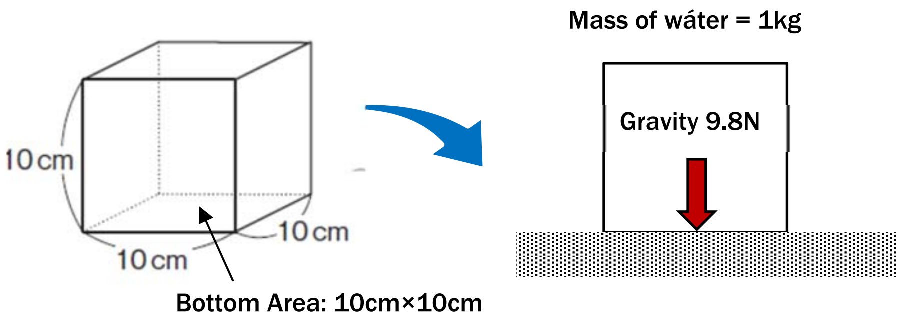


Figure 2.3 Example of pressure calculation

Bottom Area = 0.1m × 0.1m = 0.01 m^2

Volume of box = 0.1m×0.1m×0,1m=0.001m^3

The mass of water in a volume of 1 m^3 is 1,000 kg (1 ton), so the mass of water in the figure above is:

1,000 kg × 0.001 m^2 = 1 kg

Thus, the gravitational force on this water is:

1 kg × 9.8 m/s^2 = 9.8 N

The water pressure produced at the bottom is :

9.8 N / 0.01m^2 = 980 N/m^2 = 980 Pa

This means that the water pressure at a depth of 10 cm is 980 Pa.

In the field of water supply, a supply water pressure of 10 m is frequently used as a reference value.

10m → 98,000 Pa → 0.0098 MPa ≒ 0.01 MPa

3. Understanding of Water Pressure

3.1 What is the Hydraulic Head?

The magnitude of water pressure at a given location in a water pipe, converted into the height of the water column, is called the "Hydraulic Head" or "Water Head".

For example, what would the hydraulic head be if the water pressure in the following pipeline was 1 MPa (= 10 bar = 10.2 kgf/cm^2)?

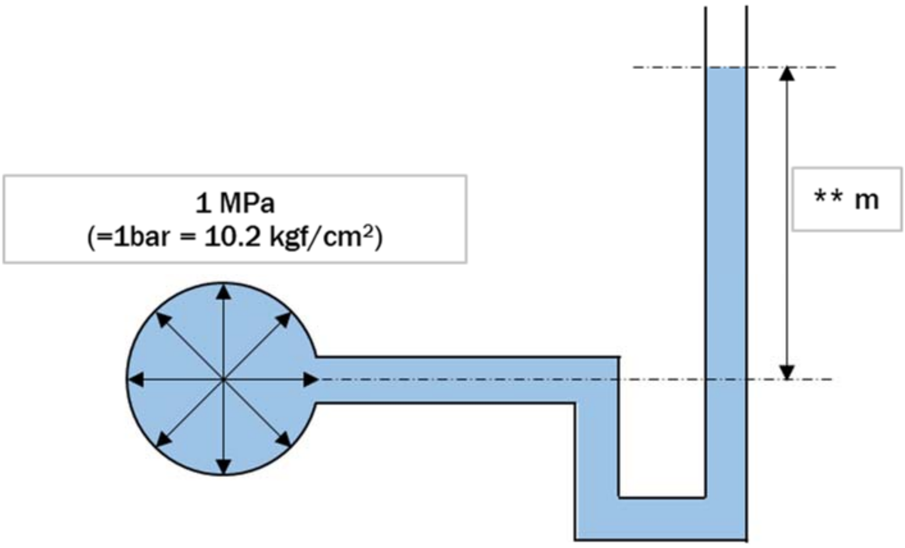
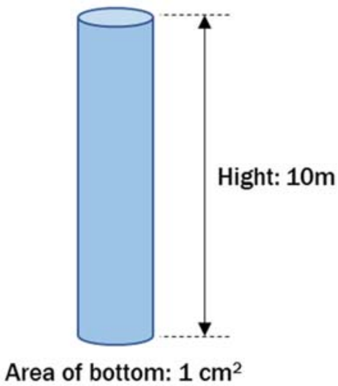


Figure 3.1 Calculation of Hydraulic Head

This can be easily calculated assuming the following water column.



Water column with 1cm^2 of bottome area and 10 m of hight

The volume of this columun is:

1cm^2×1,000cm=1,000cm^3

The density of water is 1,000kgf/m^3

Using the following relation:

1m^3=100cm×100cm×100cm=1,000,000cm^3

Thus, the weight per 1,000,000 cm^3 is 1,000 kgf.

Thus, the weight of 1,000 cm^3 of water column on the left is 1 kgf.

Figure 3.2 Simple Water Column

As the bottom area of this water column is 1 cm^2, the pressure on the bottom can be expressed as 1 kgf/cm^2, which is the pressure for a height of 10 m in the water column. In other words, it can be expressed as 1 kgf/cm^2 = 0.1 bar = 0.1 MPa = 10 m-H^{2}O.

In this way, it can be seen that a water pressure of 1 MPa corresponds to a water head of 100 m.

3.2 Static Pressure and Dynamic Pressure

Water pressure is classified into "Static Pressure" and "Dynamic Pressure".

The static pressure is the water pressure when the flow of water in a reservoir or water pipe is at a standstill.

Water in a reservoir or pipe pushes against the sides wall and bottom of the reservoir. The pressure at this point is water pressure, and the static pressure can be understood in the image below:

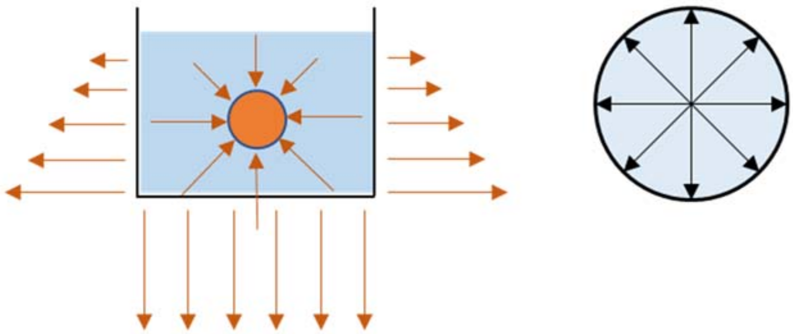


Figure 3.3 Image of static pressure

The static pressure is the water pressure at a standstill (non-waterflow), so in the case of a distribution pipe network, the difference in elevation between the water level in the reservoir and the customer's water tap corresponds directly to the static head.

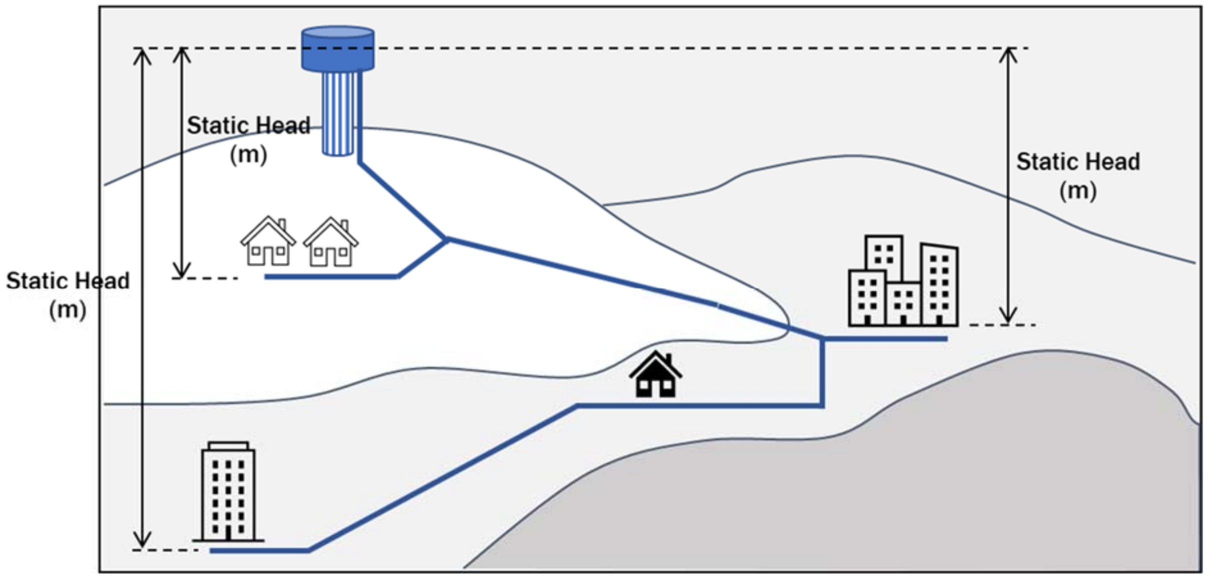


Figure 3.4 Image of static pressure in the distribution network

On the other hand, when there is a flow of water, water pressure losses due to friction in the pipe usually create a pressure lower than the static pressure. This pressure is called dynamic pressure.

The dynamic pressure is used to express the water supply pressure, as water use always occurs somewhere in the distribution pipe network.

3.3 Classification of Pressure

Pressure is classified into three types depending on how the zero reference is taken: “Absolute Pressure”, “Gauge Pressure” and “Differential pressure”.

[Absolute Pressure]

A pressure indication when a perfect vacuum is used as a zero reference. Generally, the sign “abs” is added after the unit symbol.

[Gause Pressure]

A pressure indication when atmospheric pressure is used as the zero reference. Generally, the sign G is added after the unit symbol. When a negative gauge pressure, i.e. a pressure lower than atmospheric pressure, is indicated, it is called vacuum pressure.

The pressure dealt with in water supply usually means “Gauge Pressure”. Pressure gauges that can measure positive and negative gauge pressure are called “Compound Gauge” and are often installed in wells or at pump outlets.

[Differencial Pressure]

A pressure indication that takes any pressure value other than atmospheric pressure as the zero reference, used to indicate the difference in water levels between two distribution reservoirs, the difference in water pressure before and after a valve, etc.

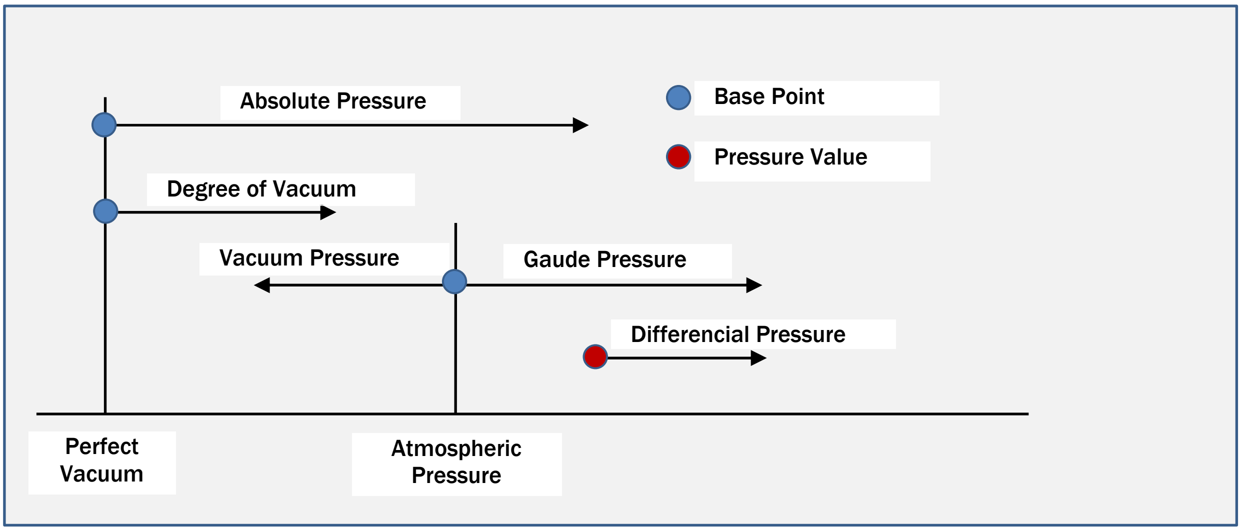


Figure 3.5 Classification of pressure indication

3.4 Understanding of "Differential Pressure"

3.4.1 Bernoulli's principle

In a steady flow*1 of an inviscid and incompressible fluid, the sum of the energy of the fluid per unit volume on the streamlines is always constant.

Note*1: A steady flow is the one in which the quantity of liquid flowing per second through any section, is constant.

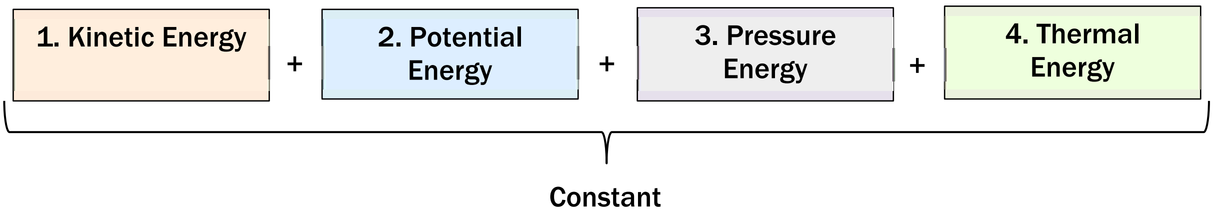


Figure 3.6 Bernoulli's principle

Bernoulli's principle holds under the following conditions:

- No change in density of fluid
- Steady flow (flow whose state does not change over time)
- Streamline flow
- No change in thermal energy of fluid
- No frictional losses
- No loss due to viscosity
- No turbulence in flow

Friction is caused by the viscosity of the fluid, but Bernoulli's principle applies to non-viscous fluids, so it can be assumed that the "Thermal Energy" remains unchanged.

Therefore, the sum of the energies (1) to (3) is constant, which can be considered as shown in the figure below:

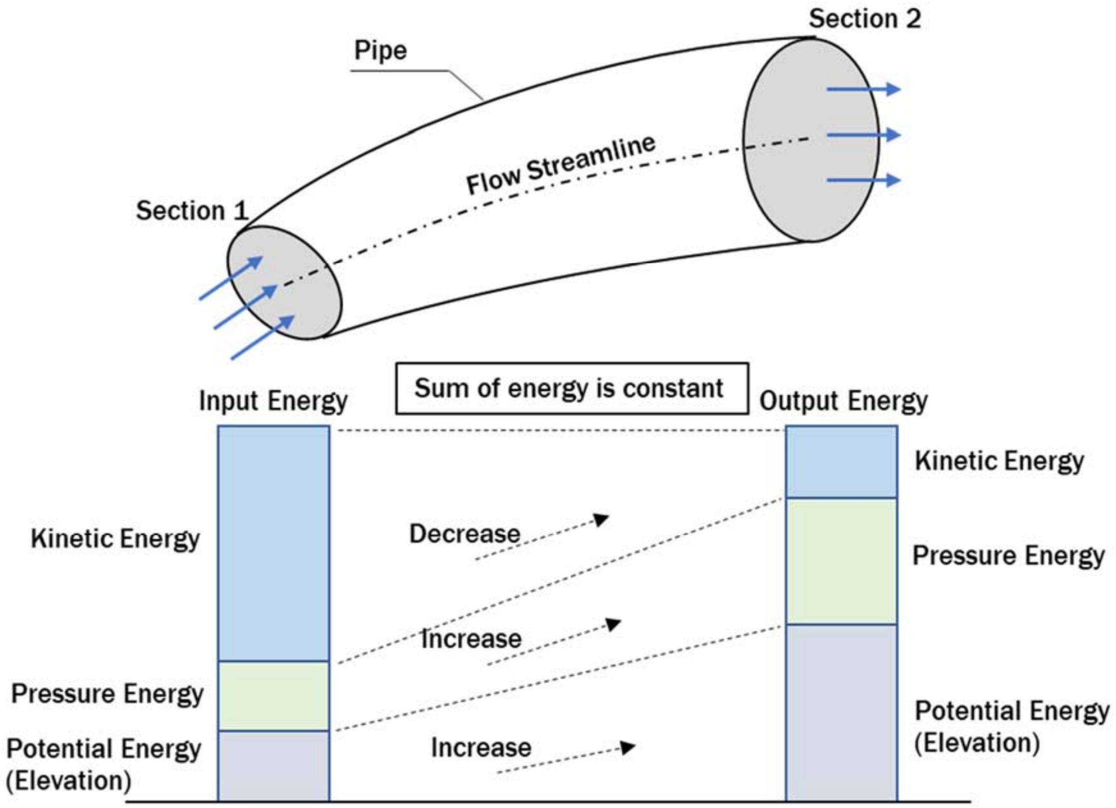


Figure 3.7 Image of law of the energy conservation

Each of the energies in this diagram can be expressed by the following equation:

$$\text{Kinetic Energy} + \text{Pressure Energy} + \text{Potential Engery} = \frac{1}{2}\rho v^2 + P + \rho g z = \text{Constant}$$

ρ: Density of fluid
v: Velocity of fluid
P: Pressure
g: Gravitational acceleration
z: Elevation

Dividing this equation by the “Specific Weight of fluid” (=ρg) allows Bernoulli's principle to be expressed in terms of “Hydraulic Head”.

$$\frac{v^2}{2g} + \frac{P}{\rho g} + z = \text{Constant}$$

The “Hydraulic Head” or “Water Head” is the energy possessed by water converted into the height of the water column. It can also be referred to as energy per unit weight of water.

The energy of a fluid includes “Kinetic Energy”, “Pressure Energy” and “Potential Energy”, which are converted into hydraulic head and are called “Velocity Head”, “Pressure Head” and “Potential Head”, respectively.

In addition to this, there are various types of lost hydraulic head as energy lost due to pipe friction, bends, inlets and outlets, etc. (proportional to the velocity head). The sum of all these hydraulic heads is called the “Total Hydraulic Head”.

When water flows through a pipe, energy is lost due to friction with the walls. This lost energy is called the “Hydraulic Head Loss”, which corresponds to Y (=hL) in the diagram above.

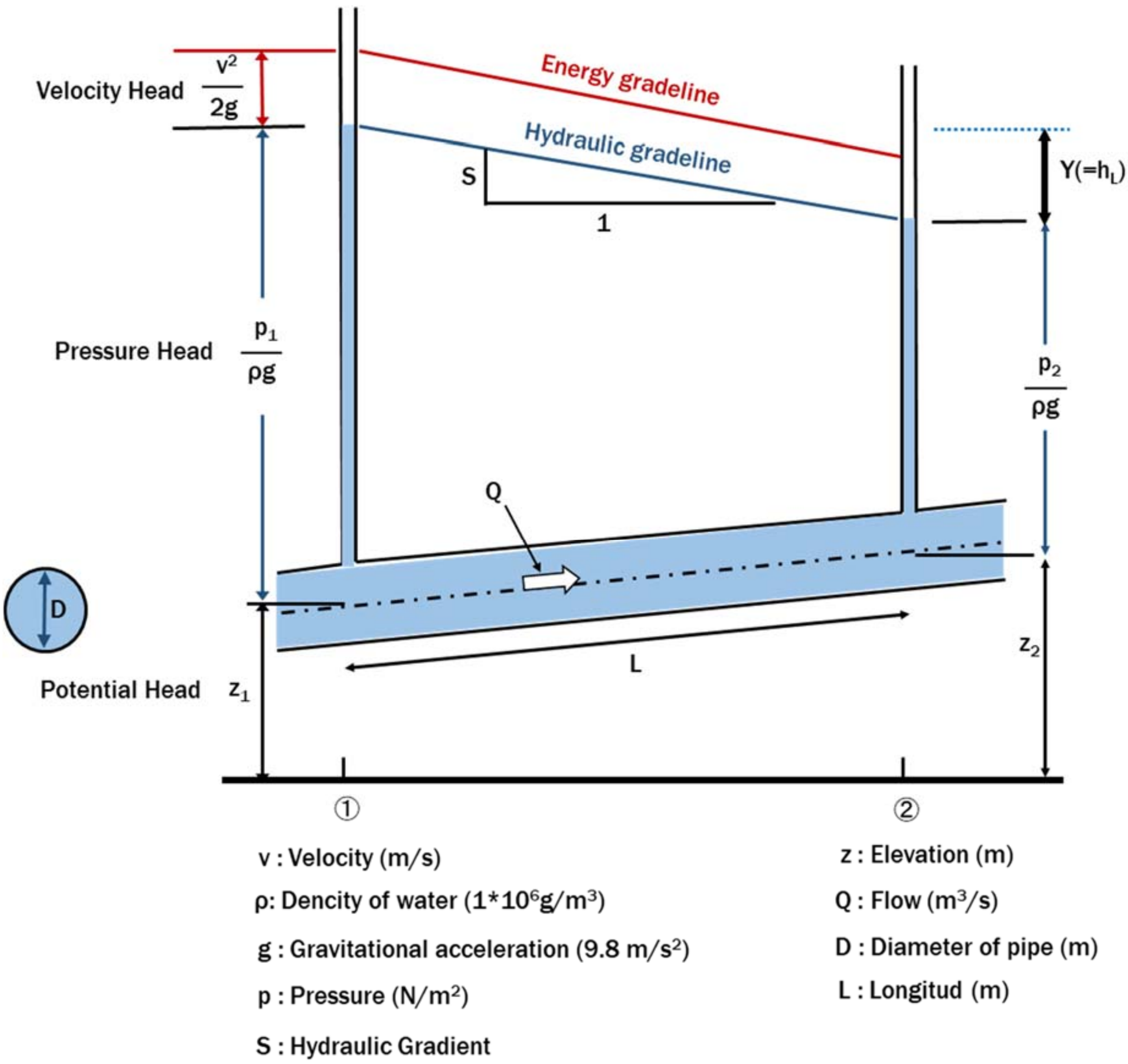


Figure 3.8 The relation between water flow and energy

3.4.2 Mechanism of Venturimeter

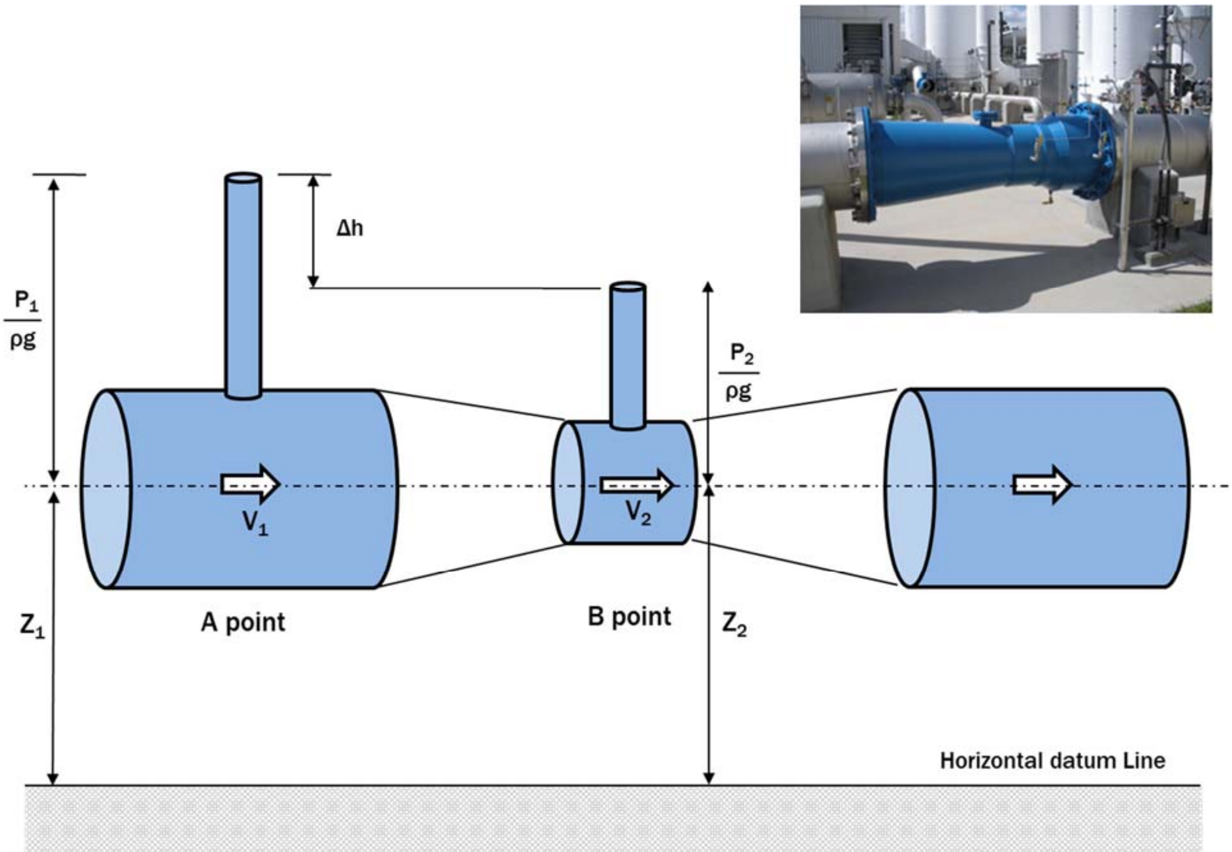
Taking the following figure as an example, the sum of the velocity, pressure and positional heads on a single streamline is constant if the loss hydraulic head (Δh) generated by the water flow is ignored.

This means that in this case the sum of the energies at points A and B is equal.

$$\frac{V_1^2}{2g} + \frac{P_1}{\rho g} + Z_1 = \frac{V_2^2}{2g} + \frac{P_2}{\rho g} + Z_2$$

Energy at A point = Energy at B point

Flow meters using the above theory are called "Venturimeter" and are summarised as follows.



$V_1^2/2g$: Kinetic Head (m)

$P/\rho g$: Pressure Head (m)

Z : Potential Head (m)

Figure 3.9 Mechanism of Venturimeter

The cross-sections of the pipes at points A and B are different. A smaller cross-section naturally results in higher flow velocities and a larger velocity head.

If the tube is horizontal, Z_1 and Z_2 are equal, so for Bernoulli's law of energy conservation to hold, there must be a difference between P_1 and P_2.

This difference is the differencial pressure head (Δh) and by measuring this value, the flow rate in the pipe can be easily calculated.

$$\frac{V_1^2}{2g} + \frac{P_1}{\rho g} + Z_1 = \frac{V_2^2}{2g} + \frac{P_2}{\rho g} + Z_2$$

Energy at A point = Energy at B point

$$\frac{V_1^2}{2g} + \frac{P_1}{\rho g} = \frac{V_2^2}{2g} + \frac{P_2}{\rho g}$$

$$\frac{P_1}{\rho g} - \frac{P_2}{\rho g} = \frac{V_2^2}{2g} - \frac{V_1^2}{2g}$$

If the flow rate in the pipe is Q and the cross-sectional area is A_1 and A_2 respectively, the above equation can be transformed as follows:

$$\frac{P_1}{\rho g} - \frac{P_2}{\rho g} = \frac{(Q/A_2)^2}{2g} - \frac{(Q/A_1)^2}{2g}$$

$$\underbrace{\frac{P_1}{\rho g} - \frac{P_2}{\rho g}}_{\Delta h} = \frac{Q^2}{2g} \times \left[\frac{1}{A_2^2} - \frac{1}{A_1^2} \right]$$

Here, the left-hand side is the difference in pressure between points A and B (Δh).

$$Q = \sqrt{2g\,\Delta h} \times \frac{A_1 * A_2}{\sqrt{(A_1 + A_2)(A_1 - A_2)}}$$

As can be seen, if the cross-sectional area of the pipe (A_1, A_2) is known in advance, the flow rate in the pipe can be calculated by measuring the differencial pressure (Δh) with a pressure gauge.

4. Control of Water Supply Pressure

4.1 Importance of Water Supply Pressure Control

In order to ensure fair and trusted water distribution, it is important to manage the distributed water volume and keep the water supply pressure within appropriate range.

To this end, KUKL is required to establish the following management system:

- Identify the areas and boundaries that each distribution reservoir covers within a larger water distribution area.
- Record how the water produced at the WTPs is distributed, by which route, to which districts and in what quantities.

Water distribution coordination requires planning the laying of distribution pipes and operating valves and other facilities to ensure that the water supply area is supplied with approximately equal water pressure.

In the DNI project, one of the sub-components of the Melamchi Water Supply Project, the water distribution network within the ring road is planned to be divided into 9 independent zones, each of which consists of several District Metered Areas, known as sub-DMAs.

The DNI project within the ring road designed to ensure that the water supply pressure at the customer taps does not fall below 0.05MPa (5 m of hydraulic head).

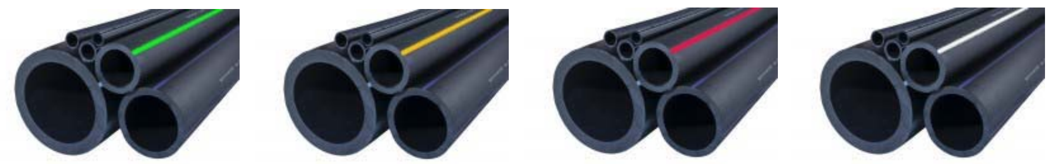
In general, the minimum dynamic pressure of water distribution pipes should ideally be between 0.15 MPa (15 m) and 0.2 MPa (20 m), while the maximum dynamic pressure should be below 0.75 MPa (75 m).

The Technical Standards of pipe materials are set on the basis of this design criteria of supply pressure. For example, the HDPE pipes are divided into six types according to their application and pressure resistance, and the appropriate material should be selected according to the conditions of use.

Table 4.1 Type and Pressure Resistance of HDPE pipe

Line Colour	Nominal Pressure	Máximum Pressure
Red	PN-2.5	0.25 MPa (0,025 bar)
Blue	PN-4.0	0.4 MPa (0.04 bar)
Green	PN-6.0	0.6 MPa (0.06 bar)
Yellow	PN-10.0	1.0 MPa (0.1 bar)
Purple	PN-12.5	1.25 MPa (0.125 bar)
White	PN-16	1.6 MPa (0.16 bar)

Source: Nepalese Standard 40



It should be noted that if the water supply pressure is greater than designed, not only will the customer use more water than expected, but excessive water pressure can also cause water leakage on the pipe.

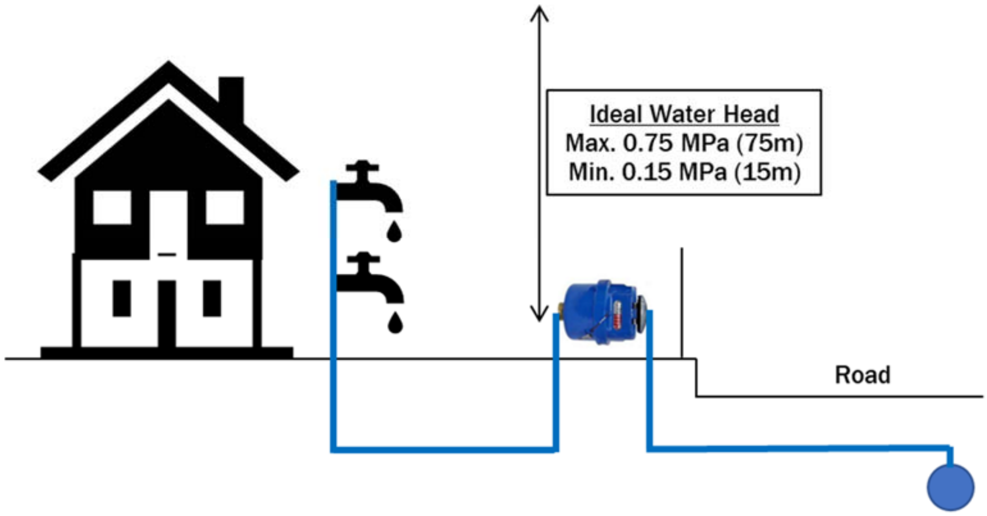


Figure 4.1 General Standard of Water Supply Pressure at the taps

4.2 Type of Pressure Gauge

4.2.1 Bourdon Gauge

Water pressure in distribution pipes is generally expressed in terms of "Gauge Pressure".

Bourdon Tube Pressure Gauges are used as instruments to measure gauge pressure.

The following is a hydrometer called a C-type Bourdon tube.

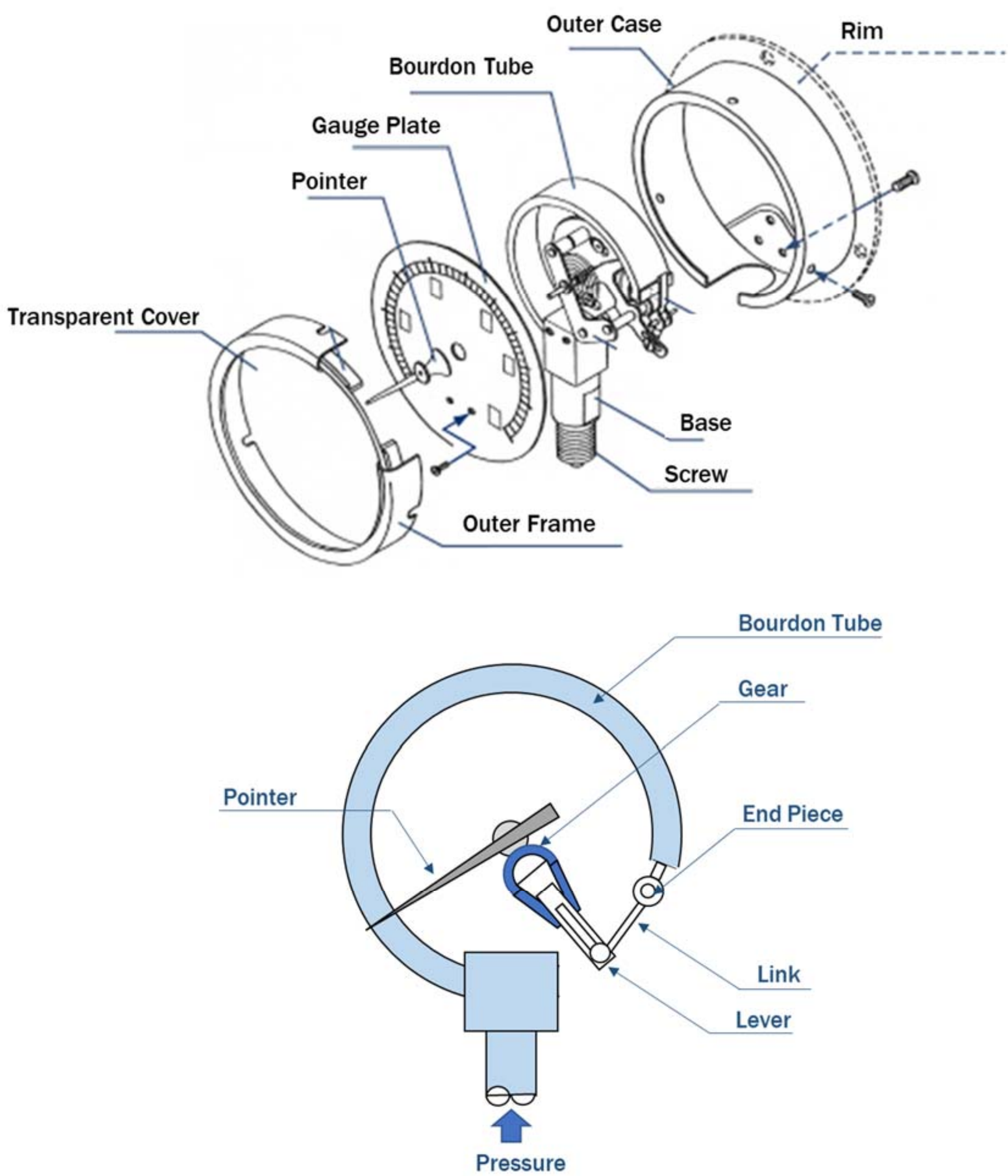


Figure 4.2 Mechanism of Bourdon Tube Pressure Gauge

The Bourdon tube is based on a patent granted by Dr. Bourdon in 1852.

They are widely used and account for the majority of pressure indicators on the market because they are simple in construction, cheap to manufacture and do not require external energy (electricity) to indicate pressure. However, it has the following drawbacks:

- The error occurs when large forces are taken out of the Bourdon tube to indicate the pressure value, so the indicating mechanism needs to be light and frictionless.
- It usually uses gears or levers and is therefore vulnerable to vibration and shock.
- The narrow interior of the Bourdon tube makes it unsuitable for use with fluids containing solids or liquids of high viscosity.

Bourdon tube pressure gauges are divided into the following types, depending on the range of pressure to be measured.

Table 4.1 Type of Bourdon Tube Pressure Gauge

Pressure Gauge	Vacuum Gauge	Compound Gauge
		
General pressure gauges measure the positive gauge pressure at a location.	For measuring negative gauge pressure.	It consists of a pressure section showing positive gauge pressure and a vacuum section showing negative gauge pressure. In particular, the installation of this gauge on the pump discharge pipe allows monitoring of abnormal pump operation (negative pressure).

4.2.2 Pressure Datalogger

(1) General

A data logger is a function or machine that mechanically determines and intermittently stores information on events that are difficult for the human eye to discern or to convert into data.

It is widely used in environments that are difficult for humans to measure. Conversely, they are also used to measure events such as very long-term weather and environmental changes.

Recording methods include paper, tape and digital information (data is often stored and displayed via a USB port to a PC), which can be used for different purposes.

- For acceleration, etc. >>> Momentary parameters
- For Temperature, humidity, flow velocity, flow rate >>> ever-changing parameters
- For Location data corrected by Global Positioning System (GPS)

(2) Use of Datalogger

Water pressure data loggers are available from a variety of manufacturers worldwide, but the LoLog 450, marketed by Halma Water Ltd in the UK, is used here as an example.

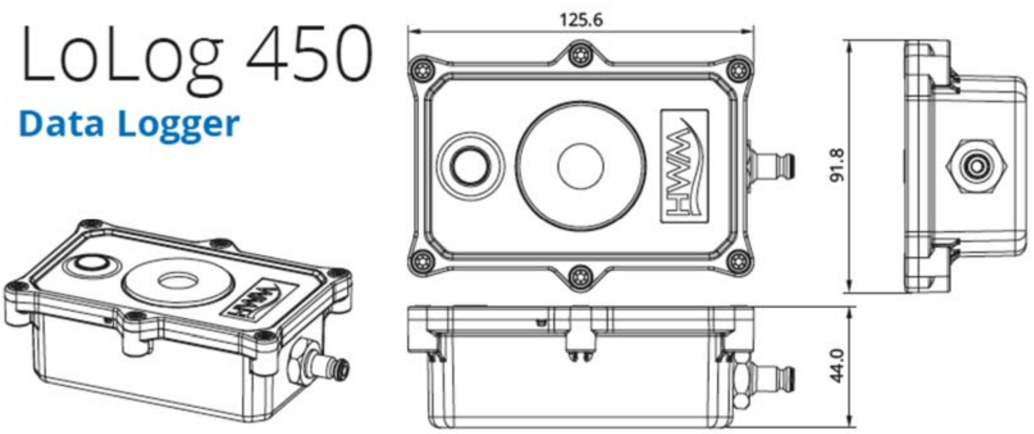


Table 4.2 Characteristics of LoLog450

Items	Description
Analogue input	Internal Pressure Transducer
Memory	64,000 recording in continuous (cyclic) operation as a standard model.
Ingress Protection	IP68
Power	Lithium battery operational for 5 years under typical operating conditions.
Communication	Serial RS232 by Infra-red port for connection to a PDA hand held computer, laptop or desktop PC 9,600 baud.
Construction	Rugged plastic enclosure.
Frequency	Sample periods in 1 second increments from 1 to 60 seconds. Then 1 minute increments from 1 to 60 minutes. Then 1 hour increments from 1 to 24 hours.
Logger ID	Up to 7 alphanumeric characters.
Site ID	Up to 127 alphanumeric characters.
Clock	On board 24 hour real time clock with date facility.

(3) Logging interval

Since the water pressure fluctuates according to changes of water volume in the distribution network, it is necessary to set an appropriate interval according to the purpose of measurement.

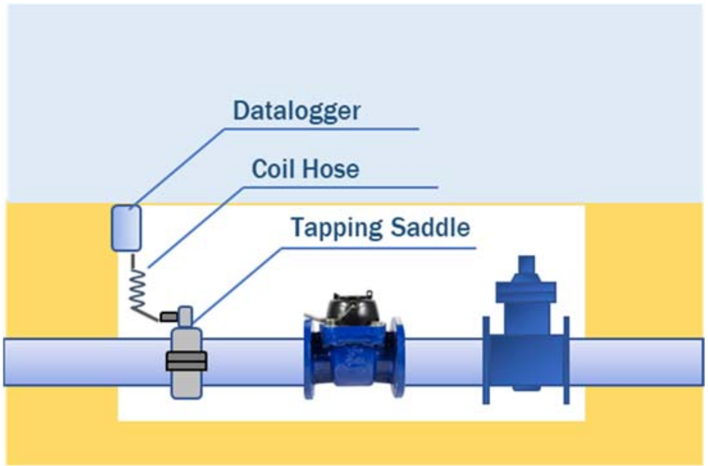
Table 4.3 Recommended interval for each purpose

Logging Interval	Purpose
1 second	Suitable for observing instantaneous water pressure fluctuations. Especially analysis of water pressure fluctuations and water hammer pressure in pump water pipes, etc. There is also a high-precision Logger that can record in 1/100 second.
10 seconds	Suitable for detailed analysis of water supply pressure in DMA. It is also possible to estimate the household use hours and usage patterns from water pressure fluctuations, and it will be the basic data for considering the renewal of the pipe network.
1 minute	Suitable for monitoring water pressure fluctuations in the distribution network. If there is a large fluctuation in units of 1 min, shorten the interval and measure again.

(4) Examples of water pressure data logger installations

[For installation in the Inlet Chamber of the DMA]

A port for pressure measurement should be provided in the DMA inflow pipe using a tapping saddle and a ball valve (incorporation valve).



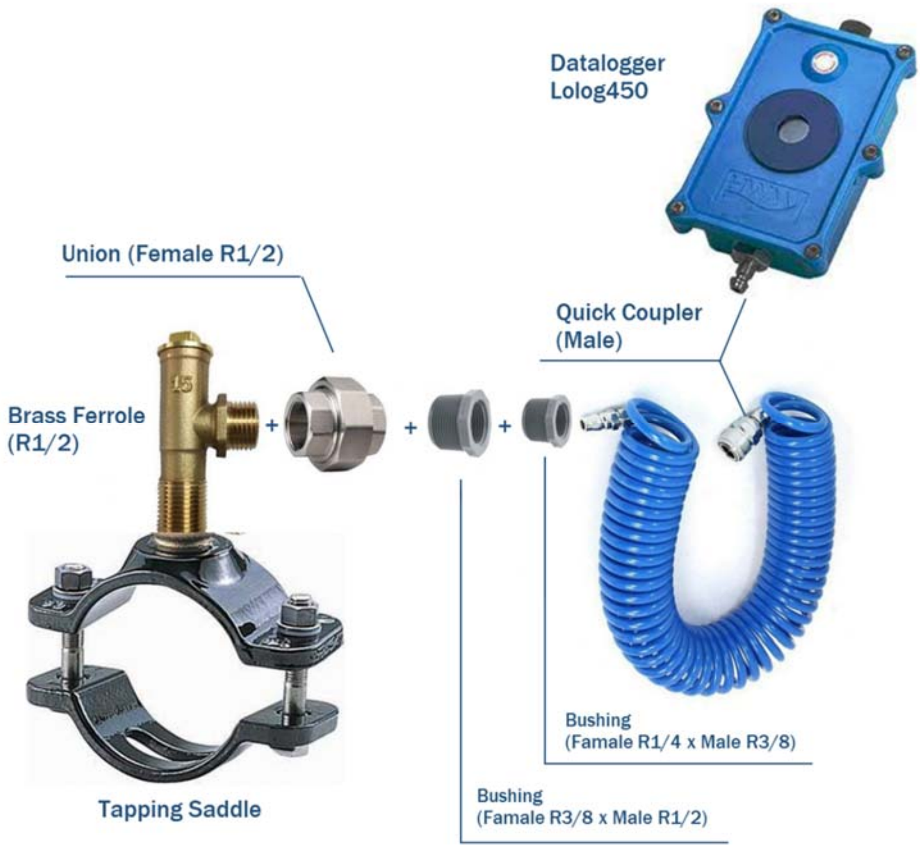


Figure 4.3 How to connect datalogger with tapping saddle

[For installation near Customer Meter]

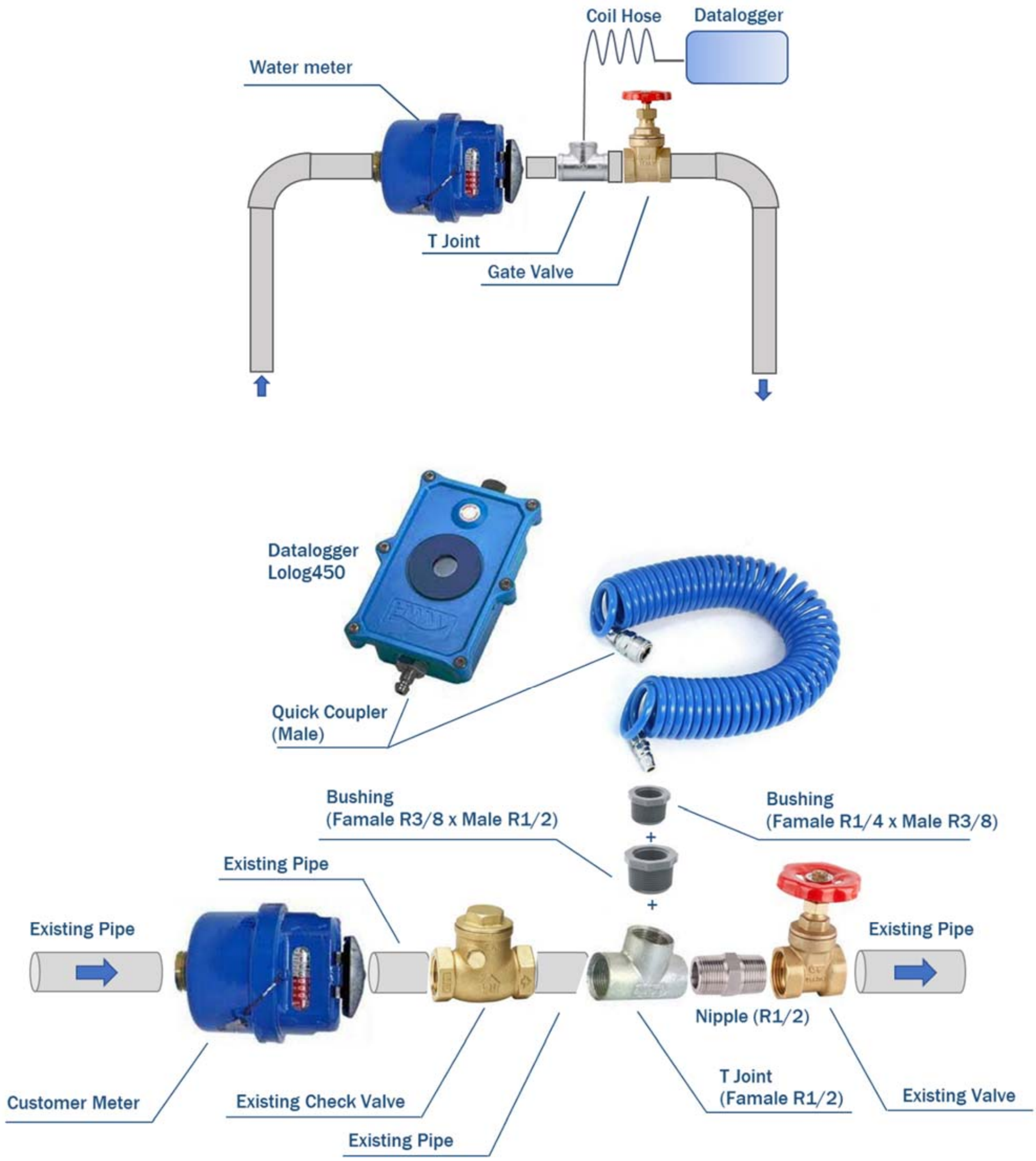


Figure 4.4 Installation of pressure data logger

5. Installation Guide of LoLog 450

5.1 Preparation

Before starting use of LoLog 450, please confirm that you have the following parts required to install the equipment.

- LoLog datalogger
- Radwin Software
- IR Reader with USB connecting cable
- Connection coiled hose for a pressure logger

Before proceeding to site for physical installation, please take the time to configure your logger in an office environment. Most settings can be configured before visiting site and this will save time at the point of install, especially if the weather is bad.

You will need to have:-

- A PC with Windows 10 or latest version installed
- A description and reference number for the installation site:

  The reference number is split into a Zone and Location format to allow for grouping of individual "Locations" into larger regions or "Zones".

  The format of the number is configured during the initial installation of the software but essentially is a 7 character code, e.g. AB123CD

5.2 Installing the software

download and run the Radwin installation file from the HWM website at http://www.hwmglobal.com)

Home » Support » Help & Downloads

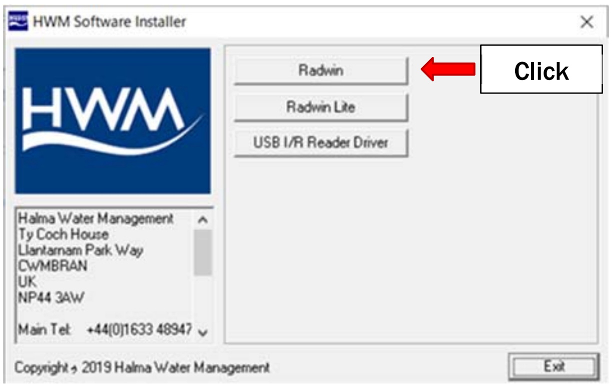
The latest version of the programming software is:

Radwin Ver 4.84

5.2.1 Steps for installation

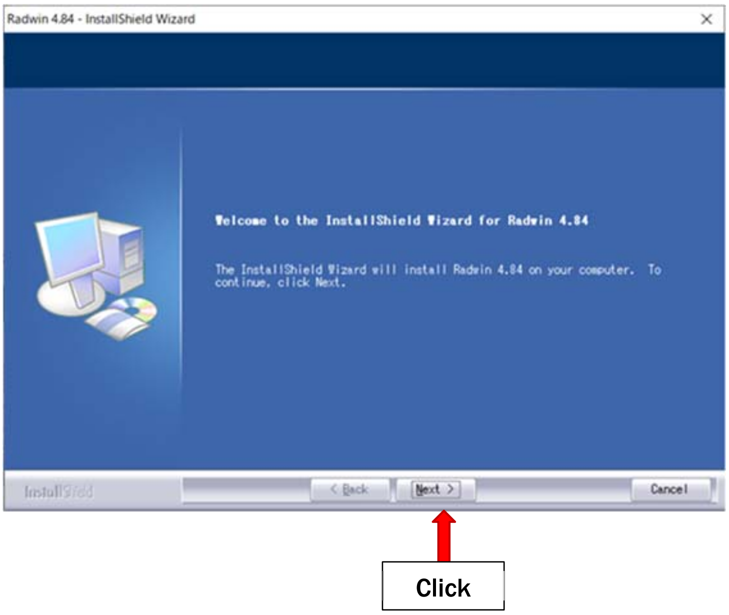
1. Double Click the Installer icon after download the file.

   Now click <<Radwin>> from the installer



The I/R Driver is normally installed automatically, however, in case it does not in step 0 below, please click the <<USB I/R Reader Driver>> after the main installation is complete.

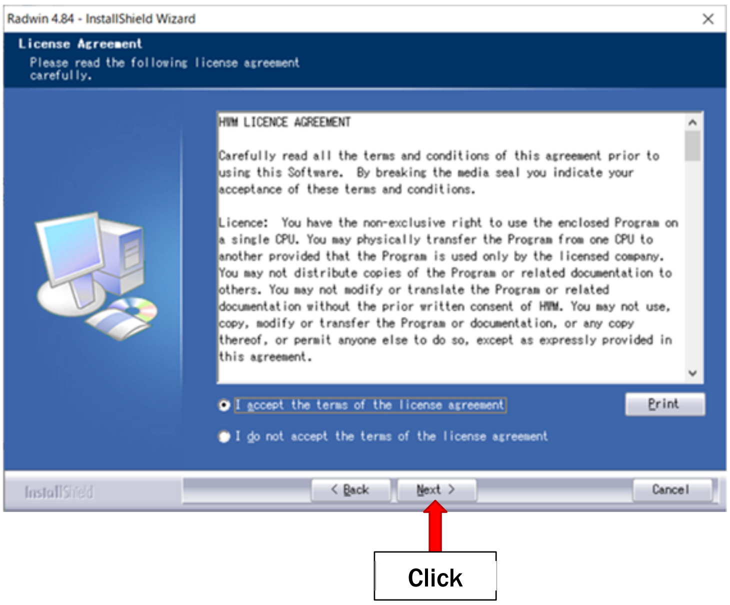
Click <<Next>>



2. Select “I accept the terms of the license agreement” and Click <<Next>>

Choose the Destination folder you wish to install to by clicking <<Change>>

The installation process now has all the information it needs to proceed so click <<Install>> to continue and wait while the installation completes.



5.2.2 First time run of Radwin

Once you have installed Radwin you need to make some initial setup choices and configurations.

(1) Creating your first Database

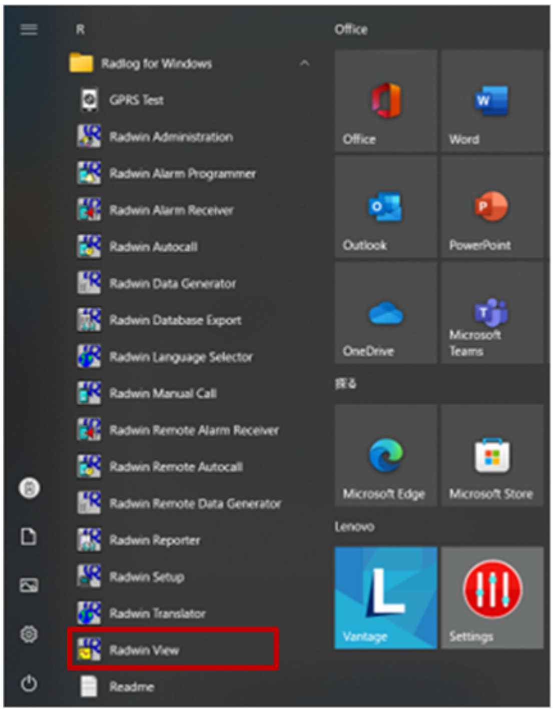
1. From the start menu, click <<All programs>> and find the program group "Radlog for Windows"

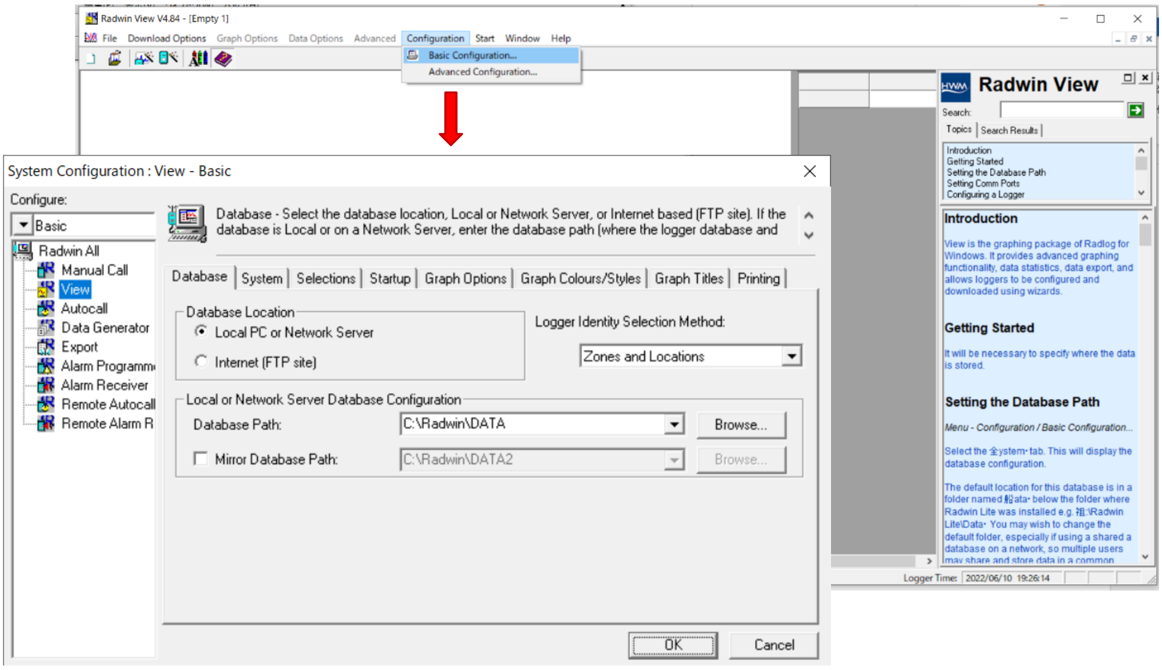
2. Click <<Radlog for Windows>> to expand the group and then click <<Radwin View>>

You may wish to "Pin" the program to your taskbar for convenience. To do this, right click on the Radwin View icon and select "Pin to Taskbar" from the pop-up menu. The program can now be conveniently started from the taskbar.

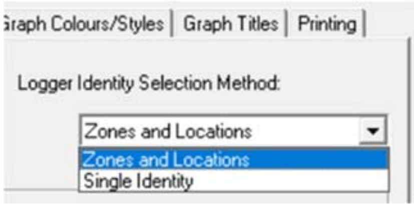
3. After the program starts, select [Configuration] >> [Basic Configuration] tab. After the programme pops up [System Configuration], select [Database] tab.

This is for local storage of configuration information and any data that you may directly download from the logger after site installation.





A note about Logger Identity Selection Method:-



A logger is identified with a single 7 digit reference ID.

If you select Single Identity from the menu then you can use the full 7 digits how you like.

E.g. account no, customer number, etc.

However, when installing a larger fleet of loggers, Radwin allows you to group individual logger Locations into larger Zones. This allows for geographic regions (Zones) to be easily indexed where large fleets are involved.

So, Locations refer to loggers

Zones contain Locations (loggers)

Many Zones may be created

Each Zone may contain many Locations (loggers)

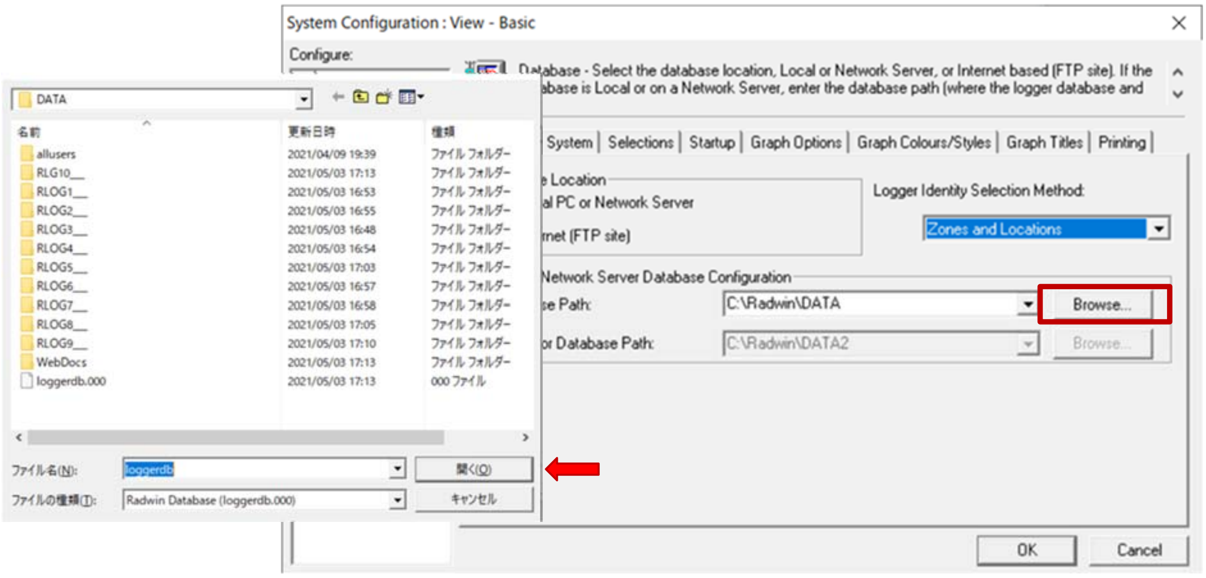
For example, split a town up into Zones then split the Zones up into Locations and deploy loggers within each Zone.

If you choose this (default) option you will be prompted (later on) to decide how the 7 digits are allocated. E.g. ZZ/LLLLL means you can have up to 99 zones with 99,999 loggers in each zone, or ZZZ/LLLL gives 999 zones with 9,999 loggers in each and so on.

In this way you can develop an indexing method to allow you to quickly find sites you wish to examine.

4. From the Logger Identity Selection Method, choose the option as described above

If you wish to change to location of the folder where the database is stored, click <<Browse...>>



Then navigate to the desired folder and click <<Open>> to choose the folder.

(2) Setting up the communications cable

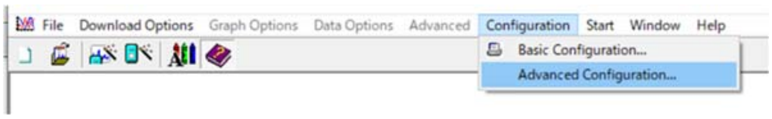
Note: The following instructions assume the use of the USB IR Reader connected to a PC USB port (with or without USB /Serial connector) or a Serial IR Reader connected to a PC serial port.

1. Connect the USB plug to a spare USB port on your computer or the Serial plug to a spare Serial port on your computer.

2. Position the reader head on the logger as shown below

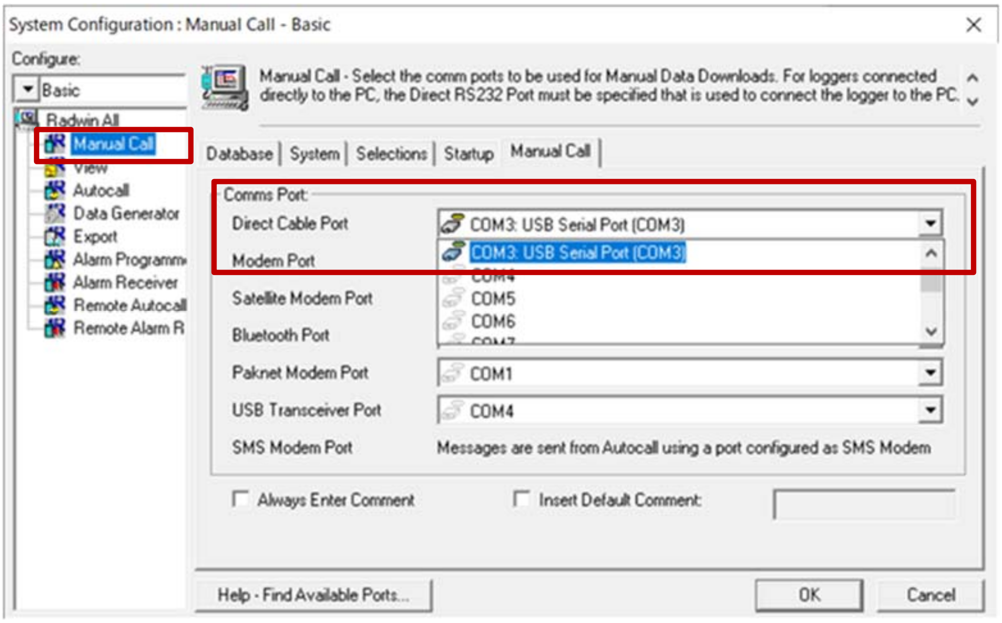
Take care to position the head over raised ring area around the window. The reader head will hold onto the logger by magnets in the ring around the window and this helps with positioning.

3. Start Radwin View again (unless already running) and from the menu select [Configuration] >> [Advanced Configuration…].



4. The menu below shows details all the setup functions available to Radwin, for the Communications port configuration click the <<Manual Call>> item from the list.

5. The Manual Call menu now appears, from the Direct Cable Port dropdown list pick the COM port that you will be using.



A note about COM port choice:

In the example above of a Laptop, you can see 3 COM ports listed, the numbers and descriptions vary from PC to PC but to summarize the types:-

- RIM Virtual Serial Port (e.g. COM1:) should be ignored as Radwin will not communicate via these types of ports. These often have high COM numbers (above 10).
- USB Serial Port (e.g. COM2:) is a genuine COM port that can be used with Radwin and is usually the USB Reader cable.
- USB to Serial Bridge (e.g. COM4:) is also a genuine COM port that can be used and is generally a USB to Serial adaptor cable.

If you are using a Desktop computer or a Laptop with a docking station, you may also see a Communications Port. This is also a valid choice for your Direct Cable Port, however there is usually more than one so check the physical indication by the socket on the back of the computer.

Tip: If you are using a USB connection, you can check you have the right one as follows:-

i. Look down the list and note each COM number that is not empty.

ii. Click <<Cancel>> to close the System Configuration menu.

iii. Remove the USB plug from the PC.

iv. Repeat steps 3 to 5 above and look for the one that has disappeared. This is the COM port you need to select in step 5.

v. Click <<Cancel>> to close the System Configuration menu again.

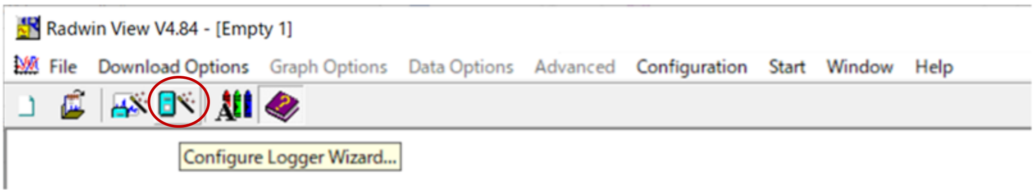
vi. Reinsert the USB cable **IN THE SAME PORT AS BEFORE** and repeat steps 3 to 5, selecting the COM port noted in step iv above.

5.3 Programming your first logger

With the logger connected to the computer as in the previous section, you now need to run the configuration wizard to set your logger ready to send in data.

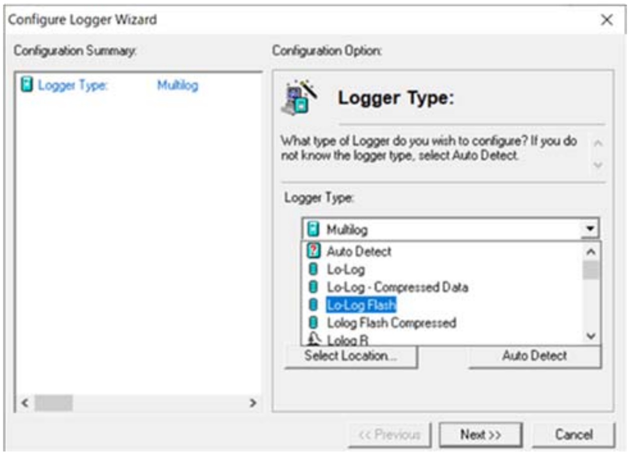
(1) Using the Configure Logger wizard

1. If you have not already done so, run the "Radwin View" program.
2. From the menu, click the button to launch the [Configure Logger Wizard].

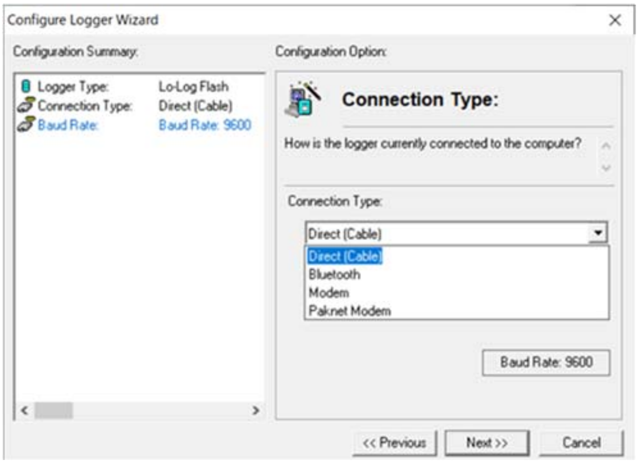


3. Radwin now needs to know the type of logger you are using. You can either select this from the Logger Type drop down menu (LoLog Flash) or click the <<Auto Detect>> button to allow Radwin to discover the type automatically.

Then click <<Next>> to continue.

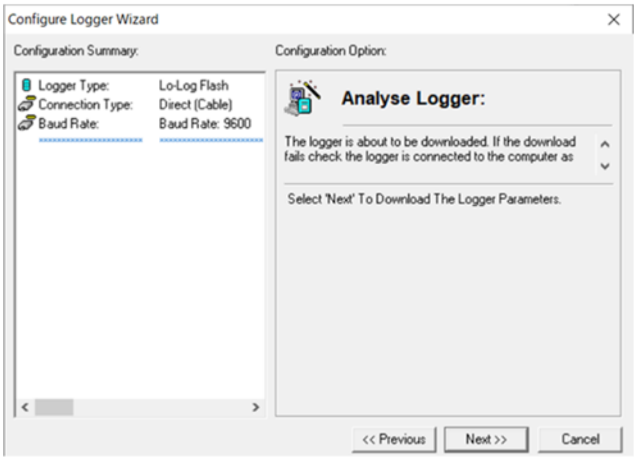


4. You need to tell Radwin how the logger is currently connected to the computer. As you are physically connected to the logger, choose the default type, “Direct (Cable)”

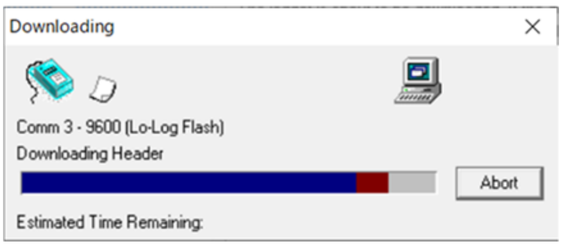


Then click <<Next>> to continue.

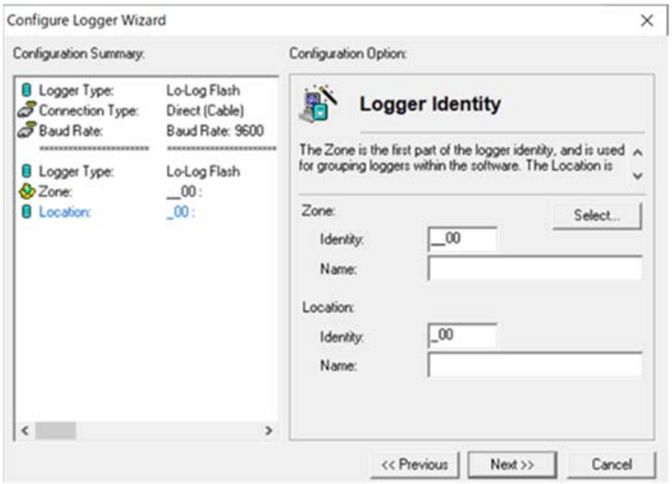
5. You are now ready to download the current settings from the logger.



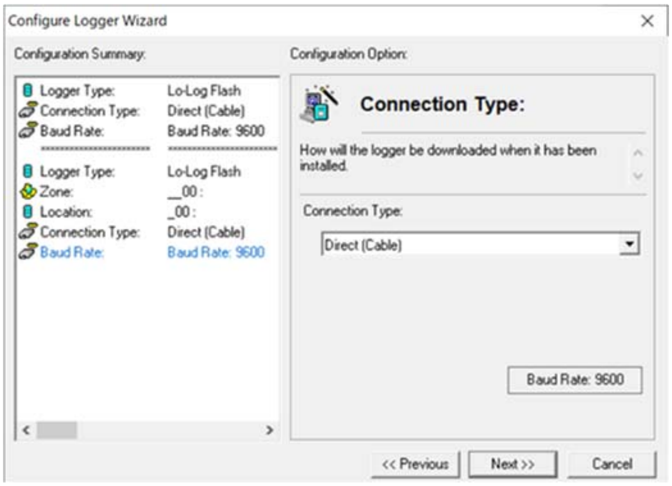
6. Radwin will now retrieve the current settings from the logger,



7. You now are able to give your logger a unique identity - Enter the details in the four fields according to your chosen Zone and Location plan as described on page 26 and then click <<Next>>.



8. You now need to define how the logger will transfer its data for downloading. For this logger it will be by 'Direct Cable'



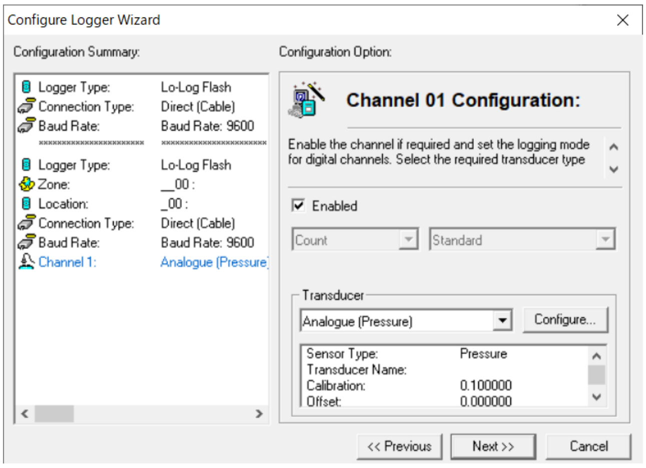
9. You now need to configure the channels (1 channel per signal/sensor) that you wish to use. (This manual show for datalogger with only 1 channel)

10. The Channel 01 configuration menu appears as below:-

To turn ON the Pressure channel, tick the "Enabled" box.

The default transducer is for a pressure transducer with a Calibration factor of 0.1. If you are configuring any other type of sensor, please refer to HWM support.

To turn ON the Pressure channel, tick the "Enabled" box.



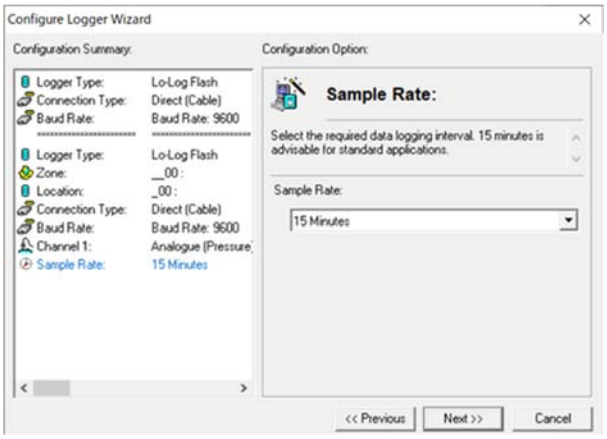
To turn ON the Pressure channel, tick the "Enable" box.

The default transducer is for a pressure transducer with a Calibration factor of 0.1.

If you are configuring any other type of sensor, please refer to HWM support.

Click <<Next>> to continue.

11. Next you need to specify the Sample Rate that you require.



In most cases the default setting of 15 minutes will be sufficient, however, if you wish to change the rate, simply select a period from 1 min to 24 hrs from the dropdown menu.

In case of analysis of the inflow water volume in reservoir using the water level fluctuation, 1 min will be convenient for this purpose.

Click <<Next>> to move on

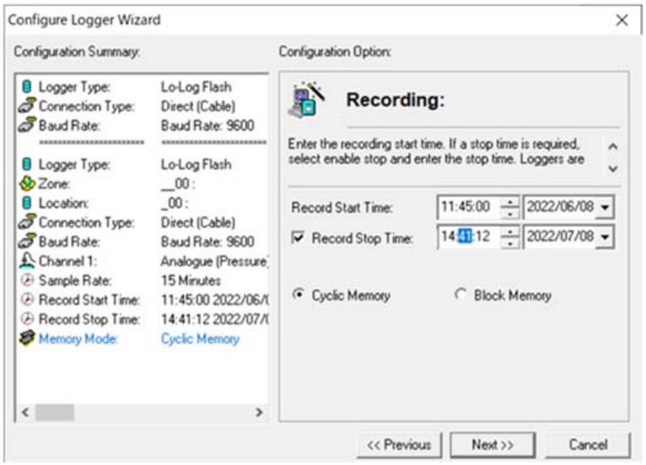
A note about Sample Rates:

- For a digital input (e.g. flow), the sample rate equates to the number of pulses counted during the period set. So, if 900 pulses were counted over the 15 minutes sample rate set above, this equates to 1 pulse/sec and if you have set 10 ltr/pulse, then the final result is 10litres/sec.
- For an analogue input (e.g. pressure, depth, etc.) the logger takes a background measurement every 30 seconds (or the sample rate, whichever is smaller).

  This background measurement is then averaged across the sample period selected. So if you set a 15 minutes "Sample Rate" above, then the logger will record the average of the 30 readings taken during the 15 minutes period selected.

If you choose a sample rate faster than 30 seconds, then the background sample period with adjust automatically to match it, <u>however this will reduce battery life</u>.

12. You now need to choose how the logger is to record data.

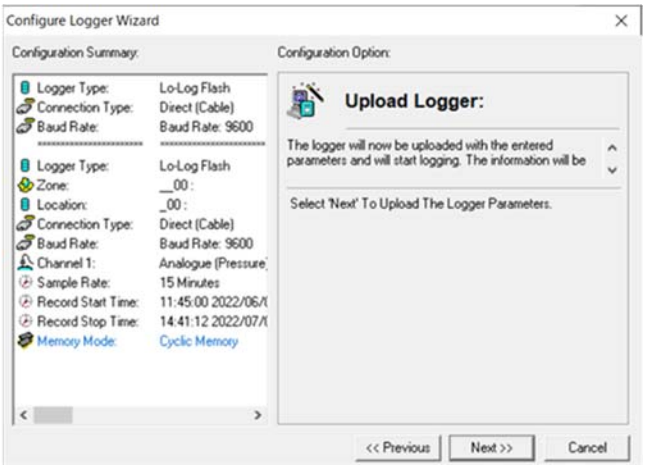


Note:- With a Lolog it will start recording when you upload it – it is not possible to set a start time and/or date in the future.

Check the time & date here are before the current time & date.

If you wish to Stop recording at a specific time, tick the "Enable Stop" box and enter the time you wish to stop recording data here.

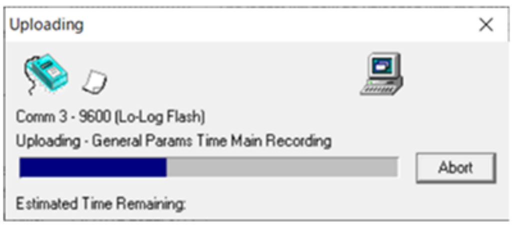
Click <<Next>> to continue.



Check your configuration in the summary box.

Click <<Previous>> to return through the menus to make any corrections.

To begin the programming sequence, Click <<Next>>

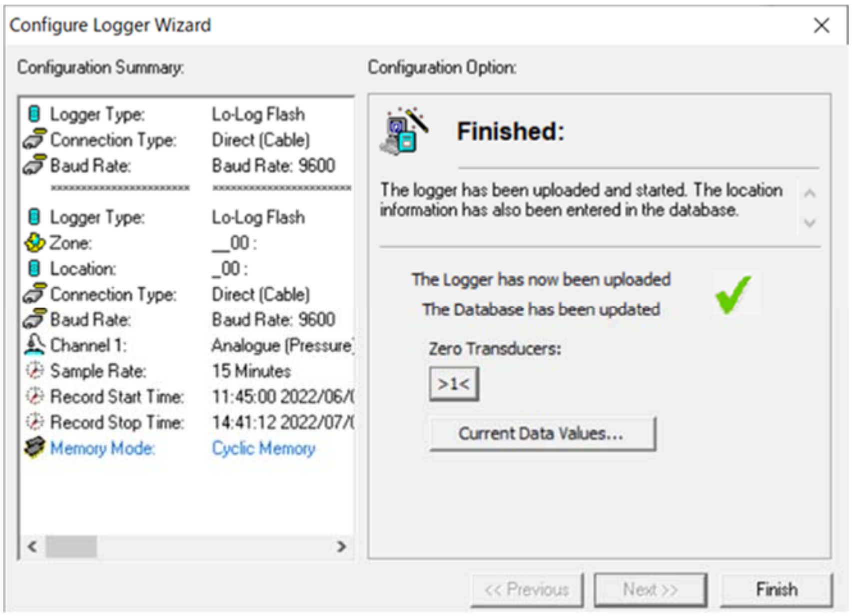


Programming will now take place…

Note that the bar will turn Red once programming begins.

Note: If the programming step fails at this point simply wait 60 seconds and retry.

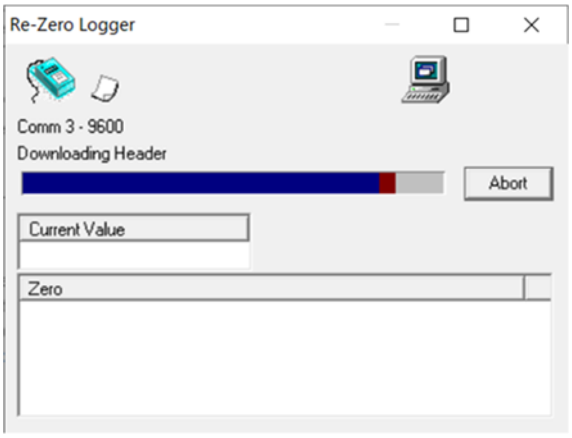
13. Radwin has now completed the programming sequence for your logger and stored its details on your computer. It is now recording and will begin logging data.



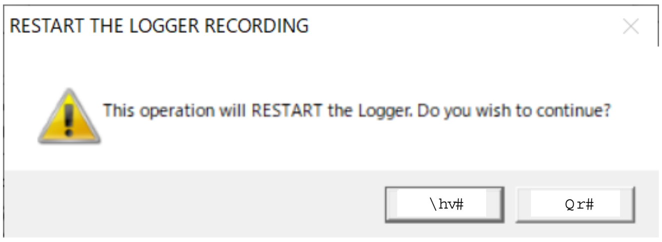
Before you select ‘Finish’…………

Select the ‘Zero Transducers’ Button 

This will allow you to ensure the pressure transducer is zeroed at the time you installed it.

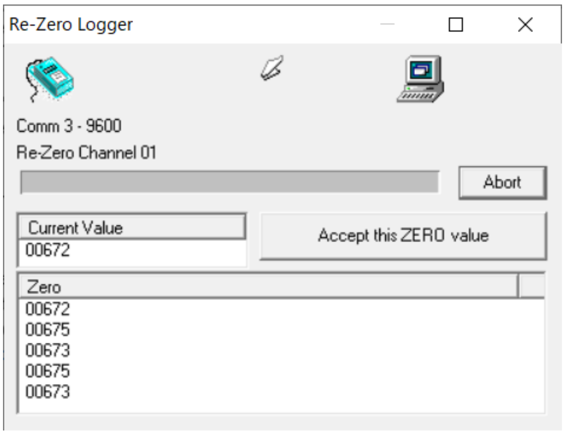


Click Yes to continue when the following message appears.

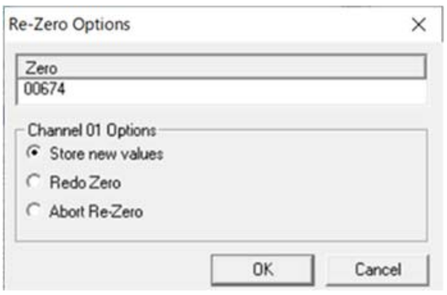


A flow of values will then appear in the **Zero** column of the **Re-Zero Logger** screen. Allow the raw Numbers in the **Zero** column to stabilize.

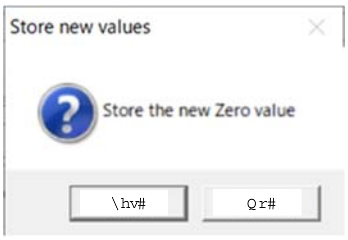
Click on the **Accept this ZERO VALUE** button when the Zero figure values are acceptable.

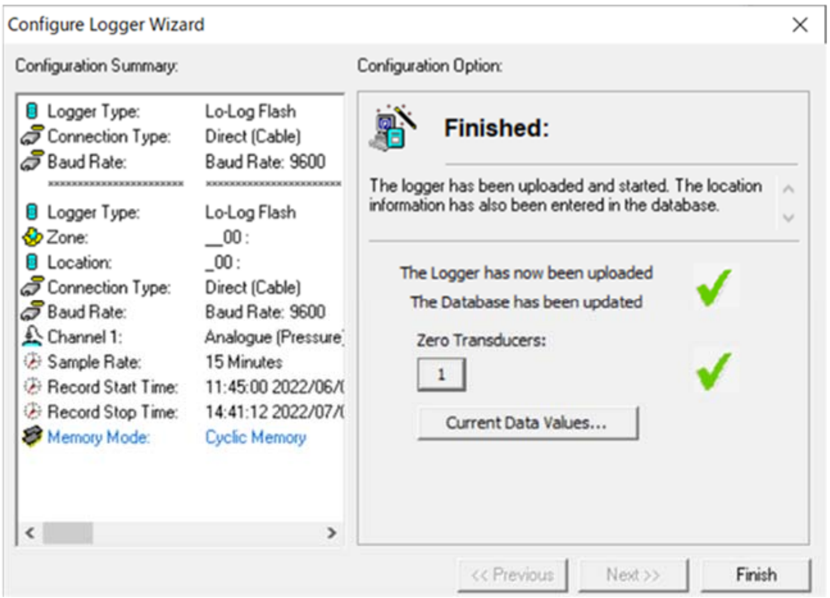


The **Re-Zero Options** screen will then appear allowing the operator the choice of either storing, re-zeroing or aborting the Re-Zero by clicking into the **Channel Options** box and clicking on the **OK** button.



If the **Store New Values** box is checked the **Store the new Zero Value** screen appears. Click on the **YES** button to store the values.

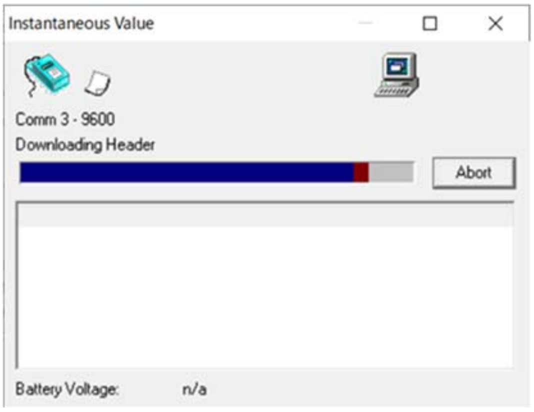




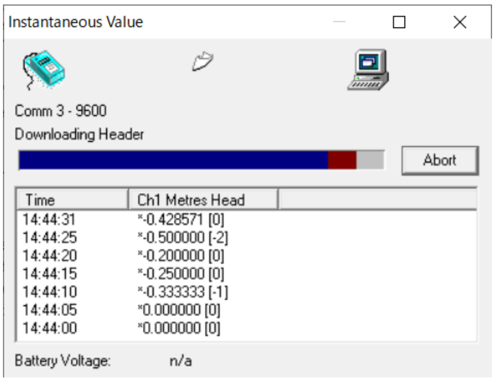
Click <<Finish>> and the Wizard will close.

You are now ready to confirm that the logger is measuring real data from the sensors by taking an Instantaneous Value –

Select the **Current data Values button** to check the instantaneous values the logger is seeing are as expected -



Radwin will now start reading the current sensor values that the logger is receiving, so for our example Pressure and Flow logger, we will see -



Click <<Abort>> when you wish to finish alternatively Radwin will automatically timeout after a period of a few minutes.

In this case, Example Ch1 reading Pressure in Meters Head.

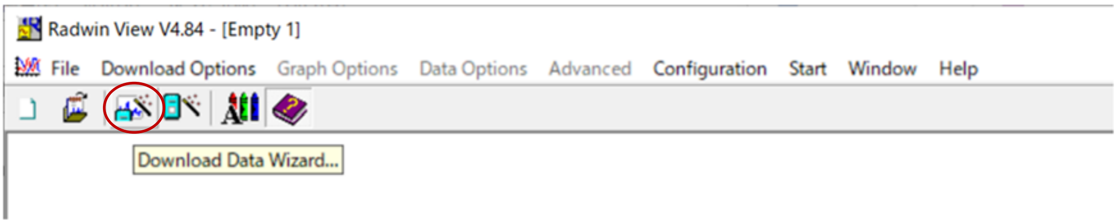
The reading taken is the average over the sampling period specified, so in this example, the last value is 0.42m over the last 15 minutes. So if you have just connected your logger, you may have to wait a few minutes for the reading to stabilize. The value in the square brackets [0] is the raw uncorrected value being measured or counted over 2 seconds.

5.4 Downloading Data from the logger and viewing results

The information that has been recorded by, and stored in, the data logger can be downloaded directly to a PC and viewed by using the Radwin Download Data Wizard.

(1) Download Data Wizard

Select the Download data wizard from the Download Options drop-down menu or the wizard icon on the title page. Proceed after each option by clicking on the Next button.



Select the type of logger (i.e. Lo Log Flash) being used and its location (from select location) – Next>>

Select the type of connection to the logger (Direct RS232) and the Baud Rate (9600) – Next>>

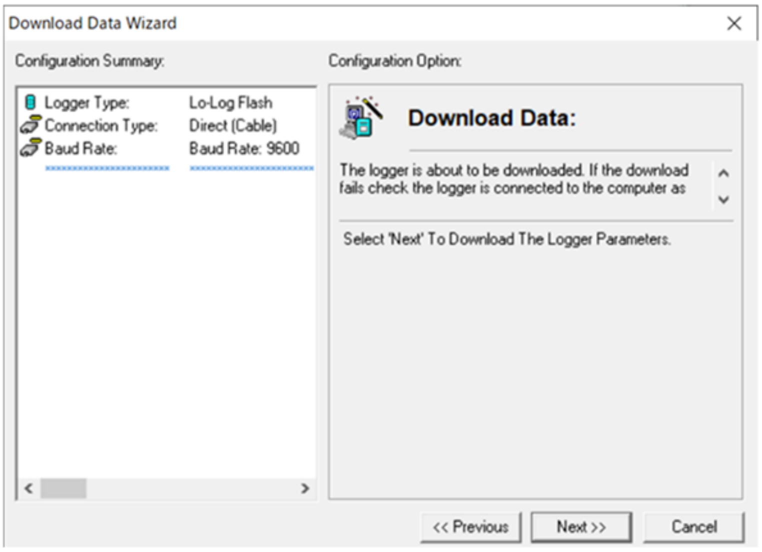
This is similar to the procedure used to configure the logger.

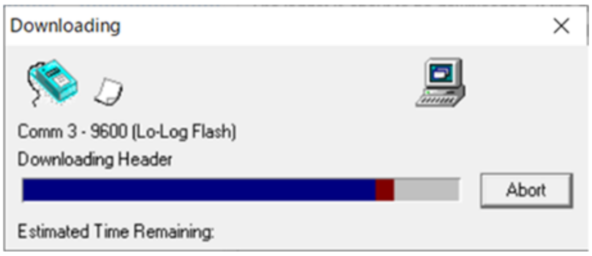
After making the above selections, the **Download Data** screen will appear.

(2) Download Data

The logger is about to be downloaded. If the download fails, check the logger is connected to the computer as specified and the connection configuration is correct.

Click the **Next** button for the software to download the logger parameters.





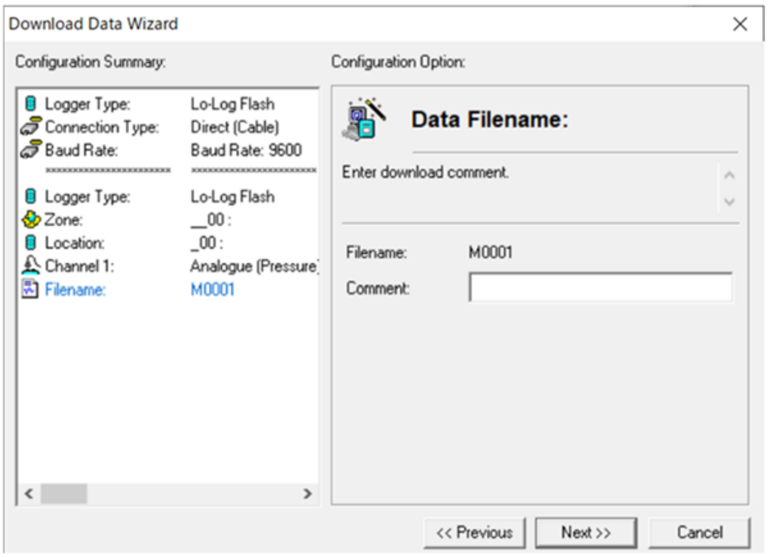
The above screen will now appear to show the Logger Parameters are being downloaded.

The wizard then allows the operator the opportunity to change the transducer configuration for the data downloaded from each channel of the logger. Follow the procedures used to configure the logger if changes are required.

Proceed through the logger configuration screens until you arrive at the **Data Filename** screen.

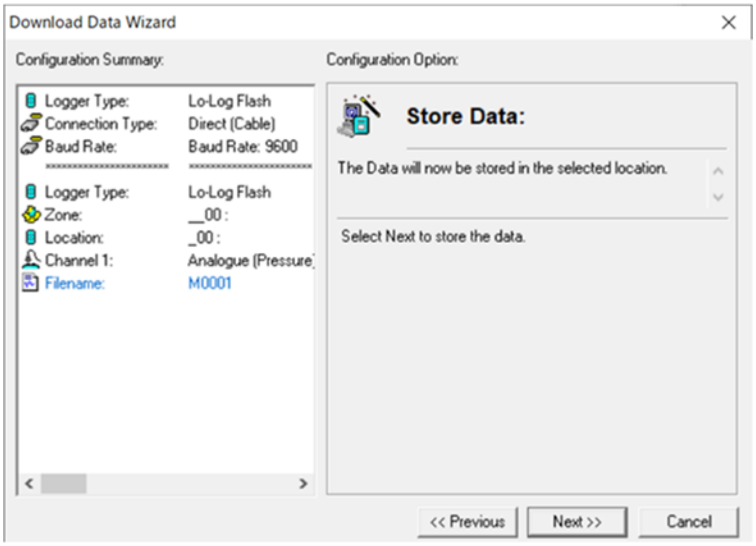
(3) Data Filename

The Data Filename screen assigns a filename for the data to be stored, but allows the operator to insert a text comment into the **Comment** field (i.e. date of transfer, logger identity) that will be stored as part of the file.



(4) Store Data

The recorded data will now be stored into the selected location shown in the Configuration Summary panel –



Click **<<Next>>** to store the data.

The Finish Screen will now appear.

Click the Finish button to exit the Download Logger Wizard.

After the Finish button has been clicked and the data downloaded, the recorded data will be displayed as a graph and data table.

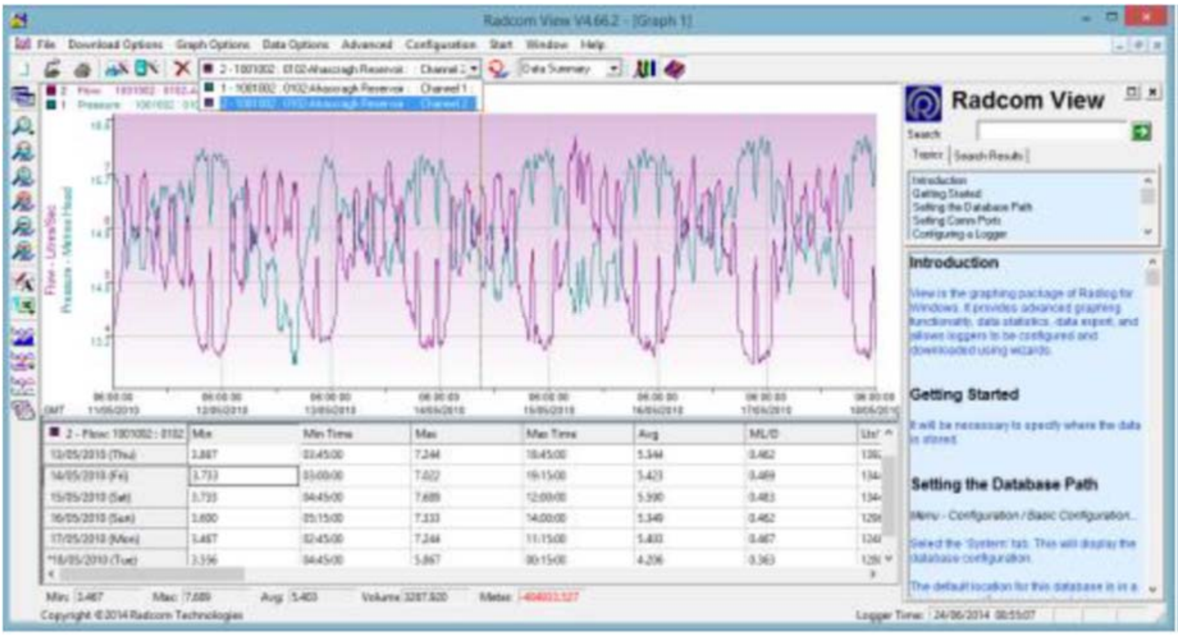
5.5 Graph and Data Table Manipulation

The graph and data table can be manipulated to display information for either channel. The type of graph and the format of the displayed data can be altered either by using the drop-down menu, the toolbars or by right clicking on the mouse.

(1) Selecting the Input Channel Data to be viewed

The graph and table will display the data stored for each channel. If the logger has a single input, the data for that channel will be displayed. If the logger has two inputs the information for the either channel can be selected by either:

Using the drop-down menu on the toolbar, clicking on the 'Cycle Through Graphs' icon or right clicking on the mouse and selecting the required channel from the Graph Select option -

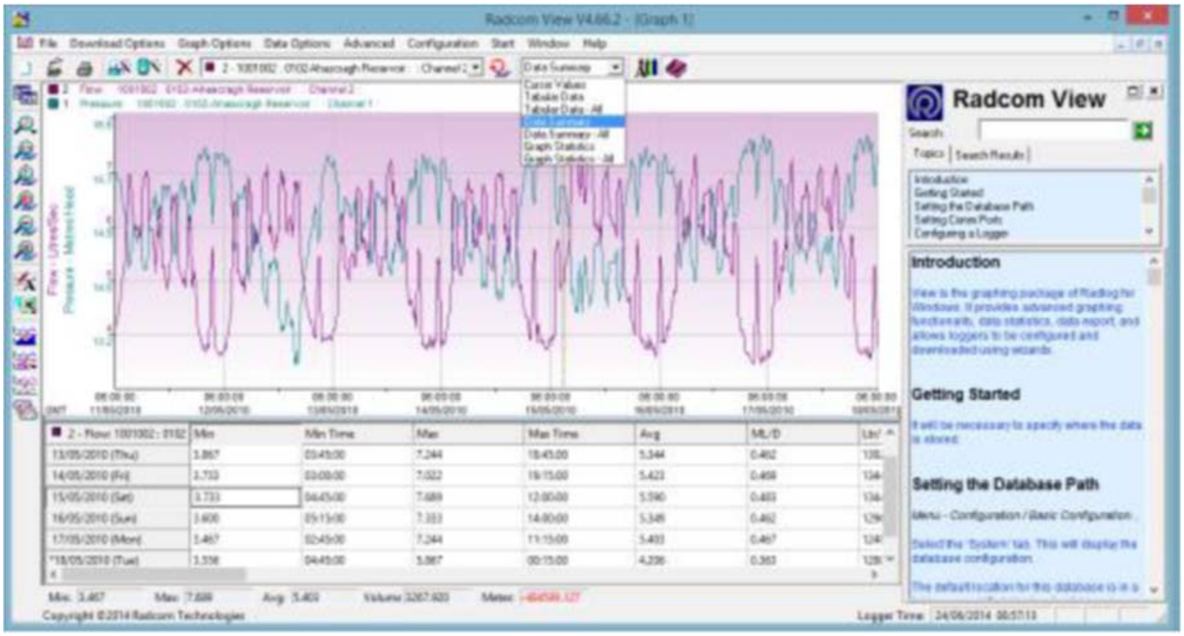


(2) Changing the Information in the Data Table

The information that is displayed in the data table below the graph can be changed to show Cursor Values, Tabular Data, Data Summary or Graph Statistics. The cursor values option displays the value for each graph, while the other options display the values for the selected channel. The information in the table can be opened in .CSV or .TXT file format. The required information can be selected by either:

Selecting the option from the **[Data Options]** tab on the main menu, or by clicking on the

Toolbar to display the options for the Table Data



The data format options are summarized in the table below -

Cursor Values	Displays graph data values for each graph in the tabular data table below the graph as the cursor is moved across the graph.
Tabular Data	Displays tabular data for the current graph in the tabular data table. The value at the cursors position is highlighted in the table as the cursor is moved across the graph.
Data Summary	Displays a daily summary for the current graph in the tabular data table. The day of the cursors position is highlighted in the table as the cursor is moved across the graph.
Graph Statistics	Displays Statistics for the current graph in the tabular data table. The statistics are for the currently visible time span of the graph.
Open CSV File (MS Excel)	Writes the contents of the tabular data table to a temporary CSV file that is automatically opened using the default CSV file viewer - normally MS Excel.
Open TXT File	Writes the contents of the tabular data table to a temporary TXT, file that is automatically opened using the default TXT file viewer.

(3) Changing the Graph Style

The operator can change the style of the graph, view the graph from different axes, remove a graph from the display, or copy and export the graphs to be viewed by other programs. These options can be selected by either:

Clicking on the **Graph Options** tab on the main menu, clicking on the **Zoom** toolbar icons , or right clicking on the mouse and selecting the required **Graph Type** or **Zoom** option -

By right clicking on the mouse and selecting **Cursor Position** from the menu, the data value (Day, Date, Time and recorded value) will be displayed for the position of the cursor in the current graph.

A summary of the options is shown in the table below-

[ZOOM OPTIONS]

Zoom Time Region	Puts the graph in Zoom X axis mode. Left click the graph once to specify the start point, and again to specify the end point.
Zoom Y Axis Region	Puts the graph in Zoom Y axis mode. Left click the graph once to specify the start point, and again to specify the end point.
Zoom Y Axis Region and Time Region	Puts the graph in Zoom XY axis mode. Left click the graph once to specify the start point, and again to specify the end point.
Zoom Out	Zooms out to the previous zoom level
Zoom Full	Displays the graph full size removing all zoom levels.

[GRAPH OPTIONS]

Points	Displays graphs as single data points.
Line	Displays graphs with data points as joined lines.
Filled Line	Same as Line but fills the area under the graph.
3D Line	Same as Line but with a 3D effect.
Bar	Each data point is displayed as a bar.
3d Bar	Same as Bar but with a 3D effect.
Remove Graph	Removes the current graph - indicated as the top most graph title above the graph
Remove All Graphs	Removes all displayed graphs. Export
Export Data	Allows an export format to be selected and exports the data to a file.
Copy Graph to Clipboard	Puts a copy of the graph on the clipboard so it may be pasted into other application as an image.

6. Protection of Water Hammer

6.1 What is "Water Hammer"?

You may heard a knocking noise in a water pipe that occurs when a tap is turned off briskly.

This is one of the most familiar water hammer phenomena.

Precisely defined, it is.

'The phenomenon of a transient rise or fall in the pressure in a pipe when the flow velocity in the pipe changes rapidly'.

Imagine water flowing steadily through a pipe!

When there are no obstructions in the pipe, the water flows smoothly and the pressure changes are very small.

What would happen if a valve at the end of the pipe were suddenly closed in this situation?

The smooth-flowing water has nowhere to go, so the pressure rises sharply just before the closed valve. This is similar to the phenomenon of passengers standing on a bus, and when that bus suddenly stops, the passengers all fall forward at once.

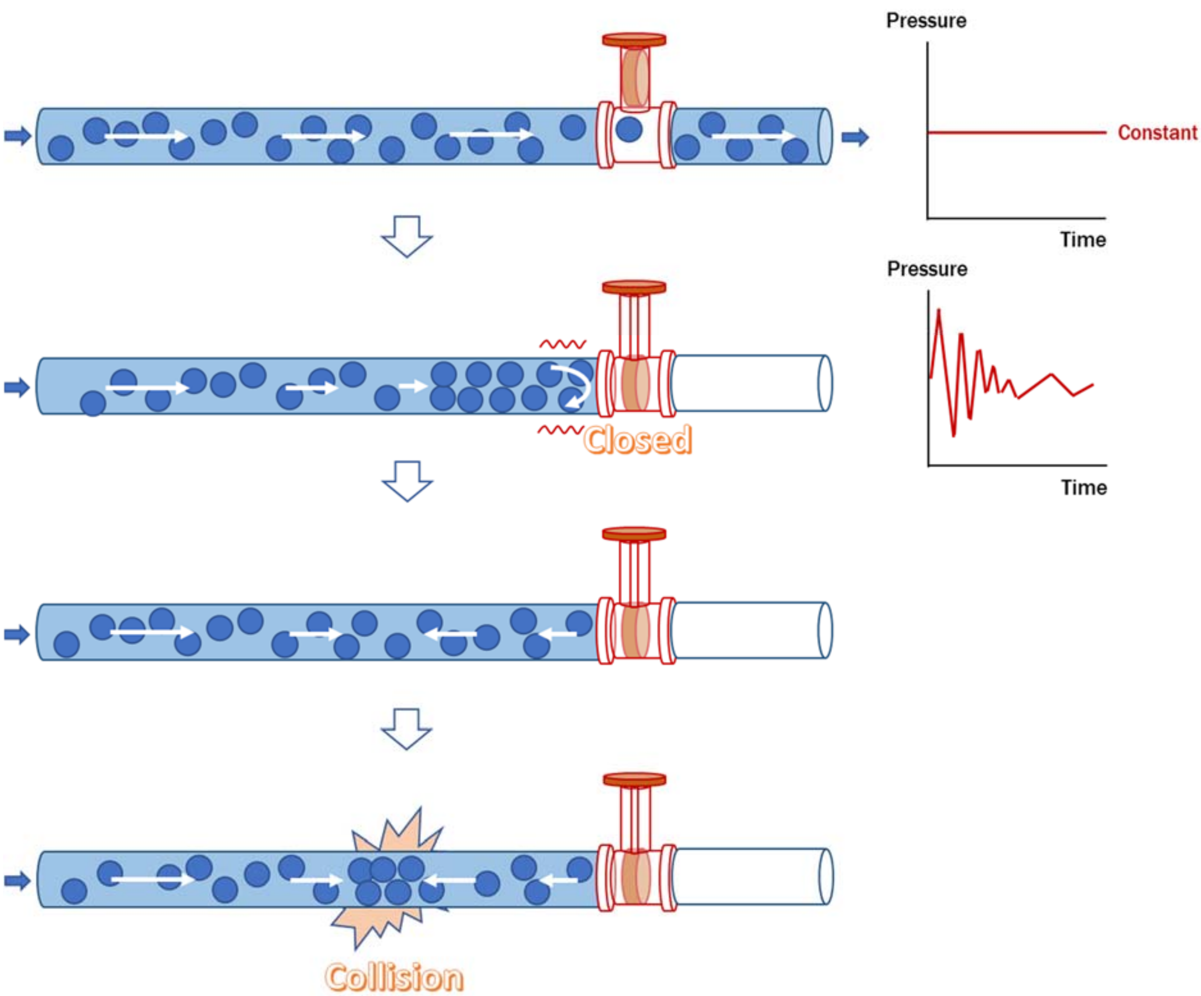


Figure 6.1 Pressure fluctuation caused by sudden closing the valve

The engineering explanation for this situation is that the ***"Kinetic Energy"*** of the flow has nowhere to go and is considered to be converted into the ***"Pressure Energy"***.

Conversely, if a previously closed valve is suddenly opened to generate water flow in the pipe, the pressure suddenly drops.

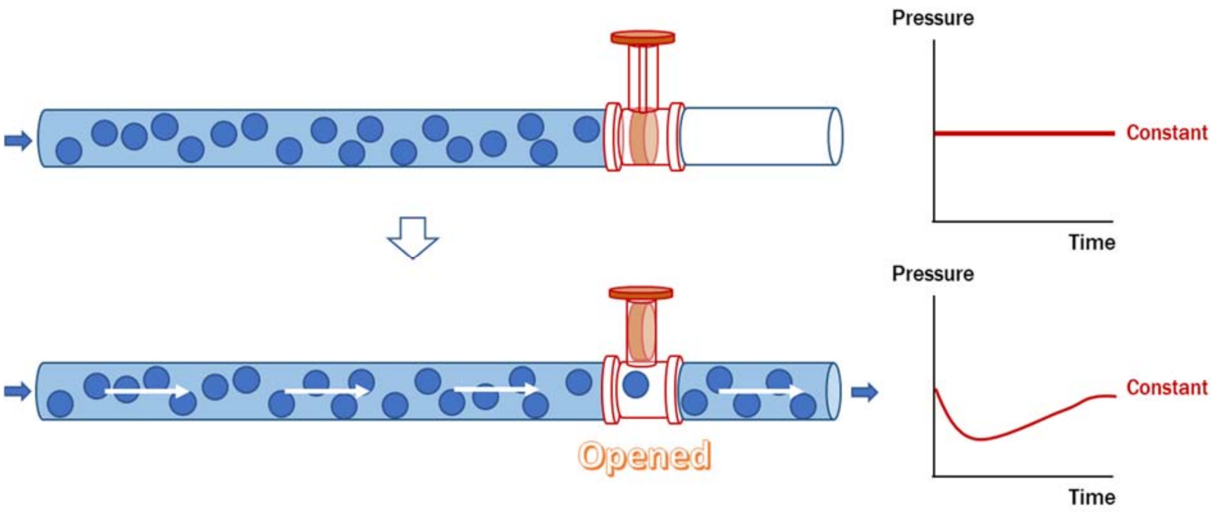


Figure 6.2 Pressure fluctuation caused by sudden opening the valve

These pressure fluctuations are transmitted instantaneously upstream and downstream in pipes and fluids. This speed is called the "Pressure Propagation Velocity': for water at 10 °C, pressure fluctuations are transmitted through the pipe at a very high speed of 1,425 m/sec.

Figure 6.3 Sound velocity in the water-filled pipe

6.2 Type of the Water Hammer

Water hammer can be caused by two types of phenomena

6.2.1 Water hammer caused by a sudden increase in pressure.

As mentioned above, this occurs when the valve at the end of the pipe is closed abruptly.

Pressure fluctuations generate a force that vibrates the pipe, which resonates with the natural frequency of the pipe and generates a nocking sound. Note that the natural frequency of a pipe depends on its material.

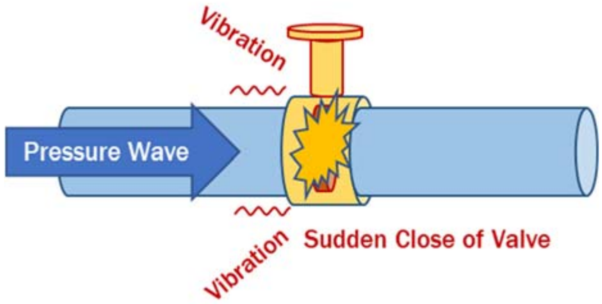


Figure 6.4 Water hammer caused by sudden increase in pressure

6.2.2 Water hammer caused by water column separation

If the pump stops suddenly, the fluid, which had previously been flowing at a steady rate, will try to move further downstream due to inertial forces.

However, the flow of water supplied by the pump is reduced, so the pressure drops sharply immediately after the pump, creating a negative pressure.

This results in a space between the mass of water that has gone ahead and the mass of water around the stopped pump, which is called ***"Water Column Separation"***.

The mass of water that has moved ahead gradually loses its force and then begins to flow back towards the point where the negative pressure is generated.

As a result, the mass of water flowing back from the downstream side collides with the mass of water remaining upstream, causing impact sounds and vibrations.

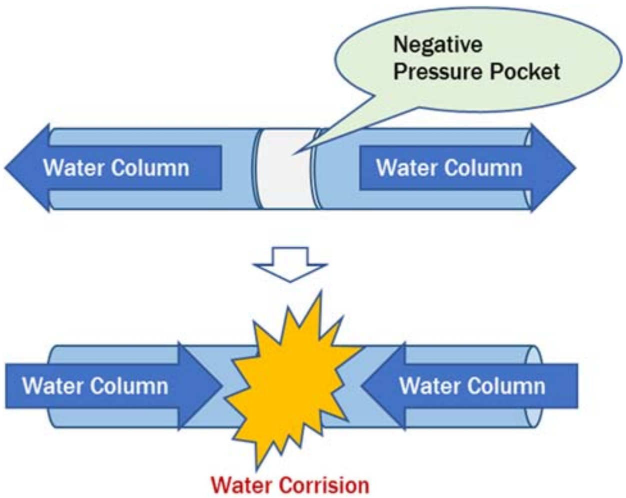


Figure 6.5 Water hammer caused by "Water Column Separation"

6.3 Problems caused by water hammer

Pressure fluctuations due to water hammer cause the following problems.

- Rapidly rising pressure causes damage to pumps, pipes, valves, joints, etc. in the pipeline.
- A sudden drop in pressure can cause dents in the pipe or the pipe can be destroyed by another increase in pressure after water column separation.
- Causing a big confusion in water pressure control system in the water supply network.

Source: https://www.taproot.com/water-hammer-what-is-it-and-how-we-can-prevent-equipment-damage/

Source: https://heatinghelp.com/blog/a-heated-exchange/

Figure 6.6 Examples of damage caused by water hammer

6.4 Reducing the risk of water hammer

6.4.1 Condition prone to water hammer

Water hammer is a particular problem in pipelines, which are generally energized by pumps to send water over a distance.

As shown in the diagram below, the water energized by the pump reaches the distribution reservoir at the final point, gradually expending energy due to losses caused by frictional forces as it flows through the pipes.

[Case 1]

The risk of water hammer is small where the terrain is gentle near the pump and rises in the vicinity of the reservoir.

[Case 2]

The risk of water hammer is high in the terrain, where there is an uphill gradient immediately after the pumps and then a gradual rise towards the reservoir.

[Case 3]

The risk of water hammer is high on terrain that climbs immediately after the pump and then drops gently after the highest point to the reservoir.

The higher the elevation near the pump, the more likely it is that water column separation will occur.

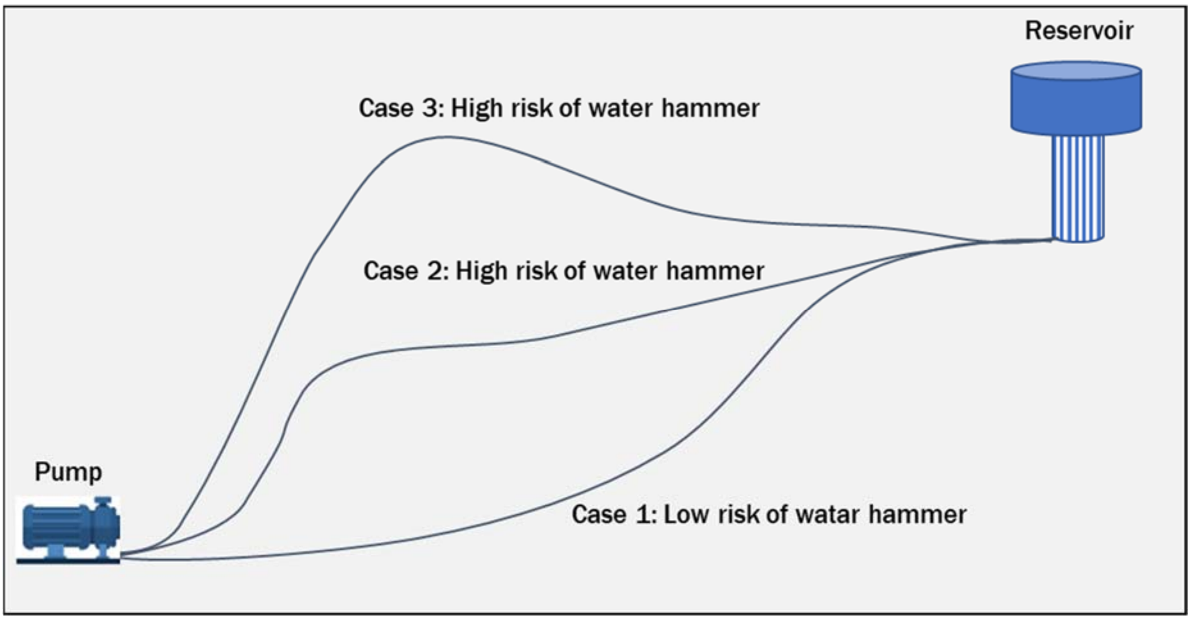


Figure 6.7 Conditions prone to water hammer

6.4.2 The measures against water hammer

(1) Operate valves in the water distribution network slowly

Particular attention should be paid to the high water pressure at the 'start of opening' and 'before closing' of the valve.

[Example of valve manipulation]

･After half a rotation of valve key, wait 10 second.

･After another half rotation of valve key, wait 10 seconds.

･After another half rotation of valve key, wait 10 seconds.

･After another half rotation of valve key, wait 10 seconds.

･After one rotation of valve key, wait 10 seconds.

･After another one rotation of valve key, wait 10 seconds.

･After another one rotation of valve key, wait 10 seconds.

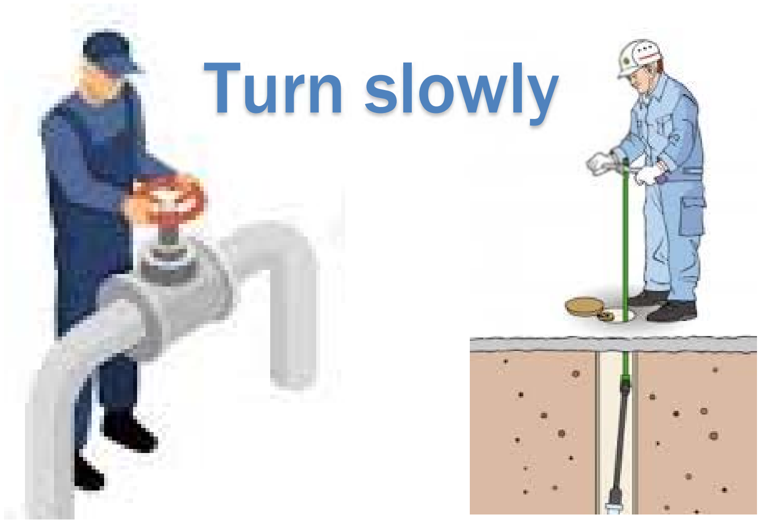


Figure 6.8 Manipulation of valve

(2) Change the type of valve

Lever-operated valves can close instantly and are therefore easy to generate water hammer.

Avoid using butterfly or ball valves that open and close with a lever, and use valves that can open and close slowly over time to reduce the risk of water hammer.

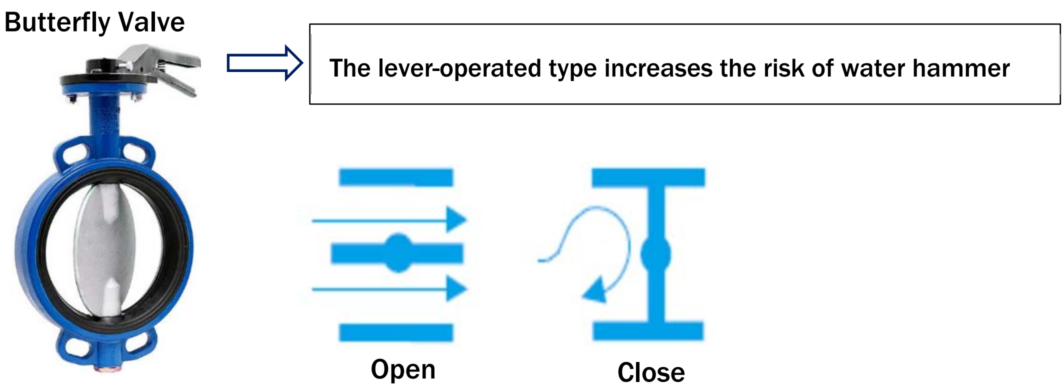


Figure 6.9 Lever-operated butterfly valve

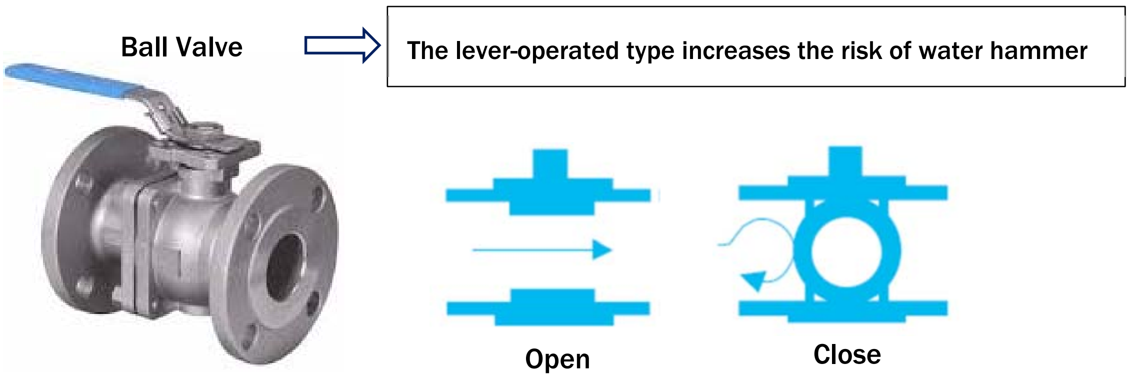


Figure 6.10 Lever-operated ball valve

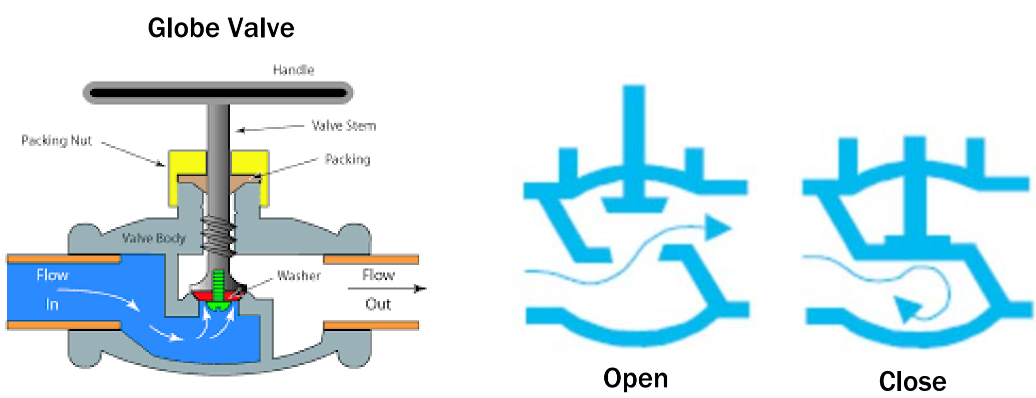


Figure 6.11 Handwheel-operated globe valve

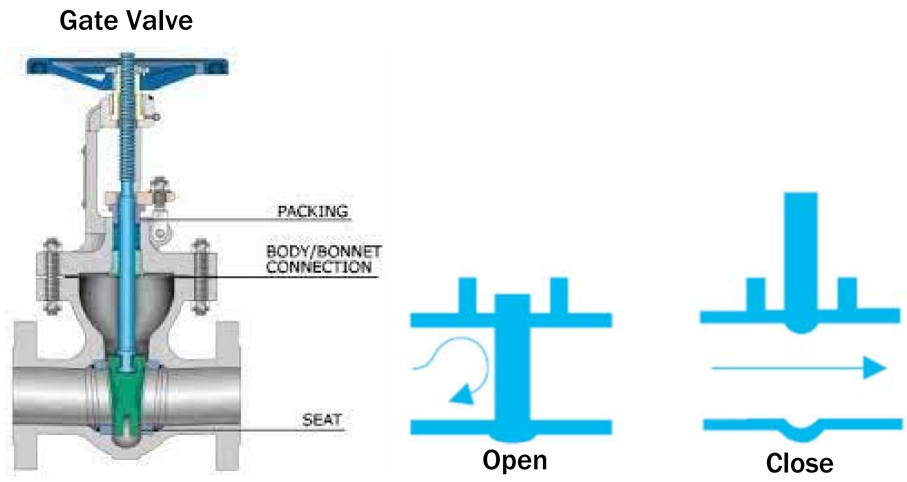


Figure 6.12 Handwheel-operated gate valve

(3) Install a check valve on the discharge pipe of pump

Check valves, also called retention valves, are mainly used to prevent fluid backflow.

Check valves such as wafer (winged) or disc-type check valves on the rise of the pipe for liquids can prevent return water hammer. However, it should be noted that swing, ball and lift valves are not effective in preventing water hammer, even if they are the same check valves.

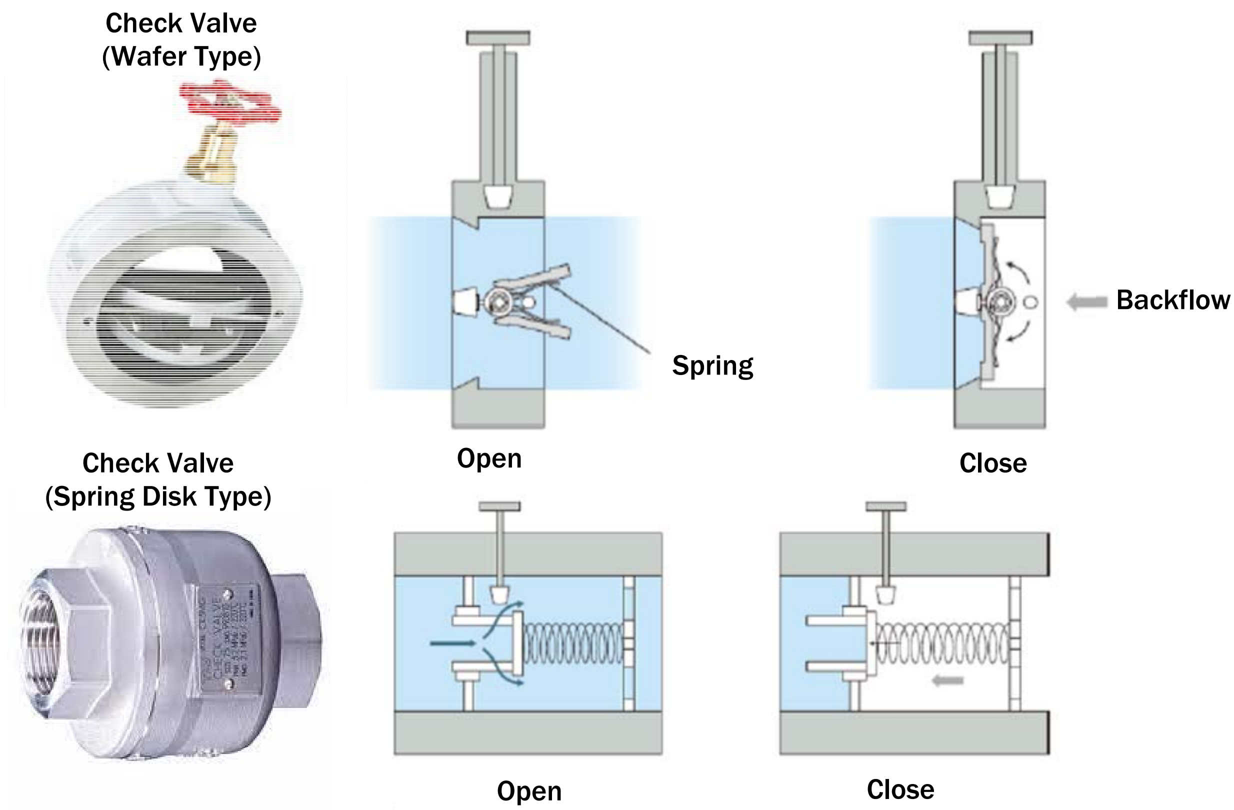


Figure 6.13 Variety of check valve

(4) Install air valves on the transmission/distribution pipe

Installing air valves at higher elevations on the transmission/distribution pipe routes is effective in reducing the risk of water hammer.

If air is introduced into the pipe, it accumulates in the higher sections of the route and obstructs the passage of water. Generally, the primary purpose of air valves is to discharge air created in the pipe.

However, if air valves are installed at a higher elevation on the pipeline route, air can be sucked in the pipe when water column separation occurs, preventing a sudden drop in pressure. This is the secondary purpose of air valves.

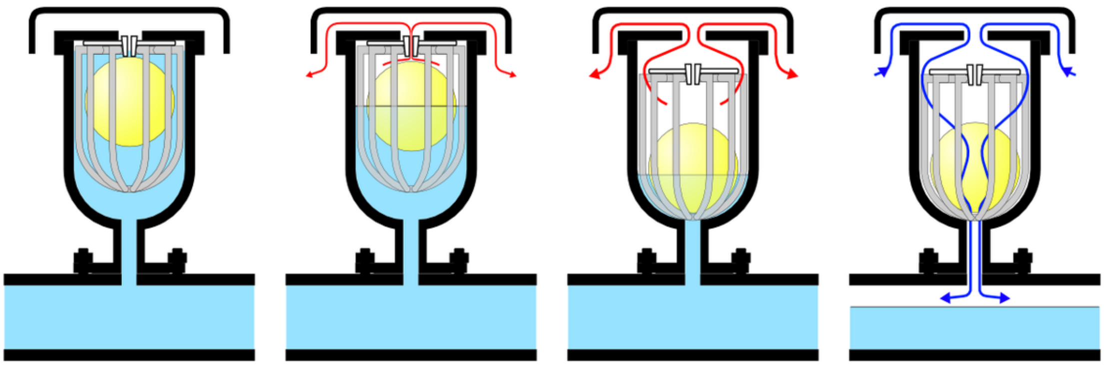


Figure 6.14 Mechanism of air valves

(5) Increase the diameter of the pipe

Increasing the diameter of the pipe reduces the flow velocity and thus reduces the abrupt changes in flow.

(6) Laying pipes in a low position

If the pipe is always filled with water, pressure drops are less likely to occur.

(7) Attach a flywheel to pump

To prevent the pump from stopping abruptly in the event of a power failure, etc., a flywheel is attached to the pump rotor to add inertial energy and stop the pump slowly.

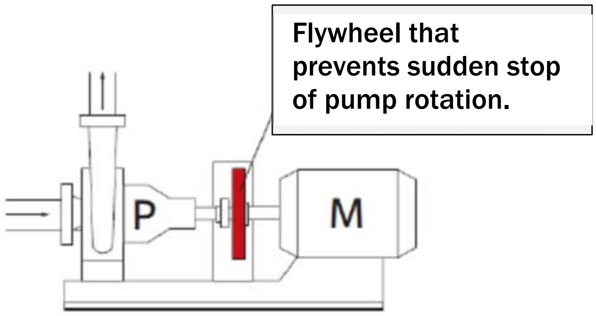


Figure 6.15 Example of flywheel of pump

(8) Construct a surge tank on the pipeline route

Surge tanks are facilities where a tank (water tank) is installed in the middle of a pipe line to feed water from the tank into the pipe line when there is a water column separation (negative pressure) in the pipe.

1) Conventional Surge Tank

Tanks with a free water surface are installed where negative pressure is likely to occur in the pipeline, and the water surface absorbs the water pressure fluctuations in the pipeline. A sufficient water surface area and a height matching the hydrodynamic gradient line are required.

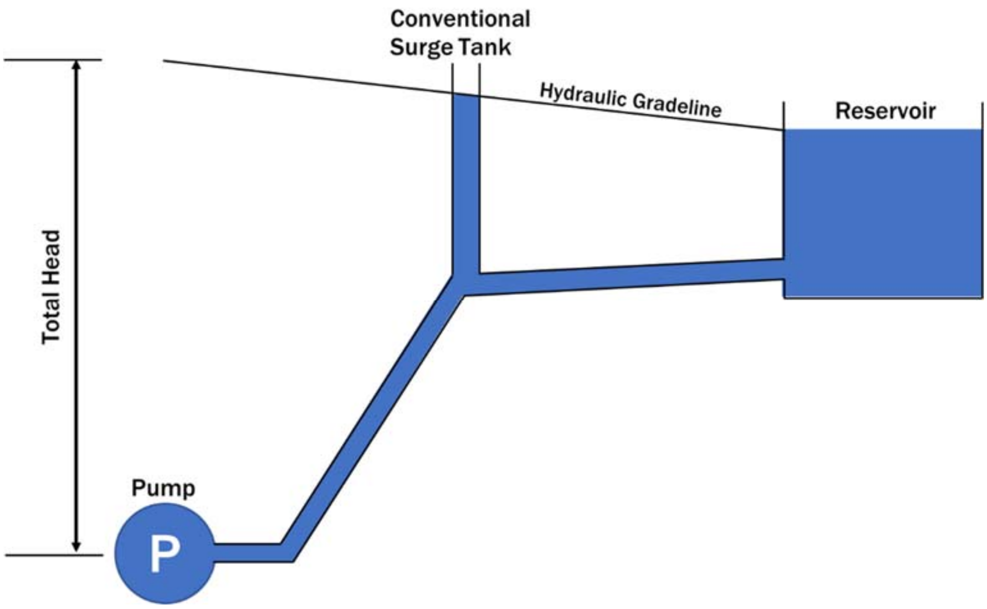


Figure 6.16 Image of Conventional Surge Tank

2) One-way Surge Tank

One-way surge tanks provide a facility for feeding the pipes with sufficient water from a tank when the pressure in the pipes drops, with the aim of preventing negative pressure. The bottom of the tank and the pipeline are connected, but a check valve prevents water from flowing back into the tank.

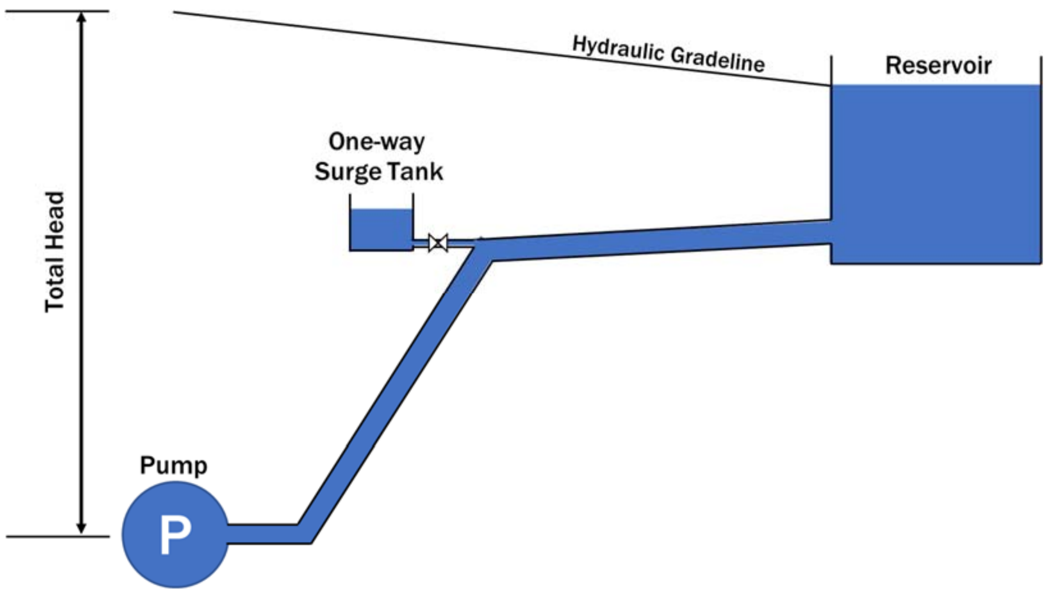
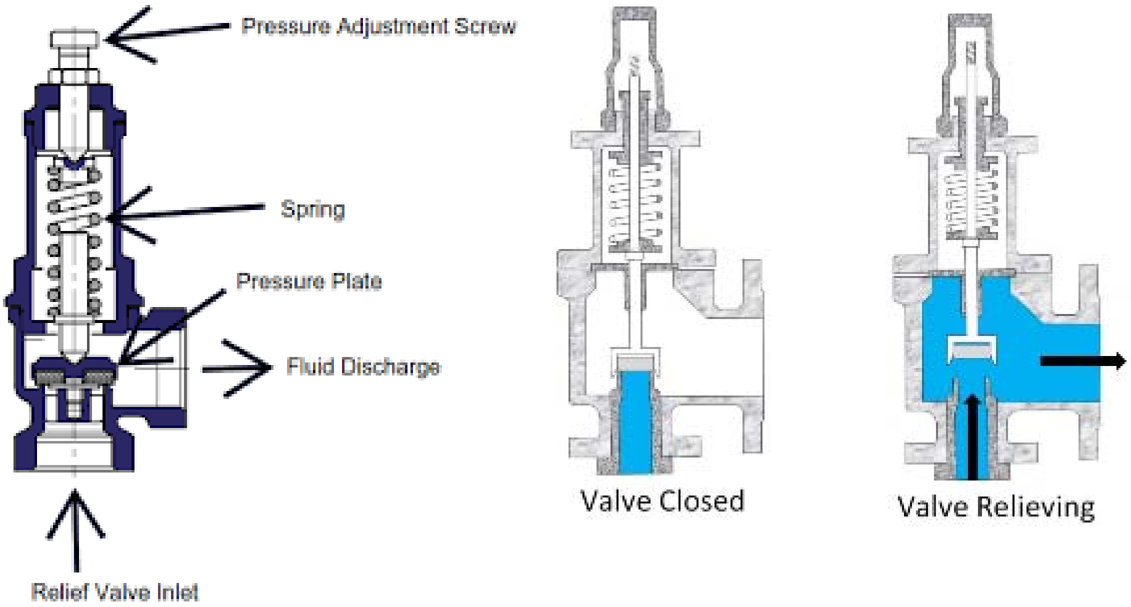


Figure 6.17 Image of One-way Surge Tank

(9) Install a pressure relief valve

Pressure relief valves are used to relieve excessive pressure in the pipe. It is often installed on the discharge pipe of the pump. If the pressure in the pipe exceeds a preset limit value, the valve on the branch side is automatically opened to release the increased pressure.

Spring Loaded Type



Pilot Operating Type

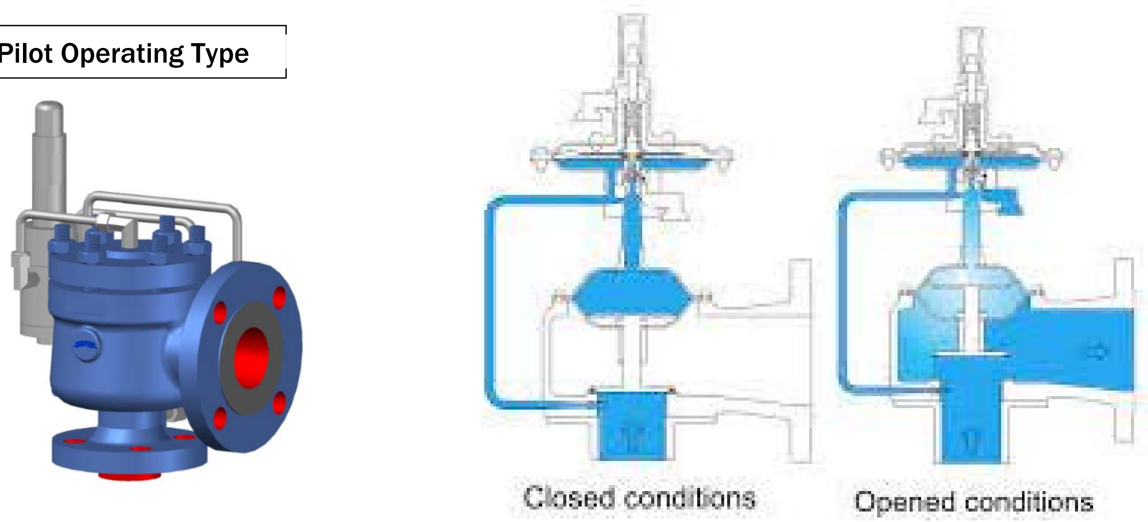


Figure 6.18 Variety of pressure relief valves

7. Achievement Test

No	Question	Yes	No
1	The weight of an object can be expressed as “mass x gravitational acceleration”.	☐	☐
2	The acceleration of gravity on Earth is 9.8 m/sec^2.	☐	☐
3	The weight of water with a mass of 1 kg can be expressed as 1 N (Newton).	☐	☐
4	The weight of water with a mass of 1 kg can be expressed as 9.8 N (Newton).	☐	☐
5	1 MPa of water pressure is approximately equal to 1 kgf/cm^2.	☐	☐
6	1 MPa of water pressure is approximately equal to 10 kgf/cm^2.	☐	☐
7	1 MPa of water pressure is approximately equal to 100 kgf/cm^2.	☐	☐
8	A water pressure of 1 MPa is equivalent to a water head of 1 m.	☐	☐
9	A water pressure of 1 MPa is equivalent to a water head of 10 m.	☐	☐
10	A water pressure of 1 MPa is equivalent to a water head of 100 m.	☐	☐
11	Water pressure is classified into “Static Pressure” and “Dynamic Pressure”.	☐	☐
12	Static pressure is less than dynamic pressure.	☐	☐
13	The water supply pressure with water in consumption is dynamic pressure.	☐	☐
14	Gauge pressure is the pressure value at zero reference to atmospheric pressure.	☐	☐
15	Absolute pressure is the pressure value at zero reference to a perfect vacuum.	☐	☐
16	When expressing water supply pressure, gauge pressure is usually used.	☐	☐
17	When expressing water supply pressure, absolute pressure is usually used.	☐	☐
18	Bernoulli's principle can be applied to any condition flow.	☐	☐
19	Bernoulli's principle is based on the law of conservation of energy.	☐	☐
20	When Bernoulli's principle is expressed in terms of water head, thermal energy can be ignored.	☐	☐
21	Bernoulli's principle implies that the sum of 'Kinetic energy', 'Pressure energy' and 'Potential energy' is constant.	☐	☐
22	Venturi meters are flow meters that use Bernoulli's principle.	☐	☐
23	In Venturi meters, the flow rate cannot be calculated from the cross-sectional area and differential pressure alone.	☐	☐
24	The water distribution pipes used may be selected without taking into account the design water pressure of the planned site.	☐	☐
25	The type of pipe should be varied depending on the water pressure conditions on the site.	☐	☐
26	For HDPE pipes in Nepal, the yellow line means PN10.	☐	☐
27	The PN value indicated on the pipe means the minimum working water pressure.	☐	☐

No	Question	Yes	No
28	The PN value indicated on the pipe means the maximum working water pressure.	☐	☐
29	In the design of pipelines, the design water pressure is the dynamic pressure plus the assumed water hammer pressure.	☐	☐
30	The minimum water supply pressure desired in a typical water system is 0.75 MPa.	☐	☐
31	The simplest hydrometer for measuring gauge pressure is the Bourdon tube.	☐	☐
32	The vacuum pressure can be determined with an ordinary pressure gauge.	☐	☐
33	Bourdon tubes can be used for all type of fluids.	☐	☐
34	Data loggers are used to record changes in water pressure that are difficult to discern with the human eye.	☐	☐
35	The data logger allows the measurement interval of the water pressure to be set freely.	☐	☐
36	The data logger has a built-in battery, allowing long-term measurements inside the chamber or near the customer's water meter.	☐	☐
37	The noise and vibration that occurs when a valve is suddenly closed in a pipeline during water supply is due to water hammer.	☐	☐
38	Water hammer is caused by sudden pressure changes in the pipe.	☐	☐
39	Sudden pressure changes in the pipe cause water column separation.	☐	☐
40	Pressure changes in the pipe are transmitted at supersonic speeds, which are approximately 1,400 m/sec.	☐	☐
41	Water hammer is more likely to occur in downhill pipelines.	☐	☐
42	Water hammer is more likely to occur in pipelines that rise steeply immediately after the pump.	☐	☐
43	Quickly closing the valves on the water distribution pipes does not cause problems.	☐	☐
44	Changing valve types can also help to avoid water hammer.	☐	☐
45	Air valves do not provide water hammer protection.	☐	☐
46	Water hammer does not occur when pumping water.	☐	☐
47	If the pump stops suddenly due to a power outage, it may cause water hammer.	☐	☐
48	A flywheel is effective in preventing the pump from stopping suddenly.	☐	☐
49	Pressure relief valves are often used near water distribution tank.	☐	☐
50	The most reliable water hammer protection is a surge tank.	☐	☐