OPERATION AND MANTINANCE OF WATER DISRIBUTION SYSTEMS

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Abstract:
The aim of this research is to assist service delivery by making information on proper Operation and maintenance practices available in a practical and accessible way. The research focuses on technical Issues of operation and maintenance. Also the research focus water distribution systems including pipes, pumps, valves, Storage Reservoirs, meters and other fittings.
The approach adopted in the research is to provide the Attendees with an Understanding Measuring system performance and the best practices in operation And maintenance of water distribution systems also it aims to provide guidance to Empower the water companies to implement a proper operation and maintenance System in practice focusing on the most Common and important aspects.

Key words:
Water distribution systems
Operation and maintenance
Service delivery
System performance

1 - INTRODUCTION:

A dependable supply of clean and safe water is The Most critical of Jordan water Company service that people require. Jordan has made great steps in addressing the Inequalities of the past in Service provision.

Unfortunately the focus on expanding service delivery and the Human migrations Because of the surrounding wars and the sudden increase in the population were Often at an adequate expense Operation and maintenance of existing infrastructure. This has resulted in increased levels of leakage and non-revenue water, maintenance Backlogs and problems with service provision.

1.1 What is operation and maintenance?

The purpose of a water distribution system is to provide an adequate and reliable supply of safe water to its users. Operation and maintenance are those activities needed to continuously fulfill this purpose.

The difference between operation and maintenance is that operation involves activities necessary to deliver the service, while maintenance involves activities that keep the system in good operating condition.

Operation includes monitoring the system state, running the system and enforcing policies and procedures.

Maintenance entails servicing, repair and replacement of system components.

When maintenance is done before a system element fails in order to prevent it from failing, this is called proactive maintenance. Maintenance done after a component failure is called reactive maintenance.

Operation and maintenance of a water distribution system can be greatly affected by the system design and construction practices used. For example, a design that specifies unsuitable pipe materials or pipes that are damaged during construction may lead to major future operation and maintenance problems for the system.

Cost is a major factor in the provision of water company's services and thus it is important that operation and maintenance is done in such a way that the required level of service is provided at the minimum cost over the long term.

It is often possible to save major costs in the future by using higher quality components or performing preventative maintenance, for example, installing a cathodic protection system on a steel pipe can ensure that the service life of the pipe is greatly extended, saving the much greater cost of replacing the pipeline.

1.2 System Integrity

System integrity is defined as the state that a water distribution system has to be in to ensure that it fulfills its purpose. Three types of integrity can be identified

- **Physical integrity** means that the system components are able to function as intended and provide a barrier between the water in the system and external threats.
- **Hydraulic integrity** means that the system is able to provide the flows and pressures required for the required level of service.
- **Water quality integrity** means that the system is able to deliver water of acceptable quality to all its users (assuming that it receives source water of acceptable quality).

The different types of system integrity are not independent, but influence each other as shown in Figure below.

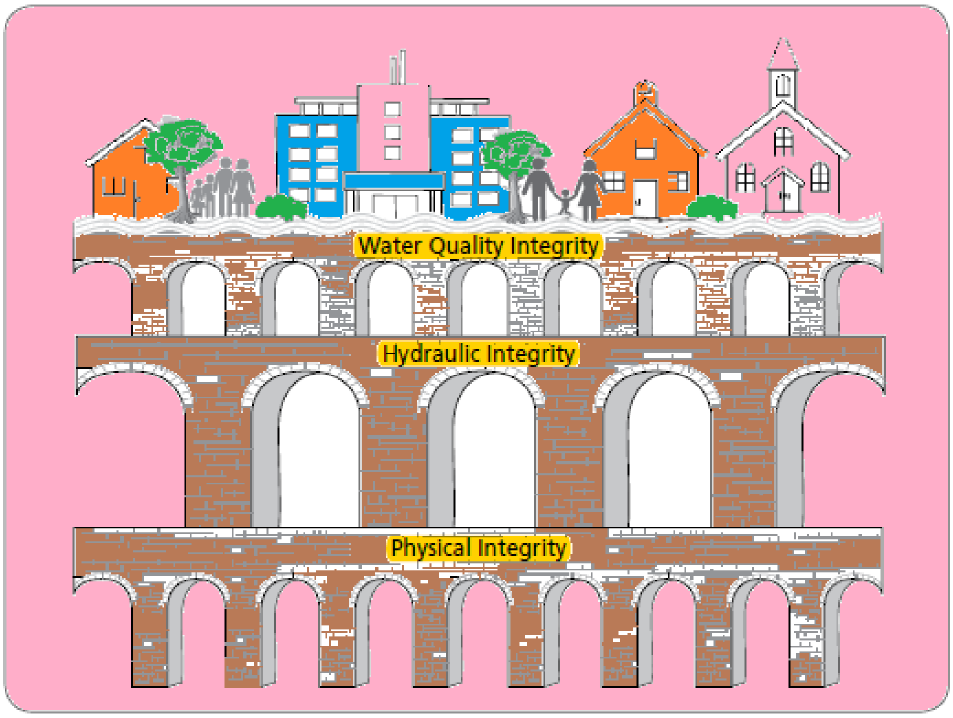

Figure (1)
Physical, hydraulic and water quality integrity are essential for providing adequate and safe Water to the public.

For example, a loss of physical integrity due to cracks in pipes May lead to a loss of hydraulic integrity through increased friction losses, and a loss of water quality integrity if polluted water outside the network is able to enter the pipes through the cracks.
Ideally, there should be no change in water quality from the time it leaves the treatment plant until it's delivered to the consumer, but in reality substantial changes may occur as a result of complex physical, chemical, and biological reactions.

2- Water distribution systems

2-1 Introduction

Water distribution systems consist of a large number of pipes and components connected in a network and functioning as a whole.

2-2 Water distribution networks

Water distribution systems are difficult to analyse due to their many components, non-linear hydraulics and complex demand patterns. As a result, computer network models are required to calculate flows and pressures in distribution systems. It is also important to measure flows and pressures in the network to monitor its behavior, and identify potential problems early.

2.3 Network hydraulics

Water distribution systems are mostly supplied from water reservoirs located at high points above the supply areas, such as hills or water towers. Thus pressures and flows in the system are driven by gravity.
If there are no demands or leaks in the system, the water will be static and the pressure head at any point in the network will simply be the difference in elevation between the reservoir's water surface and the point. This is called the static pressure.

However, when a tap in the system is opened, the pressure in the system forces water out of the tap opening to supply it to the user. Similarly, when a system has leaks, water is forced out through the leak openings.

When water flows through the pipes from the reservoirs to the consumers and leaks, friction energy losses occur, which result in a reduction of pressure at any point in the system, The higher the demand in the system is, the greater the pressure losses will be.

From this explanation it should be clear that the system pressure would be at a maximum when consumer demand is at a minimum (typically between 3:00 and 4:00 in the morning). Conversely, when the demand in the system is at a maximum (typically between 6:00 and 7:00 in the morning), energy losses are at their highest and thus the pressures in the system are at a minimum. The typical variation of Demand and pressure in a system is shown in Figure (2).

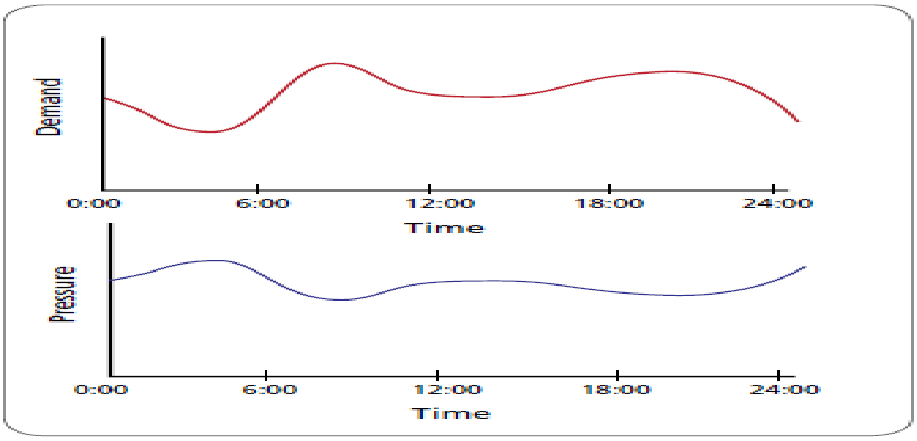

Figure 2

Typical variation of demands and pressure in a distribution system when the pressures in the system become too low, the system is not able to supply the required flow rate and the system experiences a loss of hydraulic integrity.

2.4 Hydraulic network models

It is very difficult to calculate the hydraulics (flows and pressures in the system) due to the size and complexity of the network layout, different operational conditions that may occur (for instance pumps switching on and off, and reservoir or control valves opening and closing), as well as the complex hydraulic behavior of water flowing through pipes and other components. For this reason, a hydraulic network model of the distribution system is an essential tool in the design and operation of water distribution systems.

Hydraulic network models require a lot of effort to set up, calibrate and maintain, but allow water companies to predict the behavior of the system under various conditions, such as future demand growth, valve closures, extensions and operational changes. It is essential that hydraulic models reflect the actual conditions in the field, and should thus be calibrated against measured flows and pressures in the system.

2.5 Flow measurement

Water meters are essential in the management of water distribution systems, as they record the quantities of water that enters the system, how it is transported to different parts of the network and how much is delivered to consumers. There are four fundamental drivers for water metering in distribution systems:

- **Equity.** Consumer water meters form the basis for an equitable billing system based on the quantity of water used.

- **Water efficiency and losses.** By comparing the readings consumer water meters with the total system input volume, water companies' engineers are able to estimate the level of water losses in a distribution system and identify illegal connections. Consumer meters can be used to focus the attention of users on their water consumption and encourage them to use it more efficiently.
- **Economic benefits.** Water meters form the basis of most municipal water bills, and thus have a direct impact on water companies' revenues. Consumer water meters are sometimes called the cash registers of water companies.
- **System management.** Water meters in the distribution system are essential to know how much water enters the system, where it is distributed too and what the losses in certain areas are. Water meters also play an essential role in calibrating hydraulic network models.

2.6 Pressure measurement

Pressure can be measured using a mechanical pressure gauge or an electronic pressure transducer, which converts the pressure reading to an electronic signal that can be logged or transmitted to a control room. Electronic pressure gauges are more versatile and are thus preferred. Pressure gauges should be selected based on the range of pressures expected at the measuring point. For example, pressure gauges on the suction sides of pumps should sometimes be able to read negative pressures. Where hydraulic transient pressures need to be recorded, the pressure measuring equipment should be capable of taking readings at a rate that will record the full transient wave, and not just a few points on it.

Most important is that pressure gauges and transducers should be calibrated or verified before being put in use, and at regular intervals while in use. Errors in the pressure readings may cause difficulties when interpreting and using the data. Pressures in a water distribution system are measured to monitor the level of service, but also to assist with leak detection and network model calibration.

Pressure readings are invaluable when investigating the cause of network problems, especially if the readings are available in real time. Pressure readings are normally taken at pumps, critical points in the network (i.e. lowest pressure points) and at points representing the average zonal pressure.

3- Operation and maintenance of water distribution systems

3.1 Design requirements:

Each component in a pipe network has to be designed or selected to function correctly under local conditions. However, these components function together as a unit in the network, and thus a failure of one component can affect other aspects of the system. A network should be designed and constructed with operation and maintenance in mind. The following aspects should be considered:

3.1.1 Multiple sources. A distribution served from more than one source is inherently more reliable since the network will get water even if one of the sources fails.

3.1.2 Water demand patterns and growth. Water demand tends to grow with time due to economic growth and thus the system should be designed for the demand at the design horizon, typically ten or twenty years into the future. In addition, water demand within any year is highly variable, especially in seasonal consumers use more water in summer than in winter, and peak consumption typically occurs early in the morning when people get ready for the day.

The pipe network should be designed to handle the daily peak demand during the seasonal peak demand period at the end of the design horizon.

3.1.3 A looped pipe layout is better than a tree layout as this provides robustness in the system and reduces the risk of water stagnating. A network allows water to reach consumers via more than one route and thus is better able to maintain supply even when sections of the network are isolated for maintenance purposes.

3.1.4 The maximum allowable pressure in the system should not be exceeded, particularly at night when the demand is at a minimum. It is highly recommended that the maximum pressure is kept as low as possible. Higher pressures cause pipe leaks to occur more frequently, pipe service lives to be reduced and the flow
Rate from leaks to increase it can also cause higher leakage on consumers' private plumbing systems, and result in higher levels of water wastage.

3.1.5 The minimum pressure in the system that should be maintained even under peak demand conditions. It should be noted that in some cases users are located at such high elevations that it isn't possible to provide them with the minimum system pressure. This may still be acceptable if the pressures do not drop not too far below the minimum value, but ideally such developments should be avoided. Alternatively, the pressure for high-lying consumers can be improved by installing a water tower.
3.1.6 A minimum pipe diameter should be used in the system to ensure that there is adequate surplus capacity for high demands such as for fire fighting, and that the system is more robust. In addition, it is known that smaller diameter pipes have a higher frequency of failure and thus higher maintenance costs.

3.1.7 Suitable pipe materials considering factors such as the chemical composition of the water, corrosive nature of soils. To ensure that the pipes used are able to handle the System conditions.

3.1.8 The pipe class determines the maximum operational pressure the system is able to handle. Ensure that this rated pipe pressure will never be exceeded, even in the case of a PRV or other System element failing.

3.1.9 Implement district metering areas (DMAs*)* of around 2 000 users with similar elevations, preferably supplied through a single metered point where pressure can also be controlled if required. Steps should be taken to ensure that DMAs remain isolated from the rest of the network at all times. DMAs form the core of water loss and pressure management in a distribution system.

3.1.10 Water metering should be done in accordance with a clearly defined strategy to ensure that the maximum benefit is obtained from the metering system. Water meters should be selected to have the correct size and the ability to handle the operating conditions in the system. Water meters should be installed strictly in accordance with manufacturer's requirements.

3.1.11 Use different pipe materials or colors when dual water distributions with both drinking and non-potable water are installed.

3.1.12 Reservoirs should be located in such a way that pressures in the distribution system are adequate but not excessive. Reservoirs that are located too high require more pumping energy to fill and result in excessive pressures in the distribution system. Where a system has users at a large range of elevations, reservoirs should be installed at different elevations.

3.1.13 In cases where large **water hammer** pressures may occur, for instance in large pumping lines, a water hammer analysis should be conducted and water hammer control measures implemented.

3.1.14 Ensure that all **as-built drawings and GIS** information are correct.

3.1.15 New pipes and components should be ***pressure tested after installation*** to ensure that the construction was done correctly and is leak free.

3.2 Operation

Key system parameters should be continuously monitored to ensure that problems in the system are identified as quickly as possible. The following parameters should be monitored:

3.2.1 System input flow rates from water treatment plants, bulk water suppliers and other municipalities, as well as water supplied to other municipalities. These flow rates are the largest in the system and thus accurate measurement is very important. Electromagnetic or ultrasonic flow meters are typically used and should be monitored continuously. The system input volume forms the basis for water loss estimation.

3.2.2 DMA meters should also be monitored continuously and the results analyzed for changes in consumption patterns and levels of leakage. DMA consumption patterns are important in determining accurate water demand patterns for distribution system calibration and modeling.

3.2.3 Consumption meters. Bulk consumers are the most important users of water in a municipality representing a high fraction of the total system demand. Their consumption monitoring should be given priority and should be done at least on a monthly basis, but more frequently if possible. Other consumer water meters should be read on a monthly basis. Metered consumption should be analysed to identify patterns that may indicate defective meters, meter bypassing and on-site leakage.

3.2.4 System flow rates are important for monitoring the movement of water in the distribution system and maintaining adequate reservoir water levels while ensuring that pumps are operated in the most efficient cost periods.

3.2.5 Water quality should be monitored and corrective action taken immediately If problems are found.

3.2.6 Information should be gathered from **pipe repair reports** on the type and likely cause of failures, as well as the condition of the distribution system at the failure. This information should be analysed annually to identify patterns and modify procedures if required.

3.2.7 Operators of the distribution system should be trained to correctly deal with situations that may potentially cause damage. For example, if a pressure relief valve opens to protect the system from over-pressure after the failure of a PRV, the natural reaction of an operator may be to close the pressure relief valve, thus stopping it from fulfilling its protective function.

3.2.8 Maintenance staff should be trained to ensure that repairs are done correctly and safely, and cross-connections on parallel systems do not occur. For example valves should be opened or closed slowly to ensure that water hammer pressures are not generated. Pipe repairs provide an ideal opportunity to gather data on the state of the network and thus repair teams should be trained to complete reports on the state of the system as part of their maintenance tasks.
3.2.9 Water meters. A database of all water meters should be developed and regularly updated. This database should include the reasons for meter failures and results of meter accuracy tests, and inform meter servicing, maintenance and replacement decision. Meters should be read on at least a monthly basis.

3.3 Maintenance
The following maintenance functions are important in water distribution systems:

3.3.1 Adequate **quantities of network components** should be held in water companies' stores for repair and replacement of pipes and other components.

3.3.2 Regular maintenance is important to ensure that water meters are able to function satisfactorily for as long as possible.

3.3.3 The cost of maintaining pipes should be analysed and pipes **replaced or refurbished** when at come to the end of their economic service lives.

4 - Common operational tasks

4.1 District metered areas (DMAs)
District metered areas are zones of a distribution system that are isolated from the rest of the system except for one (or sometimes more) supply points. All supply points are metered and sometimes also provided with PRVs to allow pressure management to be implemented in the DMA.
By monitoring the flow into a DMA, it is possible to analyse consumption patterns and particularly the leakage in the system by measuring the minimum night flow.
It is important to check that DMAs are isolated from the rest of the system. This is done using a zero pressure test in which the supply to the network is closed and the network pressure monitored to check whether it reduces to zero (the DMA is isolated) or not (the DMA is connected to the rest of the system through an open valve or unknown connection).
4.2 Pressure management
The International Water Association has been leading efforts on implementing pressure management in water distribution systems. Pressure management started as an effective technique to reduce leakage rates in distribution systems due to the fact that leakage is often quite sensitive to changes in system pressure. However, it is now recognized that pressure management has many other benefits for distribution

systems, including lower pipe failure rates, longer pipe service lives and improved water demand management.
To implement pressure management, a section of the network with similar elevations is isolated from the rest of the system and supplied through a single point (or sometimes more points) equipped with a water meter and PRV. These areas are called pressure management zones (PMZs) or pressure management areas (PMAs).

The **PRV** serving a pressure management zone can be controlled in four ways:

1- **Fixed-outlet pressure control** is done using a standard PRV that limits the pressure on its outlet to a certain maximum value. This is a cost-effective and simple solution, but it does not have the ability to modulate pressure in response to the demand in the system, and thus pressures will still be higher at night than during the day.

2- **Time-modulated pressure control** is done using a PRV similar to that of fixed-outlet control, but varies the pressure setting over a 24-hour period. Thus it is able to reduce pressures more during the night when demand is at a minimum. Time-modulated control is able to reduce leakage more than fixed-outlet control and is still relatively simple to implement.

3- **Flow-modulated pressure control** is done by adjusting the PRV setting based on the flow rate into the PMZ and can thus adjust system pressure to the actual demand. It is significantly more sophisticated than time-modulated control, but has the potential to reduce losses further. A major advantage of flow-modulated control is that the system is able to automatically respond when the fire service require high fire flows.

4- **Closed-loop pressure control** is done by adjusting the PRV setting based on the pressure at a critical point in the PMZ, and thus has the best potential for maximizing the benefits of pressure management. However, these systems are also the most sophisticated and expensive.

A water companies should consider all the advantages and disadvantages of the different pressure controllers in light of its needs and capabilities to operate and maintain the system. The most sophisticated system is not necessarily the most appropriate one, and it is often possible to get substantial advantages by installing a simpler system.

4.3 Dealing with low pressure problems

One of the most common problems experienced in water distribution systems is low system pressure, which is often discovered through complaints from consumers or routine pressure measurements.
If an individual consumer complains of low pressures, but the pressures in the supply pipes are normal, the problem may be due to a restriction in the consumer’s plumbing system. However, if distribution systems pressures are low, it is advisable to monitor the pressures over at least a 24-hour period. If the pressure remains low throughout the monitoring period, the problem may be caused by the consumer being at too high an elevation to supply with higher pressures, or as a result of a too low PRV setting. However, if the low pressures only occur during high demand periods, the problem may be caused by inadequate pipe capacity, a closed valve or even a blocked strainer. Once the cause of the low pressures is known, the solution is often straightforward and may include one of the following actions:

1- Making operational changes such as opening closed valves.
2- Changing PRV or pump control settings.
3- Locating and repairing leaks.
4- Adjusting pressure zone boundaries.
5- Replacing pipes.
6- Cleaning and lining pipes.
7- Installing a new elevated tank to supply the affected area.
8- Installing a booster pump.

5 – Pipes

The vast majority of a water distribution system consists of pipes and couplings to link them to each other in different configurations.
Various different pipe, lining and jointing materials have been used over the last century, and since pipes sometimes stay in service for fifty to a hundred years, it is likely that different pipe materials will be present in a given distribution system.
This section discusses the most common types of joints and pipe materials used in water distribution systems.

5.1 Joint types

Various types of joints are available to connect pipes to each other. The type of joint used is mostly determined by the pipe material used, but also by other requirements such as the ability to handle and ease of use in the field.
The most common types of joints are listed below and illustrated in Figure (3)

- **In spigot and socket (or bell and spigot)** joints, one end of a pipe section (the bell) is enlarged and provided with a rubber seal, while the other end (the spigot) is left unchanged. To join two pipes, the spigot of one pipe is pushed into the bell of the other pipe.
- **Butt fusion** jointing is used to connect HDPE pipes: the ends of both pipes are heated and then pressed together at a prescribed pressure to create a bond. The quality of workmanship in butt fusion jointing is very important to ensure a strong and lasting joint.
- **Electro fusion** is an alternative jointing method for HDPE pipes that employs special collars with built-in heating coils. The ends of the pipes are cleaned and their outer layers removed using a special scraping tool to expose virgin material. The electro fusion collar is then placed over the pipe ends and an electrical current applied to the heating coil. The heat melts the material of the collar and pipe together. Quality control is critical and it is important that pipe ends are perfectly round and clean, that the pipes are restrained throughout the fusion process and that joints are allowed to cool down fully before the restraints are removed.
- **Flanged** joints consist of both pipes ending in flanges with holes allowing them to be bolted together. A gasket is fitted between the two flanges to ensure a watertight seal.
- Large diameter steel pipes may be joined by **welding** them together in the field. Quality control is critical to ensure that welds are done properly.
- Flexible **mechanical couplings** that compress sealing rings when their bolts are tightened. These couplings can be used to join the same or different types of pipe with plain ends. It is possible to leave a gap between the pipes being joined, which is useful in valve chambers or pump stations where this gap allows components to be easily disassembled and reassembled.

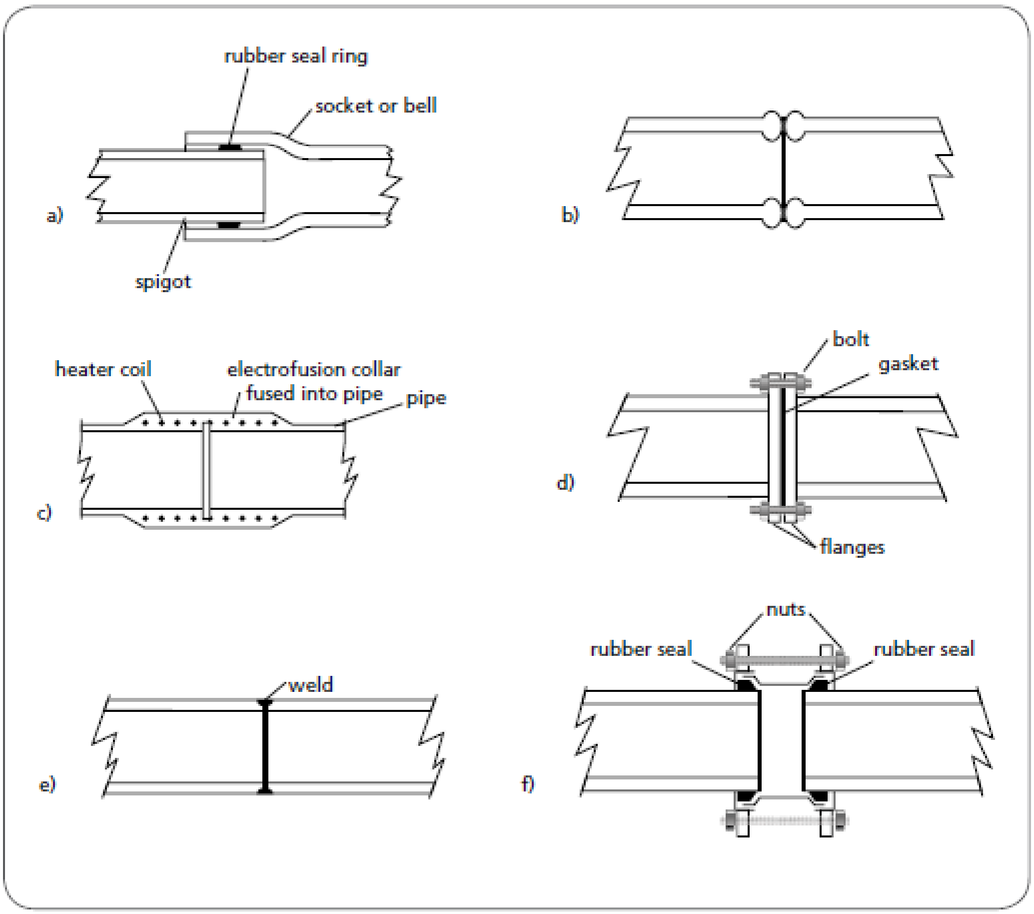

Figure 3 Common types of pipe joints: a) spigot and socket; b) butt welded; c) electro fusion) Flanged; e) welded; f) mechanical coupling.

5.2 Pipe materials

Commonly used pipe materials in water distribution systems are briefly discussed in this section from the earliest to the most modern pipe materials:

Cast iron is one of the earliest pipe materials and is still found in older distribution systems. Cast iron has much better corrosion resistance than ductile iron and steel, and was often used without any coating or lining. Disadvantages include that pipe sections are heavy and difficult to handle, that wrapping and corrosion protection is required (especially in corrosive soils) and that stray currents may accelerate corrosion.

Ductile iron pipes replaced cast iron around the middle of the 20th century and are often lined with cement mortar or bitumen. Ductile iron pipes have relatively good corrosion resistance and can handle water hammer pressures and soil loads due to its high strength. Disadvantages are the same as for cast iron pipes.

Steel pipes also came into use from about the middle of the 20th century and are still used today for large diameter pipes and high pressure applications due to its high strength. Steel pipes are susceptible to corrosion and thus need to be protected from the environment both on the inside and outside of the pipe. Cement mortar, bitumen, epoxy and hot-dipped galvanizing are used for linings. Disadvantages include poor corrosion resistance, requiring the use of linings, coatings and cathodic protection.

Stray currents may accelerate corrosion. Welding done in the field requires special equipment and training.

Polyvinyl Chloride (PVC) is presently the most commonly used pipe in municipal water supply systems. PVC pipes are lightweight and easy to handle, easy to joint and resistant to corrosion PVC pipes and fittings should not be exposed to direct sunlight for long periods as this discolors the material and makes it brittle, and thus unsuitable for use in water distribution.

High density polyethylene (HDPE) is another material that is commonly used today in water distribution systems. Unlike PVC, it is flexible, which means that it can be transported in rolls and used in trenchless installations where it is pulled through an existing pipe to replace it. It is lightweight, resistant to cracking and has many of the benefits of PVC piping. However, it is not damaged by direct sunlight and can be used in above-ground applications. Since it is supplied in long lengths, fewer joints are required. Thermal butt-fusion or electrofusion joints are generally used, but these joints are susceptible to failure if not done perfectly – something that is difficult to achieve in the field. The flexibility of HDPE makes it popular for trenchless technology installations.

Glass reinforced plastic (GRP) is a composite material that uses glass fibers embedded in a thermosetting resin, often in combination with other materials to give it the desired properties.

It is light weight and highly resistant to corrosion. Disadvantages include sensitivity to impact damage, importance of properly prepared bedding and blanket to provide support, and the difficulty of doing repairs in the field.

6.0 Reservoirs and water towers

It is important to distinguish between reservoirs and water towers as they have different functions: reservoirs are constructed on ground level and provide the bulk of the required storage volume. Where possible, reservoirs are located on higher ground above the system to provide the required pressure. However, in some cases users are located at high elevations relative to the reservoir and thus cannot be supplied with adequate pressure. In these cases water towers are commonly used to provide additional pressure for these users. Since it is expensive to provide elevated storage, water towers are sized for a few hours of peak demand only, and the pumps that supply them are sized to provide the peak user demand.

Reservoirs are mostly constructed from reinforced concrete, although smaller reservoirs are sometimes built out of bricks or steel panels. Water towers are mostly constructed out of reinforced concrete or steel panels. Jointing on all types of reservoirs and water towers are very important and needs to be specially designed and constructed to prevent leakage.

Figure 4.0 Examples of reservoirs and water towers

7.0 Pumps

Pumps are used to add energy to water in order to move it to a higher elevation, boost pressure or increase its flow rate. While different pump types exist, centrifugal pumps are almost exclusively used in water distribution systems.
Centrifugal pumps are the most commonly used pump type in water distribution systems. They use enclosed spinning disks with curved vanes called impellers to generate centrifugal forces.

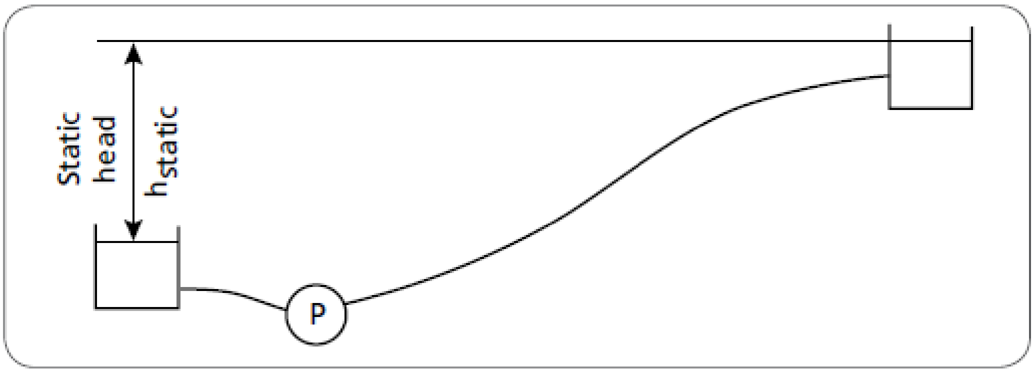

Figure 5.0 A simple pump system between two reservoirs.

7.1 Pump selection

The challenge of the designer is to select a pump that is able to supply the required flow in the most efficient way. Besides the large range of pump makes and models that can be chosen, other variables should also be considered, including the following:

- The ***pump speed*** can be increased or decreased to move the pump curve up or down respectively. This is normally done with a variable speed drive

- Pumps may be ***linked in series*** as shown in Figure 6.0 (a) to increase the pressure that can be delivered. Pumps are mostly linked in series by using multistage pumps, in which more than one pump impeller is installed on the same shaft.
- Pumps may be ***linked in parallel*** as shown in Figure 6.0 (b) to increase the flow rate delivered and to provide operational flexibility and backup.

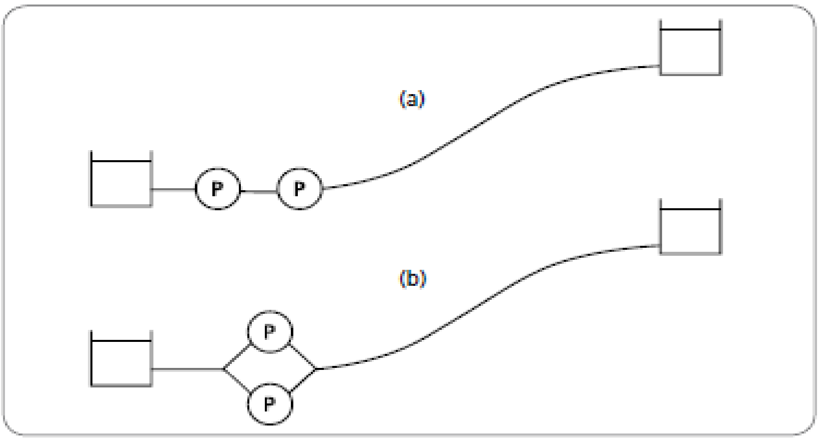

Figure 6.0 Pumps in a) series and b) parallel.

8.0 Valves

Various types of valves are used in distribution systems to shut down sections of the network, release air or regulate flow or pressure in the system. The main types are the following:

- Isolation valves
- Air valves
- Scour valves
- Non-return or check valves
- Control valves

8.1 Isolation valves

Isolation valves are used to close off and thus prevent any flow through pipes. This may be required to shut down a section of pipe for repairs or isolate one supply zone from another. Most valves are made out of steel, ductile iron or cast iron. Gate valves are typically used for isolation of small diameter pipes, while butterfly valves are used for large diameter pipes.

8.2 Air valves

Air valves are installed on pipelines to control the flow of air into and out of the system.

Pipelines should be completely filled with water under normal operating conditions, and thus any air that enters a system needs to be released. This is necessary when filling a drained pipe, or when air enters the system as bubbles or dissolved in the water. If the air is not released, it will accumulate at high points in pipes, restricting and even preventing flow altogether.

8.3 Scour valves

Scour valves are used to drain pipes for maintenance purposes. It typically consists of a reduced diameter off-take pipe closed with an isolation valve. In distribution networks, fire hydrants are mostly used to drain pipes instead of scour valves. On long pipelines, scour valves should be provided at the lowest points in the pipe profile. Each section of pipe that may require draining should be provided with a scour valve.

8.4 Non-return valves (check valve).

Non-return or check valves only allow flow in one direction. If water flows in the opposite Direction, the valve automatically closes one or more flaps or diaphragms, shutting off the flow. Non-return valves should preferably be provided with counter-weights to ensure that they fully close when there is no flow in the pipe. If this does not happen, a sudden return flow can cause the valve to slam closed violently, resulting in damage to the system.

Non-return valves should be installed whenever flow is only allowed in one direction including directly downstream of pumps, on pump bypass pipes and on large consumer connections.

8.5 Control valves

Control valves are used to control the flows or pressures in a distribution system by automatically varying their degree of opening in response to changes in system conditions.

Control valves are used where special controls are required in a network, such as flow or pressure control. Most control valves also function as non-return valves. Control valves generally have a certain range that they can operate on, and in some cases it is necessary to use more than one valve in series or parallel to get the desired results. The most common control valves in distribution systems are as follows:

• **Pressure reducing valves (PRVs)**

Ensure that the pressure on their downstream sides do not exceed a given value.

• **Flow control valves (FCVs)**

Ensure the flow rate passing through them doesn’t exceed a given value.

• **Level control valves**

Close when a reservoir is full, and opens when the water level drops to a pre-determined level.

• **Surge control valves**

Open or close to help dissipate water hammer pressures in a pipe or protect components against it.

• **Pump control valves** prevent water hammer from occurring in a system by controlling the rate at which the flow changes when pumps are started or stopped.

(a) (b) (c)

Figure 07 Examples of valves: a) large butterfly valve b) scours valve) c) air valves.

Figure 08 Examples of control valves

9.0 Water meters

Water meters are used to measure the volume of water that passes through them. All consumer connections should be metered, including supply points. Water meters are also used to measure bulk transfers (e.g. from bulk suppliers or other municipalities), consumption in district metered areas (DMAs) and the flow of water in the network. Water meters should be correctly sized and installed strictly in accordance with the manufacturer's requirements. Meter selection should be done based on lifecycle cost of the meter, including expected service life, loss of accuracy over time and failure rate, and not on purchasing price only.

Meters should be read on a monthly basis, preferably at the same time of the month. Meter readings should be verified to ensure that they do not contain errors before the readings are used to bill consumers. Metering data should also be made available to engineering and management to use for water demand management, water loss calculations and long term planning.

(a) (b) (c)

Figure 9.0 (a) consumer's meter (b) electro-magnetic meter (c) bulk consumer meter

10- Conclusions

Proper operation and maintenance are indispensable to ensure that capital investments on new infrastructure result in sustainable service provision. Without it, a new water distribution system will soon decline to a point where service provision is compromised, leading to greater water losses, financial losses and health risks to consumers. If operation and maintenance are neglected for long enough, it may become necessary to replace the system, requiring a new injection capital that could otherwise be used for other needs or stimulating economic development.

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