CHAPTER "1"

"INTRODUCTION"

1.1 General

Water may convey through pipelines by gravity flow or by pumping. The latter system will be significantly more expensive to construct, operate and maintain than similar gravity-flow systems, but in many cases, we are forced to use the pumping stations.

These are some, of many, questions that immediately confront any engineer who is involved in creating the physical infrastructure to satisfy a basic need of mankind: the delivery of water when and where it is wanted. It is the primary objective of these engineers to develop and apply their knowledge to make the system work. How do these systems work? What principles are involved, and how are the systems successfully analyzed and understood? How can the behavior of a preliminary design be evaluated, and how can the design be modified to correct deficiencies? What are the causes of transient and how to void the side effect of this phenomena?

In our project, we will try to answer these questions by applying several hydraulic principles on the current case study.

A steady flow is one in which all conditions at any point in a stream remain constant with respect to time. Or a steady flow is the one in which the quantity of liquid flowing per second through any section, is constant.

Unsteady-State (Transient) Flow:

The unsteady-state flow (frequently called transient flow) is defined as the fluid flowing condition at which the rate of change of pressure with respect to time at any position in the reservoir is not zero or constant. This definition suggests that the pressure derivative with respect to time is essentially a function of both position i and time .

Transients can produce large pressure forces and rapid fluid acceleration into a water pipeline system. These disturbances may result in device failures, system fatigue or pipe ruptures, and even the back-flow/intrusion of dirty water. Many transient events can lead to water column separation, which can result in catastrophic pipeline failures. Thus, transient events cause health risks and can lead to increased leakage or decreased reliability.

Figure 1.1 depicts how the transient evolution in a system looks like and it represents a view of the transient at a fixed point (x) just upstream of the valve that is being shut. In this graph, the pressure, P is represented as a function of time, t resulting from the operation of a control valve. In the figure, Pi is the initial pressure at the start of the transient, Pf is the final pressure at the end of the transient event, Pmin is the minimum transient pressure, and Pmax is the maximum transient pressure.

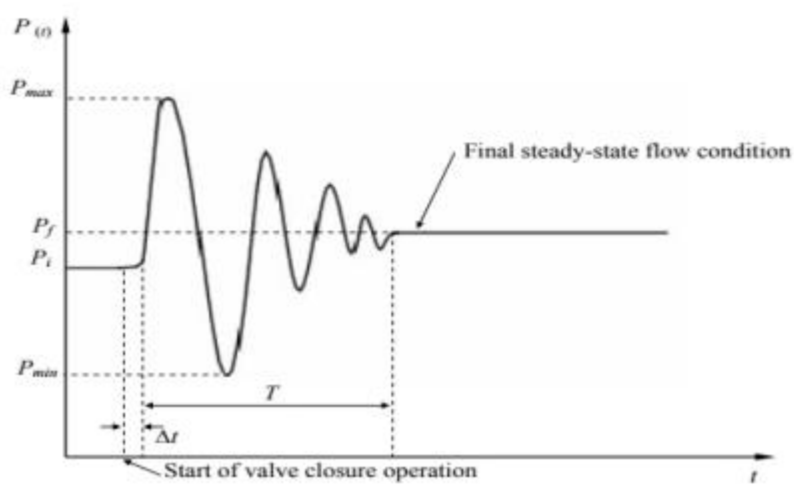


Figure 1.1: Hydraulic transients at position x in the system

Hydraulic transients occur at flow changes (rapid) in pressurised conduits and this is due to:

- Start and stop of pumps, especially stop due to power failure.
- Load changes in hydropower plants.
- Valves operations (shut-off valves).
- Check valve closure 8.
- Air pockets in pipelines, especially at pump start.
- Discharge of air through air vent and valves.

The magnitude of the transient pressure peaks depends on many factors, and some of these factors are:

- Pipeline length, configuration. The longer the pipeline the stronger the hydraulic transients. Branched pipeline configuration is better in handling transients.
- Pipeline profile.
- Rate of change of the flow. The more rapidly the flow changes, the higher are the generated hydraulic transients. Flow change depends on the valve operation, pump characteristics.
- The elastic properties of the water and the pipes. Less elastic pipes are disadvantageous.
- Possible contents of dissolved or gaseous gases in the water. Gas bubbles normally reduce transients.
- Formation and appearance of vapor pockets (cavities) in the water.
- Protective measures applied. These include surge chambers, air vessel, air valves, frequency-controlled pumps, etc.

This work presents the problem of modeling transient analysis is important and one of the more challenging and complicated flow problem in the design and the operation of water pipeline systems. Transient can produce large pressure forces and rapid fluid acceleration into a water pipeline system, these disturbances may result in device failures, system fatigue or pipe ruptures, and even the dirty water intrusion. Several methods have been introduced and used to analyze transient flow, an accurate analysis and suitable protection devices should be used to protect water pipeline systems.

1.2 Problem Definition

Transients analysis are important in hydraulic systems because it can cause rupture of pipe and pump casings, pipe collapse, vibration, excessive pipe displacements, pipe-fitting, support deformation and/or failure, and vapor cavity formation is how to analysis and to control the hydraulic transient for Ad Doha town and Ad Duheisha camp

1.3 Objectives of the Project

The main objectives of this work are to:

1) Performing the hydraulic transient system analysis with and without the protection devices.
2) Selecting the suitable protection device.
3) Performing the executable drawing plane and profile.
4) C hosing the suitable hydraulic devices (values) for the convening pipeline.

1.4 Methodology

In carrying out this work, the following research methodologies will be adopted:

- Collecting data related to the study area which required to carry out the work.
- Doing the field survey for the street where the proposed pipeline will pass.
- Using HAMMER model to calculate the hydraulic transients due to pump stop.
- Determination the suitable protecting device to protect the system integrity.

1.5 Phases of the Project

The Project will consist of four phases as shown in Table (1.1).

Table 1. 1: Phases of the project with their expected duration

Title	**Duration**							
	9/16	10/16	11/16	12/16	2/17	3/17	4/17	5/17
Data collection and field survey	■	■						
Preparing layout**.**		■	■	■				
Designing the required pumps and the conveying pipe line					■	■	■	
Using HAMMER model to calculate the hydraulic transient due to pump stop, and determination the suitable protecting device.						■	■	■

1.5.1 First Phase: Data collection and Survey

In this phase, available data and information will be collected from different sources. This phase includes the following tasks:-

1) Collecting of aerial and topographical maps for all areas.
2) Doing the field survey for the street where the proposed pipeline will pass.

1.5.2 Second Phase: Preparing Layout for the street where the proposed pipeline will pass.

In this phase layout was prepared and put in its final shape. This phase includes the following tasks:

Draw the layout of the street where the line will pass and check it more than one time to make sure that is correctly , later compare layout with the real situation in Ad Doha town. Then make adjustment and draw the final layout, this step is the most important one.

1.5.3 Third Phase: checking the used pumps and the convening pipeline.

In this phase the necessary calculations needed for the design of main trunks was completed, this phase includes the following tasks:

1) Establish a layout, which includes the street where the proposed pipeline will pass existing elevations.
2) Establish the pipeline in the street layout.
3) Establish the used pumps calculations.
4) Preparing needed different drawings for the existing pipeline.

1.5.4 Fourth Phase: Using HAMMER model to calculate the hydraulic transient due to pump stopping, and determination the suitable protecting device.

After finishing the design steps of the main pipeline and choosing the pump type, the hydraulic analysis for both steady and transient state will be carried out to choose the suitable protection devices depending on the simulation results.

CHAPTER “2”

“LITERATURE REVIEW”

2.1 Introduction to Transient Flow

In a water distribution system, system flow control is an integrated part of its operation, for instance, the opening and closing of valves, and starting and stopping of pumps. When these operations are performed very quickly, they can cause hydraulic transient phenomena to come into existence in the water distribution system, which can result in system damage or failure if the transients are not minimized.

When the steady state condition of a flow in a system is altered, the values of the initial flow conditions of the system, characterized by the measured velocity (*V*) and pressure (*P*) at positions along the pipeline (*x*), change with time (*t*) until the final flow conditions are established in a new steady-state condition.

From Figure 2.1, the physical phenomenon that occurs during the time interval *T*, between the initial and final steady-state conditions is known as the hydraulic transient. In general, surges are unsteady flows that results from relatively slow flow rate changes, and water hammer or hydraulic transients result from rapid flow rate changes.

Hydraulic transient evaluation is a complex task and it involves the determination of the values of the functions *V(x, t)* and *P(x, t)* during the time interval, *T* that resulted from a flow control operation performed in a time interval, *t*Δ. In the case of hydraulic transients, density changes of the liquid (normally water) are essential to consider. In the case of surges (mass oscillations) the flow can be considered incompressible.

Figure 2.1 depicts how the transient evolution in a system looks like and it represents a view of the transient at a fixed point (*x*) just upstream of the valve that is being shut. In this graph, the pressure, *P* is represented as a function of time, *t* resulting from the operation of a control valve. In the figure, P_i is the initial pressure at the start of the transient, P_f is the

final pressure at the end of the transient event, P_{min} is the minimum transient pressure, and P_{max} is the maximum transient pressure.

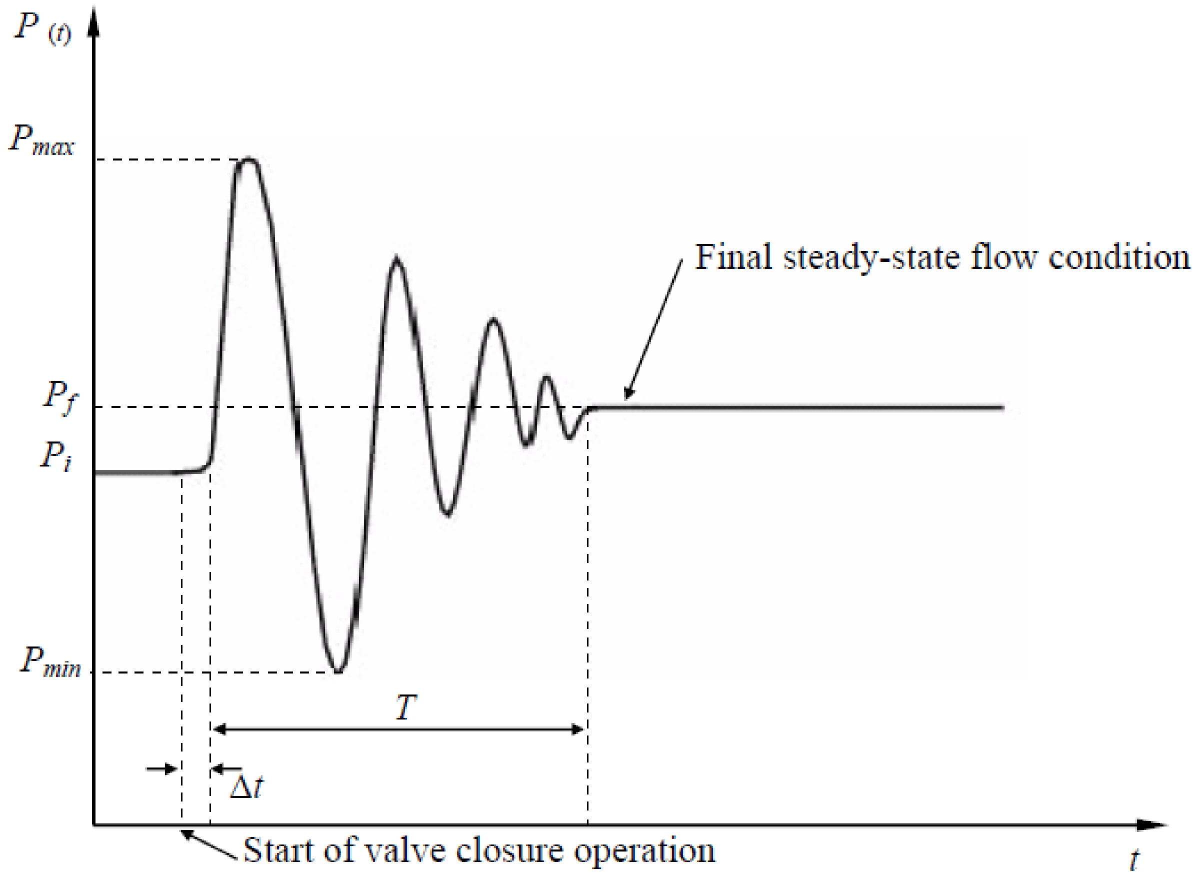


Figure 2.1: Hydraulic transient at position *x* in the system

2.1.1 Impacts of Transients

A wave is a disturbance that propagates energy and momentum from one point to another through a medium without significant displacement of the particles of that medium. A transient pressure wave, as in Figure 2.1, subjects system piping and other facilities to oscillating high and low pressures, and cyclic loads and these pressures can have a number of adverse effects on the hydraulic system.

2.1.2 Causes of Hydraulic Transients

Hydraulic transients occur at flow changes (rapid) in pressurised conduits and this is due to

- Start and stop of pumps, especially stop due to power failure
- Load changes in hydropower plants
- Valves operations (shut-off valves)
- Check valve closure
- Air pockets in pipelines, especially at pump start
- Discharge of air through air vent, valves

2.1.3 Factors Affecting the Hydraulic Transients

The magnitude of the transient pressure peaks depends on many factors, and some of these factors are:

- Pipeline length, configuration. The longer the pipeline the stronger the hydraulic transients. Branched pipeline configuration is better in handling transients.
- Pipeline profile
- Rate of change of the flow. The more rapidly the flow changes, the higher are the generated hydraulic transients. Flow change depends on the valve operation, pump characteristics
- The elastic properties of the water and the pipes. Less elastic pipes are disadvantageous
- Possible contents of dissolved or gaseous gases in the water. Gas bubbles normally reduce transients
- Formation and appearance of vapour pockets (cavities) in the water
- Protective measures applied. These include surge chambers, air vessel, air valves, frequency-controlled pumps, etc.

2.2 History of Transient Analysis Methods

Various methods of analysis were developed for the problem of transient flow in pipes. They range from approximate analytical approaches whereby the nonlinear friction term in the momentum equation is either neglected or linearised, to numerical solutions of the nonlinear system. These methods can be classified as follows:

2.2.1 Arithmetic Method:

This method neglects friction [10]

2.2.2 Graphical Method:

This method neglects friction in its theoretical development but includes a means of accounting for it through a correction.

2.2.3 Method of Characteristics

This method is the most popular approach for handling hydraulic transients. Its thrust lies in its ability to convert the two partial differential equations (PDEs) of continuity and momentum into four ordinary differential equations that are solved numerically using finite difference techniques [9]. The graphical method is also based on the method of characteristics.

2.2.4 Algebraic Method:

The algebraic equations in this method are basically the two characteristic equations for waves in the positive and negative directions in a pipe reach, written such that time is an integer subscript .

2.2.5 Wave-Plan Analysis Method:

This method uses a wave-plan analysis procedure that keeps track of reflections at the boundaries.

2.2.6 Implicit Method:

This implicit method uses a finite difference scheme for the transient flow problem. The method is formulated such that the requirement to maintain a relationship between the length interval Δx and the time increment Δt is relaxed [6].

2.2.7 Linear Methods:

By linearising the friction term, an analytical solution to the two PDEs of continuity and momentum may be found for sine wave oscillations. The linear methods of analysis may be placed in two categories: the *impedance method*, which is basically steady-oscillatory fluctuations set up by some forcing function, and the *method of free vibrations of a piping system*, which is a method that determines the natural frequencies of the system and provides the rate of dampening of oscillations when forcing is discontinued.

2.2.8 Perturbation Method:

With this method, the nonlinear friction term is expanded in a perturbation series to allow the explicit, analytical determination of transient velocity in the pipeline. The solutions are obtained in functional forms suitable for engineering uses such as the determination of the critical values of velocity and pressure, their locations along the pipeline, and their times of occurrence [3].

2.3 Physics of Transient Flow

A hydraulic transient is generated when the flow momentum of the transported liquid changes due to the rapid operation of the flow control device in the hydraulic system. Mathematically hydraulic transient is analysed by solving the velocity *V(x, t)* and pressure

P(x, t) equations for a well-defined elevation profile of the system, given certain initial and boundary conditions determined by the system flow control operations. In other words, the main goal is to solve a problem with two unknowns, velocity (*V*) and pressure (*P*), for the independent variables position (*x*) and time (*t*). Alternatively, the equations may be solved for flow (Q) and head (*H*).

The continuity equation and the momentum equation are needed to determine V and P in a one-dimensional flow system. Solving these two equations produces a theoretical result that usually reflects actual system measurements if the data and assumptions used to build the numerical model are valid.

2.4 Water Hammer Theory

Water hammer refers to the transient conditions that prevail following rapid system flow control operations. It can be used beneficially, as in the case of a hydraulic ram, which is a pump that uses a large amount of flowing water to temporarily store elastic energy for pumping a small amount of water to a higher elevation. More commonly, the destructive potential of water hammer is what attracts the attention of water engineers.

To generate equations describing the water hammer phenomenon, the unsteady momentum and mass conservation equations are applied to flow in a frictionless, horizontal, elastic pipeline. First, the momentum equation is applied to a control volume at the wave front following a disturbance caused by downstream valve action. The following equation may be developed, which is applicable for a wave propagating in the upstream direction:

$$\Delta p = -\rho a \Delta V \quad \text{or} \quad \Delta H = -\frac{a}{g}\Delta V \qquad (2.1)$$

Where $\Delta p = change\ in\ pressure.$ Pa

$\rho = fluid\ density.$ kg/m^3

a = characteristic wave celerity of the fluid. m/s

$\Delta V\ = change\ in\ fluid\ velocity.\mathrm{m/s}$

ΔH = *change in head.* m

It can be seen from the equation that a valve action causing a positive velocity change will result in reduced pressure. Conversely, if the valve closes (producing a negative ΔV), the pressure change will be positive.

By repeating this step for a disturbance at the upstream end of the pipeline, a similar set of equations may be developed for a pulse propagating in the downstream direction:

$$\Delta p = \rho a \Delta V \ \text{ or } \ \Delta H = -\frac{a}{g}\Delta V \qquad (2.2)$$

These equations are valid at a section in a pipeline in the absence of wave reflection. They relate a velocity pulse to a pressure pulse, both of which are propagating at the wave speed *a*. Assume that an instantaneous valve closure occurs at time *t* = 0. During the period *L*/*a* (the time it takes for the wave to travel from the valve to the pipe entrance), steady flow continues to enter the pipeline at the upstream end. The mass of fluid that enters during this period is accommodated through the expansion of the pipeline due to its elasticity and through slight changes in fluid density due to its compressibility.

The following equation for the numerical value of *a is* obtained by applying the equation for conservation of mass.

$$a = \sqrt{\frac{\frac{E_v}{\rho_v}}{1+\frac{E_v}{E_p}.\frac{D}{e}.C}} \qquad (2.3)$$

Where E_v and E_p are the volumetric modulus of elasticity of the fluid and pipe material (Pa) respectively, ρ_v is the density of the liquid (Kg/m^3). D and e are the internal diameter and the wall thickness (m) of the pipe respectively, and C = constant. Which depends on the axial movement of the pipe. In practical calculations. $C \approx 1$.

2.5 Full Elastic Water Hammer Equations

The water hammer equations are one-dimensional unsteady pressure flow equations given by (Wylie and Streeter, 1993):

$$\frac{\partial H}{\partial t} + \frac{a^2 \partial Q}{gA \partial x} = 0 \qquad (2.4)$$

$$\frac{\partial Q}{\partial t} + gA\frac{\partial H}{\partial x} + \frac{fQ|Q|}{2DA} = 0 \qquad (2.5)$$

In order to model the transient situation in a system, one has to solve these equations for a wide variety of boundary conditions of that system and its topologies. The full elastic water hammer equations cannot be solved analytically except by some approximate methods.

2.6 Transient Control

Ideally a hydraulic system design process will include an adequate investigation and specification of equipment and operational procedures to avoid undesirable transients. However, in reality, transients will still occur despite the design parameters; hence, remedial measures are required to keep transient conditions from seriously disturbing the proper functioning of an existing system. Unexpected sources of unsteady flow also appear in some newly constructed systems.
Two possible strategies for controlling transient pressures exist [3]

1. Focus on minimizing the possibility of transient conditions during project design by specifying appropriate system flow control operations and avoiding the occurrence of emergency and unusual system operations.

2. To install transient protection devices to control potential transients that may occur due to uncontrollable events such as power failures and other equipment failure.

Systems that are protected by adequately designed surge tanks are generally not adversely impacted by emergency or other unusual flow control operations because operational failure of surge tank devices is unlikely. In systems protected by hydropneumatic tanks, however, an air outflow or air compressor failure can occur and lead to damage from transients. Consequently, potential emergency situations and failures should be evaluated and avoided

to the extent possible through the use of alarms that detect device failures and control systems that act to prevent them.

Water usage and leaks in a distribution system can result in a dramatic decay in the magnitude of transient pressure effects.

2.7 Protection Devices

To the extent possible, the engineer would like to design flow control equipment such that serious transients are prevented. Using a transient model, the engineer can try different valve operating speeds, pipe sizes, and pump controls to see if the transient effects can be controlled to acceptable levels. If transients cannot be prevented, specific devices to control transients may be needed.A brief overview of various commonly used surge protection devices and their functions is provided in Table 2.1.

Some methods of transient prevention include [3]

- Slow opening and closing of valves: Generally, slower valve operating times are required for longer pipeline systems. Operations personnel should be trained in proper valve operation to avoid causing transients.

- Proper hydrant operation: Closing fire hydrants too quickly is the leading cause of transients in smaller distribution piping. Fire and water personnel need to be trained on proper hydrant operation.
- Proper pump controls: Except for power outages, pump flow can be slowly controlled using various techniques. Ramping pump speeds up and down with soft starts or variable-speed drives can minimize transients, although slow opening and closing of pump control valves downstream of the pumps can accomplish a similar effect, usually at lower cost. The control valve should be opened slowly after the pump is started and closed slowly prior to shutting down the pump.

- Lower pipeline velocity: Pipeline size and thus cost can be reduced by allowing higher velocities. However, the potential for serious transients increases with decreasing pipe size. It is usually not cost-effective to significantly increase pipe size to minimize transients, but the effect of transients on pipe sizing should not be ignored in the design process.

To control minimum pressures, the following can be adjusted or implemented; Pump inertia, Surge tanks, Air chambers, One-way tanks, Air inlet valves, and Pump bypass valves. To control maximum pressures, the following can be implemented; Relief valves, Anticipator relief valves, Surge tanks, Air chambers, and Pump bypass valves. These items can be used singly or in combination with other devices [3].

2.7.1 Pump Inertia

Pump inertia is the resistance of the pump to acceleration or deceleration. Pump inertia is constant for a particular pump and motor combination. The higher the inertia of a pump, the longer it takes for the pump to stop spinning following its shutoff and vice versa. Larger pumps have more inertia because they have more rotating mass. Pumps with higher inertias can help to control transients because they continue to move water through the pump for a longer time as they slowly decelerate. Pump inertia can be increased through the use of a flywheel. For long systems, the magnitude of pump inertia needed to effectively control transient pressures makes this control impractical due to the mechanical problems associated with starting high inertia pumps. Therefore, increasing pump inertia is not recommended as an effective option for controlling transient pressures for long piping systems (Walski, Chase, Savic, Grayman, Beckwith and Koelle, 2003) [3].

2.7.2 Air Chambers and Surge Tanks

Air chambers and *surge tanks* work by allowing water out of the system during high-pressure transients and adding water during low pressure transients. They should be located close to a point where the initial flow change is initiated. An air chamber is a pressure vessel that contains water and a volume of air that is maintained by an air compressor. During pump stop, the pressure and flow in the system decreases and as a result the air in the air chamber expands, forcing water from it into the system.

A surge tank is a relatively small open tank connected to the hydraulic system. It is located such that the normal water level elevation is equal to the hydraulic grade line elevation. During pump stop, the surge tank substitutes the pump and by gravity feeds the system with water. This controls the magnitude of the low pressure transient generated as a result of the pump stop.

2.7.3 One-Way Tank

This is a storage vessel under atmospheric pressure that is connected to the hydraulic system. It has a check valve (normally closed) connected to it which only allows water from the tank into the system. One-way tanks are primarily used in conjunction with pumping plants (Wylie and Streeter, 1993). The significant advantage of using a one-way tank rather than a surge tank is that the check valve allows the one-way tank to have a much lower height [3].

2.7.4. Pressure Relief and Other Regulating Valves

A pressure relief valve is a self-operating valve that is installed in a system to protect it from over pressurisation of the system. It is designed to open (let off steam) when safe pressures are exceeded, then closes again when pressure drops to a preset level. Relief valves are designed to continuously regulate fluid flow, and to keep pressure from exceeding a preset value.

An *anticipator relief valve* can be used instead of a pressure relief valve to control high pressure transient peaks. It is essential for protecting pumps, pumping equipment and all applicable pipelines from dangerous pressure surges caused by rapid changes of flow velocity within a pipeline, due to abrupt pump stop caused by power failure. Power failure to a pump will usually result in a down surge in pressure, followed by an up surge in pressure. The surge control valve opens on the initial low pressure wave, diverting the returning high pressure wave from the system. In effect, the valve has anticipated the returning high pressure wave and is open to dissipate the damage causing surge. The valve will then close slowly without generating any further pressure surges (M&M Control Service, INC).

Air inlet valves are installed at high points along the pipeline system to prevent vacuum conditions and potential column separation. Air enters the pipeline system during low pressure transient, and this air should be expelled slowly to avoid creating another transient condition. Before restarting the pumps, an adequate time should be allowed for the air that entered the pipeline to be expelled. There are varieties of valves that allow air to enter and leave a system, and their names depend on the manufacturer. These valves include air inlet valves, air release valves, vacuum relief valves, air vacuum valves, and vacuum breaker valves [3].

2.7.5 Booster Pump Bypass

Pump bypass with a valve is another protective device against pressure transients. Two pressure waves are generated as a result of reduction in flow due to booster pump stop; the wave travelling upstream is a positive transient, and the wave that travels downstream is a negative transient. A check valve in a bypass line allows free flow to the pipeline to prevent low pressures and column separation . The effectiveness of using a booster station bypass depends on the specific booster pumping system and the relative lengths of the upstream and downstream pipelines [3]

Table 2.1 Primary attributes and design variables of key surge-protection approaches

Protection Approach	Primary Attributes	Decision Variables
Check valve	Limits flow to one direction Permits selective connections Prevents/limits line draining	Size of location Specific valve configuration Antishock(dampening)characteristics
Pump bypass line	Permits direct connection and flow around a pump Can limit up-and-down surge	Size and location Exact points connected Check-valve properties
Open surge tank	Permits inflow/outflow to external storage May require water circulation Can limit up-and-down surge	Size and location Connection properties Tank configuration Overflow level
Closed surge tank (air chamber)	As pressure changes, water exchanged so volume of pressuised air expands or contracts	Location Volume(total/water/air) Configuration/geometry Orifice/connector losses
Feed tank (one-way tank)	Permits inflow into line from an external source Rquires filling	Size and location Connection properties Tank configuration
Surge anticipation valve	Permits discharge to a drain Has both high-and low-pressure pilots to initiate action May accentuate surge	Size and location High-andlow-pressure set points Opening/closing times
Combination air-release and vacuum-breaking valve	When pressure falls,large orifice admits air Controlled release of pressurised air through an orifice	Location small and large orifice size Specific valve configuration
Pressure relief valve	Opens to discharged fluids at a preset pressure valve Generally opens quickly and closes slowly	Size and location High-pressure set point Opening/closing times

(Source: American Water Works Association, 2005)

2.8 Method of Characteristics:

The principle is that the pipeline, in which transient should be studied, is divided into a number of equally long parts Δx. In Figure 2.2 the pipeline is represented by the x-axis between the coordinates *0* and *L*.

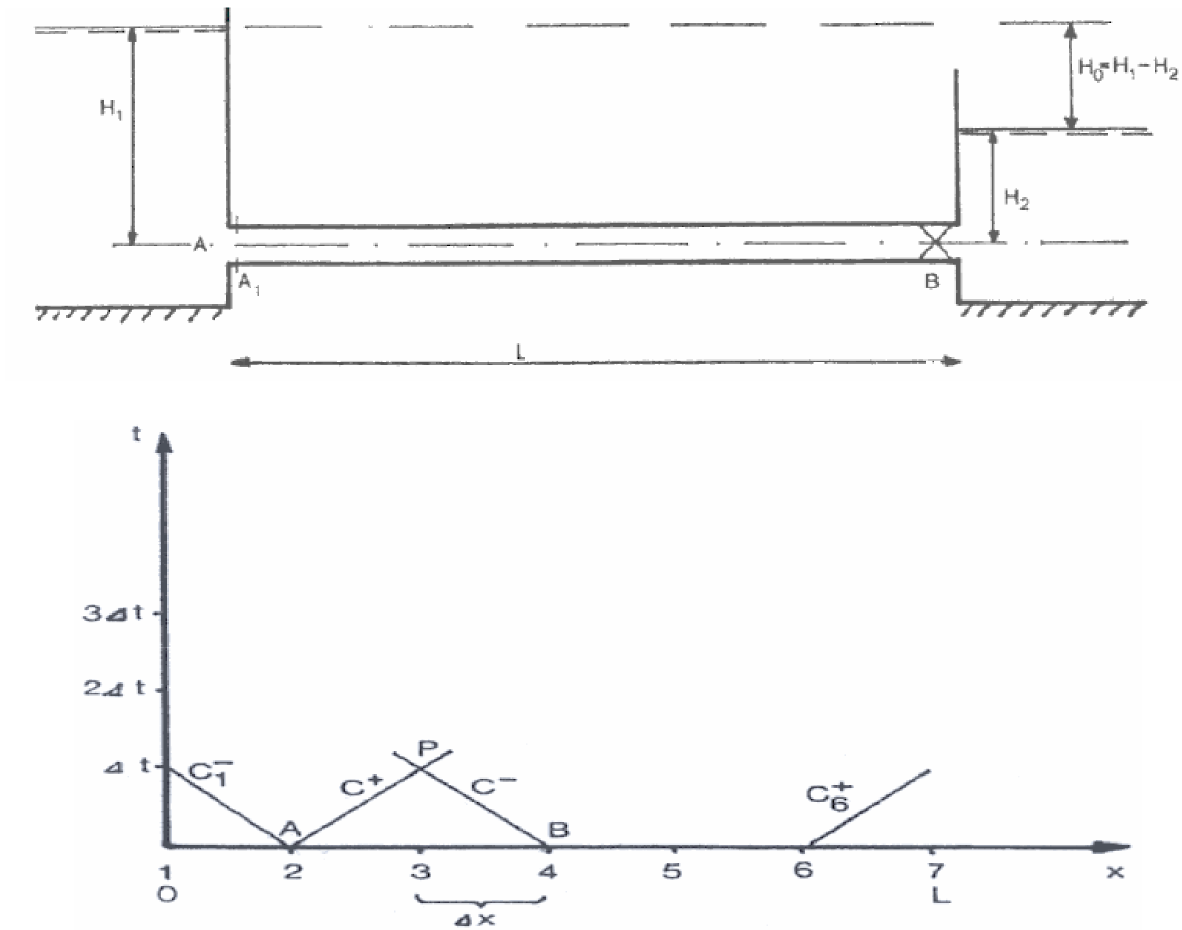


Figure 2.2: Numerical (computer) determination of pressure transient is based on division of the pipeline *0 - L* into equally long parts, defined by nodal points (L. Jönsson and P. Larsen, 1975) [11]

In each end point some kind of boundary condition, for instance a valve at $x = L$ and reservoir at $x = 0$, must be known. The pipeline in Figure 2.2 is divided into six parts, Δx, defined by seven equidistant nodal points, numbered 1-7. At time $t < 0$ steady-state

Conditions prevail in the pipeline and the water velocity and the pressure level in the different nodal points can be calculated with common frictional formula ($h_f = f.\ L/D\ .\ v^2/2g$ + possible local losses).

At time $t = 0$ the flow rate is changed, for instance by initiating a valve closure operation. On the basis of the method of characteristics water velocity and pressure levels are computed in all nodal points at time t = Δt using the corresponding values in the nodal points at t = 0 and the boundary conditions at x = *0*, *L*. After that computational procedure is repeated for the nodal points for the time t = 2.Δt using the previously computed values in the nodal points at time t = Δt and the boundary conditions.

In this way the transient pressure evolution is computationally stepped forward in time with time step Δt.

This time step Δt, should be chosen in such a way that:

$$\Delta x/\Delta t = a \qquad (2.6)$$

Where Δx = the distance between two consecutive nodal points.

Δt = the pressure wave velocity.

Equation (2.6) actually describes the C^{+} and the C^{-} characteristics respectively depending on the sign of a. Consider a C^{+} characteristic, which passes through nodal point 2 (i.e x = Δx) at time = 0 (point *A*).

At time t = Δt this characteristic passes through the point $x + a.\Delta t = x + \Delta x = 2.\Delta x$ = nodal point 3 according to equation 3.1. The points *A* and *P* are thus located on the same C^{+} characteristic. In the same way one obtains, that the points *B* and *P* are located on the same C^{-} characteristic.

The water velocity and the pressure level in point *P* can be obtained by:

$$C^{+} : \frac{1}{a}(V_P - V_A) + \frac{1}{a}(H_P - H_A) + \frac{f_A.\Delta t.V_A.|V_A|}{2.g.D} = 0 \qquad (2.7)$$

$$C^{-} : \frac{1}{a}(V_P - V_B) + \frac{1}{a}(H_P - H_B) + \frac{f_B.\Delta t.V_B.|V_B|}{2.g.D} = 0 \qquad (2.8)$$

Where:

V_A, V_B and V_P = water velocity at *A*, *B* and *P* respectively

H_A, H_B and H_P = pressure level at *A*, *B* and *P* respectively

f_A and f_B = The friction coefficient at *A* and *B* respectively

Friction is approximated by the starting velocity at *A* and *B* respectively.

This could be concisely written as:

$$C^{+}: H_P = HCP - B.V_P \quad (2.9)$$

$$C^{-}: H_P = HCM + B.V_P \quad (2.10)$$

Where :

$$HCP = H_A + B.V_A \frac{f_A.\Delta x.V_A.|V_A|}{2.g.D} \quad (2.11)$$

$$HCM = H_B - B.V_B \frac{f_B.\Delta x.V_B.|V_B|}{2.g.D} \quad (2.12)$$

$$B = \frac{a}{g} \quad (2.13)$$

$$\Delta x = a.\Delta t \quad (2.14)$$

The variables *HCP*, *HCM*, *B* do only contain known data and can thus be calculated numerically. **Equation (2.9)** and **(2.10)** give:

$$H_P = \frac{HCP + HCM}{2} \quad (2.15)$$

$$V_P = \frac{H_p - HCM}{B} \quad (2.16)$$

After calculating the pressure level H_p and the water velocity V_p in the nodal point 3 at time, $t = \Delta t$, **Figure(2.1)** shows that exactly the same kind of calculation can be performed to give pressure levels and water velocities in the inner nodal point 2,….,6 at time $t = \Delta t$. Computation of the hydraulic condition in the nodal points 1 and 7 at time t =Δt utilizes a boundary condition and one characteristic. Assume that nodal point 1 is located in the inlet from the reservoir with boundary condition $H = H_0$ for all times $t > 0$ and that nodal point 7 is a valve that is closed instantaneously at time $t = 0$, i.e. $V = 0$ for $t > 0$. One then obtains for nodal point 1 at $t = \Delta t$:

$$H_1 = H_0 \quad (boundary\ condition)$$

$$V_1 = \frac{H_0 - HCM}{B} \qquad (C_1^- \ characteristic)$$

Where HCM is computed for nodal point 2 at time $t = 0$.
In the same way one obtains for nodal point 7 at time $t = \Delta t$:

$$V_7 = 0 \qquad \text{(boundary condition)}$$

$$H_7 = HCP \qquad (C_6^+ \text{ characteristic})$$

Where HCP is computed for nodal point 6 at time $t = 0$.
Now the hydraulic conditions are known in al nodal points at time $t = \Delta t$ and with exactly the same technique as above the hydraulic conditions can be computed at time $t = 2.\Delta t$ in inner nodal points using the known hydraulic conditions at time $t = \Delta t$ as well as in the nodal boundary points 1 and 7 using boundary conditions and one characteristic [11].

CHAPTER "3"

"PROJECT AREA"

3.1 General

In this chapter, the basic data location, topography, climate, water supply and rainfall quantity of Ad Doha and Ad Duheisha town will be presented and briefly discussed.

3.2 Location and Physical Characteristics

Ad Doha

Ad Doha is a Palestinian city in Bethlehem as shown in Fig (3.1) Governorate located at 2.5km (horizontal distance) west of Bethlehem City. Ad Doha is bordered by Bethlehem city to the east,Beit Jala city to the north, Al Khader town to the west, and Ad Duheisha camp to the south as shown in Fig(3.2). Ad Doha is located at an altitude of 830m with an elevation ranging from (760-880) above sea level as shown in Fig (3.3) with a mean annual rainfall of 613mm. The average annual temperature is 16 ^{o} C, and the average annual humidity is about 60.6 and Fig (3.4) shows the contour map for Ad Doha town.

The path line that will be designed crosses the way between Ad Duheisha Pump to Al-Doha Reservoir shown in Fig (3.5)

Ad Duheisha

Ad Duheisha is a Palestinian camp in Bethlehem Governorate located 2.2km (horizontal distance) south-west of Bethlehem City as shown in Fig (3.1). Ad Duheisha is bordered by Bethlehem city to the east and north, Ad Doha city to the west, and Artas village tothe south as shown in Fig (3.2).Ad Duheisha is located at an altitude of 790mvwith an elevation ranging from (760-880) above sea level as shown in Fig (3.3) with a mean annual rainfall of 589mm. The average annual temperature is 16^{o} C, and the average annual humidity is about 60.6 percent and Fig(3.4) shows the contour map for Ad Duheisha camp.

3.3 History

Ad Doha

The name Ad Doha came more than 30 years ago, where the territories of Ad Doha were part of Beit Jala city. In the year 1977, Beit Jala mayor visited the state of Qatar for the uniting of the Palestinian municipalities with the Arab municipalities, and through this uniting, Qatar government provided a generous amount of money for Beit Jala city.

Ad Duheisha

The name Ad Duheisha came in relation to the land where the camp was established, as this area was full with trees, and according to the Egyptian language, it was called Heisha, which later was twisted intoDuheisha.

Ad Duheisha camp dates back to 1949, and its residents originate from more than 46 villages from Jerusalem.

Figure 3.8: Ad Doha town

3.4 Religious and Archaeological Sites

In terms of religious establishments, there are four mosques in Ad Doha: Al Khulafa' Ar Rashideen Mosque, Zaid Ben Thabit Mosque, Abu 'Ubeida Mosque, and Abu Sadeer Mosque as shown in Fig (3.6).

There are no archaeological sites in Ad Doha city.

3.5 Population

According to the Palestinian Central Bureau of Statistics (PCBS), the total population of Ad Doha in 2007 was 9,753; of whom 4,950 are males and 4,803 are females. There are 1,849 households living in 2,220 housing units.

3.6 Agricultural Sector

Ad Doha lies on a total area of about 1,750 dunums of which 911 dunums are considered arable land, and 333 dunums are residential land (see table 3.1) and as shown in Fig (3.7) .

Table (3.1) : Land use in AD Doha city in dunum

Total Area	Built up Area	Arable Land (911)					Area of Industrial, Commercial & Transport Unit	Area of Settlements and Military Bases
		Seasonal Crops	Permanent Crops	Greenhouses	Forests	Open Spaces and Rangelands		
1,750	333	279	496	0	7	129	506	0

Agriculture production in Ad Doha depends mostly on rainwater. As for irrigated fields, they depend on domestic harvesting cisterns.

Table (3.2) shows the different types of rain-fed and irrigated open-cultivated vegetables in Ad Doha. The most common crop cultivated within this area is tomato; there is also a half dunum of greenhouses planted with tomato.

Table (3.2) : Total area of rain-fed and irrigated open cultivated vegetables in Ad Doha city in dunum

Fruity vegetables		Leafy vegetable		Green legumes		Bulbs		Other vegetables		Total area	
RF	Irr.	RF	Irr.	RF	Irr.	RF	Irr.	RF	Irr.	RF	Irr.
0	4	0	1	0	0	0	0	0	5	0	10

Rf : Rain-fed, Irr : Irrigated

3.7 Infrastructure and Natural Resources

3.7.1 Electricity and Telecommunication Services:

Ad Doha has been connected to a public electricity network since 1975; served by Jerusalem Electricity Company, which is the main source of electricity in the city. Approximately 97.5 percent of the housing units in the city are connected to the network, and 0.1 percent are dependent on private generators, while the source of electricity is unknown for the remaining units (2.4%) (Central Bureau of Statistics, 2007).

Furthermore, Ad Doha is connected to a telecommunication network and approximately 58.5 percent of the housing units within the city boundaries are connected to phone lines.

3.7.2 Transportation Services:

Private cars are the main means of transportation in Ad Doha. As for the road network in the city; there are a total of 8km of main roads; 5km are paved and in good condition and 3km are paved but in bad condition. There are also a total of 17km of secondary roads; of which 5km are paved and in good condition, 8km are paved but in bad condition, and 4km are unpaved roads (Ad Doha municipality,2009).

3.7.3 Water Resources:

Ad Doha is provided with water by Palestinian Water Authority (PWA), through the public water network established in 1970, and about 97.3 percent of the housing units are connected to the water network, 0.1 percent are dependent on rainwater, 0.1 percent are dependent on water tanks, and 0.1 percent are dependent on other water resources, while the source of water supply is unknown for the remaining units (2.4%) (Central Bureau of Statistics, 2007). Based on the PWA estimations, the rate of water supply per capita in the communities provided with water is about 100 liters per day, but this rate varies from one community to another. The quantity of water supplied to Ad Doha in 2006 was about 223,000 cubic meters/year, therefore the estimated rate of watersupply per capita is about 65 liters/day (PWA, 2006).

Here it should be noted that many Ad Doha citizens do not in fact consume this amount ofwater due to water losses, which are about 39 percent. The loses usually happen at the main source, major transport lines, distribution network, and at the household level (PWA, 2008), thus the rate of water consumption per capita in Ad Doha is 40 liters per day. This is a low rate compared with the minimum quantity proposed by the World Health Organization, which is 100 liters per capita perday.

Ad Doha has also a public water tank with 3,000 cubic meter capacity, and its capacity can meet the city's need of water for sixdays.

3.7.4 Sanitation:

Ad Doha city has a 25km public sewage network, established since 2000. The end of the network is connected to Beit Jala private sewage network, where waste water is pumped from Bir Onah pumping station to the West Jerusalem private sewage network. According to the results of Community Survey conducted by the PCBS in 2007 and the data provided from PWA, the majority of Ad Doha housing units (94.4%) use the sewage network as a major means for wastewater disposal, 2.6 percent use cesspits and 0.1 percent of the housing units have no means for wastewater disposal, while it is unknown for the remaining units (2.9%).

Based on the estimated daily per capita water consumption, the estimated amount of wastewater generated per day, is approximately 300 cubic meters, or 109,500 cubic meters annually. At the individual level in the city it is estimated that the per capita wastewater generation is approximately 32 liters per day. The estimated quantity of wastewater collected through the sewerage network per day, is about 284 cubic meters per day, or 103,660 cubic meters annually. The wastewater resulting from the cesspits are discharged by wastewater tankers directly to open areas or nearby valleys without any regard for the environment. Here it should be noted that there is no wastewater treatment either at the source or at the disposal sites which poses a threat to the environment and the public health.

CHAPTER “4”
“FIELD WORK”

4.1 Ductile Iron Pipe:

Ductile iron has shown itself to be most suitable material for pipelines. In addition to theintrinsic qualities of the basic metal, the variety of shapes and dimensions of componentsfacilitate pipeline assembly.

The service reliability of a pipeline depends on its ability to resist ageing, exposure to soil,transported fluids or solids, temperature variations, impact and excess pressure.

Figure 4. 1: Sub-project Classic Pipes in Taweelah in the UAE

Figure 4. 2: Sub-project in Taksbt in Algeria

4.2 Field Work:

The work began with visiting to the Ad Doha municipality and the contracting company inorder to collect the necessary date for the case study and to arrange a field visit to the projectarea to take a general idea about the pipeline path, the required necessary work, and the tools toachieve our goals. The field surveys for the proposed pipeline were carried out byspectra_sp60device.

The survey work for the proposed pipeline had been finished in five days under the supervisionof Dr. Itissam Abu-Izia hand the Site engineer.

The main surveyed features were:

1. Concert well.
2. Curbstone.
3. Stone well.

4.3 Civil Work:

According to the decision made by the engineer of Ad Doha municipality about the pipelinealignment and calculated flow, we started to draw the layout by civil 3D model according tomanufacturer specifications.

4.4 Curve design:

The problem that we encountered in curve design is how to join the pipes with each other thefollowing procedures are how to determine the deflection between pipes.

The pipes are connected to each other by joint in standard form as in (see figure 5.4), but thepipe are not necessary to be straight, it follows the train and the topography so, a deflectionangle must be exist and should not exceed a threshold values presented in (see figure 5.3) and

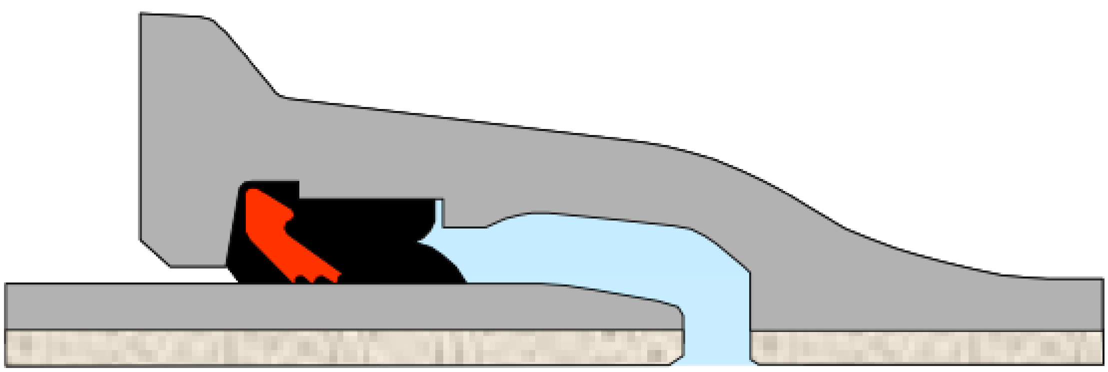


Figure 4. 3: Inner Joint structure (see table 4.1)

Figure 4. 4: Standard Vi Joint for pipes

Table 4. 1: Standard Vi Joint for pipes

DN	Class	Deflection	Axial gap aligned	Axial gap deflected	PFA
mm		degree	mm	mm	Bar
100	C40	5	33	22	16
150	C40	5	38	23	16
200	C40	4	42	22	16
250	C40	4	41	17	16
300	C40	3	38	9	16

These are some examples of the designed curves:

1) L= 86.98m R= 531.56m Δ= 9.3759 d= 0.65

2) L= 14.52m R= 189.21m Δ= 4.3964 d= 2.10

3) L= 37.01m R= 189.61m Δ= 11.1849 d= 1.8

4) L= 40.19m R= 165m Δ= 13.9548 d= 2.30

Steps for determination of the deflection angle for the first curve:

L= 86.98m R= 531.56m Δ= 9.3759 d=0 .65

- The length of pipe =6m
- # of pipe: 86.98/6= 14.49
- d =9.3759/14.49=0.65o<4o

Therefore, the deflection angle it is in rang.

4.5 Plan and Profile Work:

Using Civil 3D program to create a plan and profile for the path of pipeline starting with entering the points of surveying and connecting them to make the plan profile. (See figure 5.5)

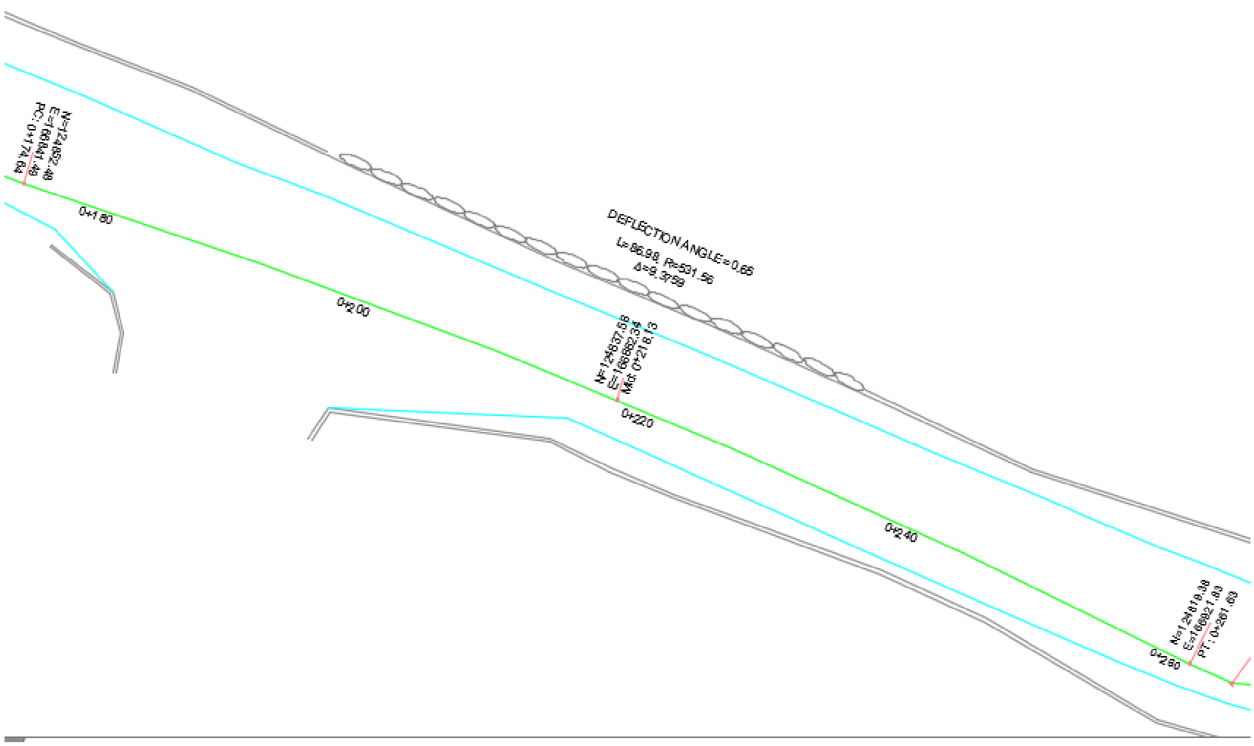


Figure 4.5: Curve design

CHAPTER “5”

“USING BENTLY HAMMER”

5.1Using Bentley Hammer

Bentley HAMMER is a very efficient and powerful tool for simulating hydraulic transients inpipelines and networks, these detailed give your hands on experienced many of BentleyHAMMER's features and capabilities, and it will help you to explore and understand thefollowing topics:

1) Pipeline Protection using Bentley HAMMER by assembling a pipeline using the graphical editor and performing two hydraulic transient analyses, without protection and with protection.
2) Network Risk Reduction using Bentley HAMMER by opening a water distribution network model created in Bentley Water GEMS and performing a hydraulic transient analysis using advanced surge protection and presentation methods.

Another way to become acquainted with Bentley HAMMER is to run and experiment with the sample files, located in the \Bentley\HAMMER8\Samples folder. Remember, F1 key has pressed to access the context-sensitive help at any time.

5.2 Pipeline Protection

Bentley HAMMER is used to perform a numerical simulation of hydraulic transients in a water transmission main and, based on the results of our analysis, recommend suitable surgeprotectionequipment to protect this system from damage.These three steps had been done:
1) Analyzed the system as it was designed (without any surge-protection equipment) todetermine its vulnerability to transient events.
2) Select and model different surge-protection equipment to control transient pressures andpredict the time required friction to attenuate the transient energy.
3) Present your results graphically to explain your surge-control strategy and recommendationsfor detailed design.

5.3 Creating or Importing a Steady-State Model

Creating an initial steady-state model of our system within Bentley HAMMER directly, usingthe advanced Bentley HAMMER Modeler interface, or import one from an existing steady-statemodel created using other software.A hydraulic transient was assembling model using both methods to learn their respectiveadvantages and note the similarities between them.

5.4 Creating a Model

Bentley HAMMER is an extremely efficient tool for laying out a water-transmission pipelineor even an entire distribution network. It is easy to prepare a schematic model and let BentleyHAMMER take care of the link-node connectivity and element labels, which are assignedautomatically. For a schematic model, only pipe lengths must be entered manually to completethe layout. You may need to input additional data for some hydraulic elements prior to a run.

5.5 Selecting The Transient Events to Model.

Any change in flow or pressure, at any point in the system, can trigger hydraulic transients. Ifthe change is gradual, the resulting transient pressures may not be severe. However, if thechange of flow is rapid or sudden, the resulting transient pressure can cause surges or waterhammer.

Since each system has a different characteristic time, the qualitative adjectives gradual andrapid correspond to different quantitative time intervals for each system. There are many possible causes for rapid or sudden changes in a pipe system, including power failures, pipebreaks, or a rapid valve opening or closure. These can result from natural causes, equipmentmalfunction, or even operator error. It is therefore important to consider the several ways inwhich hydraulic transients can occur in a system and to model them using Bentley HAMMER.The impact of a power failure simulated lasting several minutes. It is assumed that power wasinterrupted suddenly and without warning (i.e., you did not have time to start any dieselgenerators or pumps, if any, prior to the power failure). The purpose of this type of transient Times New Romananalysis is to ensure the system and its components can withstand the resulting transientpressures and determine how long you must wait for the transient energy to dissipate.For many systems, starting backup pumps before the transient energy has decayed sufficientlycan cause worse surge pressures than those caused by the initial power failure. Conversely,relying on rapid backup systems to prevent transient pressures may not be realistic given thatmost transient events occur within seconds of the power failure while isolating the electricalload, bringing the generator on-line, and restarting pumps (if they have not timed out) can takeseveral minutes.

Performing a Transient Analysis In this section, you will first simulate transient pressures inthe system due to an emergency power failure without any protective equipment in service. Aftera careful examination of your results, you will select protective equipment and simulate thesystem again using Bentley HAMMER to assess the effectiveness of the devices you selected tocontrol transient pressures.

5.6 Animating Transient Results at Points and along Profiles

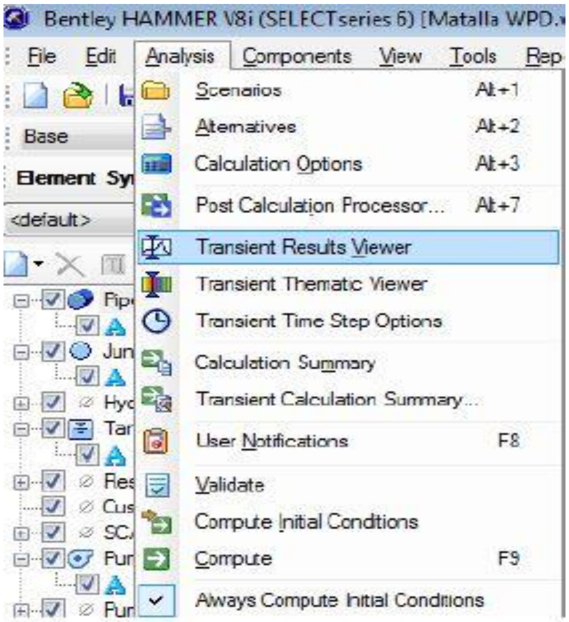
Bentley HAMMER provides many ways to visualize the simulated results using a variety ofgraphs and animation layouts. You must specify which points and paths (profiles) are of interest,as well as the frequency to output prior to a run, or Bentley HAMMER will not generate thisoutput to avoid creating excessively large output files. For small systems, you can specify eachpoint and every time step, but this is not advisable for large water networks.

For the same reason, Bentley HAMMER only generates the Animation Data (for onscreenanimations) if you select this option in the transient calculation options While you are stillevaluating many different types or sizes of surge-protection equipment, you can often comparetheir effectiveness just by plotting the maximum transient head envelopes for most of yourBentley HAMMER runs. At any time, or once you feel you are close to a definitive surgecontrolsolution, you can use Bentley HAMMER to generate the animation data files by settingGenerate Animation Data to True in the Transient Calculation Options. After the run, you canopen the Transient Results Viewer from the Analysis menu.

1) In the Transient Results Viewer, on the Profiles tab, select:

– Profile: Main.

– Graph Type: Hydraulic Grade and Air/Vapor Volume.



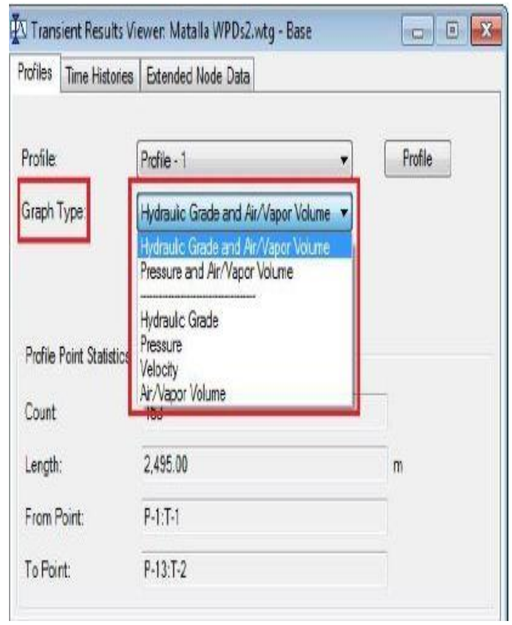


Figure 5.1: Transient results viewer **Figure 5.2:** Graph type.

2) Click the Animate button. This loads the animation data and Animation Control.

3) On the Animation Controller, click the play button to start the animation.

5.7 Viewing Time History Graphs in Bentley HAMMER

Using the Bentley HAMMER Transient Results Viewer, you can plot a transient history atany point in the system to display the temporal variation of selected parameters (such aspressures and flow).

1) Click the Analysis menu and select Transient Results Viewer.

2) In the Time Histories tab, select: – Time History: P16:HT-1 – Graph Type: Hydraulic Grade,Flow, and Air/Vapor Volume.

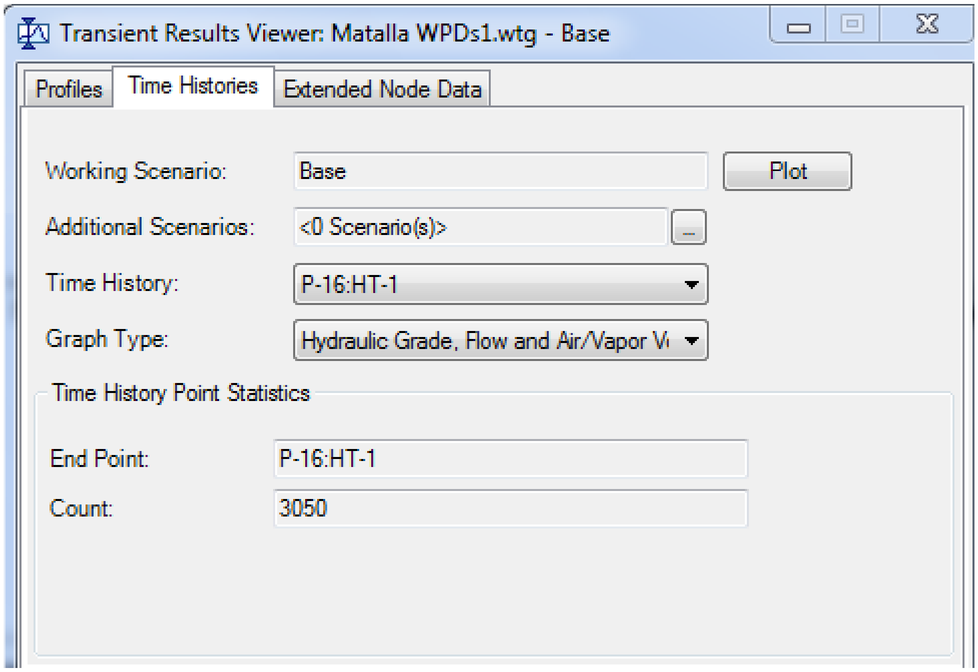


Figure 5.3: Transient results viewer - time histories.

3) Click Plot to display this transient history.

4) To view numerical data for the time history, click the Data tab. From here, you can sort the data by right clicking on the column header and choosing Sort. You can also change the units and precision for the results by right clicking on the column header and choosing Units and Formatting. Click OK to save these settings and leave the Flex Units Manager. From now on, Head will be displayed in ft. and Flow will be displayed in l/s.

CHAPTER “6”

"USING HAMMER TO ANALYSIS THE SYSTEM”

6.1 General Description of Al Duhaish Pumping Station

Al Duhaish pumping station is currently equipped with pumping units 99 \h at 50 mWc .The pumping station shall discharge water through a steel pipe ND 200 mm (8") length 2486 mto Al DOHA reservoir.

The facilities consist of the main following equipment:

1) A supply tank.
2) A pumping room with the pumps, the valves, a pressure tank against water hammer effect,instrumentation and ancillaries, the switch gears.

Hydro and electro-mechanical equipment mainly including:

1) Pumps:

a) Rated point: 130.5m3\h (27.5 l\s) at 61.22 mWC head;

b) Hydraulic efficiency: not less than 75.8%

c) Design pressure: NP 16 bars;

2) Motors

6.2 Hydraulic Analysis for Al Duhaish Pumping Station (Steady State)

6.2.1 System Description

The following figure (6.1) explains the components of the system being analyzed. We drew thissketch using hammer cad according to earth surface:-

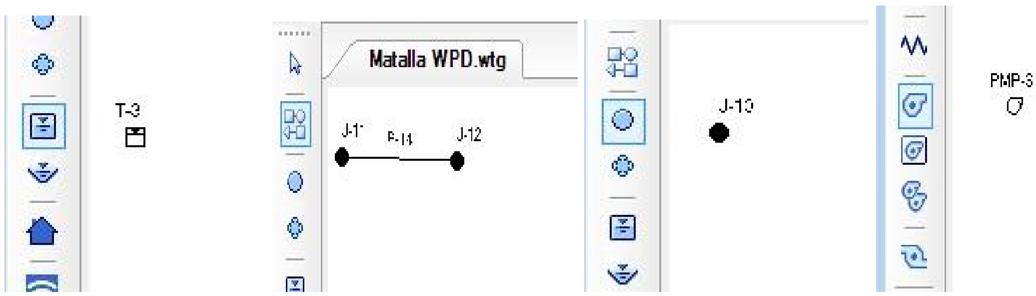


Figure 6.1: Feature of the project.

This figure (6.2) shows the general shape of the system including pipes, junction, pumps, tank, Flow direction and it is describe approximately the elevations of pipe lines.

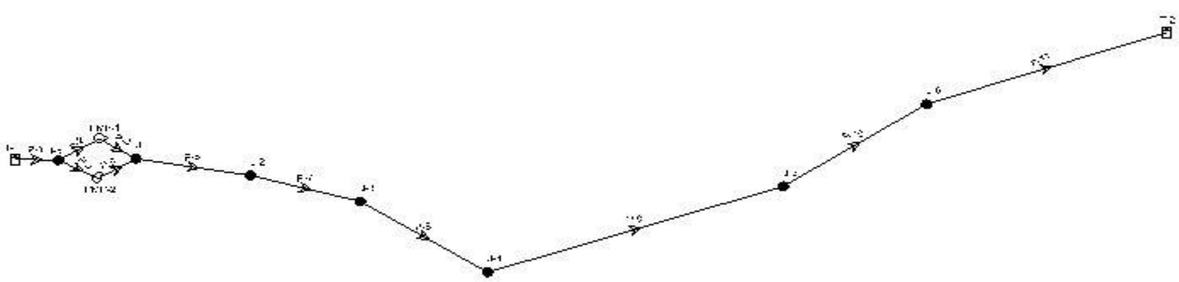


Figure 6.2: System description.

6.3 calculate head lose

6.3.1 Solution of Colebrook and white equation

Q(m^3\h)	130.5
Headless(m)	61.22

Total flow=2*/130.5m^3h=0./0725m^3s

Area=$\pi\frac{\mathrm{d}^2}{4}$=$\frac{\pi*(0.3)^2}{4} = 0.070\mathrm{m}^2$

Average Velocity=$\frac{Q}{A} = \frac{0.0725}{0.070} = 1.035 m/s$

Input:

e: pipe roughness= 0.00003m

D: Pipe internal diameter= .3m

L: Pipe length=3017m

V: Average fluid velocity=1.035 m/s

v: Kinematic viscosity=0.0000008m^2/s

ρ: Density=998Kg/m^3

Colebrook and white equation.

$$\sqrt{f} \times \left[-2 \times \log_{10}\left(\frac{e/D}{3.7} + \frac{2.51}{Re_{pipe} \times \sqrt{f}}\right)\right] = 1$$

f = 0.01489

Darcy Equation:

$h_f = f*(\frac{L}{D}) * \frac{V^2}{2g}$ $h_f = 8.17511$ m

Total head lose = 8.17511 + (8.17511*0.20)= 9.810 m

Total head = head lose + geometric head = 9.810+52.36 ≈ 62 m

6.3.2 System component

We draw a simple sketch for the system to showFigure (6.3) the component of a system:

1) The elevation for two tanks

2) Total head loss

3) Profiles of the system.

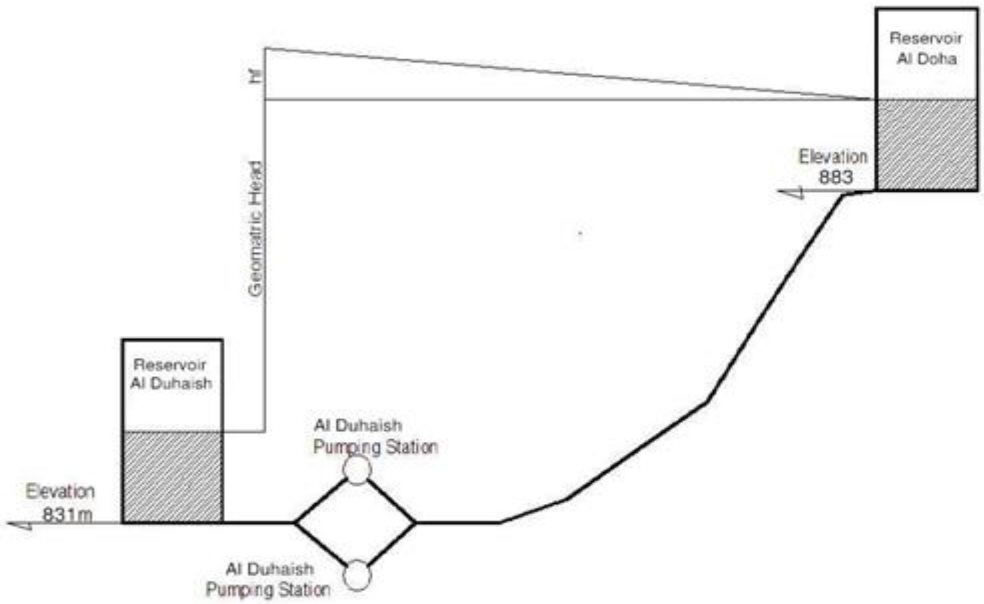


Figure 6.3: System component.

6.4 Transient State Analysis

6.4.1 Expression of the wave speed (a):

Overpressure or depression due to water hammer is strongly dependent on the wave speed propagation in the pipeline. The exact determination of the module is essential for the assessment of overpressures and depressions generated by some sort of maneuver.

The pressures wave speed depends on the fluid characteristics (its density and its compressibility) and those of the pipeline (modulus of elasticity, diameter, wall thickness, etc.)

The general expression for the wave speed is:

$$a=\frac{\sqrt{K/\rho}}{\sqrt{1+c\frac{KD}{eE}}} \quad (6.1)$$

Where:

$c = 1-\mu^2$, the pipeline is anchored against longitudinal movement.

K and ρ = the bulk modulus of elasticity and density of the fluid respectively.

D and e = the inner diameter and thickness of the pipe respectively.

E = young modulus of the pipe material.

C = coefficient that accounts for the pipe support conditions.

c = 1- $.3^2$= .91

$$a = \frac{\sqrt{K/\rho}}{\sqrt{1+c\frac{KD}{eE}}} = \frac{\sqrt{2188128000/998}}{\sqrt{1+.91\frac{2188128000*300}{3.945*207000000000}}} = 1125.276 \text{ m/s}$$

6.4.2 Moment of inertia

1) Pump impeller moment of inertia:

The moment inertia of a pump impeller may be estimate using the method relationship proposed by Wyllie as shown below.

$$P = \frac{\rho*Q*h*g}{n*3.6*10^6} \quad (6.2)$$

$$P = \frac{998 * 130.5 * 61.22 * 9.81}{0.7 * 3.6 * 10^6} = 31.039\text{KW}$$

$$I_p = 1.5 * 10^7 *(\frac{P}{N^3})^{.9556}$$

$$I_p = 1.5 * 10^7 * (\frac{31.039}{1450^3})^{.9556} = 0..346\ Kg.m^3$$

2) Motor moment of inertia:

The inertia of the pump motor is typically the largest contributor to the pump moment of inertia similarly to the pump impeller it may be estimated using a relationship presented by Wyllie etc. As shown below:

Im= 118 *$(\frac{P}{N})^{1.48}$ (6.3).

Im=118 *$(\frac{31.039}{1450})^{1.48}$= 0.4 Kg.$m^2$

Total Moment of Inertia = (I_p+Im) + 10% *(I_p+Im)

Total Moment of Inertia = (0.346.+0.4.) + 10% *(0.346.+0.4.) =0.8206 kw

6.5 System Data

All data that we get it from the field work and the pervious calculation were used and insert in hammer program according to the following:

1) Tanks data : For tank"s we need data about the elevation of base, minimum, maximum and initial as shown in the figure below:

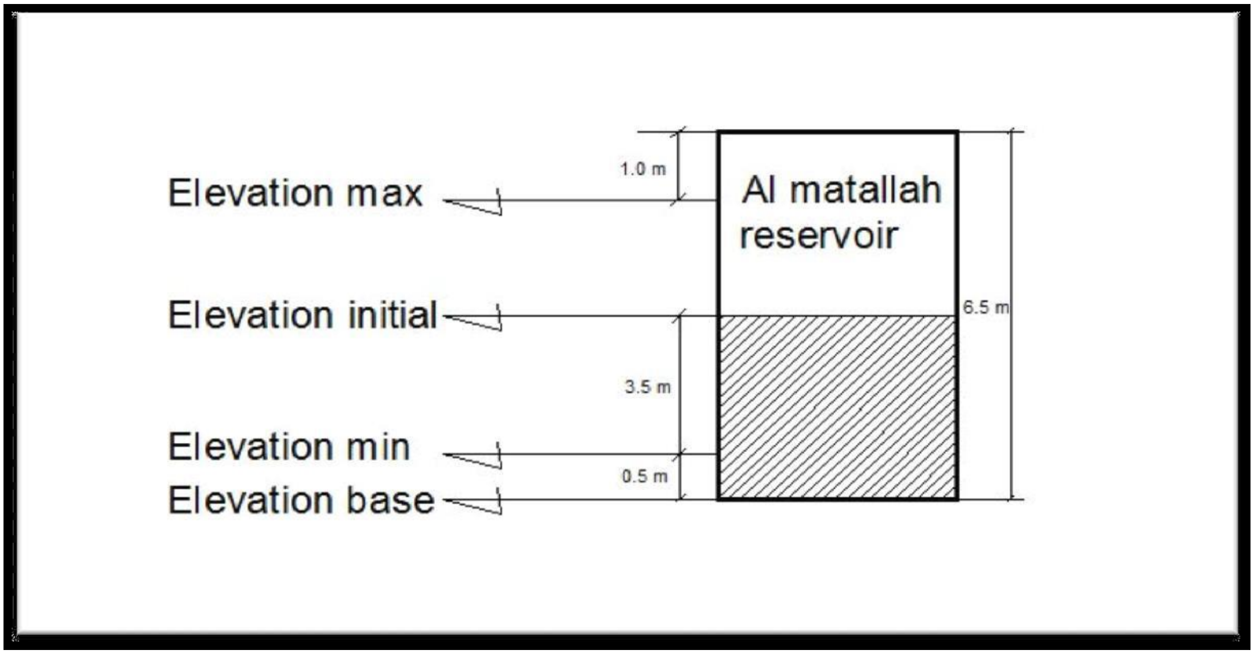


Figure 6.4: Tank data.

Table 6.1: Tanks data.

Label	Elevation (Base) (m)	Elevation (Minimum) (m)	Elevation (Maximum) (m)	Elevation (Initial) (m)	Hydraulic Grade (m)
T-1	831.22	831.50	836.00	833.70	833.70
T-2	883.06	883.20	889.06	886.06	886.11

2) **Pumps data:** Pumping station are facilities including pumps and equipment for pumping fluids from one place to another, the following figure explain the location of pumps and the flow direction.

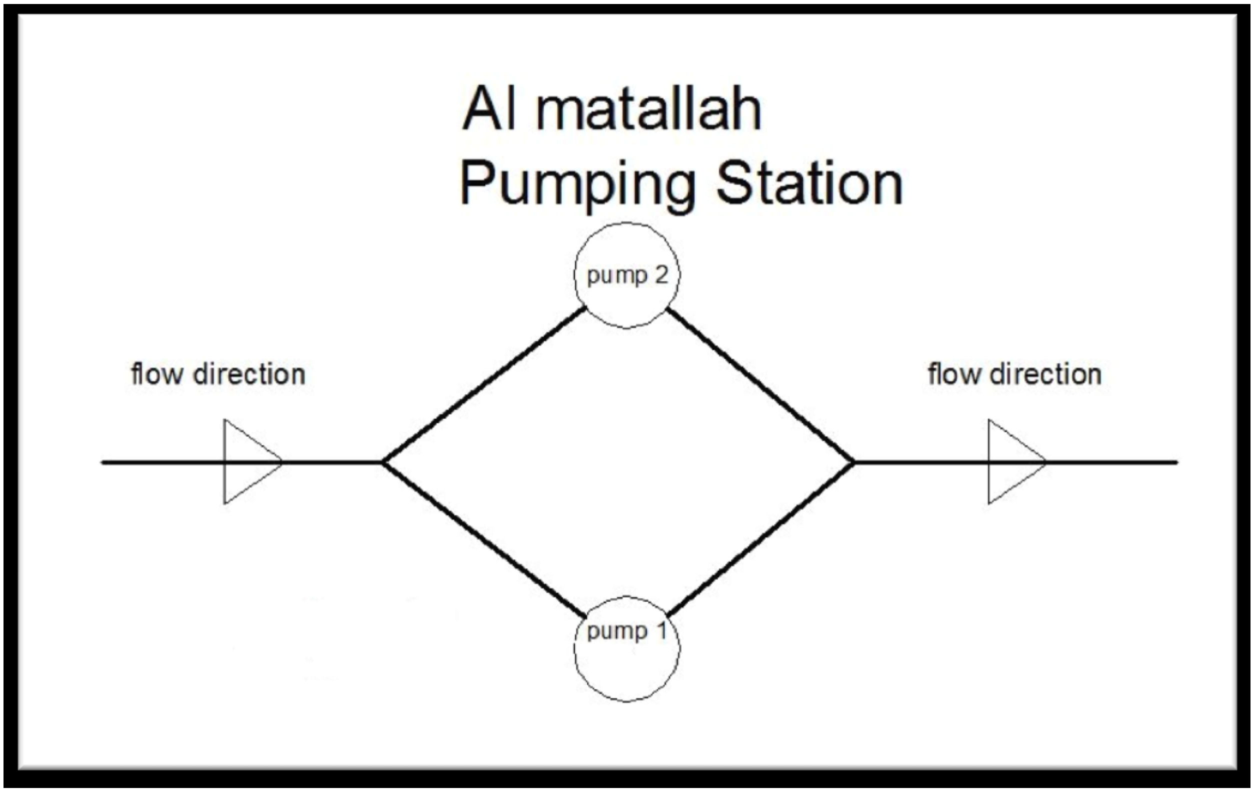


Figure 6.5: Al Duhaishapumping station

a) Pumps elevation:

Table 6.2: Pump‟s data.

Label	Elevation (m)	Flow (Total) (m3/h)	Pump Head (m)
PMP-1	**831.22**	**130.50**	**61.22**
PMP-2	**831.22**	**130.50**	**61.22**

b) Pump definition

1) Pump head:

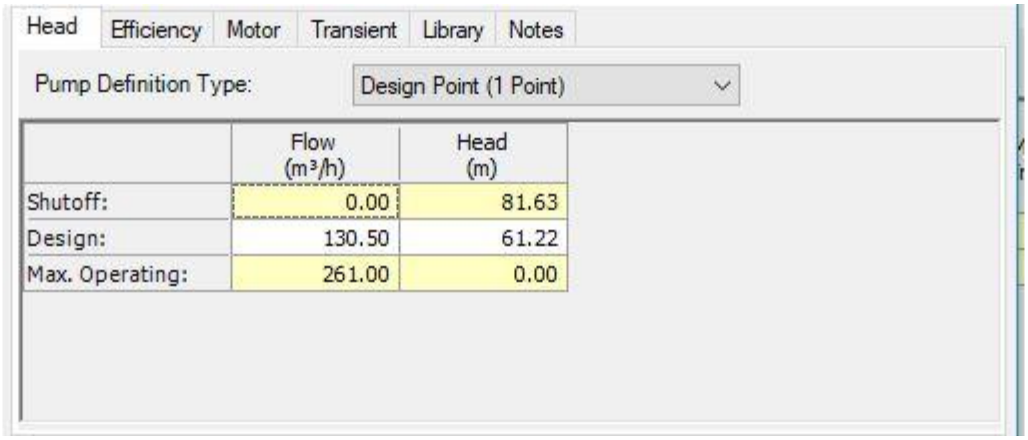


Figure 6.6: Pump head.

2) Pump efficiency:

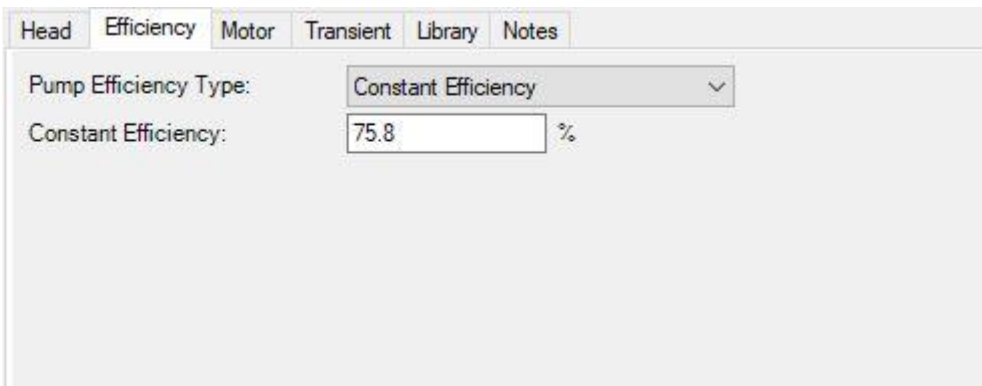


Figure 6.7: Pump efficiency.

3) Moment of inertia:

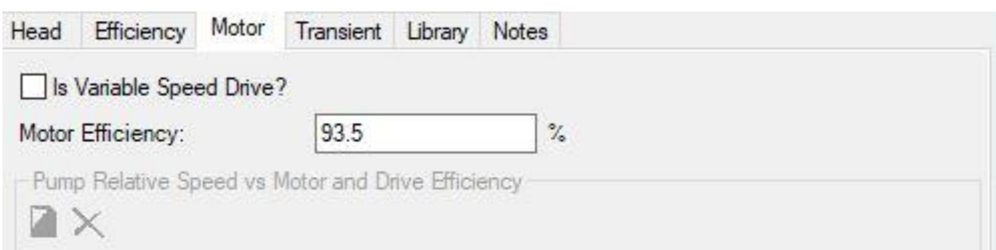


Figure 6.8: Motor efficiency.

4) Pump transient:

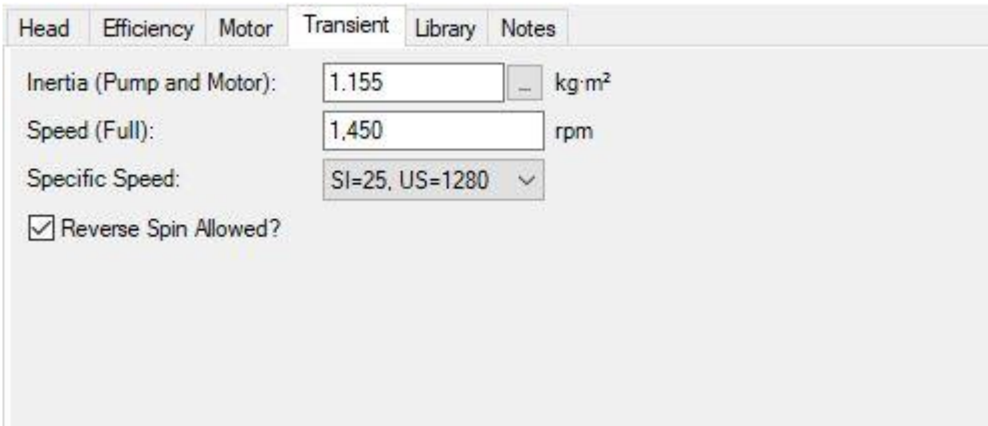


Figure 6.9: Moment of inertia.

5) **Pipe data:**Pipes used to convey fluids from one location to another, and the parameters that required to input in the hammer cad is: length, calculated diameter, type of pipe, coefficient of darcyweisbach and wave speed as shown below:

Table6.3: Pipe‟s data.

Label	Length(m)	Start Node	Stop-Node	Diameter	Material	wave speed	Darcy-weisbach
P-1	5	T-1	J-8	300	Ductile Iron	1225.27	0.00026
P-2	3	J-8	PMP-1	125	Ductile Iron	1296.28	0.00026
P-3	3	PMP-1	J-1	125	Ductile Iron	1296.28	0.00026
P-4	3	J-8	PMP-2	125	Ductile Iron	1296.28	0.00026
P-5	3	PMP-2	J-1	125	Ductile Iron	1296.28	0.00026
P-6	280	J-1	J-2	300	Ductile Iron	1225.27	0.00026
P-7	230	J-2	J-3	300	Ductile Iron	1225.27	0.00026
P-8	260	J-3	J-4	300	Ductile Iron	1225.27	0.00026
P-9	1,100.00	J-4	J-5	300	Ductile Iron	1225.27	0.00026
P-10	430	J-5	J-6	300	Ductile Iron	1225.27	0.00026
P-11	665	J-6	T-2	300	Ductile Iron	1225.27	0.00026

6) Junction data: In a fluid dynamics, pipe network analysis is the analysis of the fluid flow through a hydraulics network, containing several or many interconnected branches (junction), the aim is to determine the flow rates and pressure drops in the individual sections of the network, this is required to insert data includes: elevation, and hydraulic grade which defined as the elevations to which the water would rise.

Table 6.4: Junction"s data.

Label	Elevation(m)	Hydraulic Grade(m)
J-1	831.22	924.12
J-2	804.42	914.19
J-3	800.5	909.67
J-4	766.86	907.26
J-5	803.32	906.04
J-6	829.72	906.3
J-8	831.22	836.66

6.6 Simulation Results Without Including the Protection Device

Where the results were obtained by doing these steps:

1) Click the Compute Initial Conditions button. Close the Calculation Summary and the User Notifications dialog.

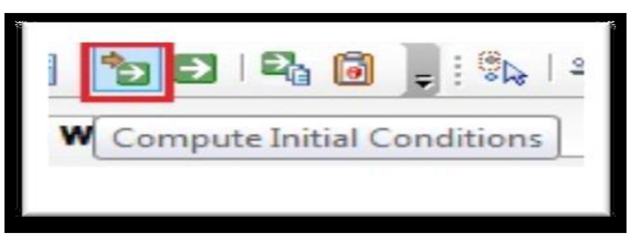


Figure 6.10: Compute initial conditions.

2) Click the Compute button. Close the Transient Calculation Summary and the User Notifications dialog.

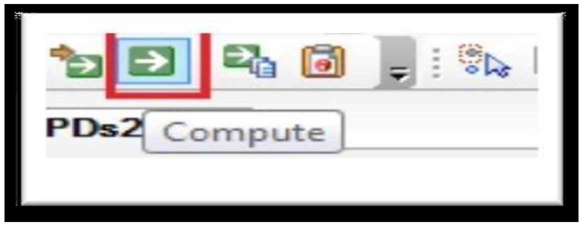


Figure 6.11: Compute transients condition.

1) Pipes data results during transients: This table explain the relationship between the previous data (pipes data, pump data, junction's data and tank data) and the results after calculated. The results is represented in a columns head maximum transient and head minimum transient, all this in the steady state as following:

Table 6.5: Pipe's data.

Label	Diameter (m)	Material	Darcy-Weisbach (m)	Wave Speed(m/s)	Head-max-Transient(m)	Head-min-Transient(m)
P-1	300	Ductile Iron	0.00026	1225.27	836.66	830.63
P-2	125	Ductile Iron	0.00026	1296.28	843.93	827.38
P-3	125	Ductile Iron	0.00026	1296.28	925.92	830.46
P-4	125	Ductile Iron	0.00026	1296.28	843.93	827.38
P-5	125	Ductile Iron	0.00026	1296.28	925.91	830.46
P-6	300	Ductile Iron	0.00026	1225.27	924.12	830.15
P-7	300	Ductile Iron	0.00026	1225.27	914.19	829.92
P-8	300	Ductile Iron	0.00026	1225.27	909.67	829.68
P-9	300	Ductile Iron	0.00026	1225.27	907.26	829.59
P-10	300	Ductile Iron	0.00026	1225.27	906.30	830.97
P-11	300	Ductile Iron	0.00026	1225.27	910.01	838.75

3) Pumps results during transients: The following table shows the result data, which belongs to pump which was head maximum, and minimum transient. This is needed to insert in hammer program: elevation, flow rate and pump head.

Table 6.6: Pump's data

Label	Elevation (m)	Flow (Total) (m^3/h)	Pump Head (m)	Head (Maximum Transient) (m)	Head (Minimum Transient) (m)
PMP-1	PMP-1	831.22	61.22	925.32	826.58
PMP-2	PMP-2	831.22	61.22	925.32	826.58

3) Tanks results during transients: The following table shows the result data which belongs to tank, which was head maximum and minimum transient and this, is needed to insert hydraulic grade as follows:

Table 6.7: Tank's data

Label	Hydraulic Grade(m)	Head (Maximum Transient) (m)	Head (Minimum Transient) (m)
T-1	**833.7**	**833.70**	**833.65**
T-2	**886.06**	**886.11**	**886.06**

4) We updated our report points and report path to reflect the replacement of J1 withHT-1. Click Analysis > Calculation Options and double-click the Base Calculation Options under the Transient Solver.

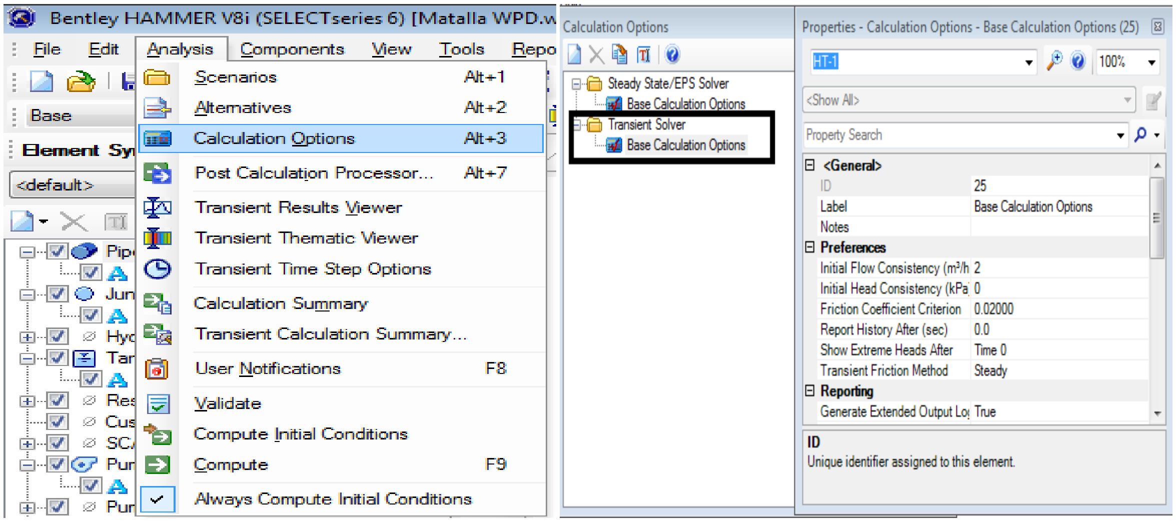


Figure 6.12: Calculation options under the transient solver.

5) Click the ellipsis button in the Report Points Collection field.

6) Add P1 / HT-1 and P2 / HT-1 to the Selected Items list. Click OK.

7) Click View > Profiles and Edit the Main Path Profile. Click Yes when prompted to auto repair the profile. The profile will open and will now include the hydro pneumatic tank, close the Profile and the Profiles manager.

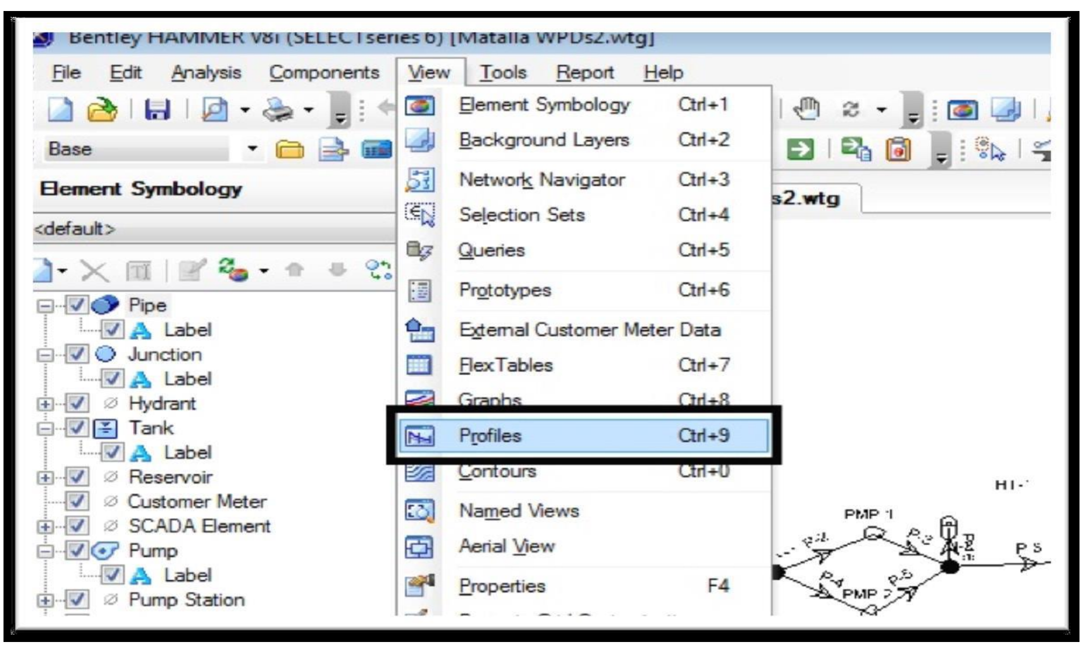


Figure 6.13: Shown the profile in Hammer Cad.

8) Select File > Save As and save the file with a new name: project1_Protection.wtg. Note: Rather than editing the original model and saving it as a new file, a better way is to create a new scenario in the original model for the transient protection simulation; we will investigate scenarios in project.

6.7 Analysis of the System by Profiles

1) Pipeline profile VS hydraulic grade line HGL: The following figure shows the pipeline profile and hydraulic grade line, which is the highest point, equals 936.94 and lowest point equals 888.40, through this figure, we can know elevations of junction from pipeline profile.

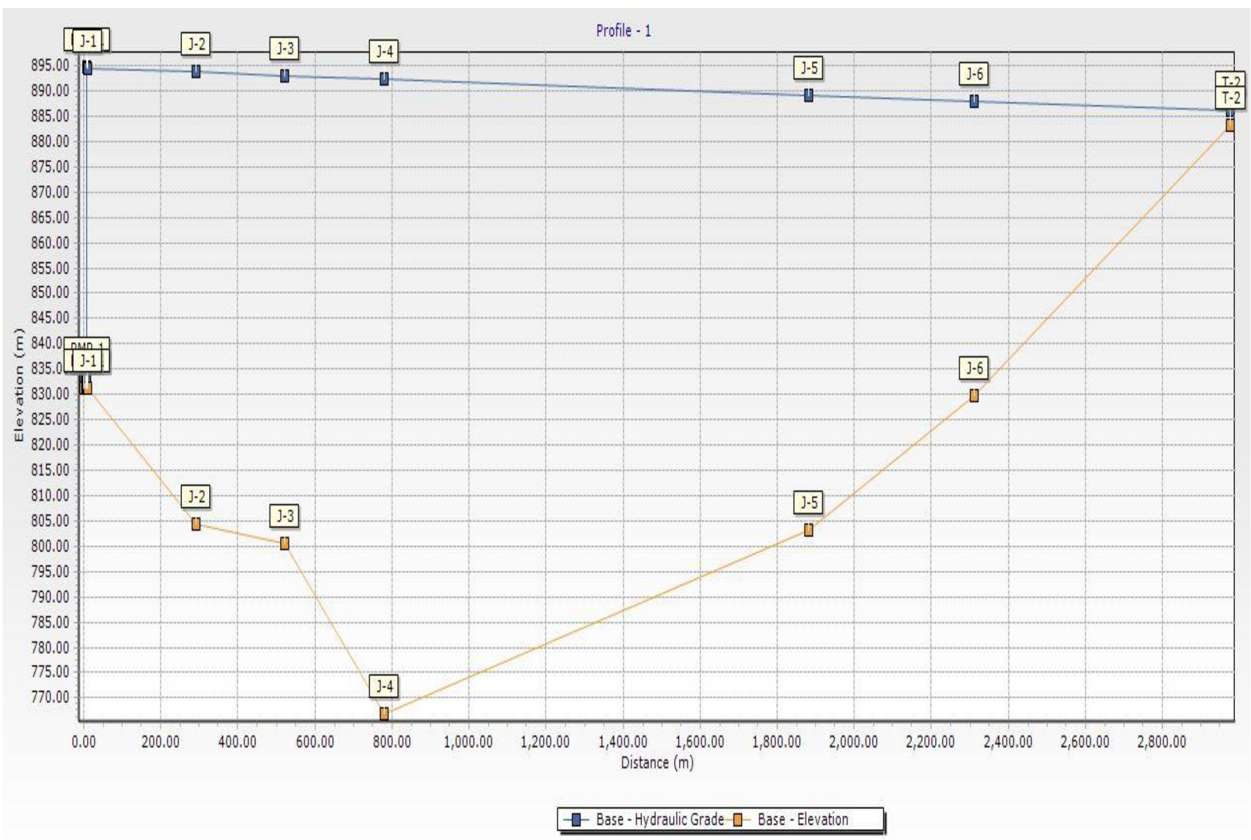


Figure 6.14: Pipeline Profile VS hydraulic grade line HGL

2) Pressure and flow VS time:

The following figure shows the pressure envelope and flow variations with time gust at the pump upstream due to to the pump stopping:

Figure 6.15: Pressure envelope and flow variations with time.

3) Pressure and flow VS time: The following figure shows the pressure envelope and flow variations with time at intermediate due to the pump stopping:

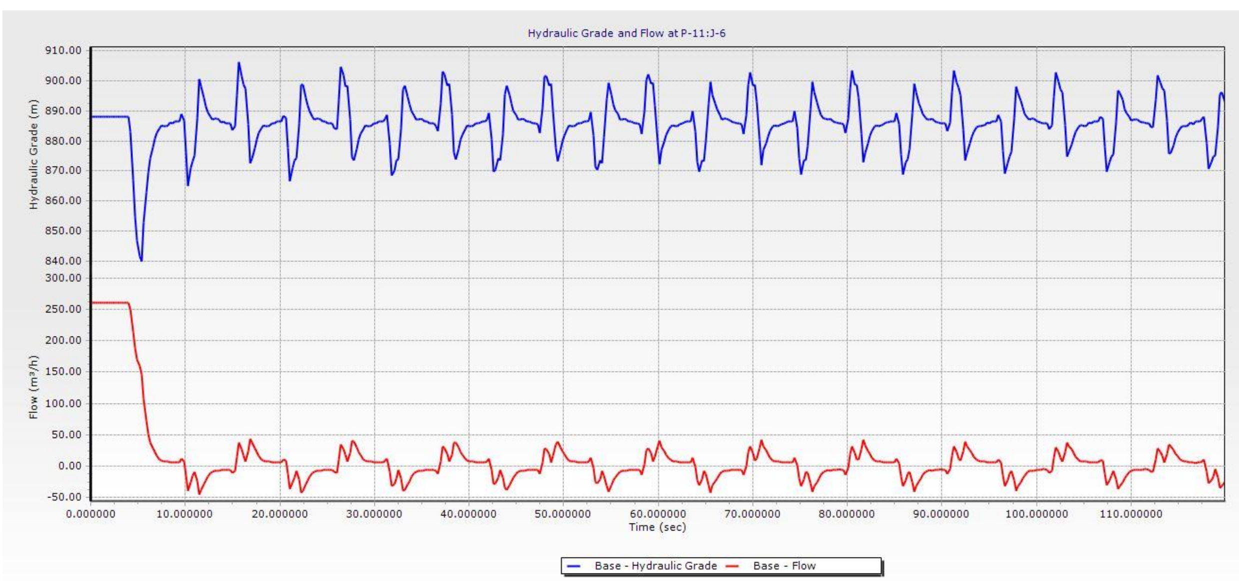


Figure 6.16: Pressure envelope and flow variations with time.

4) The following figure shows the pressure envelope with time at the tank location:

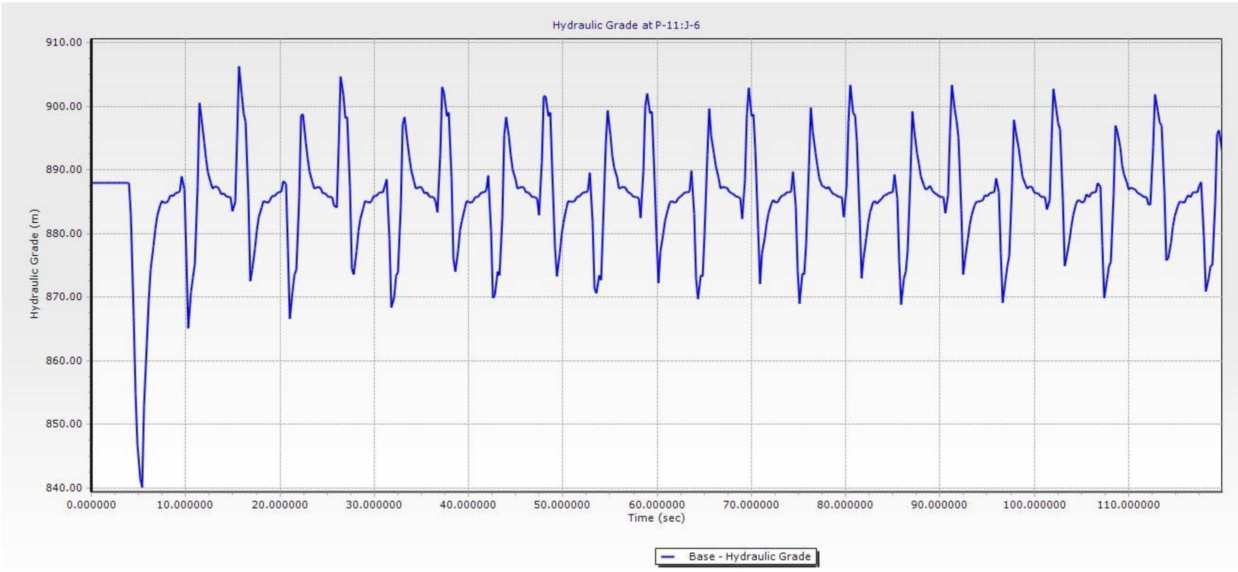


Figure 6.17: Pressure envelope with time at the tank location.

5) The following figure shows the hydraulic grade lines along the entire pipe length:

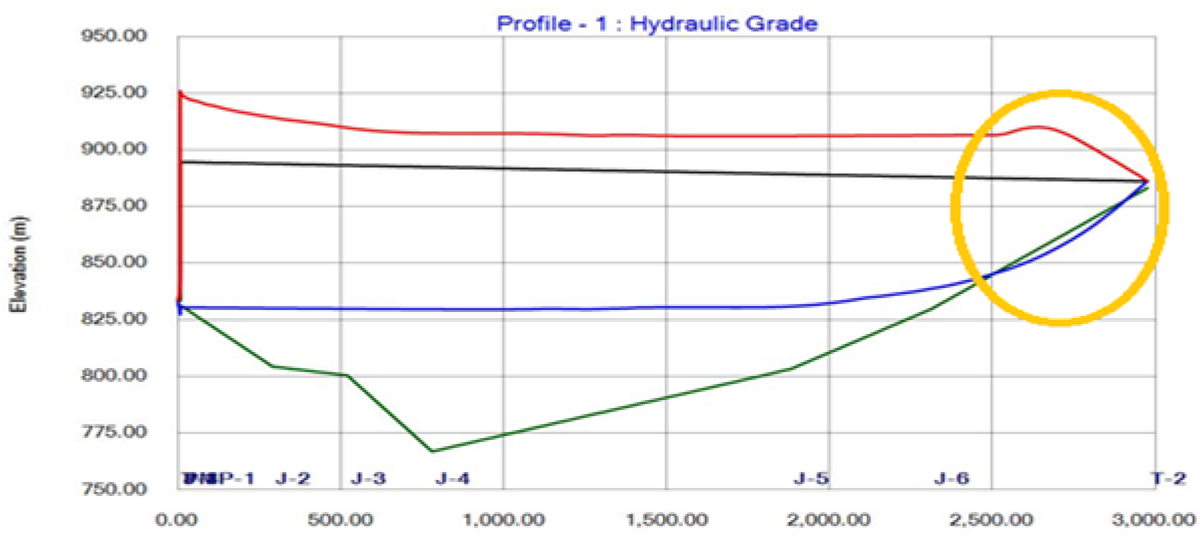


Figure 6.18: Hydraulic grade lines along the entire pipe length.

According the previous figure we get problem between station 2500 m and 3000 m, therefor another Hydro pneumatic tank must be used to solve this problem.

6.8 Surge-Protection Equipment

The ways to control water hammer are classified as either passive or active protections, protections under the first category do not require any special devices and limited to protective measures taken during the design of the facility, this is particularly the choice of the most suitable diameters of the pipes, since the average velocity of the flow is not excessive, the choice of material and class of the pipe rating pressure to reduce pressure changes with a little risk of bursting or crushing, and finally the choice of the valves whose closure durations are relatively slow, when these passive measures show insufficient protection, then it is necessary to install, one or more protective devices against overpressure and\or low pressure occur in the transient phenomena.

A brief over view of various commonly used surge protection devices and their functions is provided below. Some methods of transient prevention [3].

* Slow opening and closing of valves: Generally, slower valve operating times are required for longer pipeline systems. Operations personnel should be trained in proper valve operation to avoid causing transients.

* Proper hydrant operation: Closing fire hydrants too quickly is the leading cause of transients in smaller distribution piping. Fire and water personnel need to be trained on proper hydrant operation.

* Proper pump controls: Except for power outages, pump flow can be slowly controlled using various techniques. Ramping pump speeds up and down with soft starts or variable-speed drives can minimize transients, although slow opening and closing of pump control valves downstream of the pumps can accomplish a similar effect, usually at lower cost. The control valve should be opened slowly after the pump is started and closed slowly prior to shutting down the pump.

* Lower pipeline velocity: Pipeline size and thus cost can be reduced by allowing higher velocities. However, the potential for serious transients increases with decreasing pipe size. It is usually not cost-effective to significantly increase pipe size to minimize transients, but the effect of transients on pipe sizing should not be ignored in the design process. 80 To control minimum pressures, the following can be adjusted or implemented; Pump inertia, Surge tanks, Air chambers,

One-way tanks, Air inlet valves, and Pump bypass valves. To control maximum pressures, the following can be implemented; Relief valves, Anticipator relief valves, Surge tanks, Air chambers, and Pump bypass valves. These items can be used singly or in combination with other devices [3].

A. Pump Inertia:

Pump inertia is the resistance of the pump to acceleration or deceleration. Pump inertia is constant for a particular pump and motor combination. The higher the inertia of a pump, the longer it takes for the pump to stop spinning following its shutoff and vice versa. Larger pumps have more inertia because they have more rotating mass. Pumps with higher inertias can help to control transients because they continue to move water through the pump for a longer time as they slowly decelerate. Pump inertia can be increased through the use of a flywheel. For long systems, the magnitude of pump inertia needed to effectively control transient pressures makes this control impractical due to the mechanical problems associated with starting high inertia pumps. Therefore, increasing pump inertia is not recommended as an effective option for controlling transient pressures for long piping systems [3].

B. Air Chambers and Surge Tanks:

Air chambers and surge tanks work by allowing water out of the system during high pressure transients and adding water during low pressure transients. They should be located close to a point where the initial flow change is initiated. An air chamber is a pressure vessel that contains water and a volume of air that is maintained by an air compressor. During pump stop, the pressure and flow in the system decreases and as a result the air in the air chamber expands, forcing water from it into the system. A surge tank is a relatively small open tank connected to the hydraulic system. It is located such that the normal water level elevation is equal to the hydraulic grade line elevation. During pump stop, the surge tank substitutes the pump and by gravity feeds the system with water. This controls the magnitude of the low pressure transient generated as a result of the pump stop. 81

A. One-Way Tank:

This is a storage vessel under atmospheric pressure that is connected to the hydraulic system. It has a check valve (normally closed) connected to it which only allows water from the tank into the system. One-way tanks are primarily used in conjunction with pumping plants [Wylie at 1993]. The significant advantage of using a one-way tank rather than a surge tank is that the check valve allows the one-way tank to have a much lower height [3].

B. Pressure Relief and Other Regulating Valves:

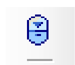
A pressure relief valve is a self-operating valve that is installed in a system to protect it from over pressurization of the system. It is designed to open (let off steam) when safe pressures are exceeded, then closes again when pressure drops to a preset level. Relief valves are designed to continuously regulate fluid flow, and to keep pressure from exceeding a preset value. An anticipator relief valve can be used instead of a pressure relief valve to control high pressure transient peaks. It is essential for protecting pumps, pumping equipment and all applicable pipelines from dangerous pressure surges caused by rapid changes of flow velocity within a pipeline, due to abrupt pump stop caused by power failure. Power failure to a pump will usually result in a down surge in pressure, followed by an up surge in pressure. The surge control valve opens on the initial low pressure wave, diverting the returning high pressure wave from the system. In effect, the valve has anticipated the returning high pressure wave and is open to dissipate the damage causing surge. The valve will then close slowly without generating any further pressure surges [M&M Control Service]. Air inlet valves are installed at highpoints along the pipeline system to prevent vacuum conditions and potential column separation. Air enters the pipeline system during low pressure transient, and this air should be expelled slowly to avoid creating another transient condition. Before restarting the pumps, an adequate time should be allowed for the air that entered the pipeline to be expelled. There are varieties of valves that allow air to enter and leave a system, and their names depend on the manufacturer. These valves include air inlet valves, air release valves, vacuum relief valves, air vacuum valves, and vacuum breaker valves [3].

C. Booster Pump Bypass:

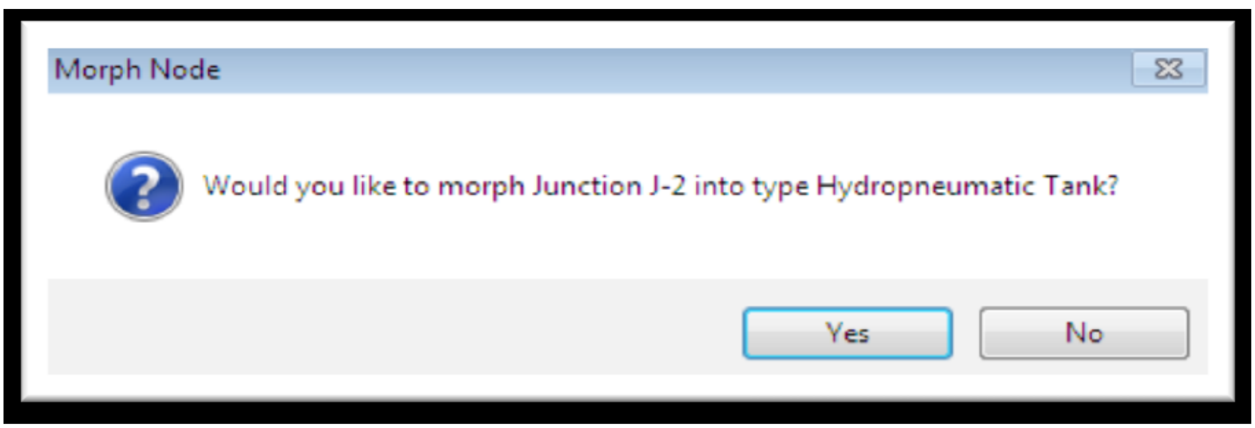
Pump bypass with a valve is another protective device against pressure transients. Two pressure waves are generated as a result of reduction in flow due to booster pump stop; the wave travelling upstream is a positive transient, and the wave that travels downstream is a negative transient. A check valve in a bypass line allows free flow to the pipeline to prevent low pressures and column separation [19]. The effectiveness of using a booster station bypass depends on the specific booster pumping system and the relative lengths of the upstream and downstream pipelines [3].

6.8.1 Using Hydro pneumatic tank in hammer cad

It is clear that high pressures are causing by the collapse of a vapor pocket at Node J1. You could install a Hydro pneumatic Tank at junction J1 to supply flow into The pipeline upon the power failure, keeping the upstream water column moving and Minimizing the size of the vapor pocket at the high point (or even preventing it from Forming). You can test this theory by simulating the system again using Bentley HAMMER and comparing the results with those of the unprotected run:

1) Click the Hydro pneumatic Tank button  on the Layout toolbar.

2) Click on J2. A prompt will appear, asking if you'd like to morph J2 into a Hydro pneumatic Tank element. Click Yes.



3) Set the Hydro pneumatic Tank element properties in the Properties editor:

a) Make sure the Elevation (Base) and the Elevation are setting to 832 m.

Figure 6.19: Hydro pneumatic tank base elevation.

b) Set the Operating Range.

Figure6.20: Hydro pneumatic tank operating range type.

c) Set the HGL (Initial) to 895 m.

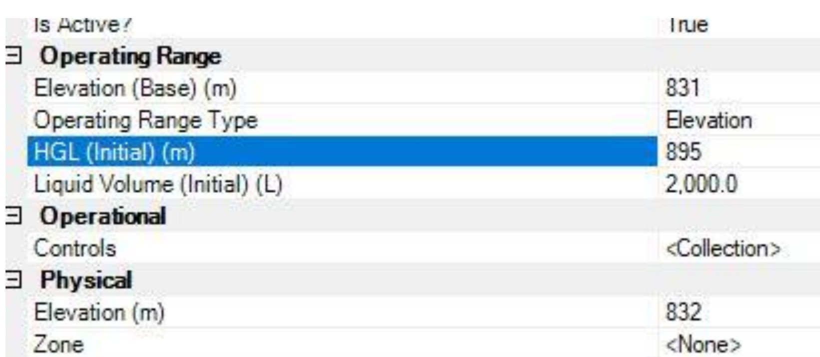


Figure 6.21: Hydro pneumatic tank initial HG

d) Set the Liquid Volume (Initial) to 2000 L.

Operating Range	
Elevation (Base) (m)	831
Operating Range Type	Elevation
HGL (Initial) (m)	895
Liquid Volume (Initial) (L)	2,000.0
Operational	
Controls	<Collection>
Physical	
Elevation (m)	832

Figure 6.22: Hydro pneumatic tank initial liquid volume.

e) Set the Minor Loss Coefficient (Outflow) to 2.5

Treat as Junction?	False
Transient (Physical)	
Hydropneumatic Tank Type	Sealed
Diameter (Tank Inlet Orifice) (mm)	150.0
Ratio of Losses	1.000
Gas Law Exponent	1.20000
Has Bladder?	True
Pressure (Gas-Preset) (bars)	3.5
Minor Loss Coefficient (Outflow)	2.50000
Elevation Type	Fixed
Transient (Reporting)	
Report Period (Transient)	10

Figure 6.23: Hydro pneumatic tank minor loss coefficient.

f) Set the Tank Calculation Model to Gas Law Model.

Controls	<Collection>
Physical	
Elevation (m)	832
Zone	<None>
Volume (Tank) (L)	3,000.0
Tank Calculation Model	Gas Law Model
Atmospheric Pressure Head (m)	10
Treat as Junction?	False
Transient (Physical)	
Hydropneumatic Tank Type	Sealed
Diameter (Tank Inlet Orifice) (mm)	150.0
Ratio of Losses	1.000

Figure 6.24: Hydro pneumatic tank gas law model.

g) Set the Volume (Tank) to 3000 L.

Figure 6.25: Hydro pneumatic tank volume.

h) Set the -Treat as Junction?- Field to true. This means that the hydro pneumatic tank is not included in the calculations of initial conditions. Instead, the HGL in the Hydro pneumatic tank is assumed the same as if there was a junction at the tank location.

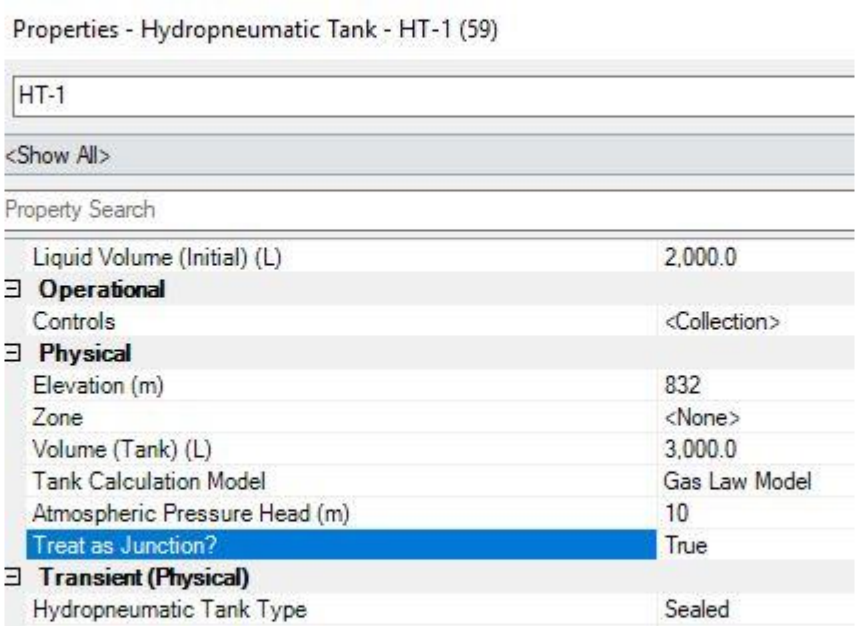


Figure 6.26: Treat hydro pneumatic tank as junction.

h) Set the Diameter (Tank Inlet Orifice) to 150 mm.

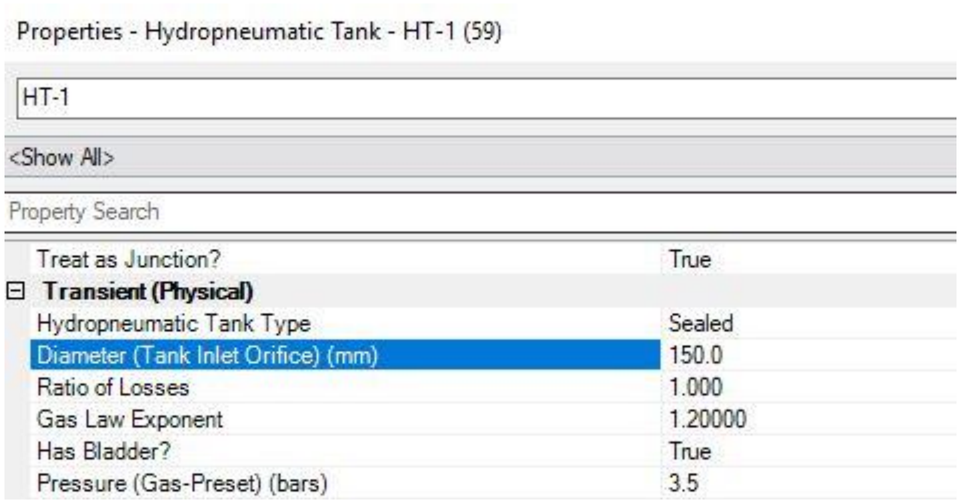


Figure 6.27: The diameter of the tank‟s inlet.

i) Set the Ratio of Losses to 1.

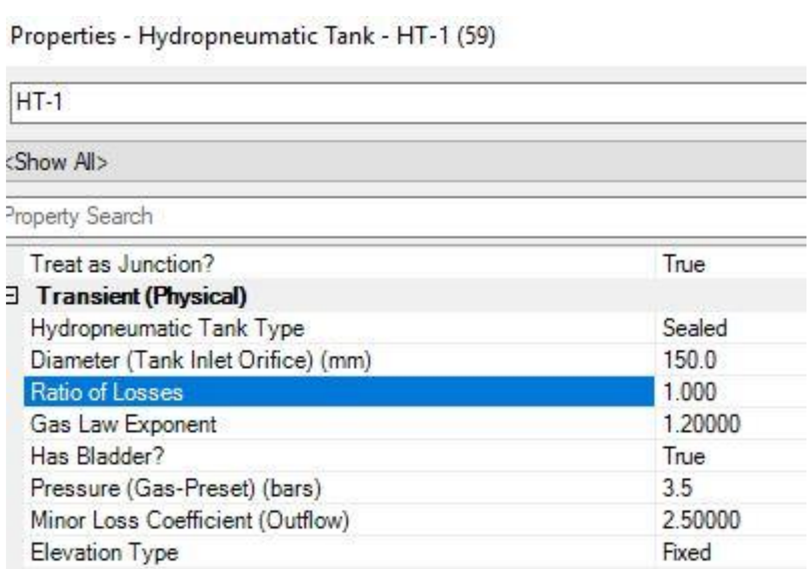


Figure 6.28: Ratio of losses.

j) Set the Gas Law Exponent to 1.2.

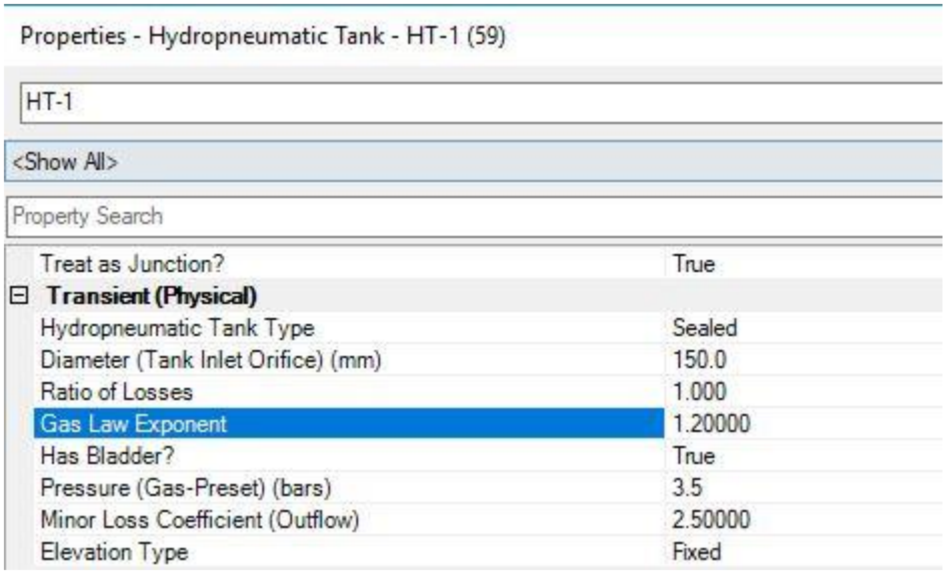


Figure 6.29: The gas law exponent.

6.8.2 Analysis with Surge-Protection Equipment

Case 1 :(firstscenario): using one Hydro pneumatic Tank:

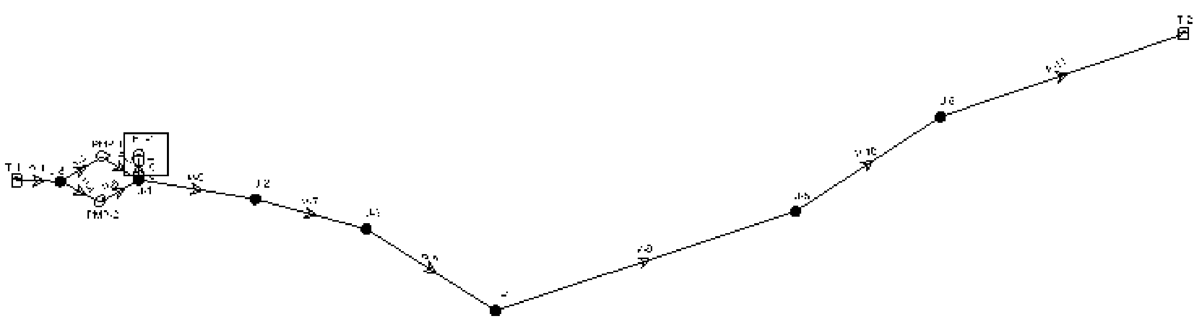


Figure 6.30: System description with hydro pneumatic tank.

Simulation Results:

1) Pipe results:

Table6.8: Pipe results with hydro pneumatic tank.

ID	Label	Length (Scaled) (m)	Diameter	Material	Darcy-Weisbache	Wave Speed (m/s)	Maximum Head Values	Minimum Head Values
36	P-1	4	300.0	Ductile Iron	0.00026	1125.27	838	829
37	P-2	4	125.0	Ductile Iron	0.00026	1296.28	848	824
38	P-3	4	125.0	Ductile Iron	0.00026	1296.28	908	861
39	P-4	4	125.0	Ductile Iron	0.00026	1296.28	848	824
40	P-5	4	125.0	Ductile Iron	0.00026	1296.28	908	861
41	P-6	10	300.0	Ductile Iron	0.00026	1125.27	908	859
42	P-7	9	300.0	Ductile Iron	0.00026	1125.27	909	859
43	P-8	13	300.0	Ductile Iron	0.00026	1125.27	907	861
44	P-9	26	300.0	Ductile Iron	0.00026	1125.27	905	863
45	P-10	14	300.0	Steel	0.00005	1125.27	898	868
46	P-11	21	300.0	Steel	0.00005	1125.27	898	869

3) Pump results:

Table6.9: Pump results with hydro pneumatic tank.

	Label	Elevation (m)	Flow (Total) (m³/h)	Pump Head (m)	Head (Maximum, Transient) (m)	Head (Minimum, Transient) (m)
26: PMP-1	PMP-1	831	130.51	61.22	908	824
27: PMP-2	PMP-2	831	130.51	61.22	908	824

4) Tank results:

Table6.10: Tank results with hydro pneumatic tank.

	Label	Hydraulic Grade (m)	Head (Maximum, Transient) (m)	Head (Minimum, Transient) (m)
25: T-1	T-1	834	834	834
47: T-2	T-2	886	886	886

5) Junction results:

Table6.11: Junction results with hydro pneumatic tank.

	ID	Label	Elevation (m)	Hydraulic Grade (m)	Head (Maximum, Transient) (m)	Head (Minimum, Transient) (m)
28: J-1	28	J-1	831	895	907	863
29: J-2	29	J-2	804	894	908	859
30: J-3	30	J-3	801	893	907	861
31: J-4	31	J-4	767	892	905	863
32: J-5	32	J-5	803	889	898	868
33: J-6	33	J-6	830	888	897	870
35: J-8	35	J-8	831	834	838	829

Graphical result representation (for case one).

1) The following figures shows the flow variation at the surge tank location from the result obtained its clear the maximum flow 80 \h and the minimum flow -196 \h.

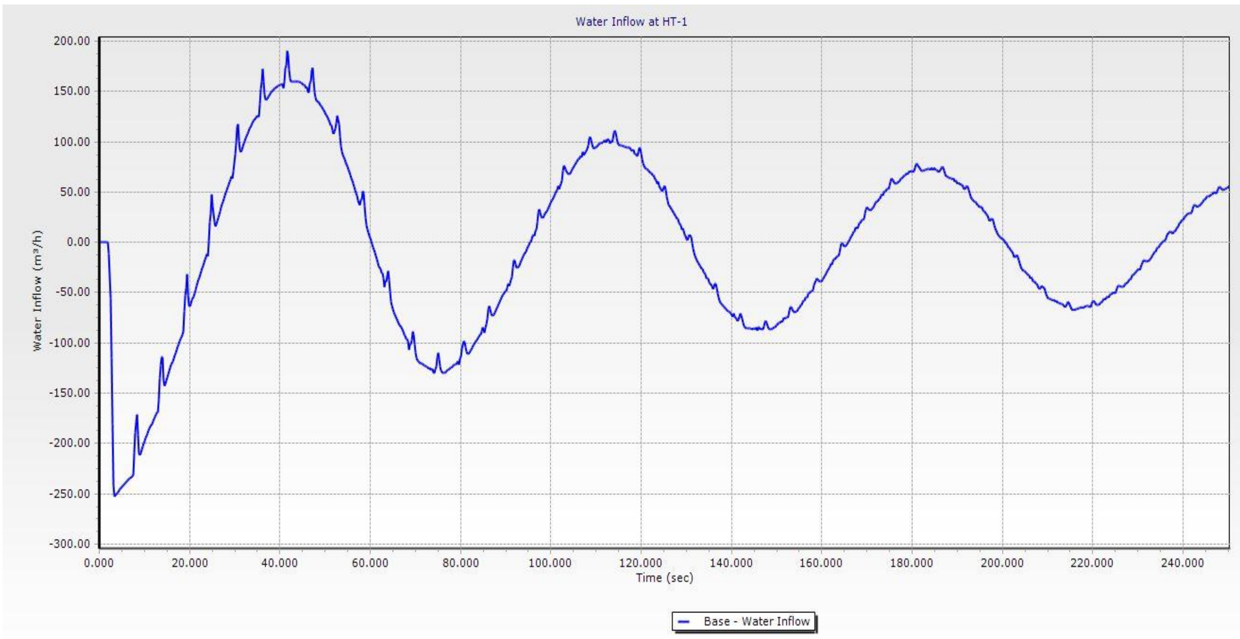


Figure 6.31: Water flow varation at the surge tank location.

2) The following figures show the volume variation at the surge tank location from the result obtained its clear the maximum volume 1500 L and the minimum volume 800L.

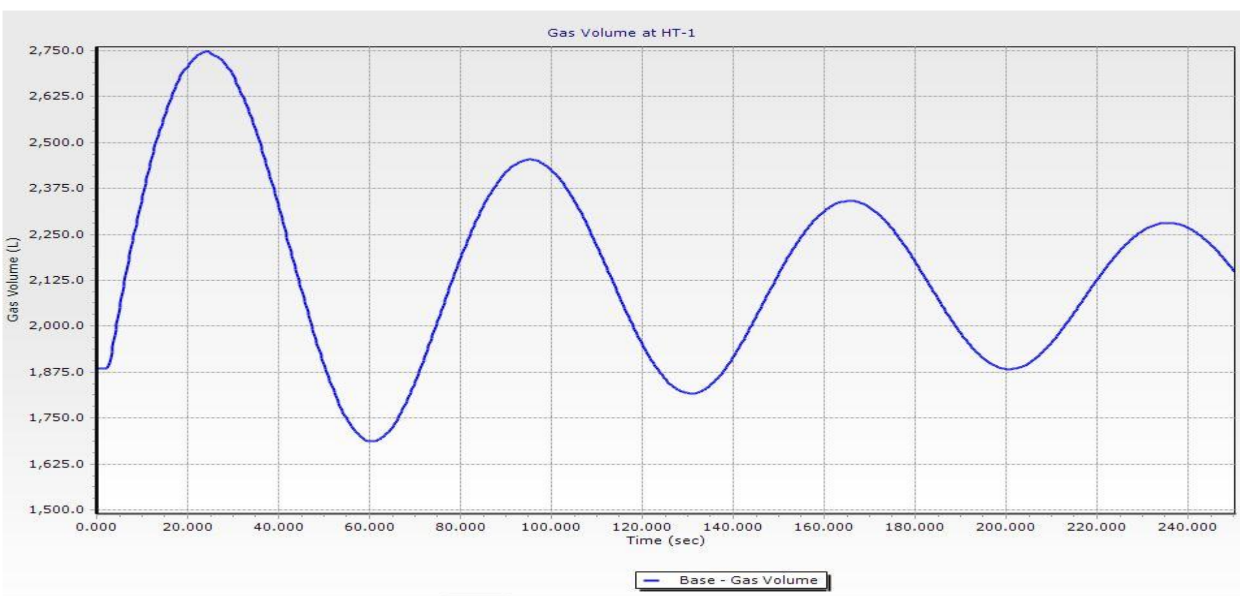


Figure6.32: Gas volume varation at the surge tank location.

3) The following figures show the pressure variation at the surge tank location from the result obtained its clear the maximum pressure 1136 kpa and the minimum pressure530 kpa.

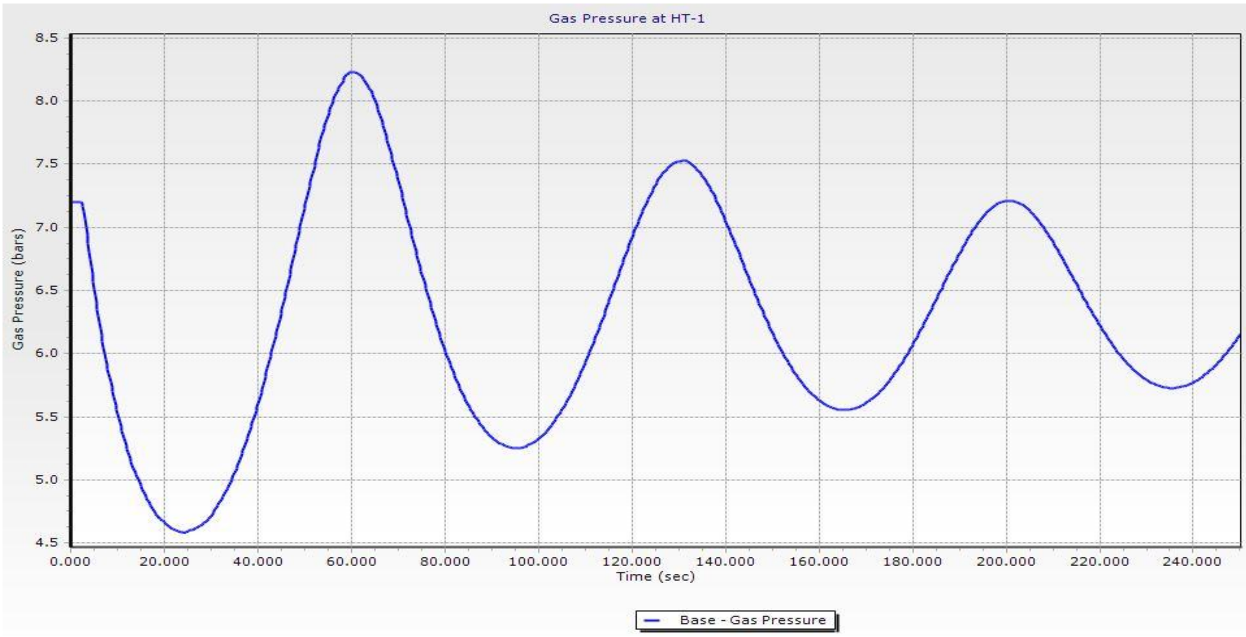


Figure6.33: Gas pressure varation at the surge tank location.

4) Hydraulic grade: The following figure shows the hydraulic grade lines along the entire pipe length:

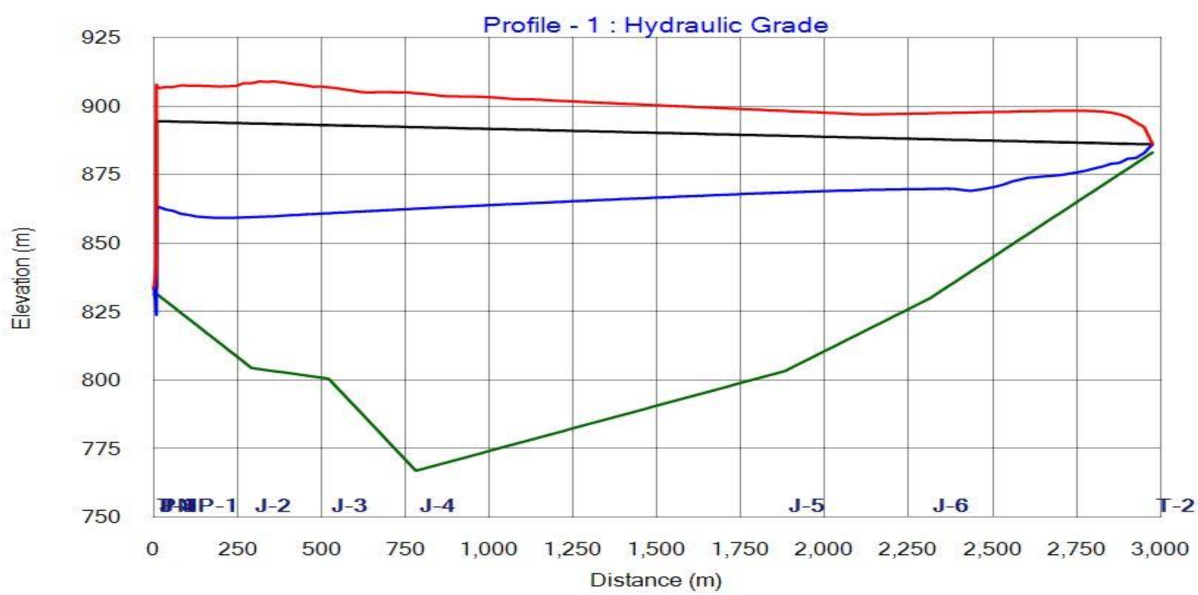


Figure6.34: Hydraulic grade lines along the entire pipe length

From the result obtained we noticed that using one surge tanks is sufficient to protect the pipeline.

CHAPTER “7”

“CONCLUSION”

7.1 Conclusion

In this project, the trial is made to create hydraulic design for a pumping station combined with conveying pipeline system using computer model for Al DOHA town, considering the street where the proposed pipeline will pass and its elevations, topographical features, accelerated development and growth of the town. By applying several hydraulic principles on the current case study the result brought out many important conclusions, the main conclusions draw from the present study are summarized below:

1) The water supply in Al DOHA pumped to the water network system by pumping stations directly which cause various problems as energy consuming and in water flow such as water hammer, since the pumping station will not work in its real efficiency and the required duty point at the network level due to the variation of water consumption.

2) The pipes are connected to each other by joint in standard form, but the pipe are not necessary to be straight, it follows the train and the topography so, a deflection angle must be exist and should not exceed a threshold values

3) Valves are used to control the amount of flow and may be globe valves, angle valves, gate valves, and butterfly valves, any of several types of check valves.

4) The path of the pipeline is from Al Duhaish pumping station which has the lowest elevation to Al DOHA Reservoir, which has the highest elevation.

5) The material that should be used in the water network tubes depending on the water pressure and tubes radius. So ductile iron is the most suitable material for pipeline, In addition to the 102 intrinsic qualities of the basic metal, the variety of shapes and dimension of components facilitate pipeline assembly.

6) Al Duhaish pumping station is currently equipped with pumping units 99 /h at 61.22 m WC.

7) The hydraulic efficiency not less than 75.8% and the design pressure 16 pars.

8) It is clear that high pressures are causing by the collapse of a vapor pocket in the system, You could install a Hydro pneumatic Tank in the system to supply flow into The pipeline upon the power failure, keeping the upstream water column moving and Minimizing the size of the vapor pocket at the high point (or even preventing it from Forming).

9)The programs we used in this design to achieve our goals are GIS, Civil 3D, HAMMER CAD.

APPENDIX A

The final layouts are prepared and presented in Appendix A

References:

[1] Çengel, Y. A. and Cimbala, J. M., Fluid Mechanics – Fundamentals and Applications, McGraw-Hill, NY, 2006.

[2] White, F. M., Fluid Mechanics, Ed. 5, McGraw-Hill, NY, 2003.

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