PRESSURE LOSS PREDICTION AND CONTROL MODEL FOR WATER TREATMENT UNITS

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Dec 2014

ABSTRACT

Water treatment compact units are widely applied in Iraq for production of drinking water. Treated water quality meets world Health Organization (WHO) standards. Present work focuses upon compact water treatment units design, power and pressure drops control modeling and simulations. Computer program software (***compact pro***) was developed to calculate the pressure losses in piping network and process equipment's. Results obtained for pressure drop unit length for different pipe diameters and roughness, show that for pipe diameter above (200 mm) for (200 m^3/hr),water pressure drop almost the same, while for pipe diameter less than (200 mm), water pressure drop is minimum for PVC and Stainless steel and maximum for galvanized steel. As the piping roughness increase, pressure drop will increase in general for any water internal flow rate. As internal flow rate increased, water pressure drop increase .This result is very important for process designer. Comparisons between results of ***Compact Pro*** Software and **Pipe flow expert** Software for different Input data, shows a good agreement which not exceed 8.6% as maximum. There are only slight change in pressure and pressure drop to the proposed model for compact water treatment unit, sensible change in pressure and pressure drop in the sand filtrations stage. Power calculations for the two water treatment stages, including shaft power for pumps motors for different piping materials. Results show that power can be saved up to more than 85 %.

ABSTRAK

Unit kompak rawatan air digunakan secara meluas di Iraq bagi pengeluaran air minuman. Rawatan air yang dijalankan adalah memenuhi spesifikasi yang telah ditetapkan oleh pertusuhan kesihetan sedunia (WHO) standards. Kajian masa kini memfokuskan mengenai reka bentuk unit rawatan air serta pemodelan dan simulasi bagi kuasa dan pengurangan tekanan. Perisian komputer (compact pro) yang dihasilkan bagi mengira kehilangan tekanan dalam rangkaian paip dan peralatan proses. Hasil yang diperolehi menunjukkan bahawa pengurangan paras tekanan per unit panjang bagi paip-paip yang berbeza diameter dan kekasaran permukaan menunjukkan bahawa paip berdiameter lebih (200 mm) untuk (200 m3.hr), pengurangan tekanan adalah lebih kurang sama. Manakala bagi paip yang berdiameter kurang (200 mm), pengurangan tekanan air ialah minimum bagi PVC dan keluli tahan karat dan adalah maksimum bagi keluli tergalvani. Apabila kekasaran paip meningkat, kejatuhan paras tekanan juga akan meningkat secera amnya bagi mana-mana kadar aliran dalaman. Apabila kadar alirang dalam meningkat, kejatuhan paras tekanan air juga meningkat. Hasil yang diperolehi ini sangat penting bagi pereka-pereka proses. Perbandingan antara keputusan yang dihasilkan oleh perisian Compact Pro dan perisian Pipe flow expert bagi input data berbeza menujukkan hasil yang hampir sama iaitu tidak melebihi 8.5% had maksimum. Hanya terdapat sedikit perubahan pada tekanan dan pengurangan paras tekanan pada model yang dicadangkan untuk unit kompak rawatan air serta perubahan yang munasabah pada tekanan dan pengurangan tekanan dalam peringkat penapisan pasir. Pengiraan kuasa untuk kedua peringkat rawatan air adalah merangkumi pengiraan kuasa pada aci bagi pam motor untuk bahan-bahan paip yang berlainan. Keputusan yang diperolehi menunjukkan kuasa boleh dijimatkan lebih dari 85%.

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LIST OF ABBREVIATION AND SYMBOLS

v	velocity, m/s
C	Hazen-Williams Coefficient
R	Hydraulic mean radius, m
J	Hydraulic gradient, m/m
n	Manning's Coefficient
H	Head loss, m
g	Gravity constant, 9.81 m/s²
D	Inside diameter, m
f	Friction factor
L	Length of the pipe, m
f	Friction factor
ν	Kinematic viscosity, m²/s
Re	Reynolds number
CV	valve coefficient
E(t)	tracking error
r(t)	desired input value
y(t)	actual output
K_p	Proportional gain
K_i	integral gain
K_d	derivative gain
$e(t)$	error signal
$r(t)$	reference input signal
$u(t)$	input signal to the plant model

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CHAPTER 1

INTRODUCTION

1.1 Overview

Recently water treatment compact units are widely applied in Iraq due to its unique benefit and importance in remote area, low capita rural water supply and Hotels and Resorts, Compact Water Treatment Systems is skidding mounted or containerized used for production of drinking or process water. Typical systems include coagulation and flocculation lamella plates settling, sand and activated carbon filtration, polishing 5 or 10 micro cartridge filters, followed by chlorination or UV. Treated water quality meets WHO (World Health Organization) standards.

Water treatment compact units are manufactured in several capacities ranging from as low of 10 m^3/hr up to 2000 m^3/hr. each compact unit compose of piping network, fittings, process equipment (clarifier ,filters and tanks) and valves.

According to the rapidly and continuous rising in power cost in the world, due to continuous increase in oil prices, renewable energy substitute the conventional energy gradually because of its easy and low cost. Most of these compact units use solar energy because its available most of year days and Iraq consider as one of countries which have sunny days almost year, so water treatment compact units used renewable energy is the main target of most of the manufactures and governments. Improvements in water treatment process and supply are important in modern society (Parsons,S.A. and Jefferson, B., 2006), (Paulus J. G., 2004).

Good design of water treatment plants will lead to reliable water supply system. Development of design and material and specifications of Piping network, equipment, valves, pumps and fitting is the key to reliable water treatment process and clean water supply in addition to minimizing power consumption (Alsaffar A. M., and Zheng Y., 2007).

Preliminary designs of any water treatment process are usually based upon several assumptions. Because of that final layout of the system is not complete, material of construction and internal surface roughness, actual type of valves are uncertain.

1.2 Background of Study

There is a difficulty to find a single tool that identifies pressure drop loss in internal flow systems and marks components which imply a higher pressure drop in a system (Donald.S.M, 1990). Pressure drop losses in such compact units are proportional to power consumptions that are higher pressure losses in the unit mean high power consumptions.

Mohammad A.M.A and Entesar K.H.,2010, submit research of modeling of conventional water supply treatment plant , the study include design of computer programs in Visual Basic V 6.0 software to design, control, and operation conventional treatment plant, Prepare computer program to design transition system and calculate the hydraulic profile for conventional treatment plant. Parts of this study focus the calculation of the hydraulic profile for conventional treatment plant.

Kate Taylor,et.al,1999, study the prediction of pressure drop and flow distribution in packed bed filters and experimental measurements of pressure drop and velocity were made using a filter bed which was snowstorm packed with spherical beads of uniform size.

Many of large valves manufacturers companies such as EMERSON Process Management, and others studied the improper valve sizing and selection for both liquid and gas applications and its effect upon pressure drop and system stability.

Petra Ross, 2014, study development of models which enable users to virtually construct a water treatment plant including pressure drop.

Worm G.I.M., et al, 2009, use modeling software to study the hydraulic beaver of drinking water treatment plants which include piping networks, filters and valves.

Model is necessary to study the compact unit performance for several operating conditions on its performance.

Pressure drop across piping networks and equipments seems to be main parameter in the development and new design of compact water treatment units to be compatible with renewable energy aspects.

1.3 Problem Statements

Water treatment units design, equipments selections and sizing is very important step in any attempt to produce water with high quality and low cost with optimum operating conditions. One of the parameters to be have high attentions is the pressure drops across water treatment unit elements such as pipes, valves, pipe fitting and process equipment such as clarifier, filters and tanks.

Unnecessary pressure drops lead to many process operating troubles in additions to loose of money. Optimum system design of compact water treatment units will lead to water with high quality with low cost.

Modelling of water treatment process and control of the parameters effecting pressure drops using software program to calculate the overall pressure drop across the system easily as can changing the properties of the system elements properties to reach integral system which verify process design conditions with minimum pressure drop.

1.4 Project Objectives

Project output depend upon the main objectives which can be useful for future further studies, these objectives can be summarized to be fulfilled. The primary objectives are:

1. To build a mathematical model that describes the hydraulic pressure drop losses in several items in internal flow system.

2. To develop a software program model and verify it for further application to simulate the pressure drop losses in a water treatment unit.

3. To identify controlling parameters that significantly affects the pressure drop to develop theoretical control model of solar powered plant and develop a mathematical model to control water tank level for compact water treatment unit.

1.5 Project Scopes

This study is very important to create a tool which can be used during process and detail design. Also the study will highlight many facts related the selection of water treatment elements (pipes, valves, equipment pipe fittings) the scope will include:

1. Mathematical model will include all equations related to pressure losses for internal flow systems, also all available data for pipe roughness and type of flow laminar and turbulent flows will considered.

2. Software model will be developing using Microsoft Visual Studio .Net 2008 with Windows Form C# project, which can simulate water treatment process to calculate the pressure losses in all equipment, piping networks and valves. The actual process data of the water treatment units will be used in simulations.

3. The study will include examinations of all controlling parameters that significantly affects the total pressure drop that eventually reduce the power and the operating cost of the compact water treatment unit. Operating pressure can be easily controlled using AC drive solar powered pumps and control valve in simulation procedures. And theoretical water tank level control system will be developing using PID controller and matlab system.

Compact water treatment units design according to the former aspects can be a good example and practice to produce water treatment units with optimum design parameters.

Compact water treatment units design according to the former aspects can be a good example and practice to produce units with optimum design.

A model will be programmed using any suitable computer language to describe the hydraulic pressure drop in several items; such as pipes, valves, fittings, filters, tanks, pumps and other components. The model will integrate information about a system design and fluid flow properties in order to calculate pressure drop per each item in the system. Physical properties will be built in the internal library of the model that user will need only to identify only the operation conditions and the physical description of the system's components.

The model will use simple formulas and charts listed in the literature that was already based either on Navier-Stock equation or on Semi-empirical formulas, one of the important references for such equations will be (Miller, 1990).

However, similar practice was published by several other literatures Knodel B. D., et. al., 1987, Abdulwahhab, et.al. 2013.

1.6 Research Significance

Clean water produce by compact units with low power is the main motivation which forces the designers and manufacturers of water treatment units to design and manufacture water treatment units with minimum pressure drops and high operating conditions. This study is very important to create a tool which can be used during process and detail design process. Also the study will highlight many facts related the selection of water treatment elements (pipes, valves, equipment pipe fittings) these facts are:

1. Pipe length and diameter should be as minimum as possible.
2. Pipe fittings also should be as minimum possible.
3. Control valves should have minimum pressure drop.
4. Process equipment should be well design to achieve minimum pressure drop with verifying process conditions.

Compact water treatment units design according to the former aspects can be a good example and practice to produce units with optimum design conditions.

1.7 Summary

Water treatment compact units are widely applied in Iraq for production of drinking or process water. Treated water quality meets WHO standards. Capacities of these units ranging from as low of 10 m3/hr up to 2000 m3/hr. Renewable energy can be substitute the conventional energy because of its high capital cost.

Most of these compact units use solar energy because its available most of year days and Iraq consider as one of countries which have sunny days almost year. Good design of water treatment plants will lead to reliable water supply system and low power consumptions to meet renewable energy requirements.

Pressure drop losses in compact units are proportional to power consumptions such that higher pressure losses in the unit mean high power consumptions.

Hydraulic profile calculations for conventional treatment plant and distributions piping network has been studied and focused by many researchers and manufactured. The prediction of pressure drop and flow distribution of plant process components such as sand filters, rectifiers, valves and pipes is very important parameter to design and manufacture such plants, because it can affect the selection of pumping systems of these units .

Unnecessary pressure drops lead to many process operating troubles in additions to loose of money, moreover electrical power consumptions can be optimize ,if the total pressure drop can be reduced as minimum.

The present study will highlight and apply this aspect to compact water treatment units, by developing a mathematical model which includes all equations related to pressure losses for internal flow systems. Software model will be used to simulate water treatment process and calculate the pressure losses in the system. Identify controlling parameters that significantly affects the pressure drop and optimize the types of pumps and other items that eventually reduce the power and the operating cost of these units. This study can be important tool which can be used for process and detail design of the units.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Pressure loss or drop in pipes, valves, pipe fittings have been the interest of many researchers due to their common use in industrial and municipal services. Many manufacturers try to design and produce process systems to fulfill the water treatment requirements including pressure drop aspects.

Pressure loss studies and calculations in pipes and other industrial and water treatment process has been studied from early time and it continue according to the development in process requirements and the progress and development in material and new technologies (Parsons, S. A. and Jefferson, B., 2006), describe in details the process of conventional water treatment plants, also different water treatment equipment and techniques are examine too. However this work is not considering the pressure drop in piping network or process in comprehensive details.

Paulus J. G., (2004) give more attention to the hydrodynamic characteristics of the water treatment plant, using diagnoses study. Alsaffar A. M., and Zheng Y, (2007), study another parameter which related to the water intake of water treatment plants. Donald.S.Miller, (1990), this book describes and investigates the Internal flow in systems, and provide a practical guide to internal flows in general and energy losses in piping and other fluid systems. Miller indicates that high Reynolds numbers savings in energy and construction costs are possible.

2.2 Pipe roughness

Commercial pipes come in many different materials and many different Sizes. The internal roughness of a pipe is an important factor when considering the friction losses of a fluid moving through the pipe, For each pipe material either a single pipe roughness value or a range of Roughness values are normally provided by the manufacturer.

2.3 Pressure loss in pipes

Pressure loss is defined as the rate at which the pipes in the plumbing system lose pressure over time. Plumbing systems rely on water pressure to push the water through the pipes. When the water loses pressure, the plumbing system can fail to provide water to the building owners. Pressure loss results from friction that the water receives during flowing inside pipes. Mohammad A.M.A. and Entesar K.H., design computer programs in visual basic V6.0 software to design control and operation of conventional water treatment plant, also the work include prepare computer program to design transition system to calculate the hydraulic profile for the same conventional water treatment plant. The software program also include using of statistical data produce an equations connect between the environmental factors and plant variables .The verifications for the program shows very good agreement.

Henryk Kudela and White F. M., 1999, Munson B.R. et.al., 1998, Nakayama Y. and Boucher R.F. Boucher, 1999, Cengel Y.A. and Cimbala J. M., 2006, McDonough J.M., 2004. Includes their studies comprehensive details of internal flow in general and pressure loss in pipes in details.

2.4 Pressure loss in valves and pipe fittings

Process engineers very often measure the pressure loss of pipe valves and fittings. Measuring the pressure loss calculations in pipe, valves and fittings is to ensure that the plumbing system will always have enough pressure to move the water throughout the home. Water pressure is lost as a result of the valves and fittings because the water has to suddenly change direction to overcome these obstructions. Pipe valves control the flow of the water in the pipes, while fittings are parts of the pipes that change direction suddenly**.**

Mohammed Abdulwahhab,et.al., 2013, studied the predictions of turbulent flow in 90° T-junction using finite element technique ,CFX 5 code ANSYIS FLUENT 13 program, and compared with both theoretical and experimental data for two cases .the pressure loss coefficient given by numerical results is higher than those for obtained from theoretical and experimental results ,anyhow this approach can be effect the design of pipe fittings in future, EMERSON Process Mangment, 2014, submit standard method to valve sizing calculations for different applications ,in this work it is clear that improper valve sizing can be expensive and it may lead to instability and others problems.

Watts water technology submit full technical information enough for sizing valves upon minimum pressure drop applications.

2.5 Previous Studies on modelling of pressure loss

Chuang Kuang Hong, (2006) develops a decision support system (DDS), (WATER-DSS computer systems) which has been developed to covers conventional drinking water treatment process in Malaysia. WATER-DSS contain two main components:

1. knowledge-based information and
2. Programming tool.

The design of drinking water treatment plant in WATER-DSS depends on the characteristic of raw water and the water quality objectives.

Worm G.I.M, et.al, (2009), the study include anew EPAnet library with the typical hydraulic elements for drinking water treatment processes well abstractions ,rapid sand filtrations and cascade and tower aeration. Hydraulic model was set up, calibrated and validated for drinking water treatment plant.

Xiaoyu Yuan, (2009), study Model Validation and New Water Control Strategies in Drinking Water Treatment Plant at Wim Mensink, the study indicates that the drinking water treatment plant can improve the current control conditions by using the five water control strategies. One of these strategies is Pressure drop control to determine pellet discharge from 1.80 mWc to 2.60 mWc.

Mohammad A.M.A. and Entesar K.H, (2010), submit a study which include a computer program designed in Visual Basic software 6.0.This program is flexible and easy to be used by practiced engineer for designing conventional water treatment plant Also, the program deals with the different environmental factors that affect the design of water treatment steps, the program can compute the hydraulic design of conventional water treatment plant, include transition system, influent and effluent structures and head losses calculations.

Matteo Nicolini, (2011), focused on optimal pressure management in water distribution networks, and pressure loss which consider as one of the most efficient and cost effective measures for reducing real losses and operational costs. In this work the methodology based on genetic algorithms, in particular using a single-objective GA for model calibration and NSGA-II in order to solve the multi-objective problem characterized by two conflicting criteria:

1. The minimization of the number of PRVs(pressure reducing valves
2. The minimization of the total water loss in the network.

The approach can save water and energy together with more efficient and sustainable management of the system.

Rickey Ting Pek Eek, et.al (2012), investigates the application of Model Order Reduction (MOR) technique to Waste Water Treatment Plant (WWTP) system. The mathematical model of WWTP is obtained by using System identification. The study includes, Prediction Error Estimate of Linear or Nonlinear Model (PEM) is proposed as the System Identification method. The result shows that the estimated Model of WWTP is a high order system with good best fit with 91.56% and 80.19% compared to the original experimental model.

Petra Ross, (2014), develop and combined existing models for a water treatment platform, which enables users to virtually construct a water treatment plant and monitor and optimize existing water treatment plants. The model takes in consideration the changes in raw water quality.

Kate Taylor, et.al, (2014), developed a CFD technique for prediction of Performance of axi-symmetric packed bed filters. The effect on pressure drop of a non-uniform voidage distribution within the filter bed was modeled. The pressure drop and velocity distribution in a model of filter System for the range of filter parameters and inlet velocities generally shows good agreement with experimental results.

2.6 Present work

The objective of the present work will focuses upon compact water treatment plants design model and simulations. Computer software will be developing to calculate the pressure losses in compact unit piping network and process equipments. The results will be compared with standard internal flow design software, Optimum minimum pressure loss design of compact water treatment unit can be examined.

2.7 Summary

Pressure loss or drop in pipes, valves, pipe fittings have been the interest of many researchers due to their common use in industrial and municipal services. Pressure loss studies and calculations in pipes and other industrial and water treatment process has been studied from early time and it continue according to the development in process requirements and the progress and development in material and new technologies.

Many of recent studies give more attention to the hydrodynamic characteristics of the water treatment plant, using diagnoses study approach. Investigations of Internal flow in systems, and provide a practical guide to internal flows in general and energy losses in piping and other fluid systems have been studied.

They realize that high Reynolds numbers savings in energy and construction costs are possible. Many of software enterprises succeed to develop and combined existing models for a water treatment platform, which enables users to virtually construct a water treatment plant and monitor and optimize existing water treatment plants. The model takes in consideration the changes in raw water quality. Hydraulic model was set up, calibrated and validated for drinking water treatment plant.

The present work objectives will focuses upon compact water treatment plants design model and simulations. Computer software will be developing to calculate the pressure losses in compact unit piping network and process equipments.

CHAPTER 3

METHODOLOGY

3.1 Overview

As a benchmark, the research will test the model on a water treatment unit that is conventionally used in several locations in Iraq to calculate pressure drop and hydraulic profile for the system.

The results will be compared to a field measurement applied to the said unit and corrections will be made to the results of the model, the following steps will be the approach in this project.

1. Derive a mathematical model that describes the hydraulic pressure drop losses in several items in internal flow system for compact water treatment unit.
2. Build software model and verify it for further application to simulate the pressure drop losses in a water treatment unit.
3. Automatic control system consist of PID (proportional integral derivative) controller will use to control the level of water in tank and organize water produced in water treatment unit and consumer demand.

Identify controlling parameters that significantly affects the pressure drop and optimize the types of pumps and other items that eventually reduce the power and the operating cost of the unit, the project flow chart is shown in Figure 3.1.

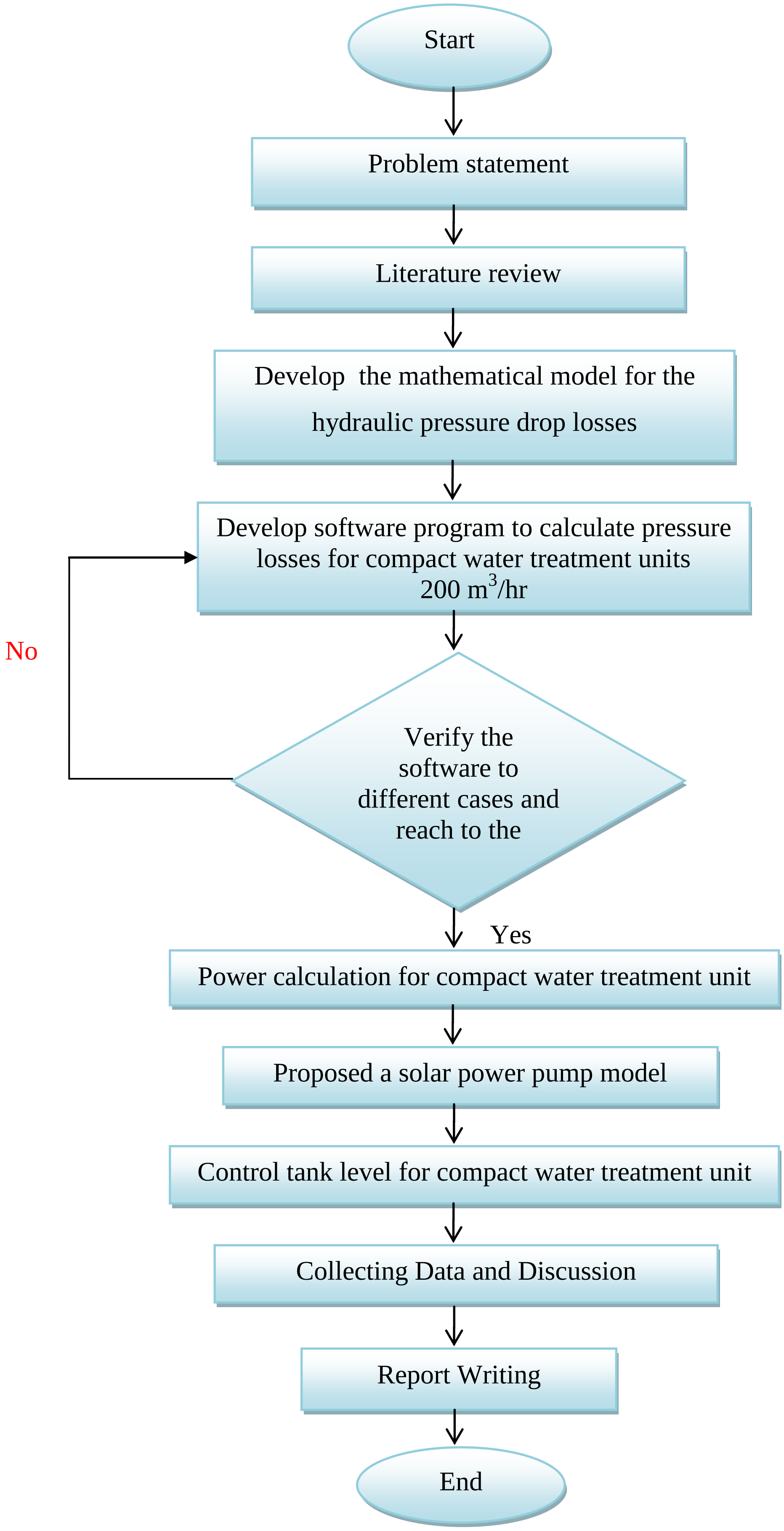

Figure 3.1: Project Flow chart

3.2 Basic Equations

This section describe the basic equations for deriving the mathematical model for the hydraulic pressure drop losses in several items in internal flow system, include the pressure drop calculation in Pipes, Fittings, and Equivalent Length in Meters to calculate pressure drop and hydraulic profile for the system

3.2.1 Pressure Drop in Pipes Calculations

Pressure drop or head loss, occurs in all piping systems because of elevation changes, turbulence caused by abrupt changes in direction, and friction within the pipe and fittings. The most common methods used to determine the head loss in pipe are:

3.2.1.1 Hazen-Williams, Manning and Darcy-Weisbach equations

The suitability of each method depends on the type of flow (gravity or pumped) and the level of accuracy required. Due to the smooth inside surface and the resistance to corrosion, ADPF fiber glass pipes have a relatively low head loss as compared to other material pipes.

3.2.1.2 Hazen-Williams Equation

The Hazen-Williams Equation is applicable to water pipes under conditions of full turbulent flow. It has gained wide acceptance in the water and wastewater industries because of its simplicity.

$$v = 0.85\ C\ R\ 0.63\ J\ 0.54 \qquad (3.1)$$

Where:

v = velocity, m/s

C = Hazen-Williams Coefficient

R = Hydraulic mean radius, m

J = Hydraulic gradient, m/m

3.2.1.3 Manning Equation

The Manning equation typically solves gravity flow problems where the pipe is only partially full and is under the influence of an elevation head only.

$$v = (1/n)\ R0.667\ J0.5 \qquad (3.2)$$

Where:

v = velocity, m/s

n = Manning’s Coefficient

R = Hydraulic mean radius, m

J = Hydraulic gradient, m/m

3.2.1.4 Darcy-Weisbach Equation

It states that pressure drop is proportional to the square of the velocity and the length of the pipe. This equation is valid for all fluids in both laminar and turbulent flow. The disadvantage is that the Darcy-weisbach friction factor is a variable.

$$H = (f.L.v^2)/2.g.D \qquad (3.3)$$

Where:

H = Head loss, m

g = Gravity constant, 9.81 m/s²

v = Velocity, m/s

D = Inside diameter, m

f = Friction factor

L = Length of the pipe, m

The well-known Reynolds number equation is used to characterize the fluid flow.

$$Re = V.D / \nu \qquad (3.4)$$

Where:

ν= Kinematic viscosity, m²/s

The types of flow of fluid from the Reynolds number are:

Laminar Flow $Re \leq 2{,}000$

Transition Flow Zone $2{,}000 \leq Re \leq 4{,}000$

Turbulent Flow $Re \geq 4{,}000$

If the flow is Laminar,

$$f = 64 / Re \qquad (3.5)$$

If the flow is Turbulent, the friction factor can be determined from the Moody diagram found in most fluid mechanics texts or calculated from the Colebrook equation.

For transition flow the pressure loss across pipes will not be considered because steady state condition flow is only the actual cases in practices.

3.2.2 Pressure Drop in Fittings

Head Loss in Fittings is frequently expressed as the equivalent length of pipe that is added to the straight run of pipe as shown below. This approach is used most often with the Hazen-Williams or Manning's equations. The approach does not consider turbulence and subsequent losses created by different velocities.

3.2.3 Equivalent Length in Meters

When more accuracy is required, head loss in fittings can be determined using loss coefficients (K factors) for each type of fittings. In this approach K-factor is multiplied by the velocity head of the fluid flow.

$$H = K (v^2/2g) \tag{3.6}$$

Where:

H = Head loss, m

v = Velocity of flow, m/s

3.3 Valve Pressure Loss & Flow

The valve coefficient CV is a number which represents the capability of a valve (or any flow component) to flow a fluid. The larger the CV, the larger the flow at a given pressure differential, is determined by counting the number of gallons that pass through the valve with 1 psi applied pressure between the valve inlets the outlet at 0 psi.

CV factors typically apply to full open/full closed valves, e.g., solenoid valves, ball valves, etc. Valves held open without aid of pressure, CV does not apply to modulating or regulating valves, spring loaded check valves, etc.

3.4 Pressure Loss in Sand Filters

The International Center for Water Technology was contracted to test the pressure loss through selected sand media filters for the purpose of comparative analysis. Four different sand media filter designs, (all 48-inch (1.25 m) diameter tanks, were tested specifically for pressure loss through clean sand media. Sand media installed in all instances as prescribed by the relative manufacturers (Yardney &Fresno Valve filters included prescribed gravel). All filters were tested with #16 sand as the filtration-grade media.

The typical flow range for a typical 48-inch filter media tank, based on a flow through rate of 18-25 gpm per square-foot of surface area is 220 – 315 gpm.

This testing was done with clean media sand, backwashed for two minutes at 200 gpm, for Pump operated at 40-50 psi, the Test results are shown in Table 3.1.

Table 3.1: pressure loss across sand filters (International center for water technology (ICWT), sand filter testing, 2008)

Flow Rate	Pressure Loss Through Sand Filter (tank inlet-to-outlet)			
	LAKOS-SST	LAKOS-PRO-II	Yardney-SS	Fresno Valve-SS
240 gpm	0.88 psi	1.36 psi	1.21 psi	1.65 psi
260 gpm	1.21 psi	1.66 psi	1.63 psi	2.14 psi
280 gpm	1.54 psi	1.96 psi	2.07 psi	2.65 psi
300 gpm	1.90 psi	2.27 psi	2.53 psi	

All testing was performed with the same pumping, piping and instrumentation for accurate comparability. Flow rates were allowed to run for at least 5 minutes to achieve relatively constant flow-through characteristics.

Testing was performed to recognized standards and protocol. Note: All sand media filters tested were provided by Claude Laval Corporation, LAKOS Filtration Division.

3.5 Calculation Method and Data Analysis

The following steps will be conducted to calculate pressure loss for present model:

1. Derive a mathematical model that describes the hydraulic pressure drop loss for in internal flow system.
2. A computer program model will be developed using Visual Basic or other suitable language to describe the hydraulic pressure drop for the process piping network and equipment.
3. The program results data will be verified with commercial software which will be fed with the same input data as present model. The benchmark model will be a conventional compact water treatment unit with a capacity of $200m^3$/hr.
4. To study the effect of overall pressure losses of all water treatment compact unit components in the system, which include both performance and power consumptions.

Figure 3.2 shows the pressure drop calculations flow chart for compact units.

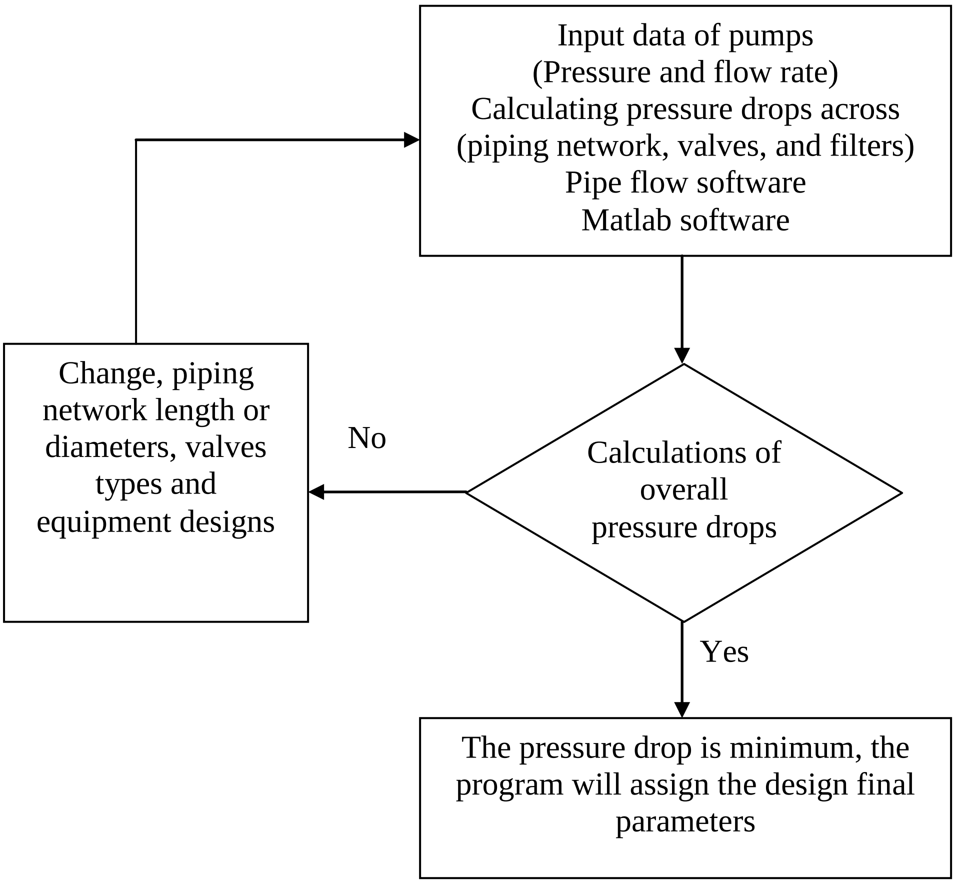

Figure 3.2: Pressure drop calculations flow chart for compact units

3.6 Pipe Flow Expert (software)

Pipe Flow is owned by Daxesoft Ltd, which is company registered in England, Pipe flow expert is software application for designing, and analyzing and solving flow rate and pressure drop in a pipe system using the Darcy Weisbach method and accurate Colebrook-White friction factors.

3.6.1 Pipe Flow Expert v6.39 2013

Pipe flow expert can model:-

- Both open and closed loop systems
- Multiple pump in series and in parallel
- Component: pipe, tank
- Pump: fix flow rate, fix head, curve with large pump database
- Fitting: Tees, Bends, pipe entry and exit
- Control valve: flow control, pressure control, back pressure
- Pressure loss component: fix loss, curve loss, CV, KV
- Multiple supply and discharge points
- Take in account gravity and change in elevation
- Fluid data base: varies liquids and gases
- Show date in different units: Metric, Imperial

Pipe flow expert can produce a result table that includes:

- Flow Rates
- Fluid Velocities
- Pressure Drops
- Reynolds Numbers
- Friction Factors
- Fitting Losses
- Component Losses
- Node Pressures
- Pump Operating Points
- Pump Head Added
- Pump Inlet Pressure
- Energy Usage Breakdown

These results can be saved on Excel sheet or on PDF file.

REFERENCES

Alsaffar A. M., and Zheng Y. (2007), *"Water Intakes - Sitting and Design Approaches"* Bechtel Corporation 9801 Washingtonian Blvd.Gaithersburg, Md 20878, Maryland, USA.

Cengel Y.A. and Cimbala J. M. (2006), *"Fluid Mechanics"*, McGraw Hill, Boston, MA.

Chuang Kuang Hong (2006) *"Development of A Decision Support System for Drinking Water Treatment Process Design (WATER-DSS)"*, Faculty of Civil Engineering,Universiti Teknologi, Malaysia.

Collins, R.F., and Jones, A.R., (2002) *"A New Method for Optimal Selection of Solar Pumping Systems"*, Kyocera Solar Inc.,7812 East Acoma Drive Scottsdale, Arizona.

Donald.S.M. (1990), "*Internal flow systems"*, volume 6 in the BHRA fluid engineering series.

EMERSON Process Mangment (2014), "*Valve sizing and selections"*, infocentral,@EmersonProcess.com.

Henryk Kudela (2012),*"Hydraulic losses in pipes*", Vitthal Khandagale.

International center for water technology (ICWT) (2008), " *sand filter testing"*.

Kate Taylor, Anthony G. S., Stuart R. and Martin S. (1999),*"The Prediction of pressure drop and flow distribution in packed bed filters"*, S&C thermo fluids Ltd ,the old tannery,kelston ,Bath, BA1 9AN,UK DERA Porton Down, Salisbury, Wiltshire, SP4 OJQ,UK.

Knodel[a] B. D. &. France[a] D.M, *"Pressure Drop in ice - water slurries for thermal storage application"*.

Mahir Dursun and Semih (2012), *"Application of Solar Powered Automatic Water Pumping in Turkey"*, International Journal of Computer and Electrical Engineering, Vol.4, No.2.

Matteo Nicolini (2010), *"Optimal pressure management in water networks: increased efficiency and reduced energy costs"*, Department of Chemistry, Physics and Environment, University of Udine, Udine, Italy. Friulian Journal of Science 14, 59-70.

McDonough J.M. (2004), *"Lectures in Elementary Fluid Dynamics: Physics, Mathematics and Applications"*, University of Kentucky, Lexington.

Mohammad A.M. and Entesar K.H (2010), *"Modeling of conventional Water treatment supply Treatment Plant"*, department of environmental engineering Babylon University, Iraq.

Mohammed Abdulwahhab, Niranjan K. I., Sadoun Fahad Dakhil (2013), *"Numerical prediction of pressure loss of fluid in a T-junction"*, Department of Marin Engineering, Andhra University,AP,India. Department of fuel & Energy, Basrah Technical College, Iraq.

Munson B. R., Young D.F and Okiisshi T. H. (1998), *"Fundamentals of Fluid Mechanics"*, John Wiley and Sons, Inc.

Nakayama Y. and Boucher R.F. (1999), *"Introduction to Fluid Mechanics"*, Butterworth Heinemann.

Paulus J. G. (2004), "*Diagnosing the Hydrodynamic Characteristics of A drinking Water Treatment Plant",* School of Engineering Faculty of Engineering, Physical Sciences and Architecture, The University Of Queensland.

Parsons, S. A. and Jefferson, B. (2006), *"Introduction to Potable Water Treatment Processes"*, School of Water Sciences Cranfield University, by Blackwell Publishing Ltd UK.

Petra Ross (2014), *"Optimization of Drinking Water Treatment Processes using models and on-line monitoring tools (Techneau)".*

Probeer Sahw and Prerna Gaur (2014), *"Photovoltaic powered Centrifugal Water Pump"*, International Journal of Electronic and Electrical Engineering .ISSN 0974-2174, Volume 7, Number 3.

Rickey T. P. E., Shafishuhaza S. and Norhaliza A. (2012), *"Modeling a/Waste Water Treatment Plant via System ID & Model Reduction Technique"* , IEEE Conference on Control, Systems and Industrial Informatics (ICCSII) Bandung, Indonesia. .

Ryan V. P. (2007), *"Solar-Powered Groundwater Pumping Systems for Domestic Use in Developing Countries",* Department of Civil and Environmental Engineering, Colorado State University, Fort Collins, Colorado 805231-1372.

Watts Water Technology (2014), *"Pressure Drop Basics & Valve Sizing",* http://www.powerscontrols.com/pages/pressureDrop.asp.

White F. M. (1999). *"Fluid Mechanics",* McGraw-Hill.

Munson B. R., Young D.F and Okiisshi T. H., "Fundamentals of Fluid Mechanics", John Wiley and Sons, Inc.

Worm G.I.M, Mesman G.A.M. , van Schagen K.M., Borger K.J. and Rietveld L.C. (2009), *“Hydraulic modeling of drinking water treatment plant operations”,* Drink. Water Eng. Sci., 2, 15–20.

Xiaoyu Yuan (2009), *“Model Validation and New Water Control Strategies in Drinking Water Treatment Plant Wim Mensink”*.