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DEVELOPMENT OF A TECHNICAL MANUAL FOR PUMPING INSTALLATIONS IN THE WATER INDUSTRY WITH EMPHASIS ON WATER SUPPLY SYSTEMS

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ABSTRACT

Pumping stations must be highly reliable, energy saving and economical, while at the same time their capital costs, operational and maintenance costs should be minimised. A technical manual for the multi disciplinary set of expertise who design, construct, operate and maintain pumping installations will help to achieve better performances. The objective of the manual is to impart knowledge on main plant and equipment, infrastructure and associated practical behaviour in pumping installations to those who design, construct, operate and maintain pumping installations. This manual covers planning, design, operation and maintenance aspects, main and ancillary equipment, and also practical behaviours. Chapter 1 has been devoted to discuss the important aspects of pumps needed for designers, operation and maintenance staff. Starting with the classification of pumps, the basics have been covered. Use of system head curves in different situations and affinity laws have been dealt with giving examples. NPSH has been dealt with critically. Pumps in series and parallel, effects of cavitation and recirculation causes of noise and vibration have also been covered. The importance of taking precautions to ensure proper design of sumps have been highlighted in Chapter 2. The adverse effects on pumps and its facilities that can result due to poor shapes and dimensions of sumps have been discussed. Basic dimensions, shapes, undesirable suction layouts and their improvements are provided to avoid mistakes. Chapter 3 summarises the guarantees and the acceptance tests for centrifugal pumps. This chapter will be useful mainly to those who are engaged in pump and other equipment testing and the approval of their performances. Chapter 4 is about pressure surges in pipe lines. The causes for pressure surges and different surge prevention measures have been discussed so that the most appropriate method for a given situation can be selected. A sample calculation has been included. Chapter 5 is on electrical equipment. Power supply and power factor, drivers, different starting methods, motor enclosures, motor protection, ratings and selection of motors, effect of temperature on life of motors, protection of electrical equipment etc. have been dealt with. Chapter 6 on pipe work valves and fittings will assist the Design Engineer to design and size the pipes and valves in pumping stations properly and the erection engineer. to install them. Recommended flow velocities and a comprehensive list of head losses in valves and fittings have been included. Chapter 7 is about basic planning and design aspects of pumping stations. Importance of minimisation of capital, operation and maintenance costs have been highlighted. Investigation procedures, selection of pump types, number of pumps, pump speed, layout of equipment, electrical facilities, positive and negative suction conditions have been discussed. Planning of electrical facilities and energy conservation have also been covered. Chapter 8 is about the civil engineering aspects of pumping stations. Importance of looking into civil as well as mechanical and electrical aspects have been highlighted. Chapter 9 deals on seven practical applications related to pumping stations. Vertical vs Horizontal pumps, performance of submersible pumps and methods of reducing energy costs, decision on whether to repair or replace the pumps, wear caused by sand in-intakes, choice of pump to suit system head, gland packing or mechanical seal are the areas covered. Chapter 10 covers the important points and how to size the ancillary equipment such as lime and alum pumps, blowers, chlorinators and overhead cranes. Different types of flow meters too have been discussed. Finally Chapter 11 summaries the aspects of operation and maintenance activities in a pumping station.

ACKNOWLEDGMENT

Although I had the intention of developing a technical manual on pumps even before the Post Graduate Course, this manual would never have emerged if not for the following people who persuaded and helped me in various ways. Dr. Sohan Wijesekera, who initiated me to continue with the Post Graduate studies and kept pressing to complete this work. Prof. (Mrs.) Ratnayake who persuaded me to continue with the Post Graduate studies and supervised my work with great interest and the necessary guidance. Mr. A.R.D. Attanayake, Mr. M.K. Hapuarachchi, Mr. J.V.G. Piyadasa, Mr. S.J.P. Wijegoonawardana, Mr. Nihal Fernando who assisted me in the proofreading of parts of the manual. Mrs. Geethani Weerasinghe who took a lot of pains in typing and editing the manual and all others who helped me in numerous ways. I am very thankful to all of them. I am also very thankful to the National Water Supply & Drainage Board and the University of Moratuwa for providing me with an opportunity to follow the post graduate diploma course leading to a MSc. Finally, my gratitude to my dear wife Chitra, for her patience, understanding and able assistance in advising and persuading me to complete this work.

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DEVELOPMENT OF A TECHNICAL MANUAL

FOR PUMPING

INSTALLATIONS IN THE WATER INDUSTRY

WITH EMPHASIS ON WATER SUPPLY SYSTEMS

1. INTRODUCTION.

A large capital is needed to design and construct pumping stations and further, day to day operation and maintenance costs will have to be borne to keep them running. Therefore these costs should be minimised, and while at the same time the pumping station should be highly reliable, energy saving and economical. To achieve these objectives the designers, operation and maintenance staff should have a good knowledge of all aspects of a pumping station. Work associated in pumping stations are of multi disciplinary nature. Therefore a technical manual on pumping installations was developed to help the Engineers to achieve better performance. The manual developed in this study is given as an Appendix to this thesis.

1.1. OBJECTIVE .

The objective of the development of this technical manual is to impart knowledge on main plant and equipment, infrastructure and associated practical behaviors in pumping installations to those who design, construct, operate and maintain pumping stations.

1.2. SCOPE .

The manual covers the main pumping equipment and associated works. Practical applications connected to pumping, ancillary equipment in pumping installations too have been covered. However, the structures plant and equipment in the treatment works are beyond the scope of the manual. The manual consists of eleven chapters as indicated below:

Chapter 1 - Introduction to pumps.

Chapter 2 - Hydraulic design of suction sumps.

Chapter 3	-	Guide to acceptance tests for centrifugal pumps.
Chapter 4	-	Pressure surges in pipe lines.
Chapter 5	-	Electrical equipment.
Chapter 6	-	Pipe work valves and fittings.
Chapter 7	-	Basic planning and design of pumping facilities.
Chapter 8	-	Civil engineering aspects.
Chapter 9	-	Practical applications.
Chapter 10	-	Ancillary equipment
Chapter 11	-	Operation and maintenance.
Annexures	-	1.1 to 10.2 and 11

2. LITERATURE REVIEW.

National Water Supply & Drainage Board's library has got many text book on various topics relating to the water industry. In addition to this there are different types of manuals and literature on different fields of water supply such as pumps, pipes and fittings, design, flow meters, dosing pumps electrical switch gear etc, published by various manufacturers. Some of these publications give specific information of their product range. However it is impossible to gather all the information and technical knowledge required for engineers who design construct operate and maintain pumping installations from a single manual or a text book. But it should be mentioned that these manuals and literature carry valuable information. In addition to the above, the author has used various literature that have been collected, hand books, related BS standards, the knowledge and experience gathered in developing this technical manual which covers the important aspects of a pumping installation.

Classification of pumps is important to understand different types of pumps and their applications.

Basic classification of pumps is generally found in text books and manuals. The Hydraulic Institute Standards (1983) and 'Karassik' and others (1989) give a detailed classification of both positive displacement and rotodynamic pumps. However Pumping Station

Engineering Hand Book (1991) simply classifies pumps according to the specific speeds without considering the applications. This may not give a good picture to a layman.

Basic definitions such as capacity, Head, Efficiency etc. are found in almost all text books and manuals but however their units of measurement vary. For example feet and meters, gallons, US gallons and m^3 etc. What is used in the manual are the ISO units as indicated in Pumping Station Engineering Hand Book (1991).

A detailed analysis of different situations of system curves are given in the technical literature published by Peerless Pumps (1977) and this will be very useful for practical applications. Basic affinity laws are found in all texts but the technical literature of the Peerless Pumps (1977) provide them along with the relations with size factor 'K' which is the ratio of the impeller diameters of the Prototype and the model. This is valuable in model testing of pumps.

Specific speed which is used to determine the type of pump is defined as $N * Q^{1/2} / H^{3/4}$. As the units used in US, UK, Japan and Germany vary, the values given for specific speed in text book and manuals vary. This can lead to confusions.

But the books published in Japan Eg: Kubota Pump Hand Book (1977) and also the Pumping Station Engineering Hand Book (1991) the measurement of flow is in m^3/min where as in other countries it varies. On m^3/min and meters basis, the specific speeds range from 100 to 2500 for Radial Mixed and Axial flow pumps. What is adopted in the manual for specific speed is this ISO range of values. The specific speed value formerly used based on hydraulic power out put is highlighted in the German KSB Manual (Undated). Their unit of measurement of flow is m^3/sec. and meters for head. Hence according to their units the specific speed ranges from about 10 to 300 over the range of impellers.

There are different views among engineers about the rotative speeds of pumps. High speed pumps are smaller, cheaper but wears quickly and emanates more noise and vibration. On the other hand slow speed pumps are large, expensive and long lasting. One can not decide the speed of the pump as he wishes. Maximum rotative speed of pumps are highlighted in the Hydraulic institute Standards (1983) in terms of $NPSH_A$. In the Pumping Station Engineering Hand Book (1991) and the Seminar Papers by Ebara Pumps Ltd. (1995) this aspect is highlighted in terms of Suction Head. This method is straight forward rather than calculating $NPSH_A$. This method has been adopted in the manual.

Definitions of NPSH and cavitation can be found in text books as well as in manuals but discussions on practical applications are limited. However 'Karassik' (1989) which is a question and answer format text book gives the details of the field test for NPSH. Technical literature published by Weir Pumps Ltd. (1988) gives practical aspects of the NPSH which are useful to the practicing engineer and are incorporated in the manual with examples. Further Pegson Pumps Ltd. (Undated) gives a method to obtain $NPSH_R$ curve, when the flow and impeller dimensions are known. However, author felt that this is not very important as all manufacturers generally provide $NPSH_R$ Curve.

Recirculation is a phenomenon generally not discussed and it is difficult to find in text books and manuals. However this phenomenon also brings about pulses similar to cavitation. Aspects of recirculation has been discussed in a paper published by 'Karassik' (1984). Recirculation has been discussed in the manual in brief as this must be understood by operational staff.

Noise and vibration of centrifugal pumps have been discussed in various publications. Technical literature published by Weir Pumps Ltd (1988) and Peerless pumps Ltd. (undated) have provided very useful information giving probable causes and methods of identification. What is included in the manual is a summary of these accounts necessary for the operational staff.

Pump components are manufactured from various materials to suit the application. What is indicated in the manual for various components of pumps are the materials recommended by pump manufacturers. The related BS standards are also have been indicated.

Most of the literature found on Suction Sumps are based on the basic information provided by Hydraulic institute standards (1983). A detailed analysis of suction sumps are found in both Pumping Station Engineering Hand Book (1991) and in the Seminar Papers published by Ebara Pumps Ltd. (1995). Basic dimensions for suction sumps as well as for different suction arrangements have been provided in the manual. In addition to this incorrect designs and their improvements have been discussed in both publications with diagrams. The important ones have been included in the manual to guide the design engineers.

Different countries follow different standards in the case of acceptance tests for centrifugal pumps. For example, in Germany DIN 1944 (issue 10.68) is in use and is given in SIHI Technical Manual. (1988). In Japan JIS (B 8301-1976) is in use and is given in the Kubota Pump Hand Book Vol. 1 (1977). Hydraulic Institute Standards (1983) also provides a test code for testing of centrifugal pumps. As the Water Board is following ISO test code the author has incorporated the important points of the ISO Class 'C' and 'B' acceptance tests based on ISO 2548 of 1973 to guide the engineers involved in pump testing.

Various studies have been done in different countries on the subject of pressure surges in pipe lines and computer software are available to solve complex situations. What is given in the manual is based on the graphical method given by 'Parmakian' (1963), the training literature received from Water Industry Training Association of UK (1988) and lecture notes prepared by 'Fleming' of Weir Pumps Ltd. (1983). The information provided in the manual will be useful to the design engineer to determine the surge effect and how to prevent it using the most appropriate method.

In the preparation of the Electrical sections of the manual, necessary guidance was obtained from the Senior Electrical Engineers of the Water Board.

Both KSB Design Manual (undated) and SIHI Manual (1988) recommend the same safety margins for different sizes of drive motors. Technical literature provided by 'Franklyn' motors (1988) gives a detailed account of the performance of submersible motors and pumps and how to prevent failures. 'Kosow' (1992) give how the life of electric motors are affected by the working temperature, type of enclosures and motor selection. These have been incorporated in the manual. Motor protections and the comparison of the performance of energy efficient motors with that of standard motors have also been included in the manual as indicated by motor manufacturers. GD^2 charts indicated by Pumping Station Engineering Hand Book (1991) have been included in the manual.

Technical Manual by 'Pont-A-Moussan' gives an account of pipes. 'Warring' (1984) gives the recommended flow velocities for suction and delivery pipes as indicated in the Hand Book of valves, piping and pipelines. The figures given in Kubota Pump Hand Book (1977) and Pumping Station Engineering Hand Book (1991) tally with the above figures. Two simple general equations are provided to estimate the suction and delivery pipe sizes. These have been included in the manual. Further authors experience on PVC and asbestos pipes with respect to NWSDB schemes have been indicated with examples.

Head loss in pipes can be calculated using different formulae. German books such as SIHI Manual (1988) and KSB Pumps Lexicon (1990) recommend Colebrook equation; where $1/f = -2 \log[2.51/Re\sqrt{f} + K/D + 1/3.71]$ for the simple reason that this equation covers the transition range between hydraulically smooth and hydraulically rough. However friction charts have been developed with K = 0.1 and for water at 12 °C. Therefore corrections will have to be done for Kinematic Viscosity at the correct water temperature in two stages namely for quantity and head. Then;

$Q = Q_x * 1.236/\nu$

Where Q in m^3/Hr and ν in mm^2/Sec.

Then after reading the head loss at this flow again from the charts head loss can be calculated by the formula

$H = H_v (\nu / 1.236)^2$ where ν is in the Kinematic Viscosity.

This is not a straight forward method. However Hazen Williams formulae charts are straight forward. The accuracy of the head loss value will depend on the assumed value of 'C'.

What is recommended in the manual is to use Hazen Willaims equation for raw and potable water pipe lines with a 'C' value of 120 as recommended by 'Karassik' (1986) and 'Colebrook' Equation for sewage because it covers the transitional range between hydraulically rough and hydraulically smooth.

Pumping Station Engineering Hand Book (1991) gives a step by step account of the basic planning and design procedures of pumping stations mainly for large irrigation works. On the other hand, Kubota Pump Manual (1977) gives the planning aspects of prime movers only. The author also consulted Senior Engineers in the planning and design division as well as others in formulating the Chapter 7 - Basic Planning and Design Aspects and Chapter 8 - Civil Engineering Aspects for which also the available literature is limited.

Reducing, rising energy costs should be handled from planning and design stage. Pumping Station Engineering Hand Book (1991) presents different methods available to reduce energy costs and also provides an indicator ($kWHr/m^3$) to monitor the energy consumption in pumping stations. Technical literature from Flygt Pumps (Undated) gives the variations of energy consumed when different number of pumps are used for different systems. These have been discussed and illustrated in the manual graphically.

Pump wear caused by sand in intake wells is not common only to Sri Lanka. This question had been raised and answered by 'Karassik' (1989). He has discussed this problem and has given the following recommendations.

(i). To use hard materials such as austenitic manganese steel or martensitic white iron as used in dredge pumps.

(ii). To coat the principal parts of the pump with natural rubber or neoprene.

(iii). To use slower speed pumps.

In the technical literature provided by Peerless Pumps (1977) this problem has been dealt with in a more detailed manner. However the final recommendations can be summarised to be same as above.

The knowledge on the subject of flow meters appears to be inadequate among engineering staff. 'Furness' (1990) gives an analysis of different types of available flow meters, their characteristics and applications. ISO 4064 of 1977 is the standard, NWS&DB was using for the purchase of water meters (both domestic and bulk). from 1997, second edition of ISO 4064 will be used. A summary of the comparison of BS 5728-1 of 1986 which was in par with ISO 4064 of 1977 and the BS 4064 of 1997 is given in the manual. Author has covered important aspects of the ISO in the manual but strongly recommends to go through both ISO standards.

3. CONTENTS

3.1 CHAPTER 1 - INTRODUCTION TO PUMPS

Pumps being the main equipment in a pumping station. Chapter 1 has been devoted to discuss the important aspects needed for designs, operation and maintenance staff. commencing with the classification of the pumps basics have been discussed.

The use of system head curves in different situations, an affinity laws have been dealt with. NPSH which is a vital factor, has been dealt with critically. Running pumps in series and parallel, the effects of cavitation and recirculation, the causes of noise and vibration have been discussed. Tables for vibration identification, likely causes and vibration severity levels have been included.

3.2 CHAPTER 2 - HYDRAULIC DESIGN OF SUCTION SUMPS

The importance of taking precautions to avoid mistakes in design of sumps have been highlighted and the adverse effects on pumps and its facilities that can result due to poor shapes and dimensions have been discussed. Basic dimensions, shapes, undesirable suction layout and their improvements have been included to avoid mistakes.

3.3 CHAPTER 3 - GUIDE TO ACCEPTANCE TESTS FOR CENTRIFUGAL PUMPS

This chapter has been designed as a short guide based on ISO code for Class C and Class B acceptance tests mainly for those who are engaged in pump and other equipment testing and the approval of their performances.

This chapter summarises the guarantees and the purpose of these tests. Permissible error percentages of measuring devices and different measured quantities, conversion of test results to nominal speed of rotation have been dealt with. Cavitation testing and the verification of guarantees for Capacity, Head and Efficiency have also been included.

3.4 CHAPTER 4 - PRESSURE SURGES IN PIPE LINES

Pressure surges can damage pipe lines and other equipment if they are not adequately protected. Different surge prevention measures have been discussed and tabulated against related variables to assist the design engineer to select the most appropriate device. At the beginning of this chapter, the main causes for a surge to develop and also the reflection of the pressure wave with time have been discussed.

Next, how to obtain graphical solutions using surge analysis charts taking into consideration the pump torque and speed variations have been discussed. Further a sample calculation has been included. Charts to calculate surge pressures and GD^2 have been included. Nomograms to illustrate the changes to code of practice have also been included.

3.5 CHAPTER 5 - ELECTRICAL EQUIPMENT

This chapter deals with basics of electrical engineering and the electrical equipment associated with the water industry. Starting with power supply, power factor and its improvements, different types of starters and their applications and, different types of drivers have been dealt with. Then the ratings and the selection of motors, effects of temperature on motors, different types of enclosures, system faults and motor protection, different degrees of protection of motors against foreign bodies and water have been discussed.

3.6 CHAPTER 6 - PIPE WORK, VALVES AND FITTINGS

This chapter will assist the design engineer to design and size the pipes and valves in pumping stations properly and the erection engineer to install them. Recommended suction and delivery flow velocities for different sizes of pipes have been included. A comprehensive list of head losses in valves and fittings in terms of $v^2/2g$ have been included to assist the design engineer.

3.7 CHAPTER 7 - BASIC PLANNING AND DESIGN ASPECTS

The importance of planning and design aspects has been highlighted. Cost minimisation and the reliability of the pumping station have been pointed out to the designers, construction and operations staff. Basics of investigation procedures with respect to intake and high lift pumping stations, areas to be covered and future demands have been discussed. Civil engineering aspects of planning, reliability, durability, safety, flexibility of pumping stations and environmental consideration have been covered. Under planning of pumping equipment, selection of pump types, determination of type of shaft, number of pumps, speed of pumps, layout of equipment and electrical facilities have been dealt with. Finally the importance of energy conservation has been dealt with.

3.8 CHAPTER 9 - CIVIL ENGINEERING ASPECTS

Often complaints are made by Electrical and Mechanical Engineers than Civil Engineers do not pay enough attention to their areas and the converse is also true when Civil Engineers are asked to achieve impossible structural designs.

Therefore the aim of this chapter is to provide those of a mechanical and electrical background with an insight to civil engineer's problems when designing a pumping station. The author has indicated that all civil, electrical and mechanical aspects should be looked into from the very beginning and the appointment of a Project Manager who understands all aspects of the project is of importance in the case of a major project. Finally importance of safety measures have been included.

3.9 CHAPTER 9 - PRACTICAL APPLICATIONS

This chapter deals with seven practical applications related to pumping stations which I think is of interest to those who deal with pumping stations. The topics are ;

* Vertical or horizontal pumps.
* Performance of submersible motors, pumps and bore holes.
* Reducing energy costs.
* Repair or replace the pump.
* Wear caused by sand in-intakes.
* Choice of pump to suit system head.
* Gland packing or mechanical seal.

3.10 CHAPTER 10 - ANCILLARY EQUIPMENT

In this chapter I have indicated the important points aspects and how to size the following ancillary equipment related to pumping station in brief.

* Lime and Alum dosing pumps.
* Blowers.
* Chlorinators.
* Flow meters.
* Overhead cranes.

3.11 CHAPTER 11 - OPERATION AND MAINTENANCE

This chapter summarises the importance of proper operation and maintenance. The requirement of trained personnel, stocking of necessary spares, proper tools and importance of record keeping have been highlighted. Importance of the operation of pumps at its best efficiency point and the requirement to follow the manufacture's instructions with regard to starting and stopping procedures have been pointed out. Further the operational problems that can arise due to mechanical, electrical and or hydraulic troubles have been discussed. Finally this chapter gives how preventive maintenance should be planned and carried out with respect to electrical and mechanical equipment and also to the necessity to monitor the pumping station efficiency.

3.12 ANNEX 11

Sample design calculations for a treated water pumping station are appearing in Annex 11.

4. ASSESSMENT OF THE MANUAL

4.1 METHOD OF ASSESSMENT

For the purpose of assessing the contents of the manual, a copy of the manual was circulated among eleven engineers along with a questionnaire (Annexure 1). The cross section of the persons among whom the manual was circulated are as follows.

No.	Designation	Division	Field of specialisation	Years of experience in water industry
1.	DGM	O&M	Electrical	> 15
2.	AGM	P&D	Civil	> 15
3.	AGM	O&M	Civil	> 15
4.	C.E	O&M	Mechanical	11 - 15
5.	C.E	O&M	Electrical	11 - 15
6.	C.E	O&M	Electronic	11 - 15
7.	C.E	P&D	Mechanical	11 - 15
8.	C.E	P&D	Civil	11 - 15
9.	C.E	O&M	Civil	11 - 15
10.	Engineer	RWS	Civil	> 15
11.	Engineer	P&D	Civil	> 5 < 10

4.2. RESULTS OF THE ASSESSMENT

The table below gives the levels of relevance and the interest of the engineers selected for the survey on the chapters of the manual.

Chapter	1	2	3	4	5	6	7	8	9	10	11
Relevancy %	82	64	64	36	64	82	46	46	73	73	73
Interested %	100	82	82	82	91	82	64	46	91	82	82

The table below gives the levels of adequacy, accuracy and usefulness as indicated by the engineers selected for the survey on the chapters of the manual.

	Chapter	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
	Insufficient	00	27	00	18	09	00	00	00	10	10	40
A	Sufficient	82	73	73	64	64	82	90	100	60	60	60
%	Excessive	18	00	27	18	27	18	10	00	30	30	00
	Poor	00	00	00	00	00	00	00	00	00	00	00
B	Moderate	22	56	22	44	37.5	22	37.5	43	25	14	62.5
%	High	78	44	78	56	62.5	78	62.5	57	75	86	37.5
	Not useful	00	00	00	00	00	00	00	00	00	00	00
C	Moderately useful	30	50	50	50	20	20	25	62.5	11	33.3	50
%	Very useful	70	50	50	50	80	80	75	37.5	89	66.7	50

A = Adequacy B = Accuracy C = Usefulness

All engineers indicated that there is a need for a manual on the subject of pumping installations and that this manual will be mainly useful to design operation and maintenance Engineers. Usefulness range from Deputy General Managers downwards. It was also revealed that engineers have to refer to various text books and manuals on the subject.

Mainly Electrical and Mechanical Engineers have indicated that areas like telemetry automation and electronics should have been covered in the manual. Inclusion of a sample design of a pumping station was another comment made.

4.3. DISCUSSION

From 4.2 it can be seen that the relevance is generally high except for Chapters 4, 7 and 8. Chapter 4 is the Pressure Surges in pipe lines. Generally in the Water Board Mechanical Engineers are of the view that it is the Civil Engineers work and vice versa. Hence automatically this has been reflected in the survey. On the other hand the interest of the engineers on this subject is very high. Therefore it is the authors view that an Engineer who has done Hydraulics or Fluid mechanics should handle this area.

Chapter 7 is on basic planning and design aspects and chapter 8 is on civil engineering aspects. All Electrical and Mechanical Engineers have indicated that these areas are not relevant to their work. The most probable reason for this situation is that Electrical and Mechanical Engineers are not involved at the planning and design stage. The author has pointed out in the manual that the aim of the Civil Engineers should be compared with those of Electrical and Mechanical Engineers from the very beginning to avoid conflicts at a later stage. The author's recommendation is that any project on pumping stations should be handled by a group of Civil, Electrical and Mechanical Engineers.

Adequacy has been rated sufficient by most of the Engineers. 40% of the Engineers have indicated that the contents in chapter 11 - Operation & Maintenance is insufficient where as 60% have indicated as sufficient.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

1. From 4.2 above, it can be seen that the relevance of the chapters in the manual is generally high.

2. Both Civil and Mechanical Engineers are of the view that pressure surges in pipelines are not relevant to their work. However, they all are highly interested in the subject.

3. Electrical and Mechanical Engineers are of the opinion that Planning and Design aspects are not relevant to their work.

4. Adequacy of the chapters in the manual has been rated sufficient by most of the Engineers.

5. From the contents of the manual and literature review, it can be seen that Sand problem in intake wells is a common problem in other countries also.

6. As highlighted in the manual. PVC and Asbestos pipes are very vulnerable to surges and fail prematurely due to fatigue. Hence, these pipes should not be used in pumping mains.

5.2 RECOMMENDATIONS

1. To achieve main objectives of a pumping station the designers, construction and operation staff should be well experienced and well trained. Junior engineers should be exposed to all fields of their deciplines and well trained prior to giving responsibility.

2. Strict specifications should be drawn out and technical proposals should be evaluated by competent personnel. Cheaper bids and expensive bids can be eliminated and only the remaining ones could be evaluated. However a policy for this method should be formulated.

3. All projects should be handled by a group of expertise and in the case of large projects project managers who can understand all areas should lead this team.

4. Proper planning and design aspects should be followed. Civil Engineering designs should commence only after pump designers decide on the pump type. This should not be done arbitrary but guide lines should be followed.

5. Energy costs are rising every year and the economic life of pumps are very much greater than their capital cost. Hence reducing energy costs from the planning and design stage is must. High efficiency pumps should be selected depending on the application. Energy efficient motors should be specified against standard motors. Evaluations should be based on both capital and operational costs.

6. There are areas such as surge analysis where the knowledge of engineers are limited but it is not proper to ask bidders to give a proposal when the engineer is not fully competent. The knowledge of engineers in these areas should be strengthened by providing them with training.

7. Mistakes done in the past should be analysed discussed and corrective action should be taken to avoid such mistakes.

5.3 RECOMMENDATION FOR FURTHER STUDY

Inclusion of a chapter on electronics, telemetry automation and remote operation is a need to make this manual complete. However this is a specialised exercise on electronic and electrical engineering. The author recommends that Electrical and Electronic Engineers contribute their valuable services to add another chapter to this manual.

Annex 1

Development Of A Technical Manual For Pumping Installations In The Water Industry – Questionnaire For Assesment.

1. Designation

DGM	AGM	CE	ENG.

2. Division

O&M	P&D	CONST.

3. Field Of Specialisation

Civil	Elect	Electro	Mech

4. Year Of Experience In Water Industry

0 – 5	6 – 10	11 – 15	> 15

5. Need Of A Manual On Above Subject

High	Low

6. What Do You Refer To At Present On Above Subject ....

7. Please Indicate The Chapters Relavant To Your Work And Or Of Interest To You

Chapter	Relevant To Work	Interested
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		

8. Please Indicate Your Opinion On Adequacy, Accuracy and Usefulness
f This Manual To Water Board Engineering Staff By Putting 1, 2 or 3 carefully.

a). Adequacy : 1 – Insufficient, 2 – Sufficient, 3 – Excessive.

b). Accuracy : 1 – Poor And Need A Lot Of Improvement.

2 – Moderate And Need Some Imporvements.

3 – High And No Imporvement Needed.

c). Usefulness : 1 – Not Useful, 2 – Moderately Useful.
3 – Very Useful.

Chapter	Adequacy	Accuracy	Usefulness
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			

9. To Whom Do You Think That This Manual Will Be Useful.
(You May Tick More Than One Box)

DGM	AGM	CE	Engineers			Any Others Please specify
			Design	O&M	Const.	

10. Any Other Areas That Should Have Been Covered In The Manual

....

11. Any Other Comments :

....

Thank You Very Much For Spending Your Valuable Time On This.

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TECHNICAL MANUAL

FOR

PUMPING INSTALLATIONS

IN THE WATER INDUSTRY

WITH EMPHASIS ON WATER

SUPPLY SYSTEMS

BY

L.S.P.J. DE SILVA

MARCH 1997

PREFACE

How is the subject matter treated? For whom is it suitable? May be two questions you might ask when you see a new manual.

My aim is to present a sound but a simple treatment on pumping installations for Water Board Engineering staff, who design, construct, operate and maintain pumping installations.

No previous knowledge of the subject is assumed but fundamentals of engineering have been used. A summary of the subject matter is appearing under the abstract. Much of the material in this is taken from other manuals, technical bulletins, equipment manufacturer's technical literature and related standards.

Great care has been taken to check the manuscript but errors may be discovered. I shall be thankful if these are brought to my notice. I also invite views and suggestions and a critical analysis regarding the subject matter presented in the manual so that improvements can be made.

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NOTATIONS

H	-	Total Head (m)
H_d	-	Delivery Head (m)
H_s	-	Suction Head (m)
$\frac{V^2_d}{2g}$	-	Velocity Head in delivery side (m)
$\frac{V_s^2}{2g}$	-	Velocity Head in suction side (m)
g	-	Acceleration due to gravity ms^{-2}
Q	-	Capacity (m^3/Hr), (m^3/min), (m^3/sec)
ρ	-	Density (kg/dm^3)
P	-	Power (kW)
η_p	-	Pump Efficiency (%)
η_m	-	Motor Efficiency (%)
η_o	-	Overall Efficiency (%)
η_G	-	Gearing Efficiency (%)
BEP	-	Best Efficiency Point
H_f	-	Friction Head (m)
N	-	Speed (RPM)
$NPSH_A$	-	Net Positive Suction Head Available (m)
$NPSH_R$	-	Net Positive Suction Head Required (m)
N_s	-	Specific Speed (RPM)
S	-	Suction Specific Speed (RPM)
$NPSH_{crit}$	-	NPSH Critical (m)
σ	-	Thoma's Cavitation Constant
H_{vp}	-	Saturated Vapour Pressure (m)
RMS	-	Root Mean Square
a	-	Wave Velocity (m/s)
V	-	Velocity (m/s)
E	-	Young's Modulus (kgf/m^2)
D	-	Diameter (m)
L	-	Length (m)
GD^2	-	Moment Of Inertia (kgm^2)
e	-	Pipe Thickness (m)
P	-	Number Of Poles
A	-	Cross Sectional Area (m^2)
PN	-	Nominal Pressure (Bar)
DN	-	Nominal Diameter (m)