

# **WORLD HEALTH ORGANIZATION**

**(East Mediterranean Region)**

## **SEMINAR**

**ON**

**PREVENTIVE MAINTENANCE OF PIPED WATER SUPPLY SYSTEMS**

**AMMAN-JORDAN**

**MARCH 22-27, 1986**

WORLD HEALTH ORGANIZATION  
( East Mediterranean Region )

SEMINAR  
ON  
PREVENTIVE MAINTENANCE OF PIPED WATER SUPPLY SYSTEMS

AMMAN , JORDAN

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BACKGROUND PAPERS AND OTHER COURSE MATERIAL

Prepared By  
Y. D. MISRA

WORLD HEALTH ORGANIZATION

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SEMINAR ON PREVENTIVE MAINTENANCE OF PIPED  
WATER SUPPLY SYSTEM

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BACKGROUND PAPERS AND COURSE MATERIAL

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1. Need for a Preventive Maintenance Programme.
2. Implementation of a Preventive Maintenance Programme.
3. System Design and Preventive Maintenance.
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6. Preventive Maintenance and Water Quality.
7. Guide Lines on Preparation of Tender Specifications  
of Pumping Plants, Selection and Standardization  
etc. Parts A and B.

## NEED FOR A PREVENTIVE MAINTENANCE PROGRAMME

### 1. INTRODUCTION

Need for Preventive Maintenance is well established "Prevention is better than cure". Advantages of Preventive Maintenance are also well known. These include :

- (a) Economic Benefits
- (b) Stability in supply
- (c) Increased life of Plants
- (d) Reduced Downtime
- (e) Safety of Plants and Operators
- (f) Ensuring quality of water
- (g) Efficient Working
- (h) Management's confidence ( in ensuring safe, efficient and uninterrupted Water Supply )
- (i) Consumer's Satisfaction

In short, for any Water Supply Scheme, Preventive Maintenance is an 'Absolute Necessity'. It is a 'Pre-requisite'. 'Wait a complaint' system of Maintenance has no place in Modern Management.

### 2. PREVENTIVE MAINTENANCE OF WATER SUPPLIES - A PRIMARY HEALTH CARE

Publications reveal that about 40% of the diseases in the developing countries are water borne. Water supplied by ill-maintained piped water supply systems, quite often, is partially or wholly either unsatisfactory or suspicious. Such schemes are sometimes implemented with the help of other countries or UN agencies. Writer has seen reports where in some cases donor countries/Agencies have felt that if this is condition of maintenance, it was better if they had not contributed in construction of these schemes. Preventive Maintenance of these water supply schemes will go a long way in enabling these plants to produce and supply water of acceptable quality and in turn reduce water borne diseases. Good Preventive Maintenance is in fact - 'A Measure of Primary Health Care' United Nations Agencies like WHO, UNICEF and several donor countries are giving substantial assistance, technical and financial to various developing nations to promote 'Primary Health Care'. There are reasons to believe that once Piped Water Supply System ensures supply of water of reasonably good quality, primary health of people is automatically taken care of to quite some extent. Thus, only construction of new water supply projects is not sufficient, its proper maintenance specially Preventive Maintenance is essential to improve health of people.

### 3. PRE-REQUISITES TO PREVENTIVE MAINTENANCE

Soon after commissioning of a new water supply scheme, its preventive maintenance should start. In case Preventive Maintenance is started of an old scheme, rehabilitation of existing works is a pre-requisite. Experience has shown that in many countries (Specially developing ones), Water Supply Plants/Works/equipment some times :

- (a) Are damaged beyond reasonable repairs.
- (b) Have outlived their life, but are found to be still working inefficiently with frequent breakdowns.
- (c) Are undersized.
- (d) Have in-adequate instrumentation and metering.

Before practising a good preventive maintenance programme, it is necessary to rehabilitate all such plants/ works/equipment after identifying them. Where-ever necessary additional works be done and instruments/meters provided. A programme can be designed which may include preparation of inventory of all such items. Necessary works in respect of these must be done for a result oriented preventive maintenance programme to follow.

### 4. OTHER PRE-REQUISTIES

- (a) Staff recruited for operation and Maintenance should be intelligent, qualified, trained and knowledgeable.
- (b) Their professional status should be regularly improved through proper training and Refresher Courses.
- (c) Adequate Funds.
- (d) Controlled inventory of spare parts, consumable and Servicing material, tools and instruments.
- (e) Proper Recording System.
- (f) Good House Keeping.

It has been realised at every level that newly constructed systems, how-so-ever well designed and constructed must be maintained well to ensure safe, efficient and uninterrupted water sypply to people. But at the same time it must be accepted that it is possible only when their basic design is good and these have been constructed with best material and high workmanship. Design and construction should be such so that its maintenance is simple and could easily be done by the local staff available. Large sums of money have been spent and will be spent in future also for constructing new water supply schemes. It is essential that immediate consideration is given through such seminars to ensure their maintenance and

correct the existing condition of malfunctioning of several plants in various countries.

## 5. COMPONENTS OF A PIPED WATER SUPPLY SYSTEM

Every item of a piped water supply system needs preventive maintenance. These need be identified and categorised for working out convenient systems and programmes. for correct identification and categorization, inventory of individual water supply schemes is necessary. However, in absence of that, a general list covering surface, sub-surface and ground water supplies is given below. Those not applicable in respect of scheme or a group of schemes can be deleted.

### 6. 1 Surface water supplies with full or partial Treatment.

This includes

- (a) Intake works
- (b) Raw Water Pumping Machinery including Electrical and Appurtenant works.
- (c) Machines for Alum dosing and other connected equipments
- (d) Sedimentation Tanks and Clarifloculators
- (e) Rapid Sand Filters
- (f) Slow Sand Filters
- (g) Chlorinating Machines
- (h) Clear Water Reservoirs - underground, semi sunk and elevated.
- (i) Clear Water Pumps and associated equipment
- (j) Transmission Mains and Distribution system - Pipe Lines, Valves, fittings, etc.
- (k) Water meter and metering equipment
- (l) Quality control gadgets and apparatus

### 6. 2 Ground and sub-Surface water supplies include wells both Shallow and deep, springs and infiltration galleries. Springs are natural and general hygienic conditions have to be maintained and water quality constantly monitored. Following will have normal preventive maintenance programmes :

1. Open Shallow Wells
2. Tube Wells
3. Infiltration galleries.

Other items in such schemes can be selected from list 6.1

## **7. WATER SUPPLY AND SANITATION DECADE**

We are passing through the water supply and sanitation decade. A large number of projects both for drinking water supply and sewerage are being designed and constructed the world over. Unless there is awareness and determination for their proper operation and maintenance, schemes constructed will not deliver benefits for which these are meant.

## **8. CONCLUSION**

Advantages of Preventive Maintenance have been described above. Looking to its importance and its impact over health of people, it is both timely and appropriate to discuss ways and means of supplying more and better drinking water to people by practising Preventive Maintenance.

## IMPLEMENTATION OF A PREVENTIVE MAINTENANCE PROGRAMME

### 1. INTRODUCTION

Need for a Preventive Maintenance Programme having been established, problem before us is how to implement it. Ways and means of implementing a programme will depend on size and type also. Field conditions and individual constraints play an important part and have to be taken into account. It is a continuous process on basis of which breakdowns can be foreseen and anticipatory repairs and replacements done. For implementing these programmes, motivation should be from the highest level. Looking to its importance, incentive need be given to those associated with the programme. The main idea of this paper is to classify and quantify work to be done and describe the methodology.

### 2. PREVENTIVE MAINTENANCE PROGRAMME

Implementation of a Preventive Maintenance Programme requires careful planning and preparatory work. It includes :

- (a) Classification of Water Supply Units
- (b) Developing a team of Trained Personnel
- (c) Preparing System Design and Preventive Maintenance Manuals
- (d) Making inventory of items required
- (e) Information and Data Collection
- (f) Record keeping system

2.1 Size of a Water Supply Unit is a major consideration in deciding whether preventive maintenance programmes should be unitwise or in some other way. While large schemes will have to be divided into districts/areas (if not already divided to facilitate their management), the smaller ones should be clubbed together to form a reasonable Maintenance Unit. Broadly following can be adopted :-

- (a) Large Schemes - Divide into Districts/Areas (Number will depend on size and type of scheme)

Alternatively, divide into following stages of Water Supply System :

- I. Intake Works
- II. Production of Water
- III. Distribution System



- (b) Medium and small schemes - Make one programme for each
- (c) Very small schemes - Make Groups (Number will depend on size and type of scheme)

## 2.2 LOCAL RESOURCES AND EXPERTISE

For implementing a preventive maintenance programme, local availability of resource and expertise is necessary. A report on Saudi Arabia mentions that when breakdowns occur, repairs are usually not made unless a community is completely out of water. In this event, contractors from Riyadh are hired at considerable expense. In some cases larger communities have hired foreign technicians to run their systems, but this has not been successful since they stay for short periods. All this has been attributed to lack of emphasis on developing local resources and expertise. For ensuring proper operation and maintenance (including preventive maintenance) of public water supplies, the first problem before the Municipal Officials is the availability of 'Trained Personnel'.

2.3 System Design and preventive maintenance manuals have been dealt within the next paper. Adequate inventory of spare parts, T & P (Tools & Plants), and necessary consumable items are required to be arranged in advance.

## 3. IDENTIFICATION AND INVENTORY

After Preventive Maintenance units have been established as per procedure indicated in 2.1 inventory of each scheme has to be prepared. For very small schemes 'FORM-1' is recommended. For small, medium and large schemes, more than one format will be required. For sake of demonstration four forms have been designed 2, 3, 4, 5. These forms may not fit in a particular scheme, but can be of assistance to the participants in preparing these for their individual needs.

## 4. RECORD KEEPING

A proper system need be designed for keeping Preventive Maintenance record. This matter has been included in the paper on System Design.

## 5. PROCESS OF IMPLEMENTATION

For discussing the process of implementation, it will be better to consider each stage of the system mentioned in 2.1. Alongwith this a decision has also to be taken about formation of Preventive Maintenance Teams - and whether there should be separate teams doing only this work or this work should be got done by routine Maintenance and repair crews. Probably in most of cases, it may be considered better to have separate teams. These separate teams will have a pre-assigned work. Where the utility is very small and independent it may even be sufficient to get Preventive Maintenance work done by the crew doing normal repairs and maintenance work. So there are three ways of doing this work.

- (1) A Separate crew may do the Preventive Maintenance work of several small schemes.
- (2) Depending upon size, there may be one or more Teams to carry out Preventive Maintenance work in the Utility.
- (3) In individual cases it may be found to be more appropriate to get the Preventive Maintenance works done by the regular repairs and maintenance gangs. If necessary, these gangs can be strengthened.

**6. CONCLUSION**

Above process for implementation of Preventive Maintenance Programmes having been finalised for each scheme or a group of Schemes, Systems will have to be designed for executing them and this is a subject for discussion of next paper.

## SYSTEM DESIGN AND PREVENTIVE MAINTENANCE

### 1. INTRODUCTION

System Design means Systematization. Systematization of any work is important and more so of Preventive Maintenance. One thing more, how-so-ever well the system may have been designed, it will not work unless there is will and determination. A Water Supply System needs constant maintenance. Maintenance staff have to keep a vigil and surveillance of the whole system, and ensure regular inspections. Frequency of maintenance varies, from hourly to yearly and in some cases even three yearly.

### 2. SYSTEM DESIGNS

This work should consist of the following:

- (a) Classification and Inventory
- (b) Information and Data Collection
- (c) Identification of jobs and keeping record of work done.

2.1 For Classifying the various items and preparing their inventory. Forms prescribed in the earlier paper are to be adopted with necessary modification as per requirement in individual cases.

2.2 Information and Data Collection should include:

- (1) Complete specification of the machinery and equipment.
- (2) Addressee of Manufacturers/Dealers/Suppliers of various machinery, equipment, spare parts, chemicals, Tool and Plants, Consumable items etc.
- (3) Addressee of firms/parties who can take up critical repairs-Emphasis should be given on local resources.
- (4) Continuous flow of information regarding inventory to management.
- (5) Backfeed information from field.

### 3. RECORDING SYSTEM

One of the most important items of work is keeping a proper record of preventive maintenance done and to keep a watch whether they are being done as per time schedule. Simultaneously, on each machine/Equipment/Appurtenant work, what jobs are to be performed and checks made has to be identified. It is recommended that comprehensive cards be prepared in which maintenance jobs required to be done be specified and those done recorded datewise. These cards may be called Preventive Maintenance Cards or 'PM Cards'. Items for which these <sup>cards</sup> need be maintained will vary from scheme to scheme. In general, PM Cards, for the following are suggested:-

- (1) Diesel Engines
- (2) Transformers
- (3) Electric Motors
- (4) Oil/Air Circuit Breakers
- (5) Starters
- (6) Pumps
- (7) Clariflocculators
- (8) Chlorinators
- (9) Bleaching Powder Dozers
- (10) Sluice/Non-Return Valves/Pen Stocks
- (11) Clear Water Reservoirs
- (12) Air Blowers/Compressors
- (13) Production Meters
- (14) Fire Hydrants/Scour Valves
- (15) Air Valves
- (16) Distribution System

Note: Special System Design is being recommended for Distribution System.

- 3.1 Experience has also been shown that if a record of Breakdown maintenance is also simultaneously kept. It is very valuable. This has been incorporated. Hence these PM Cards will also serve as running record on work done whether Preventive or Corrective. One side of the card lists hourly, monthly, six monthly and yearly PM jobs/checks, while other side has a proforma for recording works done.

#### 4. **METHODOLOGY**

Preventive Maintenance is required to be done in practically all the items of a Piped Water Supply System. But certain items like moving machinery, Alum Dozers and Chlorinators wear fast. These should be identified and PM Cards prepared for them. In small Water Supply Schemes, it is not necessary to design a code numbering system; but for large ones it is necessary. For code numbering separate design is being made available.

- 4.1 For remaining items a separate system Design is being recommended.

#### 5. **RECOMMENDATION**

Since it is a Seminar, it will be premature to list recommendations. A document on the recommendations of the Seminar based on the discussions held will have to be prepared.

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East Mediterranean Region -

PM CARD NO.

Seminar of Preventive Maintenance  
Ma rch 22 - 27, 1986

Water Supply Scheme :

Statement of Preventive/ Breakdown Maintenance

Done on Diesel Engine No.: DEN

Year of Installation

Total Number of Hours Run

Specifications of Engine

| Date | Description of Work Done | Initials of Technician who did the work | Signature and Remarks of the Engineer |
|------|--------------------------|---|---------------------------------------|
|      |                          |   |                                       |

## DIESEL ENGINE :

- Hourly** : Keep constant watch ever sound, abrupt change in temperature, leakage of fuel etc. and any other abnormality.
- Check lubricating oil, top up if necessary  
Check that the cooling system is in order and free from obstructions.
- Monthly** : 1. Clean Air Cleaner.  
2. Check outside nuts, bolts, etc., for tightness ( The cylinder head nuts must not be tightened when the engine is hot.)  
3. Check fuel system for leaks.  
4. Clean deposits from exhaust system.  
5. Lubricate the bearings and grease all nipples.
- Six Monthly** : 6. Check the valve clearance and adjust if necessary.  
7. Fit new oil filter.  
8. Fit new air cleaner element ( Paper element type )  
9. Drain sump, flush and refill with new oil if dirty.
- Yearly** 10. Clean the fuel tank.
- Two yearly** 11. Decarbonize  
12. Check the crank sheft bearings and renew if clearance is excessive.

**Note :** The above maintenance recommendations are for average operating conditions. Under very heavy duty conditions, air cleaners, lubricating oil and fuel filters will require more frequent attention.

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PM Card No.

Seminar on Preventive Maintenance  
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STATEMENT OF PREVENTIVE/ BREAKDOWN MAINTENANCE

Name of Scheme \*

Clariflocculator No. CIF

Capacity of Clariflocculator

Make And Other Specifications

Year of  
Construction

| Date | Description of work done | Signature of Technician who did the work | Signature & remarks of Engineer |
|------|--------------------------|--|---------------------------------|
|      |                          |  |                                 |

## CLARIFLOCCULATORS

- Hourly : Check whether System working or not  
Record timings of desludging in Log Sheet
- Monthly : 1- Lubricate/ Grease Bearings, Trolley  
Wheels  
2- Check Reduction Gears, Top oil if  
necessary  
3- Check alignment and grouting of rails  
4- Check condition of Rubber Tyres of  
Wheels (if used)
- Six Monthly : 5- Check condition of Steel Tyres  
(if used)  
6- Check turn table Mechanism, Lubricate  
and do Oil topping if required.
- Yearly : 7- Down the clariflocculator, check chains,  
sprockets, gear boxes  
8- Check steel frame under water  
9- Check scraper blades; Tighten Blade  
Nuts; Repair or Replace wasted/  
corroded/ rusted Blades  
10- Paint all the steel work and equipment.  
Portion under water be done with special  
paint suitable for water submerged  
steel frames.

NOTE : For Preventive Maintenance of Motors same  
action be taken as given in Cards for Motors.



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Name of Scheme

Statement of Preventive & Breakdown  
Maintenance of Transformer No.

Capacity ( KVA and Voltage Ratio )

Year of  
Installation

| Date | Description of work<br>done | Initials of<br>Technician<br>who did the<br>work | Signature and<br>Remarks of the<br>Engineer |
|------|-----------------------------|--|---|
|      |                             |  |   |

## Transformers

|             |   |
|-------------|---|
| Monthly     | Make General Inspection and check Silica Gel.<br>See if there' is no spilling of Transformer Oil  |
| Six Monthly | Top up Transformer Oil, Check Temperature Gauge, Ventilating Pipe and Tap changing Device.<br>Check Terminal Boxes - Both H.T. and L.T.<br>If there is any melting out of compound, open and redo the joints. |
| Yearly      | Check Dielectric Strength of oil. Centrifuge or change if and as necessary.<br>Tighten Bolts and Nuts. Check if earthing is intact. Change Silica Gel before rainy season.                                    |
| 5 Yearly    | Take out core, Check windings repair if necessary, over haul clean and reset.   |

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Name of Scheme

PM Card No.

Statement of Preventive and Breakdown  
Maintenance done on Electric Motor No.

Year of  
Installation

Specification of Electric Motor

| Date | Description of<br>work done | Initials of<br>Technician<br>who did the<br>work | Signature<br>and Remarks<br>of the<br>Engineer |
|------|-----------------------------|--|--|
|      |                             |  |  |

## Electric Motor

- |  |  |
|--|--|
| Daily (Hourly<br>or<br>Once in<br>3 Hours) | (a) Keep watch over sound/ vibrations, changes in current and voltage, Temperature and sparking or over-heating of slip Rings. |
|  | (b) Record following on log sheet.   |
|  | (i) Current  |
|  | (ii) Voltage   |
|  | (iii) Power Consumption  |
| Weekly                                     | (a) Check and tighten foundation bolts.  |
|  | (b) Check all Terminals, Contacts, Sliprings and Carbon Brushes. Carry out necessary cleaning Repairs/ Replacements.           |
|  | (c) Check Coupling alignment and bolts.  |
|  | (d) Examine Bearings, Clean, Oil / Grease.   |
| Monthly                                    | (a) Blow out dust with Air Blower  |
|  | (b) Check if earthing is in-tact   |
|  | (c) Check Air Gap  |
|  | (d) Check if rotor is free   |
| Two Yearly                                 | (a) Completely disassembly the motor, clean, replace defective/wornout bearings, carbon brushes and holders etc.               |
|  | (b) Blow out, clean, revarnish, dry and reassemble totor and stator.   |

Note :- After 10/15 years or after a number of repairs windings of statator and Rotor become undependable due to long life and weathering effect. It is then desirable to cut the old winding and provide new windings.

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Name of Scheme

PM Card No.

Statement of Preventive and Breakdown  
Maintenance done on Pump-Centrifugal No.

Specification of Pump-Centrifugal

Year of  
Installation

| Date | Description of<br>work done | Initials of<br>Technician<br>who did the<br>work | Signature and<br>Remarks of the<br>Engineer |
|------|-----------------------------|--|---|
|      |                             |  |   |

## Pumps Centrifugal

Daily (Hourly or  
Once in 3  
Hours)

- (a) Keep audio, visual check on sound, vibrations, leakage from glands (glands should be so tightened that about 30 to 40 drops leak per minute) gauges on suction and delivery sides. Check temperature specially of bearings and glands by feel. Note following observations on log sheet.
- (b) Readings of gauges on suction and delivery sides.
- (c) Readings of Flow Meters - Indicating, Integrating, Recording.

Weekly

- (a) Check by hand free movement of Pump and Motor assembly.
- (b) Check alignment of coupling, Rotating Assembly
- (c) Check Gland Packing, Replace in necessary.
- (d) Check and tighten if necessary coupling and Foundation bolts.
- (e) Ensure that Lubrication system at every place, whether by oil or grease, is working properly. Check all grease cups and Lubricating oil chambers. Top up replace as necessary.
- (f) Clean Foot Valve.

Monthly

- (a) Check all valves on suction and delivery side including sluice, Non Return, Butterfly valve for smooth operation, effective closing and opening, leakage from gland.
- (b) Check accuracy of all gauges and flow meters. Adjust if necessary.
- (c) Open Inspection cover in the Pump casing (if provided) and take out boulders or foreign matter entangled in impeller or casing.

Six Monthly

- (a) Check wear and tear of Bearings, bushes, sleeves. Replace/Repair as necessary.
- (b) Observe shut off pressure.

Yearly

- (a) Make a thorough general inspection of the Pump
- (b) Test performance of the Pump as given in Schedule-II.
- (c) In case (a) and (b) demand, open the Pump completely, clean, replace/ repair defective parts. Impeller, shaft, sleeves, sealing water system, bearings, wearing rings, stuffing boxes should be carefully examined.

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Name of Scheme

Statement of Preventive and Breakdown  
Maintenance of Borehole Turbine Pumping Set No.

Specification of the Pump Set

Year of  
Installation

| Date | Description of<br>work done | Initials of<br>Technician<br>who did the<br>work | Signature and<br>Remarks of the<br>Engineer |
|------|-----------------------------|--|---|
|      |                             |  |   |

## Borehole Turbine Pumping Set

Daily (Hourly or  
3 Hourly)

Apart from filling of following inlog sheet watch lubrication system. The pump may be oil/ water lubricated. In oil lubricated pumps, oil should drop @ 2 - 3 drop per minute.

- (1) Voltage and Current
- (2) Depth and Pressure gauges.
- (3) Water Meter if any.

Weekly

- (1) Check Gland sealing, replace packing if required.
- (2) Check and tighten foundation bolts.
- (3) Check moving and fixed contacts of starter and switch. Repair / Replace as necessary.

Monthly

- (i) Check the Impeller settling and do re-adjustment if necessary.
- (ii) Have a check on the amount of tensioning required on the shaft tubes.
- (iii) Clean and grease motor bearing.
- (iv) Check leveling of discharge head.
- (v) Blow out Motor.

Yearly

- (1) Re-do the tube tensioning. Conduct performance test, if performance is much below the original test figures, carry out complete over hauling of the Pump and Motor. Worn out parts be replaced.



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Name of Scheme

Statement of Preventive and Breakdown  
Maintenance of Submersible Pumping Set No.

Year of  
Installation

Specification of the Pump Set

| Date | Description of<br>work done | Initials of<br>Technician<br>who did the<br>work | Signature and<br>Remarks of the<br>Engineer |
|------|-----------------------------|--|---|
|      |                             |  |   |

## Submersible Pumping Set

Daily (Hourly or  
3 Hourly)

Keep watch and note in log sheet :-

- (1) Current
- (2) Voltage
- (3) Depth and pressure gauges

Significant change in sound be analysed.

Weekly

- (1) Check starter specially the over load relay.
- (2) Check Moving and fixed contacts of starter and Switch. Repair/ Replace as necessary.

Monthly

Check Sluice and non-return valves for proper functioning.

Yearly

- (1) Conduct performance Test. If necessary take out the Pumping Plant. Dismantle it. The moving parts of motor and pump be checked and replaced if required.
- (2) Examine Bearing and Thrust Plates. Replace if necessary. Re-adjust the imp-ellers and coupling.

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Name of Scheme

PM Card No.

Statement of Preventive and Breakdown  
Maintenance done on Chlorinator No.

Year of  
Installation

Specification of Chlorinator

| Date | Description of<br>work done | Initials of<br>Technician<br>Arrange to<br>look well | Signature and<br>Remarks of the<br>Engineer |
|------|-----------------------------|--|---|
|      |                             |  |   |

Gaseous Chlorinators (Pressure/ Gravity/  
Vacuum Type)

- |                               |  |
|-------------------------------|--|
| Daily (Hourly or<br>3 Hourly) | <ul style="list-style-type: none"><li>(a) Keep check over leakage of chlorine from joints and cocks by using Liquor Ammonia White fumes of Ammonium chloride are indication of leakage.</li><li>(b) Ensure adequate supply of water to chlorinator.</li><li>(c) Note following in Log Sheet.<ul style="list-style-type: none"><li>I. Rate of chlorine doze in Kg/hour and Low Pressure Gauge.</li><li>II. Weight of cylinder in case it is on weight Bridge.</li></ul></li></ul> |
| Weekly                        | <ul style="list-style-type: none"><li>(a) Check working of solutionizer Tower/ Injector.</li><li>(b) Turn cylinder valve and ensure its working.</li></ul>   |
| Monthly                       | <ul style="list-style-type: none"><li>(a) Check Moisture Trap, Replace fill if necessary.</li><li>(b) Check safety equipment and let operators under go the drill in use of safety apparatus.</li></ul>  |
| Six Monthly                   | <ul style="list-style-type: none"><li>(a) Full servicing of the equipment, including examination of daphrams, filters, washers, Nuts, High Pressure Pumps, Electrical equipment etc.</li></ul>   |
| Yearly                        | <ul style="list-style-type: none"><li>(a) Replacement of weathered Hoses.</li><li>(b) Dismantle solutionizer Tower, clean and reassemble.</li><li>(c) Open valves and other Parts. Reassemblable after Servicing.</li><li>(d) Paint external parts.</li></ul>  |

## PREVENTIVE MAINTENANCE OF DISTRIBUTION SYSTEM

### 1. INTRODUCTION :

Broadly, Water Supply System consists of Intake works, Treatment works and Distribution System. But for the consumer, it is the Distribution System which is the most significant. Public demand for more and better water is increasing every day. It is, therefore, necessary that this part of the water supply system is given due importance and care. The same Distribution System, if well operated and well maintained will provide better service to public. Continuous or uninterrupted supply is always preferable. But problem is how to achieve it.

### 2. Preventive Maintenance Programme.

Maintenance of a Distribution system is carried out in two parts, corrective and preventive. For improving the status of water supply, it is the Preventive Maintenance which is important. It requires identification of certain jobs which need be done in a systematic and regular way. For example, in a system where number and frequency of leakages is high, a scientific study is necessary to identify the causes and make a time scheduled programme for rectification of defects and shortcomings in the existing system. Leakages occur due to failure of pipes and their joints. Causes of 'More and Frequent Leakages' are :-

- (1) Joints not made properly or poor workmanship.
- (2) Less cushion over pipes.
- (3) Inferior quality of pipes.
- (4) Pipes damaged due to internal and external corrosion.

This is generally due to ~~corrosive~~ action of water it

carries or soil in which these pipes are laid.

- (5) Improper design.
- (6) Other causes of failure of pipes and joints include water hammer, absence of thrust blocks, metal fatigue, vibrations due to traffic, sinking of pipes line due to beam action, improper operation.

2.1 Main components of distribution system apart from service Reservoirs are mentioned in 'FORM 5' - Inventory of Main Items of Distribution System. But before designing a programme for preventive maintenance of distribution system, it is necessary to have a detailed plan showing :-

- 1. Complete network of pipeline system, showing size of pipelines, length of segments, type of pipes used.
- 2. Reduced levels at several and relevant places.
- 3. Location and details of water reservoirs.
- 4. Location and size of ~~service~~<sup>sluice</sup> valves, non return valves, Air Valves, Fire Hydrants, Scour Valves, Dead Ends.
- 5. Boosters / Zonal Pumping Station.
- 6. Stand Posts.
- 7. Water Pressure in distribution system during morning and evening peak hours.

Description of pipelines should be as under :-

Length in Meters/ Diameter in mm/ Type of pipe used.

Normally following pipes are used in distribution network :-

- (a) Cast Iron with lead joints.

- (b) Ductile Iron/ Cast Iron with Tyton joints.
- (c) Asbestos cement pipes with detachable joints.
- (d) PVC/ HDP Pipes.
- (e) Steel mains
- (f) Prestressed concrete pipes.
- (g) R.C.C. Pipes
- (h) G.I. Pipes mostly used in House Connections. For example in a distribution system a segment PVC of pipe line 520 Meters long, 150 mm in diameter should be shown as :-

520/150/(d)

## 2.2 Testing of Pressure Pipes

The field test pressure to be imposed should be not less than the greatest of the following :

- (i)  $1\frac{1}{2}$  times the maximum sustained operating pressure ;
- (ii)  $1\frac{1}{2}$  times the maximum pipeline static pressure ; and
- (iii) sum of the maximum sustained operating pressure or the maximum pipeline static pressure and the maximum calculated surge pressure

subject to a maximum equal to the works test pressure for any pipes and fittings incorporated in the pipe line. The field test pressure should wherever possible be not less than two-thirds of the works test pressure appropriate to the class of pipe except in the case of spun iron pipes and should be applied and maintained for at least 4 hours.

Where the field test pressure is less than two-thirds the works test pressure, the period of test should be increased to at least 24 hours. The test pressure shall be

gradually raised at the rate of nearly 1 kg/cm<sup>2</sup>/min. In the case of spun iron pipes, the hydrostatic test pressure after installation is to be adopted instead of the works hydrostatic test pressure which is 35 kg/cm<sup>2</sup> uniformly for all classes of pipe.

Hydro Static Test pressure at field after installation is generally 1/2 to 2/3 of Hydro Static Test pressure at works, but duration is many times more, sometimes 4 to 24 hours instead of 15 to 35 seconds at works. If pressure measurements are not made at the lowest point of the section, an allowance should be made for the static head between the lowest point and the point of measurement to ensure that the maximum pressure is not exceeded at the lowest point. If a drop in pressure occurs, the quantity of water added in order to re-establish the test pressure should be carefully measured. This should not exceed 0.1 litre per mm of pipe dia per km of pipeline per day for each 30 m head of pressure applied.

The allowable leakage during the maintenance stage of pipes carefully laid and well tested during construction, however, should not exceed

$$qL = \frac{ND}{115} \frac{P}{P}$$

where.

$qL$  = allowable leakage in lpd ;

$N$  = number of joints in the length of the pipeline ;

$D$  = diameter in mm ; and

$P$  = average test pressure in kg/cm<sup>2</sup>

This figure is applicable to spigot and socket CI



pipes and AC pressure pipes, thrice this figure may be taken for steel and prestressed concrete pipes.

- 2.3 Jobs to be carried out as a part of this programme are :-
- (a) Regular inspections of distribution system. For this an inventory of jobs to be done is necessary. Programme should be so arranged that each segment along with its valves and specials be inspected once a week.
- (b) Though inspections be done weekly, but all the things need not be noted every week. Observation to be made can be divided as under :-

- Weekly
- (i) Observe leakages on pipelines, stand posts, Fire Hydrants, Air Valves etc.
  - (ii) Check Pressures at critical predetermined points. (These points will serve as base in subsequent studies/ surveys). Investigate in case change is significant.
  - (iii) Study Water Level records in Reservoirs . Take preventive measures in case of serious deviations.
  - (iv) Check if water level and other gauges and meters are in working order.
- Monthly
- (i) Open Scour Valves and Flush the system.
  - (ii) Flush dead ends (Fire Hydrants be provided at dead ends).

- Six Monthly
- (i) Inspect reservoirs and other civil Engineering structures
  - (ii) Check Bulk meters and repair/ calibrate, if necessary.
  - (iii) An inventory be prepared of out of order consumer meters. Those considered damaged or defective be replaced/ repaired.
- Yearly
- (i) Carry out waste control drill.
  - (ii) Carry out Leak Detection Survey
  - (iii) Assess unaccounted for water.
  - (iv) Measure 'C' Valve in selected sections of Pipeline net-work where pressure drop appear high.
  - (v) Clean and disinfect water Reservoirs and paint date of cleaning.
  - (vi) Cleaning pipe lines with a view to remove incrustation, tuberculation, slime growth and deposit of Sediments. Normal methods employed are :-
    - (a) Mechanical cleaning by using steel springs or Polyurethane foam swabs.
    - (b) By using chemicals including chlorine.
    - (c) Pressure flushing
    - (d) By using compressed gas. Observations made be noted on proforma enclosed as appendix.
- 2.4 By practising pipe cleaning, C. Valve in certain cases is increased from 5.5 to over 100. In bigger diameter pipes cement lining increased 'C' Valve substantially and it proved that it was much more economical to cement

line the pipes than laying a supplementary main or to replace the old main with a new and bigger main. Study about possibility of achieving economy by cleaning, cement lining and by special treatment like 'Calgon Treatment' should i.e. Treatment with sodium Hexameta phosphate ( W a P O 3 )<sub>6</sub> should form an important part of Preventive Maintenance. There is no scope here of describing these methods. Sufficient literatures is available describing these processes and their possible advantages.

### 3. Leak Detection and Waste Control

In every distribution system, some per centage of water remains unaccounted for. If it is upto 15%, it is reasonable, but any thing beyond 25% is serious and calls for immediate measures to check leaks and wastage. Unaccounted for water is just like disappearance of money from pocket.

### 4. Detection and Location of Leakages

Surface leakages can be observed visually while for underground (not visible on surface) leakages we need equipment and apparatus. The various methods adopted are :-

- (a) By observing visually
- (b) By sound (Aqua phone or Battery Operated) Leak detector.
- (c) Using chemicals like Nitrous Oxide
- (d) Use of Electronic leak detectors
- (e) Using Radio Isotopes.

- 4.1 Regarding methods of Leak Detection an extract from World Health Organization Project Report No. INDIA 0176: 03, Bombay is attached as annexure to this document.

#### Methods of leak detection

The methods of assessment of waste discussed so far will generally give an indication of the vicinity of the leakage, the accuracy depending on the detail of the investigation. It is then necessary to locate the actual leak position before repairs can be undertaken.

It is necessary to know the exact pipe alignment before leak location can be undertaken.

Several methods are available for leak location, generally dependent upon detection of the sound generated by the escaping water.

Sounding, the process of locating a leak by maximum intensity of sound, may be carried out by direct or indirect methods.

- |          |                       |
|----------|-----------------------|
| Direct   | - on pipe or fittings |
| Indirect | - on ground surface   |

#### Leak noise

Water generates noise in escaping through a hole and plays against surrounding material. Local erosion may form a cavity around the pipe above or below free water level.

Noise is set up as a result of the following factors :

(a) Turbulence through the orifice producing mechanical vibrations in the pipe.

- (b) Jet turbulence through the orifice or in the cavity.
- (c) Water hitting sides of the cavity.

Experimental work at WRA has shown that for a jet leaking into stones, the jet break-up noise is transmitted through soil and into the pipe at medium frequencies. Direct sounding is best here, since higher frequencies are attenuated through soil.

For a jet leaking into water, jet break-up noise is reduced but cavitation produces high frequency noise. This is best heard on the pipe i.e. by direct sounding. Depth of cover affects higher frequencies by linear attenuation and lower frequencies are less attenuated. Unfortunately traffic noise may also be at low frequencies. In practice the nature of the surface, tarmac, paving blocks, cobbles, setts etc., has a greater effect than the depth of cover on the transfer of sound.

Since leaks may occur in any condition, it must be accepted that leak noise is covered by a wide band of frequencies.

Taking these considerations into account and adding comments related to equipment, the factors affecting the performance of leak detection by acoustic methods may be summarised as follows :

- (i) Character of noise at source, especially the frequency spectrum.
- (ii) Depth and type of ground cover causing variable attenuation of frequencies.
- (iii) Extraneous noise ; traffic has random frequency, but other types of interference may be more easily

identified when using ear only.

- (iv) The contact of any pick-up with the surface affects frequency response.
- (v) Pick-up design ; both mechanical and electrical.
- (vi) Amplifier characteristics and internal noise level.
- (vii) Indicating method, meter or earphone.

It is interesting to note that factors (i), (ii) and (iii) are those over which an operator has little or no control. The remaining four factors can be made constant to some extent when for instance, one operator always uses the same piece of equipment. Hence the apparent success of certain equipment is often due to the skill and constancy of skill and handling procedure of the operator concerned.

#### Equipment and methods

##### Stethoscope or sounding rod

This is a traditional method, the use of which entails considerable skill, but the leak must be audible. The leak noise transmitted to surface or pipe fitting is transferred to the operator's ear by using some form of 'stick' made of iron, steel etc. A typical example used by Bombay Municipal Corporation consists of a 4 ft. long, half-inch diameter mild steel rod, fixed with a

cup like shape brass cap of 2" diameter at one end. In severe cases air transfer is sufficient, i.e. the sound can be heard without any aid. In the WRA's and CPHERI's and BMC's experience, it has been established that a skilled inspector can accurately locate the position of a leak in 80% of cases, using a sounding rod.

#### Electronic amplifying devices

These instruments detect and amplify the noise level. Certain frequency ranges can be chosen to amplify the leak noise selectively or filter out some unwanted noises. However, this equipment is also susceptible to extraneous noises. It will treat them in the same manner as the leak noise, possibly increasing the unwanted noise internally in the instrument. Examples of this equipment are the 'M.Scope', Terroscope and Detektron.

#### Method of use of sounding rod and electronic equipment

Once a section of water main has been established as leaking through step test checks location of the leak is carried out by sounding along the main. In U.K., such a sounding traverse is carried out by direct sounding on hydrants, stop-cocks, until the approximate position is determined. Then local indirect sounding

on the ground surface is made to pin point the position. In Bombay the practice has been to carry out a sounding traverse along the line of the main at about three feet intervals on the ground surface.

It happens occasionally that the high velocity of flow in pipelines creates a hissing noise which may be mistaken for a leak. In such conditions the sounding traverse is made along the length of the pipe to determine if the noise persists. If it does it is unlikely to be due to leakage.

Generally the use of sounding rods alone will enable a leak position to be pin-pointed, but it is frequently necessary to follow up with electronic equipment to determine the exact leak position.

Following street location by metering and step tests, the location of a leak is first indentified as a 'service' or 'main' leak if it is not otherwise possible to pinpoint it by maximum sound intensity. Sounding is carried out on consumers stop-valves, first with them open and then closed. If the sound continues after closing, this indicates that the leak is on the main. If the sounding ceases on closing, the leak is occurring beyond the stop valve.

Pin-pointing of the exact location is carried out by further sounding to identify the position of maximum sound intensity.



### Nitrous oxide

Nitrous oxide is used as a tracer to locate leaks in water mains, of large and small diameters, which cannot be traced by traditional techniques. The gas is mixed with water in the main and is released at points of leakage. It is then detected using special portable equipment. Detailed description of this technique is given in Appendix C.

### Cut and cap

With this procedure, the main is isolated from all other connections and water is supplied to the main from a meter. The main is cut and capped in the centre. If flow still continues the leak lies between the meter and the end cap ; if the flow through ceases, the leak is downstream of the centre capping.

The process is repeated with successive sub-division of the main into even smaller sections. In some cases, a valve is cut into the main instead of capping it.

An alternative may be to freeze the main instead of cutting and capping it.

### Correlation technique (LINDA)

This is a technique which has been developed by the WRA which is used where sounds can be heard which give no indication of the exact location of the leak. It is not currently available as a routine procedure but has been

proved on site.

The technique isolates the specific sound pattern of the leak and determines its time of arrival at various points along the main.

Sound recordings are made simultaneously on a multi-track tape recorder from several points on the main. The time lag between the same sound pattern on any two tracks is obtained by correlating (multiplying together and integrating) one tape with another. This results in the formation of a correllogram. When a series of correllograms has been obtained along the main it is possible to find the position of the leak by means of a graphical construction.

#### Halogen compounds

The main is filled with air dosed with a substance containing one of the halogens, normally carbon tetrachloride or freon and the escaping gas is detected by a sensitive commercial instrument.

One of the problems is the danger of introducing gas under pressure into a main, especially where a high pressures are necessary to make the leak apparent. A 115 or 230-volt power supply is required for the detection equipment.

#### Other methods

Much of the skill associated with leak detection is

not only a matter of intelligent handling of equipment. The operator's knowledge of the geography and environment of an area often contribute to the efficiency of detection. The following is a typical list of points of evidence which, directly or indirectly may lead to location of a leak.

Knowledge of other services crossing the line of the main.

Recent excavations to other services.

Discolouration of walls/buildings.

Moss on walls.

Uneven road surfaces, discolouration.

Uneven pavements.

Recent severing of supply to old services.

Hydrants recently used by contractors, fire brigades etc.

Loss of supply or pressure reduction to adjacent premises.

Radioactive tracers can be used which are very sensitive, but at operational levels of radioactivity present health hazards.

Any distribution system has a large number of joints.

Even after taking all possible measures, some leakage will occur through it. Upper limit of such leakage is taken as 250 gallons/day/inch dia/pipe/mile.

##### 5. Waste Control

Wastage in distribution system is through is because of several reasons. Prominent among these are :-

1) Leakages in pipe lines of the undertaking.

- 2) Leakages in service connections, abandoned mains and through valves, ferrules, hydrants etc.
- 3) Unregistered connections.
- 4) Faulty and damaged meters.
- 5) Wastage of water through unmetered connections (Paying fixed charges).
- 6) Theft of water.
- 7) Through stand posts.

5.1 Leak detection and waste control is in itself a vast subject. Leakages deteriorate status of water supply and drains off valuable revenues of the Water Undertaking.

Further it leads to :

- i) 'Poor Maintenance due to Lack of Revenue'.
- ii) 'Water Shortage and Low Pressure'.

5.2 There are various methodologies being practised.

But the main principle is the same i.e. unaccounted for water is equal to difference between water produced and water for which undertaking gets revenue. For carrying out these studies, distribution system is divided into Zones and Sub-zones.

Zone - Is a part of the distribution system which has hydraulic boundaries, generally created because of geographical conditions.

Sub-zone - A Segment of distribution Zone which can be Segregated hydraulically by closing Sluice Valves.

Generally, study for assessment of 'wastage' or 'unaccounted

for water' is done sub-zone wise. Various type of meters are used to measure/ assess incoming flow into the Sub Zone. Water supplied to various consumers through meters and to unmetered consumers is measured/ assessed as accurately as possible. Evaluation of wastage is done as under :-

$$\% \text{ Wastage} = \frac{\text{Wastage as assessed in 24 hours} \times 100}{\text{Total flow into the System in 24 hours}}$$

#### 6. Case Study

To get an idea about the benefits achieved by implementing a 'Leak detection and Waste Control', programmes, results achieved in Bombay can be quoted :-

#### WORKS DONE IN BOMBAY

Bombay Municipal Corporation, M/s Binnie and Partners and CPHERI had jointly carried out an investigation in Napean Sea Road area of Bombay. The highlights of a case study are brought out in brief.

Napean Sea Road zone is fed by a 12' dia. outlet from Malabar Hill reservoir. The age of the main ranges from 70 to 110 years. The pressure survey showed considerable drop and hence this was selected for a case study.

Napean Sea Road zone has 7½ hours supply and hence night flow measurement was not possible. The study was limited upto municipal limit for waste assessment and leak detection.

Zone was divided into five sub-zones and the waste assessment was carried out independently in each sub-zone

by revenue by pass meter. After waste assessment the pipe alignment, leak detection and repairs were carried out and the zones were again tested for final loss.

| SUB ZONE     | Initial Loss<br>(gals/in dia./<br>mile/day | Final Loss<br>(gals/in dial/<br>mile/day). |
|--------------|--|--|
| 1ST SUB ZONE | 7,170                                      | 4,780                                      |
| 2ND SUB ZONE | 6,140                                      | 1,205                                      |
| 3RD SUB ZONE | 73,000                                     | 6,280                                      |
| 4TH SUB ZONE | 75,600                                     | 4,210                                      |
| 5TH SUB ZONE | 3,680                                      | 3,440                                      |

Test results show that there is remarkable improvement in the water loss in subzones 3rd and 4th. It was observed that these losses are attributed to (i) leakage on disused connections, (ii) unregistered connections, and (iii) underground leakage of main pipe and at ferrule connections."

#### 7. Economics of Waste Control

There is a problem in dealing with this issue accurately. Identifying and evaluating in figures all benefits accrued and expenditure incurred is difficult. But this should not stop us from making as accurate assessments as possible. Assessments of benefits is also problematic. Suppose in a system supplying 10 mld water, it has been possible to save 1 mld. Saving of water is 10% . But

it does, in all cases, mean that after implementing the programme, revenue will increase by 10% or expenditure decreased by 10%. If undertaking purchases bulk water, then there may be a saving of nearly 10%, but in case raw water is free, savings will be equal to the cost of Electricity used for pumping and chemical used for treatment apart from some improvement in terminal pressures due to reduced draw off in the areas where leakages were heavy.

#### 8. Metering

Preventive Maintenance of water meters used on consumers' connections is important to ensure proper billing and collection. There should be a programme for replacing defective and worn out meters and also for correcting inaccurate ones. Experience has shown that poor installation conditions and tampering of meters have been the main reasons in some countries for defects and damage in water meters. Standardization of installation of meters and educating public together with choice of proper design of meter will be effective in meeting the situation. Use of wet dial water meters will reduce tampering.

8.1 At the end of each month the Meter Reader will furnish a statement of defective/ damaged/ inaccurate meters in proforma enclosed. It will be better if all these meters are taken out and in their place new/ overhauled tested meters installed. Meters taken out from

consumers connections should be sent for repairs. But taking out old meters, sending them for repairs should be properly recorded in Meter Ledgers.

#### 9. Record and Record Keeping

Keeping adequate record in a scientific way is an integral part of system designed for Preventive Maintenance of a Water Supply Scheme. Records provide an excellent document to know things done and to be done. PM records till when maintenance was last done, when time for next check is approaching. This enable maintaining a pre-determined schedule to ensure that nothing is forgotten and left undone.

9.1 What records are to be maintained is mentioned in discription already made. These records should be carefully preserved and filed in a systematic way so that they can be available when required. Maintenance of these records costs little, but these are of great value subsequently.

#### 10. Formation of Preventive Maintenance Teams

This depends on several factors specially size of the Water Supply Undertaking and their number in case of small schemes. In large undertakings several Preventive Maintenance Teams will have to be formed. Whether this team is entrusted with the work of Breakdown maintenance or not will again depend on Volume of work involved. This procedure will help Preventive Maintenance as per schedule. Say in a medium size Scheme with 100 MLD supply for a population of say 4000,000 and having conventional Treatment System, Preventive Maintenance may preferably



be done separately at following places :-

1. Intake works and Raw Water Pumping Station.
2. Treatment works and Clear Water Pumping Station.
3. Distribution Systems.

(a) Boosters and Zonal Pumping Stations.

(b) Pipeline net work.

10.1 Teams may consist of following. These teams can do Preventive Maintenance for 2 weeks and during the remaining part of the month do Breakdown or other maintenance jobs.

1. Intake works and Raw Water Pumping Station.

|                 |   |
|-----------------|---|
| Electrician     | 1 |
| Filter Mechanic | 1 |
| Helpers         | 2 |

2. Treatment works and Clear Water Pumping Station.

|                 |   |
|-----------------|---|
| Electrician     | 1 |
| Filter Mechanic | 1 |
| Helpers         | 2 |

3. (a) Electrician

(b) Helper

(b) Plumber

Mechanic

Helper

10.2 Since number of Installations and area will be large in case of 3, team 3 (a), may probably be able to cover all Booster / Zonal Pumping Stations in 2 weeks, but team 3 (b)

may remain busy through out the month. Teams 3 (a) and 3 (b) will also require transport. Teams which are required to do preventive as well as Breakdown maintenance, may do preventive maintenance on a different day if some breakdown occurs.

10.3 These teams must be equipped with (a) proper tools and testing meters, (b) ordinary spares like contacts of electric switches, carbon brushes, (c) material like, pig lead, lubricating oil, grease, emery paper, electric tape.

10.4 For small schemes like rural water supply a circuit will have to worked out in which preventive maintenance of say 7 to 10 Schemes could be done in a week. For remaining days the team could either be given another circuit or deployed on other overhauling/ repair work.

10.5 Size of Teams and time indicated above is for checking and doing minor jobs. If, however, inspection reveals that some major jobs/ repairs are to be, in that case more staff and time shall be required. This extra staff may either be drawn from other sections, or temporary hand recruited for a specific time or job be got done on contract. All jobs done must be recorded on PM Cards.

10.6 For obtaining satisfactory end results first a firm conviction in the management about the urgent necessity of Preventive Maintenance Programmes and then strong will to implement them are necessary. Experience has shown that without this even the best of plan will not work.

World Health Organization  
East Medeterrian Region

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Seminar on Preventive Maintenance

(March 22 - 27, 1986), Amman -

Preventive Maintenance of  
Distribution System

Name of Scheme

Description of Zone/Sub Zone

Average Daily Water Supply in MLD

---

| Date | Description of<br>work done | Initials of<br>Technician<br>who did the<br>work | Signature of<br>Engineer | Remarks |
|------|-----------------------------|--|--------------------------|---------|
|------|-----------------------------|--|--------------------------|---------|

---



## Code Numbering System

### 1. INTRODUCTION

As mentioned in para 4 of System Design and Preventive Maintenance, code numbering is necessary for large water supply schemes. In Small Schemes, it is not essential. In large schemes, first the system as a whole has to be divided into stages :-

1. Intake Works.
2. Treatment Works
3. Main Pumping Stations.
4. Distribution System.

Code 1, 2, 3, 4 be given in numbers of various items contained in each of the above works. Main coding may be done as shown on Annexure attached 'Code Numbering System'.

### 2. Detailed Code Numbers

At works specified by 1, 2, 3, 4 there is a large number of each item. For example, Sluice Valves and Pumps are present at each work and that also many in numbers. All these have to be numbered systematically :-

(a) Sluice Valves at Intake Works -Number as below :-

1/SV/1

1/SV/2

1/SV/3

.....2

(b) Sluice Valves in Zones of Distribution System -

Number as below :-

4/I/SV/1

4/I/SV/2

4/I/SV/3

2.1 As has been mentioned earlier Inventory Forms are a model. Identification numbers and Code Numbers could even be same. Once code numbering system has been established, in the Inventory Forms also instead of Identification numbers codes could be used.

2.2 As far as possible all machinery and equipment should be painted with these code numbers to facilitate day to day working.

Code Numbering System

| Item       | Abbreviation      | Intake Works<br>1  | Treatment Works<br>2 | Main Pumping Station<br>3 | Distribution System |                      |                   |                   |
|------------|-------------------|--------------------|----------------------|---------------------------|---------------------|----------------------|-------------------|-------------------|
|            |                   |                    |                      |                           | Zone I<br>4/I       | Zone II<br>4/II      | Zone III<br>4/III | Zone IV<br>4/IV   |
| Tubewell   | TW                | 1/TW               | -                    | -                         | 4/1/TW              | 4/II/TW              | 4/III/TW          | 4/IV,             |
| Bar Screen | BS                | 1/BS               | -                    | -                         | -                   | -                    | -                 | -                 |
| Sump Well  | SW                | 1/SW               | -                    | -                         | -                   | -                    | -                 | -                 |
| Foot Valve | FV                | 1/FV               | -                    | 3/FV                      | -                   | -                    | -                 | -                 |
| Pump       | PM                | 1/Pm               | 2/Pm                 | 3/Pm                      | 4/I/Pm              | 4/II/Pm              | -                 | 4/IV,             |
| Motor -LT  | <u>Mt</u><br>LT   | <u>1/Mt</u><br>LT  | <u>2/Mt</u><br>LT    | -                         | <u>4/I/Mt</u><br>LT | <u>4/II/Mt</u><br>LT | -                 | <u>4/IV</u><br>LT |
| Motor -HT  | <u>Mt</u><br>H.T. | <u>1/Mt</u><br>H.T | -                    | <u>3/Mt</u><br>H.T.       | -                   | -                    | -                 | -                 |

Note : If item has two words, use 2 Block Letters for abbreviation. If item has only one word, use first letters in Block and other in Small.

## PREVENTIVE MAINTENANCE AND WATER QUALITY

### 1. INTRODUCTION

In spite of all efforts made to produce pure, safe and wholesome water through conventional treatment viz. Coagulation, filtration and disinfection, there are chances of secondary pollution in the distribution system.

Common causes of pollution in the distribution system are:

### 2. INTERNAL AND EXTERNAL CORROSION

Consumers' service pipes are mostly of galvanised iron. Quite often these pipes pass through waste water. Internal corrosion is due to aggressive nature of water while external corrosion is caused by corrosive action of soil and waste water through which pipes often pass.

### 3. LEAKS

Leakages in pipelines develop because of number of reasons. During non-supply hours waste water from the drains etc. enters into the pipelines.

### 4. DEAD ENDS AND STAGNATION

If the distribution net work is not properly designed and operated, and water remains stagnant, deterioration in water quality occurs. In such cases slime growth is caused.

### 5. INTERMITTENT SUPPLY

Water utilities with intermittent supply have comparatively frequent complaints of deteriorated water quality when supply begins. Vacuum created in the pipelines during off hours leads to back siphonage. Sometimes " No water pressure " occurs in pipeline due to power failures.

#### 5.1

In view of the above, Under Preventive Maintenance Programmes, with protection of consumers' communication pipes by P.V.C. or C.I. casing pipes, this problem of contamination can be controlled. Frequent checking of distribution system, timely repairs, scheduled sampling for bacteriological examination and overall monitoring will be effective in ensuring supply of good quality water. Similarly, surveillance of raw water resource and necessary chemical and bacteriological analysis done in a scheduled manner, will help checking stream pollution.



(2)

5.2 The frequency of collection of samples, for bacteriological examinations, to be collected from the distribution system, depending upon the population, should be as follows:

| Population served | Maximum interval between successive sampling | Minimum No. of samples to be taken from entire distribution system. |
|-------------------|--|---|
| Upto 20,000       | One Month                                    | One Sample per 5,000 of population per month.                       |
| 20,001-50,000     | Two weeks                                    |   |
| 50,001-100,000    | Four days                                    | One sample per 10,000 of population per month                       |
| More than 100,000 | One day                                      |   |

5.3 It is well proved that by practising preventive maintenance regularly, not only, water supply systems are economically run but also standards of water quality can also be well maintained.

GUIDELINES ON PREPARATION OF TENDER SPECIFICATIONS  
ON ECONOMIC PUMPING PLANT. SELECTION AND  
STANDARDISATION ETC.

1. INTRODUCTION

- 1.1 For selecting a pumping plant which may be most suitable, both technically and economically, proper and accurate drafting of technical specifications in tender documents is a PRE-REQUISITE. First, therefore, guidelines are necessary for preparation of tender specifications for pumping sets.
- 1.2 In the tender specifications, some information has to be given by the Board and some information/details need be asked from the firms. It is proposed that tender specifications be divided in two parts.

PART-A

- 1.3 In this part the Board should give pointwise, the necessary information to the tenderer. Simultaneously the tenderer must be told what information/ details he has to furnish along with his offer and what aspects he should take into account in offering the most suitable pumping set.

PART-B

- 1.4 This part consists of (I) cost schedule and (II) schedule of technical performance. For (I) various items proposed to be purchased should be described with detailed specifications in serial order. Then a tabulated form, Schedule I as shown on page / 2 be prepared in the same order on which the firms may be asked to quote their prices. For (II) a tabulated proforma has been prepared and is attached as Schedule II. Tenderers be asked to submit technical performance of the pumping set on the same. Relevant information/ details which need be furnished by the

National Water Supply & Drainage Board and also those which need be asked from the tenderers, together with guidelines wherever necessary are stated in the following paras under Parts A & B.

PART -A

2. Description of the Scheme in brief :

Under this item the Board should give broad outline of the Scheme for which the proposed pumping plant is being purchased and will be installed.

3. Scope of work :

Information about the extent of work and aspects covered by the contract be made available here. Normally these should consist of :

- (a) The supply, delivery and erection of electric motors, starting apparatus, cables, electrical instruments, switch-gear and all electrical accessories as specified.
- (b) The supply, delivery and erection of pumps complete with all valves, pipe connections, pneumatic depth gauges, shafts, bearings and all accessories as specified. Pump and motor will have common base plate.
- (c) The supply, delivery and erection of all gauges, copper tubings, floor plates, and all such accessories as necessary and as specified.
- (d) The supply, delivery and erection of all auxilliary apparatus and pipes, valves and connections between the pumping units including all cable connections on the consumer's side of the Electric Supply Co's. main meters.
- (e) The supply, delivery and erection of metering apparatus.
- (f) The supply of spare pgrts, tools and other material

necessary for the satisfactory maintenance of the plant as specified.

(g) The testing and setting to work of all works, painting, running the installation for a period of 30 days and giving one year's guarantee against any manufacturing defect noticed during the day to day running.

(h) The contract shall include the execution of the whole of the works specified as well as all works of a temporary nature, which may be required to complete the works, but not specifically mentioned in the specifications: the intention being that the contractor shall execute as part of the contract everything requisite to make the whole plant complete and perfect as a first class pumping installation.

(i) The firm shall likewise arrange as part of the contract all tools, implements, as well as any other apparatus which the engineer of the Board may at any time direct for satisfactorily installing the plant or during the testing or maintenance of the plant, and shall include the services of competent technician required for the completion of the work.

(j) The firm shall also arrange for a competent representative during the installation, trials, official testing and subsequent running of the installation, but in no circumstances shall the employees of the Board be responsible for any damage done to the plant.

(k) If during the 30 days' running period or during the official test any further work is considered necessary

or any adjustments are required, the same shall be carried out by the firm.

(In short the contract shall include everything from start of the suction point upto the delivery just outside the pump house as shown in the accompanying drawing.)

4. Procedure of execution of work :

- 4.1 The pumping plant and the accessories shall be laid out and installed in the way shown in the accompanying drawing or as per drawings submitted by the firm and approved by the engineer of the Board.
- 4.2 The whole work shall be done to fulfil the various Acts and Regulations of the country relating to factories and electrical installations and as per directions of the engineer of the Board.
- 4.3 After the contract has been accepted by the Board, the firm shall submit the drawings as stated in description of Schedule I. The first item of work shall consist of laying of foundation. This shall be done by the Board but the firm shall depute its representative to inspect the work and ensure that foundation has been constructed to its satisfaction and that grouting holes are of proper size and correctly located and take responsibility for these. Other civil works like laying of pipe and cable trenches etc., should also be done in the presence of firm's representative or the firm should take responsibility that these have been laid & constructed to its satisfaction.

For grouting the bed plate necessary grouting material and mansons etc., shall be made available by the Board's engineer and the bed plate grouted under the direction and supervision of the firm's representative.

4.4 After grouting of bed plate, work shall proceed step by step and the firm shall keep Board's engineer should also inspect and check the work at every stage. If there is any shortcoming, it should be pointed out to the firm immediately and not at the end. If the engineer requires any tests to be carried out at any stage of the installation, the firm shall arrange and do the same. But engineer's checking and testing during the installation shall in no way relieve the firm from its contractual obligations. Firm's responsibility for quality of work and its accuracy shall remain with it till the installation is passed in the official test, taken over after running period and no defects attributable to the firm having been noticed in one year after taking over.

4.5 After installation has been completed, the firm will give one to two weeks notice to the engineer for conducting official test which shall be conducted as described later in Part-B.

5. Description of water to be pumped :

Following details should be provided to help the firm in selecting a proper pump for water to be handled.

(a) Turbidity and maximum size of solids likely to flow in the pumps.

(b) Temperature and pH value.

- (c) Physical and chemical analysis reports, if available.
- (d) Any other aspect worth mentioning.

6. Description of location including altitude :

This information should be furnished alongwith mode of transport, nearest port-station etc.

7. Duty conditions at which the pump will generally be required to work :

This is one of the most important items of pump specifications. It has to be done with great care and stated in the tender specifications. A typical example of specifying total head and discharge in case of borehole (tubewell) is shown as Annexure II to this appendix. In case of surface water etc., calculations will have to be made as shown in Annexure III. If it is required to run the pump at different speeds to meet different demands, necessary details should be given to enable the firms to offer suitable speed reduction arrangements. In case of borehole turbine and centrifugal pumps, efficiency and power consumption vary with varying heads. Hence it is all the more necessary to work out duty conditions as accurately as possible and select a pump with maximum efficiency at duty condition. On the other hand if there are chances of the operating point to keep on varying, firms may be intimated of the possible range of operation and pump of non over loading type may be asked for. In that case efficiency in the entire working range should be taken into account while selecting the pump.

## 8. Suction Details ;

8.1 To prevent occurrence of cavitation, firms may be advised to ensure and satisfy themselves of the following :

- (i) Adequacy of suction sump
- (ii) Correct location of suction pipes in the sump and insufficient clearances round suction ballmouth.
- (iii) Minimum length of suction pipeline.
- (iv) Sufficient waterway area in the suction strainer etc.

8.2 Satisfactory performance of a centrifugal pump depends to a large extent on proper sizing and alignment of the suction pipeline. Though some guidelines are also given in description of items of schedule I, the following thumbs rule may be kept in view by the Board while preparing / finalizing layouts.

- (i) Suction pipes be kept as short as possible.
- (ii) Firms may be advised to keep actual suction lift at site 20% less than maximum possible limit quoted by the manufacturers.
- (iii) Pipes and specials should be very carefully and accurately jointed to prevent any air leak.
- (iv) Diameter of suction line should limit velocity of water to nearly 6.5 ft. or 2 meters per second. For this the following table can be followed.

| Size of pipes in inches/mm | Maximum imperial gallons per minute permissible on suction side |
|----------------------------|---|
| 3" or 80 mm                | 85  |
| 4" or 100 mm               | 150   |
| 5" or 125 mm               | 250   |
| 6" or 150 mm               | 400   |
| 7" or 175 mm               | 600   |
| 8" or 200 mm               | 800   |
| 9" or 225 mm               | 1000  |
| 10" or 250 mm              | 1300  |
| 12" or 300 mm              | 1800  |



|               |      |
|---------------|------|
| 14" or 350 mm | 2400 |
| 16" or 450 mm | 4000 |

---

- (v) Alignment of the suction pipe should either be horizontal or gradually rising towards the pump to avoid air pockets.
- (vi) Where even reducers are required, eccentric reducers should be used. Sudden enlargement and reductions in diameter of suction pipe as well as short bends should be avoided.
- (vii) When In case strainer is used, it should provided a water way area not less than 3 to 4 times the area of the suction pipe.
- (viii) When a foot valve is used, it should not come in interference with the incoming stream, else whirl pool will be formed and air will be pumped-in.

8.3 Sketches on the next page give a rough idea about alignment of suction pie line.

#### 9. Type of Pump

It is better if exact type of pump is left to the supplier for quoting. However, guidelines on basis of which tenderers will have to quote are as under :-

- a. For Tube Wells: Firms may be asked to quote any type of pump including borehole, submersible etc., but preference may be given to one of them - To enable suppliers to quote suitable pumps for tube wells, its completion diagram together with verticality test and yield test reports must be furnished. As an example an arbitrary report

with imaginary figures is enclosed. Annexure II. Usually tubewells give sand on starting. However, water clears after some time. Hence sand content of water after 10/15 minutes run should be noted and when clear the same may be adopted.

- b. For Raw Water ; For pumping raw water from rivers and impoundments to the treatment works, generally low head pumps are required. However, if treatment works are located far, high head pumps will be required. While designing pump houses, through it is admitted that overall economy is kept in view but from the point of view of day to day maintenance and operation, suction lift should be kept minimum not exceeding 4.5 m (about 15'). Abnormally high suction lift beyond the rating of the pump generally causes reduced performance in discharge, head and efficiency. Further, it leads to excessive vibration and cavitation.

For gland sealing arrangement, it is desirable that clear water, preferably filtered water be made available. Raw water with turbidities beyond 30 ppm should not be used for gland sealing.

If the pump house has been specially designed for a particular type of pump, whether vertical or horizontal, the same should be clearly stated in the tender specifications. Drawing of the pump house, with existing pumps if any, must be furnished. If vertical, whether dry pit or wet pit should be mentioned. Beyond that i.e. the design of the pump

whether it should be radial, axial, or mixed flow; details of suction and delivery, number stages etc., should be left to the tenderer to quote, which in their opinion should be the best in performance, in cost and in day to day operation and maintenance. Maximum size of solids that are likely to flow in the pumps must be mentioned.

- c. For Clear Water ; It requires the same information/ details which have been described in (b) above.

10. Pump Speed

- 10.1 What should be the pump speed often becomes a point of controversy. In submersible pumps in tubewells speed of 2900 rpm is always acceptable, because with lower speeds size of both motor and pump becomes bigger and it is generally difficult to accommodate the larger unit inside the tube wells. Lower speed pumping sets cost more.

In case of centrifugal pumps, lower speeds can be adopted, but the commercial aspect must be carefully considered as low speed electric driven pumping sets costs more. Speed has much to do with the head also (as  $N \times H^2$ ). Hence in case of high head pumps, higher speed is commercially very advantageous. But increase in speed tends to increase maintenance and, therefore, a suitable balance has to be achieved between initial cost and maintenance cost. Apart from cost other facts also need be considered. In fact temperature, speed and altitude have an effect on suction lift.

## 10.2 Effect of Temperature, Speed and Altitude over Suction Lift for Centrifugal Pumps

Pumps with not too high a speed, liquid temperature upto 68°F and an installation at low altitude, can have suction lift including friction losses, velocity head and other causes upto 20' (but in practice efforts should be made to keep it upto 15'. 15' suction lift will provide more trouble-free operation, specially in charging and starting the pumps). At higher temperatures and in case of higher altitudes this figure is reduced. In all cases where the utmost suction lift is essential, it is advisable to consult the manufacturers and request them to furnish necessary data and test results on which its recommendations are based. These should then be critically examined in the Board's office. The following table indicates the suction lift in relation to temperature of the liquid, number of revolutions and altitude of the erection-site of the pump.

| WATER TEMP.          |             |         |      |      |      |      |      |       |  |
|----------------------|-------------|---------|------|------|------|------|------|-------|--|
| IN DEGREES F         |             | 50      | 68   | 86   | 104  | 122  | 140  | 158   |  |
| Suction lift in feet | at 1450 rpm | 21      | 20.5 | 19   | 16.5 | 13   | 9    | 0     |  |
|                      | at 2900 rpm | 15      | 14   | 12.5 | 10   | 6.5  | 2.5  | 0     |  |
| Altitude in feet     |             | 0- 1500 | 3000 | 4500 | 6000 | 7500 | 9000 | 10000 |  |
| Factor 'f'           |             | 1.0     | 0.9  | 0.79 | 0.7  | 0.62 | 0.54 | 0.47  |  |

For altitudes above 1500 ft. the suction lift must be multiplied by the factor 'f'.

10.3 The speed relationship to temperature and altitude may be kept in view. Before coming to a final conclusion on speed, based on the speed which is proposed to be adopted, specific speed may be calculated from the following :

$$N_s = \frac{1.096 N \sqrt{Q}}{H^{3/4}}$$

$N_s$  = Specific speed of the pump

$N$  = Speed of pump in RPM

$Q$  = Discharge in imperial gallons per minute of a single suction impeller

$H$  = Total Head per stage in FT

10.4 Total suction lift that centrifugal pumps can create while working against different total heads and specific speeds are given in diagrams on pages 12,13,14 (curves taken from Hydraulic Institute Standards). In case this suction lift is less than that at which the pump has to work, proper speed may be selected which may give the desired total suction lift.

1.05 However, the fact remains that the higher the speed of the pumping set, the greater the attention it requires in day to day maintenance. Also some parts are subject to more wear and tear. In view of this practical problem, the following broad guideline is also taken into consideration :

Small Pumping Sets - Maximum Speed - 2900 RPM (upto 10 BHP)

Medium size Sets - " " - 1450 RPM (Between 10 BHP and 200 HP)

Large size Sets - " " - 950/750 RPM Above 200 HP

.....

11. Arrangements and Details of Existing Pumps

If the pump required is to work in parallel or in series with the existing other pumps, a detailed sketch of the existing installation along with their performance curves and other details should be given in the tender documents to enable the firm to examine suitability of the pump offered for running it in parallel to the existing pumps or as the case may be.

12. Performance Curves

While the firms will be asked to furnish the complete performance figures and curves of the pump offered by them the Board should advise the suppliers to quote for pumps which have a uniform or efficiency as possible throughout its entire range of working. Also pump characteristics should be such that should not impose an excess load on the motor during any portion of working. It may be mentioned in the specifications that the supplier shall ensure that B.H.P. of the motor being offered is such that it does not draw more than its full load current under any circumstances of working in the entire range.

12.2 Tenderers may be asked to furnish the following performance curves for the pumps offered:

1. Discharge - Head
2. Discharge - Efficiency
3. Head - B.H.P. absorbed at pump shaft
4. Head - Current drawn by motor.

In 2 above Discharge is measured and Efficiency calculated at the specified speed (RPM) for large pumps, Net positive suction head (NPSH) required at the duty point i.e. at the

specified flow and speed of rotation should be enquired from the firm. For cavitation free performance of a pump, it is necessary that available NPSH is always higher than the required NPSH.

13. Workmanship etc.

The materials, workmanship and finish of the complete work shall be of the best quality and in these respects Sri Lanka/British Standards shall be followed.

14. Interchangeability

Corresponding parts of all the machines, apparatus and equipment shall be standard and interchangeable. Nuts, bolts, screws etc. shall conform to Sri Lanka/British Standards.

15. Deviations from Prescribed Specifications

Design, layout, construction, materials etc. shall all be as per specifications provided in this tender documents, but in case firms can suggest any alteration or deviation with a view to obtain economy, increased efficiency and safety, facility in operation and maintenance, the firms may submit the same and these will be carefully considered while awarding work. But firms must provide similar guarantees for deviations/alterations suggested by them.

16. Reinstatement of Works damaged/broken during execution of work

The firms may be informed in this para that in case any work land, property, fencing or the like are damaged/broken/alter by them during the course of their work whether intentionally for the facility of executing the work, or inadvertently or by mistake, the same shall have to be reinstated to the

original condition at their own expense and no claim shall be considered by the Board.

17. Firms must be advised to inspect the site before tendering and satisfying themselves about everything regarding the work. Firms may clearly know that it will be in their interest to inspect the site of work, read the tender document carefully before submitting their offer. In case of any doubt or difficulty they should discuss the matter with Board's engineer before submitting their offer. It will be presumed that the firms have satisfied themselves about the scope of works, various dimensions, levels, character and nature of work before submitting their offer.



DESCRIPTION OF ITEMS CONTAINED IN  
COST SCHEDULE (SCHEDULE I)

1. Provisional Sum

If during the execution of work or at any other stage it is considered necessary to do any other work or supply any other items, then the firm shall be bound for the same up to an amount of Rs. 50,000/= on rates settled mutually terms of payment being the same as in the main contract.

2. (a) Electrical Switch Gear

Type of circuit breaker/isolating switch will depend on full load current to be carried by it. There is no defined policy but experience has shown that use of I.C. T.P. switches (Iron Clad Triple Pole switches with our without neutral links) on circuits carrying more than 100 Amps. is accompanied with more maintenance problems. As such on circuits carrying more than 100 amps. it is adviseable to use air or oil circuit breakers, in spite of their higher cost.

However to provide further protection and servicing facility to circuit breakers, back-up protection by isolators with H.R.C. fuses should be provided wherever possible.

So far as these isolators with H.R.C. fuses (or I.C.T.P. switches) are concerned, these are simple equipment and it will be sufficient to specify 3 to 4 good makes and tenderer should be asked to include and quote for any in his offer. But as for circuit breakers, it is necessary to give detailed specifications and while drafting these, following considerations be made.

Circuit breakers could either be air break or oil circuit

breakers. In case of oil circuit breaker, the oil tank should be designed to be pulled out easily and should have arrangement to indicate correct oil level in tank.

The breakers should be provided with both :-

- (a) Main contact
- (b) Arcing contact

Following releases shall also be provided :-

- (a) Over current releases ( time lag )
- (b) Under voltage release
- (c) Earth leakage release
- (d) Single phasing preventer

For overload releases, current setting arrangement shall be provided.

Contact terminals shall be so designed that adequate contact pressure is maintained in all conditions of working. It shall be preferred if both moving and fixed contacts are of rolling - butt pattern type and close with a self-wiping action. Design and fixing of the contacts should ensure easy inspection, servicing and replacement. Contact tips should be of special alloy/silver-plated/nickel plated to provide smooth contact and resistance to are wastage.

Suitable inter-looking arrangement is necessary. The whole circuit breaker should be housed in a strong C.I. or M.S. enclosure of adequate size so that when opened, enough space is available for change of contacts and for other routine repairs and maintenance. Size and design of the enclosure should ensure adequate precaution against any contact between the live parts and any part of the enclosure.

A cord of rubber or of any other suitable material be provided along the periphery of the front door and other openings to make the panel dust-proof.

In case of panels, sides of covers should be covered by asbestos cement sheets which are to be inserted between the panels. For end panels, steel side covers are necessary.

As for cabling arrangement, the same should be simple to provide easy opening and closing of terminals. It is preferable if they are brought out to a terminal board for making cable connections.

Other general conditions shall fulfil the relevant provision of the Sri Lanka Standards or British Standards.

For the circuit breaker offered, the supplier shall furnish the following information :-

1. Rated voltage
2. Normal current rating
3. Breaking capacity in MVA at 415 V
4. Rated short circuit current
5. Tripping delay characteristics.

For motors above 20 B.H.P. where squirrel cage induction motors are offered, use of auto-transformer type starters may be specified. It may be further mentioned that tapings of the auto transformer starter are so chosen considering the starting. Current required by the pumping set that starting current being limited to 150% of the normal full load current.

Number of switches/breakers and their capacities will depend on the number of the motors to be controlled and their sizes. If there are more than one pumping set, it will require a panel, preferably

totally enclosed, metal clad, fabricated out of M.S. sheets and angles. There will be one main incoming switch/breaker and then one for each pump. In case a switch is required for lighting purposes, it should be specifically specified along with rating.

Panel Instrumentation - Extent of instrumentation depends on number and size of pumping sets to be controlled. However, in case where number of pumps is more than one, and circuit breakers have been used the switch gear panel is normally equipped with following instruments

1. KWH meter of adequate capacity with CIs if current is high on each circuit breaker.
2. Volt meter - to be provided on main incoming circuit breaker (0 - 500 V) with selector switch for each phase
3. Power factor meter - on the main incoming
4. Frequency meter - on the main incoming
5. Ammeter on each circuit breaker of capacity  $2\frac{1}{2}$  times the full load current with selector switch.
6. Relays as mentioned above on each circuit breaker
7. Single phasing prevention device for each motor

In case of small pumping sets using I.C.T.P. switches 3,4,6,7 could be omitted.

Switch gear should be floor mounted with about 3ft (1 metre) space left behind for conducting repairs.

While the firm will quote total cost of the switch gear on Schedule I, break up showing cost of each item i.e. each switch/circuit breaker etc. shall be given on a separate sheet.

## 2( b) Earthing Material

All material required for earthing the entire electrical installation as per local regulations shall be included in this item.

If there are no local regulations, double earthing of the complete system connected to a permanent earthing plate buried in ground surrounded with Coal upto sub-soil water level or up to suitable depth considered necessary, depending on ground conditions should be provided.

### 3. Cables

Necessary length of copper or aluminium cables - PVC insulated from electric Supply Companies breaker/metering point to the consumer's panel and then from switches to starters and starters to motors should be included. It may be desirable to name 3 or 4 good makes and contractor asked to provide any of these.

### 4. Pumps

Detailed description of the pumping set including its working and duty conditions having already been given in the general description pages .. to .. , only type of pump and dual duty conditions need be given. However, it will be helpful, if possible, to state metals for Shaft and Impeller. In medium to large centrifugal pumps it has become modern practice to provide stainless steel shafts of generous diameter to provide a factor of safety of 2.0. In raw water pumps with fairly high turbidity or where wear and tear is expected to be high, stainless steel impellers should be provided. For fair conditions, bronze impellers will suffice. Shafts should be provided with protective sleeves of bronze or brass wherever necessary. There are various types of stainless steel and bronze sleeve. Composition of these alloy metals should be left to the manufacturers to adjust according to their detailed design requirement. Pump casing should be of heavy closed-grain cast iron or semi-steel casting. The

Pump should be fitted with renewable bushes and wearing rings. Water passages in impellers etc. should be filled and scraped to perfectly smooth surfaces. Impellers must be statically and dynamically balanced. All parts should be designed to withstand action of sand, other solids and abressive matter in water.

#### 5. Motors

Motors shall be of robust make, mounted on a common base plate (either cast or of fabricated mild steel).

The following details should invariably be given :-

- (i) Power available : Suitable for power supply - 400 V.  
AC 3 Ph, 50 Cy.
- (ii) Type : Continuous running type, screen protected, drip proof with extended shaft for taking a pulley to provide a flexible coupling with the pump to be driven.
- (iii) Class of Insulation: This should be given after studying the working conditions - In normal conditions class 'E' insulation.
- (iv) A short description of site and duty conditions including ambient temperature and altitude. For higher altitude specially designed motors should be used.
- (v) RPM
- (vi) Whether tests will be required to be done at site or whether manufacturers certificate will suffice. In former case tests required to be done should be specified.
- (vii) Type of Rotor : Whether squirrel cage or slip rings. In lattercase it may also be mentioned whether brush

lifting device is required. It is suggested that for motors above 250 H.P. brush lifting device may be desired with short circuiting device and with meter locking system.

(viii) a) Method of starting :

Maximum permissible temperature rise. Normally 40°C above ambient is considered sufficient.

(ix) If possible, fault carrying capacity of the system to which motor is connected be given.

(x) B.H.P.: Duty conditions of the pump having been described, a decision about the B.H.P. of the motor should be left to the tenderer. It may however be stated that maximum power absorbed at the pump shaft should be between 80% and 90% of the B.H.P. of the motor during the entire range of working of the pump.

(xi) Manufacturers must give a certificate that rotors are statically and dynamically balanced. Regarding other aspects the motor should conform to the relevant Sri Lanka standard or British standard.

The supplier may be asked to furnish following information :

1. Rated output.
2. Efficiency of the motor at following loads :

Full load

$\frac{3}{4}$  "

$\frac{1}{2}$  "

$\frac{1}{4}$  "

3. P.F. of the motor at following loads :

Full load

$\frac{3}{4}$  "

$\frac{1}{2}$  "

$\frac{1}{4}$  "

4. Rotor voltage and winding connections.
5. Rotor current at rated output.

For guidance, following table gives standard voltages and sizes of motors recommended.

| Supply                    | Voltage                   | Recommended Size in HP |          |
|---------------------------|---------------------------|------------------------|----------|
|                           |                           | Minimum                | Maximum  |
| Single Phase<br>AC. 50 Cy | 250 V                     | -                      | 2.5      |
| 3 Phase AC.<br>50 Cy.     | 400 V                     | 1.0                    | 350      |
| 3 Phase AC<br>50 Cy.      | 6,600 V<br>or<br>11,000 V | 350                    | Any H.P. |

Squirrel cage induction motors being most simple and easy to maintain, as far as possible and to the size permitted by the local electricity authority, should be used. On tube wells, motors with hollow shafts should be used on bore hole turbine pumps.

#### 6. Starters

Broadly, types of starter are as under :

1. Direct on line
2. Star Delta
3. Auto-transformer
4. Rotor Resistance Starters

Use and selection of starters is linked up with :

- (a) Size and type of motor to be started
- (b) Limitations imposed by local electricity authority.

In submersible pumping sets, because of technical limitations, generally only SQUIRREL CAGE induction motors are used.



Thus, use of direct line starters is limited to very small size motors. Starters of type 2 and 3 above can normally be used on submersible pumping sets. Where wound rotor motor is used, rotor resistance starters have to be used. Regarding other cases, either of the two starters i.e. Star Delta or Auto-transformer starter can be used. Between the two, with selection of suitable tapings, it is possible to limit starting current to lower values by using auto-transformer starter. As such, generally local electricity authorities do not permit use of Star Delta starters beyond a particular size.

Type of starter should, therefore, be decided keeping the above considerations in view.

7. All the gauges on suction and delivery site along with necessary copper tubing, nipples, etc.

Under this item water pressure gauges of suitable range of dia. between 4" and 6" (10 to 15 mm) shall be supplied. Pressure gauge on the delivery side shall have a range 60% to 75% higher than the duty head. Pressure gauge on the suction side will have a suction gauge (if pressure is always negative) an ordinary pressure gauge (if always positive) and a compound gauge of the pressure is sometimes positive and sometimes negative. On the suction side, range should be vacuum 30" Hg. and on pressure side same as on delivery side. It generally is convenient for the operator if both the gauges are installed at one place on the wall on a polished teak wood or metallic board at height of about 5' from ground. Both the gauges should be provided with copper connection pipes of heavy gauge 6 mm in diameter. In case length of connecting

pipe is too long for suction gauge, it could be provided and fixed at a closer place.

8. Reflux and Sluice Valves as per description/drawing water meter/metering equipment.

Number and type of valves required should be assessed and described. British standard provides two classes of sluice valves Class I upto a pressure of 600 ft.(182.8m) and Class 2 upto a pressure of 800ft (243.8 m). Class of valves may, therefore, be chosen depending on pressure existing in the main. Valves with flanges and handwheels should be used near the pumping plants. Since sluice valves near the pumping sets are operated quite frequently, only high quality valves should be used. It is advised that 3 or 4 of the best makes may be mentioned in this item and the tenderer may quote for any. Other details should be as provisions of B.S. on sluice valves.

9. Water Meter/ Metering Equipment

This equipment should be so arranged that it is possible to measure the discharge of each pump individually and also the combined discharge of all or a group of pumps. If all pumps are not covered by one metering equipment, more meters may be provided so that no water is supplied unmeasured. Metering equipment could be of following type.

- (a) Full flow meter - This may be used if flow is small.
- (b) Venturi Meter (alternatively with Dall Tube) with indicating, recording and integrating arrangement - for large flows.
- (c) If flows are large, cheaper measurement of flow is possible through Venturi Tubes.

Which arrangement is required shall be clearly stated.

10. (a) Pipes, Tees, Bends, Taper and other specials including chequered plates etc. as per drawing/ description

It is desirable that a proposal in the form of a drawing is furnished by the Board along with tender documents to enable them to work out lengths, sizes and quantities of various items under this sub-head. In case preparation of drawings has not been possible due to unavoidable reasons, a lucid description of the layout should be given so that the tenderer may be able to estimate the actual requirement of these items.

In case a drawing has been prepared, lengths, numbers, and sizes of straight flanged pipes and sizes, description and numbers of tees, bends and tapers etc. should be worked out and list furnished. The firm shall quote for the same.

The firm shall, however, be at liberty to suggest any other layout arrangement and in that case shall quote for such items which become necessary according to the arrangement suggested by it. While the total cost shall be filled in Schedule I, detailed cost of each pipe length and each special shall be quoted by him in a separate sheet supporting the total given in Schedule I.

On the suction side, care must be taken that alignment of the pipe line is such that there are no chances of any air pocket being created. Wherever reducers are required, they should be of eccentric type. Refer figure on next page.

On the suction side, flanged or screwed pipes shall be used and not spigot and socket type. Apart from above, all guards under safety acts or required for other reasons, chequered plates for covering trenches carrying cable, pipes etc. alongwith drip pans and necessary piping for disposal of water shall be worked out and quoted lump sum under this item.

10. (b) Foot Valve on Exhauster Set with items for appurtenant work

Under this item tenderers shall quote items for required for charging the pumps, if required. If suction pipe is small in diameter, foot valve may be supplied, else a suitable motor driven exhauster set, complete with piping arrangement to make it a complete job should be quoted for. Necessary switch and wiring material will also be included in this item.

11. (a) Tools as per description

- (i) One set of D/E Spanners, standard sizes of best make.
- (ii) One set of one ended spanners to fit in every size of bolts.
- (iii) One set of box wrench - standard size.
- (vi) Screw drivers 12", 8", 6", - 2 Nos. of each.
- (v) Pliers - two large and two small.
- (vi) Hammers with handles - 2 lbs. and 1 -lb. each.
- (vii) Pipe wrenches 24", 18", 12" one ach.
- (viii) Chain wrench 6" - 1 No.

11. (b) Lifting Tackle

Type of lifting tackle whether ordinary lifting pulley block or a travelling crane or of the type necessary to lift the

heaviest load in the pump house for assisting in taking it out of the pump house, shall be described in the tender specifications and quoted for by the tenderer. Regarding the capacity of the tackle and maximum height of lifting required, may either be given by the department or the firms may be asked to work out the same and quote. Full details, e.g. make, capacity, lifting height etc. of the equipment offered should be furnished by the tenderers.

12. Spares as per description for P mps, Motor and Switchgear.

(a) For Pumps - In case of raw water pump one complete set of rotating assembly will be supplied apart from the following. However, in case of clear water pumps only the following spares shall be supplied :-

I. CENTRIFUGAL

- |                                    |        |
|------------------------------------|--------|
| 1. Impellers                       | 2 Nos. |
| 2. Shaft with key                  | 1 No.  |
| 3. Shaft Sleeves                   | 1 set  |
| 4. Bearings                        | 1 set  |
| 5. Wearing Rings                   | 1 set  |
| 6. Lock-nut                        | 1 No.  |
| 7. Gasket                          | 1 set  |
| 8. Gland                           | 1 set  |
| 9. Packing necessary for one year. |        |

II. BORE HOLE PUMPS

1. One complete set of bowl assembly alongwith complete rotary assembly.

2. Line shaft - 3 lengths
3. Line shaft coupling - one full set for complete replacement.
4. Shaft enclosing tube - 3 lengths
5. Column Pipe - 3 lengths
6. Column Pipe Coupling - 3 Nos.
7. Impellers - 1 set
8. Line shaft bearing - 1 set
9. Packing for one years requirement.
10. Top bowl bearing - 1 set
11. Intermediate bowl bearing - 1 set

#### Submersible Vertical Turbine Pumps

For submersible pumping set it is advisable to have a complete pump with motor as spare, in case public water supply is from only one tubewell. In case, there is another working tubewell in the system, then between the two, one pumping set should be spare. In addition the following spares for pumps and motor may be had :-

1. (a) Impellers            1 set  
       (b) Pump shaft        1 No.
2. Sand collar        1 No.
3. Bearings            1 set  
    (including thrust bearing)
4. Pump motor coupling - 1
5. Cable clamps - ½ set.
6. Motor cable splices - set
7. Cable terminals - 1 set
8. Terminal Box - 1
9. Access hole plug - 1
10. Cable - for one replacement.

(b) For Motors (except Submersible Motors)

- |  |           |
|--|-----------|
| 1. Winding coils (including coils for rotor (if used)) | - 1/3 set |
| 2. Bearings  | 1 set     |
| 3. Brushes   | 3 sets    |
| 4. Slip Rings  | 1 set     |

(c) For Switch Gear

- |                              |        |
|------------------------------|--------|
| 1. Fixed and moving contacts | 3 sets |
| 2. Overload coil             | 1 set  |
| 3. No volt coil              | 1 No.  |

13. Drawings of Machinery & Equipment

Upon acceptance of the tender the firm shall send four sets each of :

(a) Dimensioned drawings for the foundation which have to be prepared.

(b) Dimensioned drawing of the machinery and equipment contained in the order along with complete set of catalogues and technical literature containing all the information regarding design, installation, operation and maintenance of the machinery and equipment being supplied and erected.

Cost of the above, if any, shall be quoted under this item. In case these are to be supplied, word 'FREE' may be mentioned.

14. Painting

Painting of the whole installation including pipes and valves with 3 coats of approved paints.

15. Erection, Commissioning and setting to work of the complete unit

By and large, pumps are robust machines, and if installed well and maintained properly, give long trouble-free service.

All the machinery has to be installed with the best workmanship. Except for the Civil Engineering works, this item shall provide for all the works, including arranging of tools and plant required for installing the pumping set. All consumable items like grease, lubricating oils, packings, gaskets etc. items like oil for first filling of oil circuit breakers, dangers plates, power wiring starting from the incoming switch/circuit breaker etc. In short this is a comprehensive item which includes supply of all the above materials. Carrying out the necessary works erecting the machinery and appurtenant equipment, commissioning and setting the whole thing for regular operation. Lump sum amount shall be quoted for the whole work.

16. Running the installation for 30 days during which the firm shall employ its own staff.

After the pumping set has been commissioned and put into regular working, the firm shall intimate this to the Board and ask the Board the date from which 30 days normal running of the plant shall be started. The Board shall arrange normal running of the plant within one week of having received the information. If a longer period is taken by the Board, the firm shall be entitled to wages of watchmen, if engaged.

During the above period, the firm shall engage its own staff for the running and maintenance of the plant, also provide for all oils, lubricants and consumable stores, except electricity. During this period, the firm shall also arrange



for training of the staff on operation and maintenance of the plant, if desired by the Board, without any charge. When this running period is coming to end, the firm shall intimate this position to the Board and ask the Board to depute its representative for conducting official test of the plant and taking it over.

17. Official Test

On receipt of the above intimation, Board shall depute its representative to conduct the official test of the pumping plant. This test shall be conducted at field/site where installed and shall be the official test for acceptance of the plant. During the test the technical representative of the firm shall also be present. Test shall be performed on the basis of Schedule II.

**SCHEDULE I**

| S.No.          | Description of Item                         | Quantity or Number | Unit | Rate | Amount |
|----------------|---|--------------------|------|------|--------|
| 1              | 2   | 3                  | 4    | 5    | 6      |
| 1.             | Provisional Sum                             |                    |      |      |        |
| 2.(a)          | Electrical Switch Gear                      |                    |      |      |        |
| (b)            | Earthing Material                           |                    |      |      |        |
| 3.             | Cables                                      |                    |      |      |        |
| 4.             | Pumps                                       |                    |      |      |        |
| 5.             | Motors                                      |                    |      |      |        |
| 6.             | Starter                                     |                    |      |      |        |
| 7.             | Gauges                                      |                    |      |      |        |
| 8.             | Valves                                      |                    |      |      |        |
| 9.             | Water Meter/Metering Equipment              |                    |      |      |        |
| 10.(a)         | Pipes and specials                          |                    |      |      |        |
| (b)            | Foot Valve or exhaustor Set                 |                    |      |      |        |
| 11.(a)         | Tools                                       |                    |      |      |        |
| (b)            | Lifting Tackle                              |                    |      |      |        |
| 12.            | Spares for Pumps, Motor and Switch Gear     |                    |      |      |        |
| 13.            | Drawings                                    |                    |      |      |        |
| 14.            | Painting                                    |                    |      |      |        |
| 15.            | Erection, Commissioning and setting to work |                    |      |      |        |
| 16.            | Running the installation                    |                    |      |      |        |
| 17.            | Official Test                               |                    |      |      |        |
|                | <b>TOTAL</b>                                |                    |      |      |        |
| Total in words |   |                    |      |      |        |

Witness

Signature of Firm's Official/Contractor

**SCHEDULE - II**

**Schedule for Guaranteed Performance of Pumping Set**  
Length of Air Line

| S. No. | Pressure gauge Reading | Depth gauge Reading | Water Level below ground | Height of Pressure gauge above Depth gauge | Approximate Frictional losses in Pump Rising main | Total Head | Discharge of the Pump Per Minute | Water Horse Power from f and g | Kilowatt Input to Motor | Overall Efficiency of Pumping Set | Manufacturers Motor Efficiency | Pump Efficiency | Remarks |
|--------|------------------------|---------------------|--------------------------|--|---|------------|----------------------------------|--------------------------------|-------------------------|-----------------------------------|--------------------------------|-----------------|---------|
|        | a                      | b                   | c                        | d  | e   | f          | g                                | h                              | i                       | j                                 | k                              | l               | m       |
| 1.     |                        |                     |                          |  |   |            |                                  |                                |                         |                                   |                                |                 |         |
| 2.     |                        |                     |                          |  |   |            |                                  |                                |                         |                                   |                                |                 |         |
| 3.     |                        |                     |                          |  |   |            |                                  |                                |                         |                                   |                                |                 |         |
| 4.     |                        |                     |                          |  |   |            |                                  |                                |                         |                                   |                                |                 |         |
| 5.     |                        |                     |                          |  |   |            |                                  |                                |                         |                                   |                                |                 |         |

**NOTES**

1. While taking observations different Heads/Discharges may be obtained by operating the sluice valve on delivery side.
2. In above chart No. 3 may be duty point and 1.2 and 4.5 should be below and above the duty point.



**INVENTORY OF ITEMS OF INTAKE WORKS**

| Sl. No. | Source     |                      |                       | Intake Works - Structures, Valves, P.I. |            |            |             |              |                   | Raw Water Machinery |                         |              |                    |                          |                        |                        |                     |
|---------|------------|----------------------|-----------------------|---|------------|------------|-------------|--------------|-------------------|---------------------|-------------------------|--------------|--------------------|--------------------------|------------------------|------------------------|---------------------|
|         | Tube Wells | Surface Water Col. I | Surface Water Col. II | Bnt. Screen                             | Sump Wells | Pan-Stocks | Foot Valves | Slide Valves | Non Return Valves | Air Exhausters      | H.T. Oil & Air Breakers | Transformers | H.T. & L.T. Cables | L.T. Breakers & Switches | Pumps with H.T. Motors | Pumps with L.T. Motors | Auxiliary Machinery |
|         | A 2        | B 2                  | C 2                   | D 2                                     | E 2        | F 2        | G 2         | H 2          | I 2               | J 2                 | K 2                     | L 2          | M 2                | N 2                      | O 2                    | P 2                    | Q 2                 |
|         |            |                      |                       |   |            |            |             |              |                   |                     |                         |              |                    |                          |                        |                        |                     |

1. Surface water which do not require sedimentation, Clarification and filtration

2. Surface water which require full treatment

INVENTORY OF ITEMS OF TREATMENT WORKS

| Item<br>Name<br>&<br>Location | Chemical Dosing Equipment |                    |                |             | Main Treatment Works            |                      |          |          |              |                                 |                     | Miscellaneous    |                  |                        |            |
|-------------------------------|---------------------------|--------------------|----------------|-------------|---------------------------------|----------------------|----------|----------|--------------|---------------------------------|---------------------|------------------|------------------|------------------------|------------|
|                               | Prechlorination           | For other<br>-line | Flash<br>Mixer | For<br>Alum | Plain Sedimen-<br>-tation Tanks | Chlorina-<br>-tators | S. S. F. | R. S. F. | Chlorination | At Blowers<br>or<br>Compressors | Wash Water<br>Pumps | Sluice<br>Valves | Per-<br>-sulfate | Water Meter<br>Reading | Ultrasonic |
| Identification<br>Number      | A 3                       | B 3                | C 3            | D 3         | E 3                             | F 3                  | G 3      | H 3      | I 3          | J 3                             | K 3                 | L 3              | M 3              | N 3                    | O 3        |



## INVENTORY OF MAIN ITEMS OF DISTRIBUTION SYSTEM

| Stn. In. mm. | Length in Meters | No. of Pipes | No. of Non-return Valves | No. of Air Valves | No. of Butterfly Valves | No. of Other Valves | No. of Fire Hydrants | No. of Stand Posts | No. of Venturi Meters Installed | No. of Bulk Meters | No. of Scour Valves | Dead Ends Nos. | Boosters Nos. | Secondary Chlorinators Nos. |
|--------------|------------------|--------------|--------------------------|-------------------|-------------------------|---------------------|----------------------|--------------------|---------------------------------|--------------------|---------------------|----------------|---------------|-----------------------------|
| A 5          | B 5              | C 5          | D 5                      | E 5               | F 5                     | G 5                 | H 5                  | I 5                | J 5                             | K 5                | L 5                 | M 5            | N 5           | O 5                         |



**PUMP DEFECTS AND THEIR REMEDIES**

| CAUSES   | SYMPTOMS                         |                        |                    |                                  |                                    |                                   |  |                               |                  |                             |
|--|----------------------------------|------------------------|--------------------|----------------------------------|------------------------------------|-----------------------------------|--|-------------------------------|------------------|-----------------------------|
|  | The pump fails to deliver liquid | Capacity is inadequate | Head is inadequate | The pump cuts out after starting | Power required by pump is too high | Excessive leakage of stuffing box | Packing must be renewed too frequently | The pump vibrates or is noisy | Bearings heat up | Pump runs heavily or seizes |
| Pump and suction line are not sufficiently primed with the liquid handled                        | X                                |                        |                    | X                                |                                    |                                   |  |                               |                  | X                           |
| Excessive suction lift   | X                                | X                      |                    | X                                |                                    |                                   |  |                               |                  | X                           |
| Insufficient margin between suction lift and vapour pressure                                     | X                                | X                      |                    | X                                |                                    |                                   |  |                               |                  | X                           |
| Liquid contains gas  |                                  | X                      |                    | X                                |                                    |                                   |  |                               |                  |                             |
| Air pocket in suction line   | X                                | X                      | X                  | X                                |                                    |                                   |  |                               |                  |                             |
| Air leak in suction line   |                                  | X                      |                    | X                                |                                    |                                   |  |                               |                  |                             |
| Air leaks into pump along stuffing box   |                                  | X                      |                    | X                                |                                    |                                   |  |                               |                  |                             |
| Foot valve too small   |                                  | X                      |                    |                                  |                                    |                                   |  |                               |                  |                             |
| Foot valve partly clogged  |                                  | X                      |                    |                                  |                                    |                                   |  | X                             |                  |                             |
| Foot valve and suction line not fully submerged  | X                                | X                      |                    | X                                |                                    |                                   |  | X                             |                  |                             |
| Connection of water seal on suction stuffing box blocked   |                                  |                        |                    | X                                |                                    |                                   | X                                      |                               |                  |                             |
| Lantern ring in stuffing box incorrectly fitted  |                                  |                        |                    | X                                |                                    | X                                 | X                                      |                               |                  |                             |
| Speed too low  | X                                | X                      | X                  |                                  |                                    |                                   |  |                               |                  |                             |
| Speed too high   |                                  |                        |                    |                                  | X                                  |                                   |  |                               |                  |                             |
| Incorrect direction of rotation  | X                                |                        | X                  |                                  |                                    |                                   |  |                               |                  |                             |
| Total manometric head of the system greater than the manometric head of the pump                 | X                                | X                      | X                  |                                  | X                                  |                                   |  |                               |                  |                             |
| Total manometric head of the system lower than the manometric head of the pump                   |                                  |                        |                    |                                  | X                                  |                                   |  |                               |                  |                             |
| Specific gravity of liquid handled is not what it was originally supposed to be.                 |                                  |                        |                    |                                  | X                                  |                                   |  |                               |                  |                             |
| Viscosity of liquid handled is not what it was originally supposed to be                         |                                  | X                      | X                  |                                  | X                                  |                                   |  |                               |                  |                             |
| The pump is operating at too low a capacity  |                                  |                        |                    |                                  |                                    |                                   |  | X                             |                  | X                           |
| Parallel connection is unsuitable for the specific operating conditions                          | X                                | X                      | X                  |                                  |                                    |                                   |  |                               |                  | X                           |
| Line, impeller or pump casing clogged  | X                                | X                      |                    |                                  | X                                  |                                   |  | X                             |                  | X                           |
| Pump set incorrectly aligned   |                                  |                        |                    |                                  | X                                  | X                                 | X                                      | X                             | X                | X                           |
| Foundation not level   |                                  |                        |                    |                                  |                                    |                                   |  | X                             |                  |                             |
| Pump shaft warps   |                                  |                        |                    |                                  | X                                  | X                                 | X                                      | X                             | X                | X                           |
| A rotating part runs against a stationary part e.g. impeller runs against wearing rings          |                                  |                        |                    |                                  | X                                  |                                   |  | X                             | X                | X                           |
| Bearing (s) defective  |                                  |                        |                    |                                  |                                    |                                   |  | X                             | X                | X                           |
| Wearing rings are worn   |                                  | X                      | X                  |                                  |                                    |                                   |  |                               |                  |                             |
| Impeller is damaged  |                                  | X                      | X                  |                                  |                                    |                                   |  | X                             |                  |                             |
| Pump shaft or shaft sleeve locally at the stuffing box is worn                                   |                                  |                        |                    |                                  |                                    | X                                 |  |                               |                  |                             |
| Stuffing box incorrectly packed  |                                  |                        |                    |                                  | X                                  | X                                 |  |                               |                  |                             |
| Type of packing used unsuitable for liquid handled   |                                  |                        |                    |                                  |                                    | X                                 |  |                               |                  |                             |
| Impeller out of balance  |                                  |                        |                    |                                  |                                    | X                                 |  |                               |                  |                             |
| Failure to apply water-cooling when handled hot liquids  |                                  |                        |                    |                                  |                                    | X                                 |  |                               |                  |                             |
| Clearance between pump shaft and bore of pump casing at the bottom of the stuffing box too great |                                  |                        |                    |                                  |                                    |                                   | X                                      |                               |                  |                             |
| Liquid for water seal contains impurities  |                                  |                        |                    |                                  |                                    |                                   | X                                      |                               |                  |                             |
| Gland overtightened  |                                  |                        |                    |                                  |                                    |                                   | X                                      |                               |                  |                             |
| Axial fit of complete pump shaft with impeller incorrect   |                                  |                        |                    |                                  |                                    |                                   |  | X                             | X                | X                           |
| Insufficient or excessive lubrication  |                                  |                        |                    |                                  |                                    |                                   |  |                               | X                |                             |
| Lubricant contains impurities  |                                  |                        |                    |                                  |                                    |                                   |  |                               | X                |                             |
| Bearings incorrectly fitted  |                                  |                        |                    |                                  |                                    |                                   |  |                               | X                | X                           |