DIRECTORATE OF WATER SUPPLY
DIRECTORATE GENERAL CIPTA KARYA
MINISTRY OF PUBLIC WORKS
REPUBLIC OF INDONESIA

DIRECTORATE GENERAL
INTERNATIONAL COOPERATION
MINISTRY OF FOREIGN AFFAIRS
KINGDOM OF THE NETHERLANDS

MDP PRODUCTION TEAM

TRAINING MATERIALS FOR WATER ENTERPRISES

VOLUME 8

	GUIDE FOR USERS OF TRAINING MATERIALS
●	TRAINING MODULES
	GENERAL
	ORGANISATIONAL
	Basic knowledge / skills
	Processes/procedures
	Equipment/materials
●	TECHNICAL
	Basic knowledge/skills
	Processes/procedures
	withdrawal
	treatment
	distribution
	consumption
●	Equipment/materials
	TAPE / SLIDE PROGRAMMES

MDP PRODUCTION TEAM
DHV - IWACO - TGI

DIRECTORATE OF WATER SUPPLY
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DEPARTMENT OF PUBLIC WORKS
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MDP PRODUCTION TEAM

TRAINING MATERIALS FOR WATER ENTERPRISES

VOLUME 8
TRAINING MODULES
TECHNICAL (equipment/materials)

DHV CONSULTING ENGINEERS
IWACO B.V.
T.G. INTERNATIONAL

JAKARTA
APRIL 1985

P R E F A C E

This volume is part of the Final Report of the MDP Production Team which produced Training Materials for Water Enterprises as part of a project under the bilateral cooperation programme between the Government of the Republic of Indonesia and the Government of the Kingdom of the Netherlands.

This Final Report contains the following volumes:

Volume 1	Guide for users of training materials	
Volume 2A	Training Modules,	GENERAL + ORGANIZATIONAL (basic knowledge/skills)
Volume 2B	Training Modules,	GENERAL + ORGANIZATIONAL (basic knowledge/skills)
Volume 3	Training Modules,	ORGANIZATIONAL (processes/procedures; equipment/materials)
Volume 4	Training Modules,	TECHNICAL (basic knowledge/skills)
Volume 5A	Training Modules,	TECHNICAL (processes/procedures)
Volume 5B	Training Modules,	TECHNICAL (processes/procedures)
Volume 6A	Training Modules,	TECHNICAL (Withdrawal + Treatment)
Volume 6B	Training Modules,	TECHNICAL (Withdrawal + Treatment)
Volume 7	Training Modules,	TECHNICAL (Distribution + Consumption)
Volume 8	Training Modules,	TECHNICAL (equipment/materials)
Volume 9	Tape/slide programmes	

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TRAINING MODULES

Module : **IDENTIFICATION OF PIPES AND FITTINGS**	Code : TEG 100
	Edition : 20-03-1985
Section 1 : I N F O R M A T I O N S H E E T	Page : 01 of 01/11

Duration :	90 minutes.
Training objectives :	After the session the trainees will be able to : - identify AC, uPVC, (Grey) cast iron, ductile iron and galvanized iron pipes; - identify bends, tees and branches.
Trainee selection :	- Pipelayer; - Pipeline Inspector; - Construction Supervisor; - Head of Sub-section Purchasing; - Head of Sub-section Warehousing; - Head of Section Distribution; - Head of Sub-section Distribution & Connections; - Head of Sub-section Supervision.
Training aids :	- AC pipe; - uPVC pipe; - (Grey) cast iron pipe; - Ductile iron pipe; - Galvanised iron pipe; - Bends; - Tees; - Branches; - Specimens of corroded pipes and fittings; - Handout : TEG 100/H 1.
Special features :	-
Keywords :	Pipe identification/fitting identification/pipes and fittings.

1. Introduction	
- Important to be able to recognise different types of pipes and fittings because: . pipes and fittings are designed for specific pressures etc.; . use of wrong material may cause leakage etc.	
2. A.C. Pipes	
- Most A.C. pipes used in Indonesia come from Australia. - Manufactured to Australian Standard AS 1711.	
- 4 classes of pipe related to pressures. - Identification marks on pipe. - Length of pipe colour coded.	Show markings on AC pipe
3. uPVC Pipe	
- Not all uPVC pipe available in Indonesia is suitable for use in water supply.	
- Pipes are available in 3 pressure classes.	Show examples of markings
- Markings different, depending upon standard used in manufacture.	Show differences in markings
4. Spun (Grey) Iron Pipe	
- Little used nowadays, except as cast fitting for A.C. pipe.	Show example of case fittings
5. Ductile Iron Pipe	
- Available in Indonesia.	
- Manufactured to various standards e.g. Japanese, Australian, British.	Show examples of markings

6. Galvanised Iron Pipes	
- Available in Indonesia and used up to 150 mm diameter.	
- Normally manufactured to British standard BS 1387/67.	
- Markings on pipe wall.	Show marking
7. Bends	
- Bends available in a variety of materials.	
- Angle of bend is normally marked on the side: 11.25°, 22.5°, 45°, 90°.	Show examples
- Bends normally have joints at the end e.g. a. spigot and socket; b. double spigot; c. flanges.	Show examples
8. Tees	
- Sizes are marked on outside of the tee.	Show marking
- Various joints on ends of tee e.g. : a. spigots; b. spigot and flanges; c. flanges etc.	Show examples
9. "Y" Branches	
- Normally a 45° branch from the straight.	Show example
- Sizes marked on outside.	Show marking
10. Summary	Give H 1

	Identification of pipes and fittings TEG 100/H 1

AC pipes are supplied in 4 standard lengths, usually being identified by a coloured band around the end of the pipe :

BAND COLOUR	LENGTH (metres)
Red	3.85
Yellow	3.70
Green	3.55
Violet	3.40

3. uPVC PIPES

These are manufactured from granules of polyvinylchloride (PVC) which are mixed with up to 6% additives and heated. The mixture is then extruded to form straight lengths of pipe, or cast in moulds to produce PVC fittings.

Finished pipes may vary in colour from white to blue/grey. After exposure to sunlight pipes may show a brownish discolouring.

There are many varieties of PVC pipe available in Indonesia but not all are suitable for water supply. Some contain more than 6% additives, which makes them brittle and unable to withstand water pressure. It is, therefore, important to identify the class of pipe before laying.

Pipes suitable for water supply are available in 3 classes. Class names have not yet been standardised in Indonesia and those adopted by 3 major manufacturers are given below :

CLASS			WORKING PRESSURE (metres head)
PRALON	RUCIKA	WAVIN	
VP	AW	II	100
AZ	D	III	80

Depending on the manufacturer, pipes are made with outside diameters which conform to either Japanese Standards (JIS K 6714) (Pralon & Rucika) or International Standards (ISO) (Wavin). Pipes and fittings made according to the two standards are not interchangeable.

Usually the class name is marked on the side of the pipe, but this is not always the case. Where the class name is omitted the pipe must be identified by comparing the wall thickness with pipe specimens from the same manufacturer.

4. (GREY) CAST IRON PIPE

This is made in an electric furnace. It is silver/grey in colour and contains flakes of graphite (see enlarged picture below). It is due to these graphite flakes that grey iron may be cut, without lubricant, by means of equipment producing a controlled crack. The resulting crack tends to be uneven and of crystalline appearance.

Grey cast iron pipes are hardly used for water supply purposes any more, although many older, existing mains are made of this material. Its present use is mainly for fittings for asbestos cement pipelines.

Fig. 1. Enlarged picture of grey cast iron (left) and ductile iron (right).

5. DUCTILE IRON PIPE

This is manufactured by a process similar to that of grey cast iron. The difference is that when the iron is molten, magnesium is added to the mix. This produces a metal structure in which the graphite is spheroidal, rather than in the form of flakes (see enlarged picture above). The resulting material is much stronger than grey iron, and special cutting methods should be adopted.

Ductile iron pipes from Japan are manufactured in 3 classes, according to working pressure. Class 1 is the strongest. Pipes which conform to Japanese Standards are marked as follows on the face of the socket:

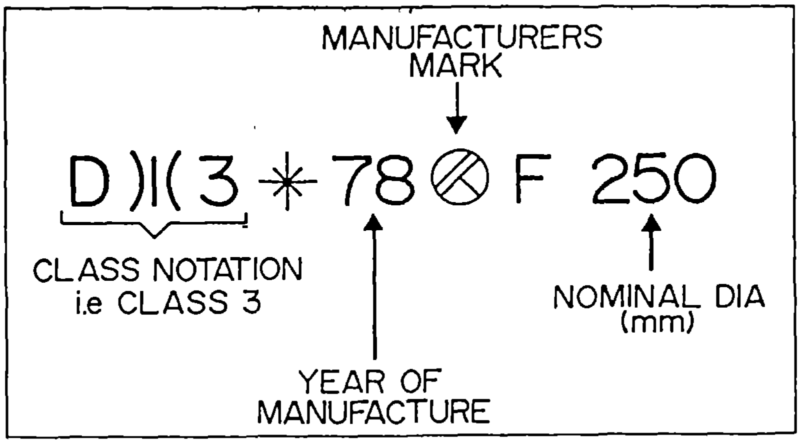


Fig. 2. JSO pipe markings.

Ductile iron pipes are also available from Australia. They are of one class only, made in accordance with Australian Standard AS 1723 and British Standard BS 4772. They can be identified by the red-painted socket face.

To protect against corrosion the pipes are usually coated externally with a black bituminous paint, and lined internally with cement mortar. The internal surface of the mortar lining is coated with synthetic resin to prevent break-down of the cement lining and to lengthen its life.

6. GALVANISED IRON PIPES

In some parts of Indonesia galvanised iron is used for sizes up to 150 mm diameter.
Various grades of pipe are available, but not all are suitable for water supply purposes.

Pipes manufactured according to British Standard 1387/1967 can be used. They are identified by the following markings on the pipe wall:

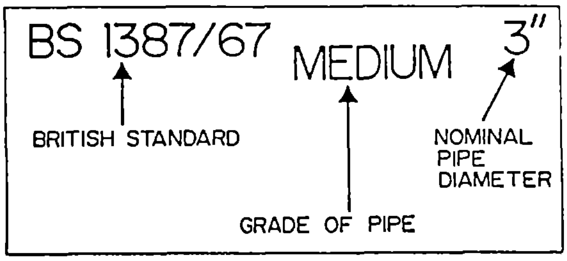


Fig. 3. Pipe markings according to British standard.

7. BENDS

These are used to change the direction of the pipeline, the degree of change being the angle of the bend. Standard bends are available to produce changes of 11.25°, 22.5°, 45°, 90°.
The angle of the bend is usually marked on the wall of the pipe. Some bends produce the same degree of change over a shorter body length, as shown below.

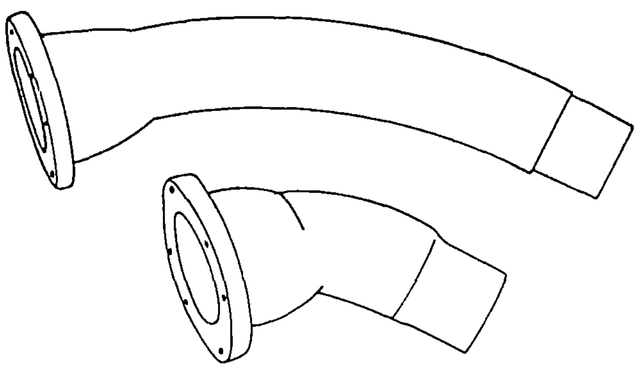
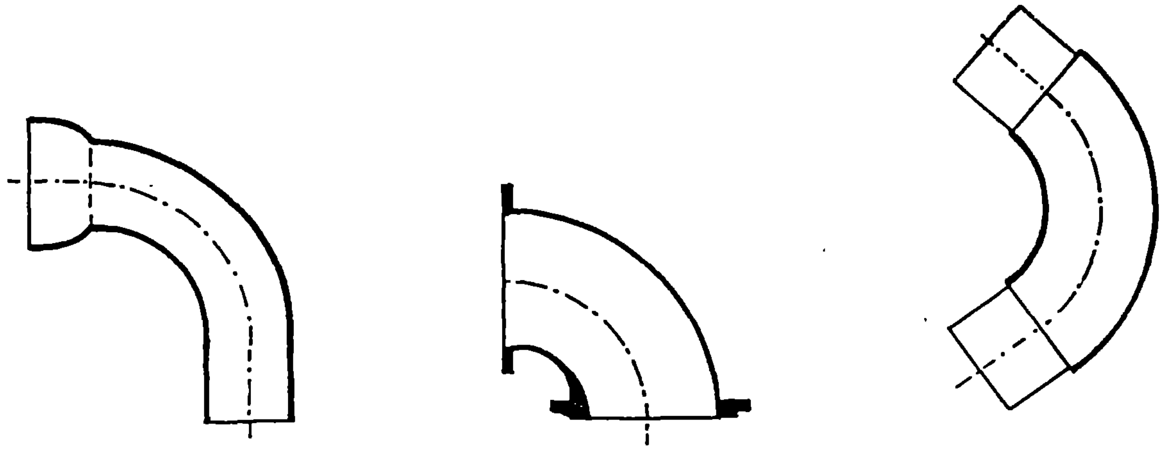


Fig. 4. Bends.

With the exception of asbestos cement it is common practice to use bends and fittings of the same material as the main.
This reduces the risk of excessive corrosion due to change of material and avoids the need for special couplings.

Bends can be either spigot and socket type, double socket, double spigot or flanged (see below).



SPIGOT & SOCKET TYPE

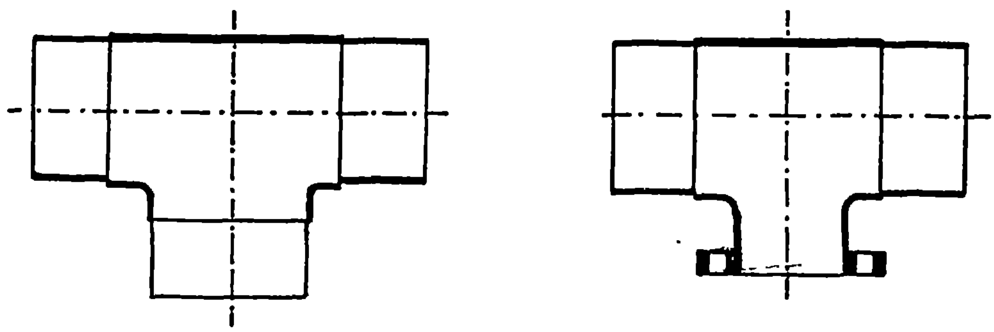
FLANGED TYPE

DOUBLE SPIGOT TYPE

Fig. 5. Various types of bends.

8. TEES

These allow a secondary pipe to be laid at 90° to the main pipeline. They are shaped like the letter "T" (in English pronounced "Tee"). The outlets may be combinations of spigot, socket and flanges.



ALL - SPIGOT "T"

WITH FLANGED BRANCH

Fig. 6. Typical T-pieces.

9. "Y" BRANCH PIPES

These allow a secondary pipe to be laid at angles other than 90° to the main pipeline. They are usually made with a 45° angle but other angles can be made to order.

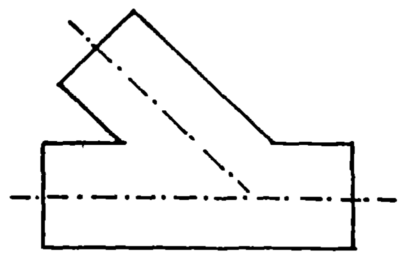


Fig. 7. "Y"-branch.

10. SUMMARY

It is important to be able to recognize different types of pipes and fittings because these are designed for specific pressures etc. Use of wrong materials may cause leakages etc.
Pipes and fittings used in Indonesia are made of the following materials:
- Asbestos cement (AC);
- uPVC;
- (Grey) cast iron;
- Ductile iron;
- Galvanized iron.

Markings on the pipes give information about strength and sometimes length of the pipes.
It is common practice to use bends, "Tees" and "Y" branch pipes of the same material as the main.

* * *

Duration :	90 minutes.
Training objectives :	After the session the trainees will be able to: - list the 3 main methods of stacking pipes, with their advantages and disadvantages; - use all methods in practice.
Trainee selection :	- Pipelayer; - Pipeline Inspector; - Construction Supervisor; - Head of Sub-section Warehousing.
Training aids :	- Ropes; - Slings; - Stacking model; - uPVC pipes (40 lengths of Ø 100 mm pipe); - Viewfoils : TEG 120/V 1-3; - Handout : TEG 120/H 1.
Special features :	-
Keywords :	Pipe handling/pipe stacking.

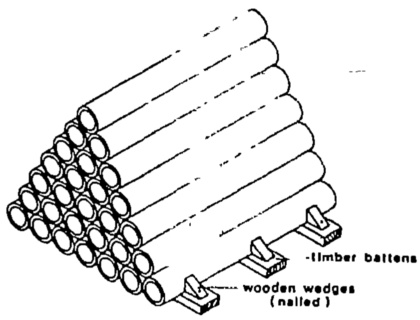
1. Introduction	
- Each type of pipe used has different characteristics regarding : . strength . weight.	Use whiteboard
- Storage of pipes is different for each type of pipe.	
2. Stacking Techniques	
- There are basically three types of pipe stack : . pyramid stack . box stack . cross stack.	Use whiteboard
3. Pyramid stack	
- Is easier to construct but : . stores less pipes for ground area covered; . uses additional materials e.g. wedges, spacing timber, etc.	Show V 1 Demonstrate stacking with model
- Requirements to construct a pyramid stack: . sockets alternate in stack; . base must be securely wedged; . ground must be level.	
4. Cross Stack	
- Allows more pipes to be stacked for the ground area covered.	Show V 2
- Pipes are stacked cross-wise with sockets and spigots alternating.	
- Stack is approximately square.	Demonstrate stacking with model
- Timber supports and wedges.	

5. **Box Stack**	
- Stack is in the form of a box.	Show V 3
- Normally used by manufacturers to transport pipes, with the addition of timber sides.	
- Pipes are stacked with length in one direction only (not cross stacked).	Demonstrate stacking with model
- uPVC normally stacked this way.	
6. **Handling Pipes**	
- Pipes are handled in two ways . with mechanical equipment, or . manually.	
- Slings and ropes are used for lifting pipes.	Show slings and ropes Demonstrate lifting with slings and ropes
- Spreader beams are used for more equal division of forces on pipes.	
- Slings and ropes have safety (weight) limits.	
7. **Safety**	
- Pipes are bulky and heavy, therefore : . special care required to lift pipes; . use gloves, safety-hats and shoes.	

8. **Exercise** - Explain exercise. - Do exercise (20 minutes). - Discuss results.	Have trainees stack pipes (uPVC for convenience) a. Pyramid stack b. Cross stack c. Box stack
9. **Summary**	Give H 1

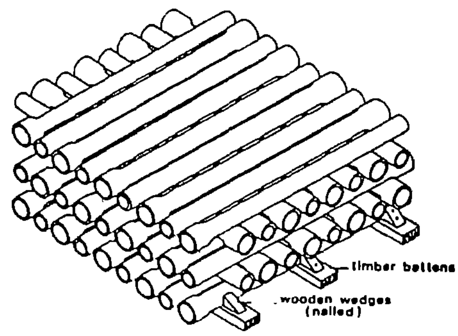
Module : **HANDLING AND STACKING OF PIPES**	Code : TEG 120
	Edition : 20-03-1985
Section 3 : T R A I N I N G A I D S	Page : 01 of 01

Pyramid stack TEG 120/V 1



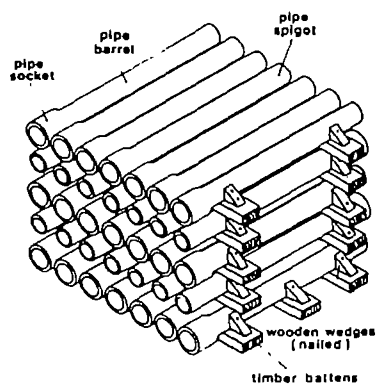
PYRAMID STACK

Cross stack TEG 120/V 2



CROSS STACK

Box stack TEG 120/V 3



BOX STACK

Handling and stacking of pipes TEG 120/H 1

1. INTRODUCTION

Every type of pipe used in main laying has different characteristics regarding :

a. stacking
b. weight.

The storage of pipes depends largely on the material used. For convenience pipes are normally stored on site in stacks.

2. STACKING TECHNIQUES

There are three basic types of pipe stack :

a. pyramid stack
b. cross stack
c. box stack.

Each one has advantages and disadvantages compared to the others.

3. PYRAMID STACK

This is the easiest of all the stacks to construct but stores less pipes for the ground area covered. It is also expensive in additional material e.g. wedges, spacing timber etc.

Basically the pipes are laid side by side on the ground with the sockets alternating. The next layer comprises one number of pipes less than the previous layer. The base layer should be well wedged and sufficient timbers and wedges placed between each layer of pipes. It is essential that the ground selected for any pipe stack should be level (see fig. 1 on next page).

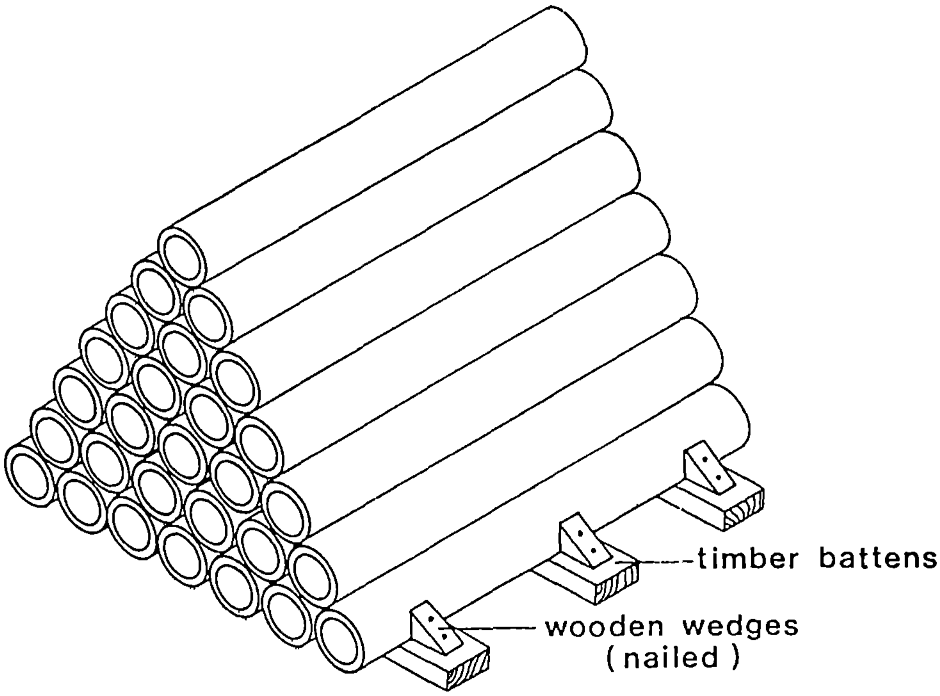


Fig. 1. Pyramid stack.

4. CROSS STACK

This type of stack allows for more pipes to be stacked for the ground area covered.
For this stack,pipes are stacked in layers with sockets alternating, and each layer is at 90' to the layers above and below. This means that the stack itself is approximately square. The layers are normally separated by timber supports and the end pipes are wedged securely. There is a maximum height to the stack depending on the diameter of the pipes (see fig. 2 on next page).

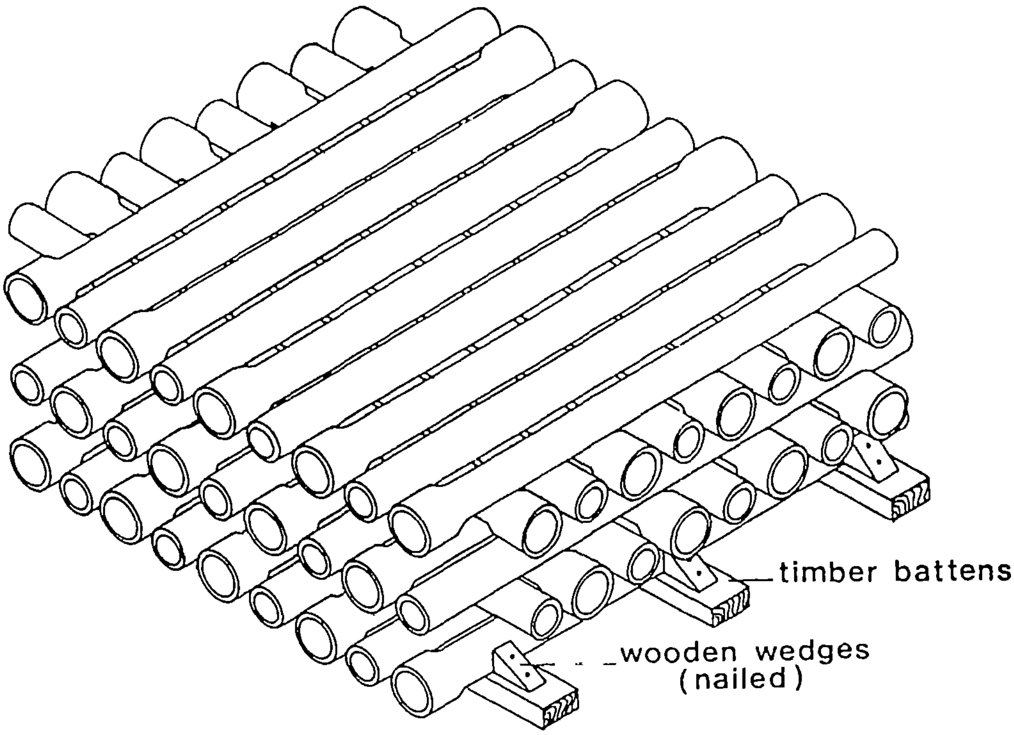


Fig. 2. Cross stack.

5. BOX STACK

This type of stack is normally transported directly from the manufacturer. The sides of the stack and base are constructed of timber very similar to a crate and the pipes are placed inside, all running in the same direction but with the sockets alternating. It is difficult to reconstruct on site because of the construction of the box.
Because of the lightness of uPVC pipes this is the most common form of pipe stacking used by manufacturers of this type of pipe.

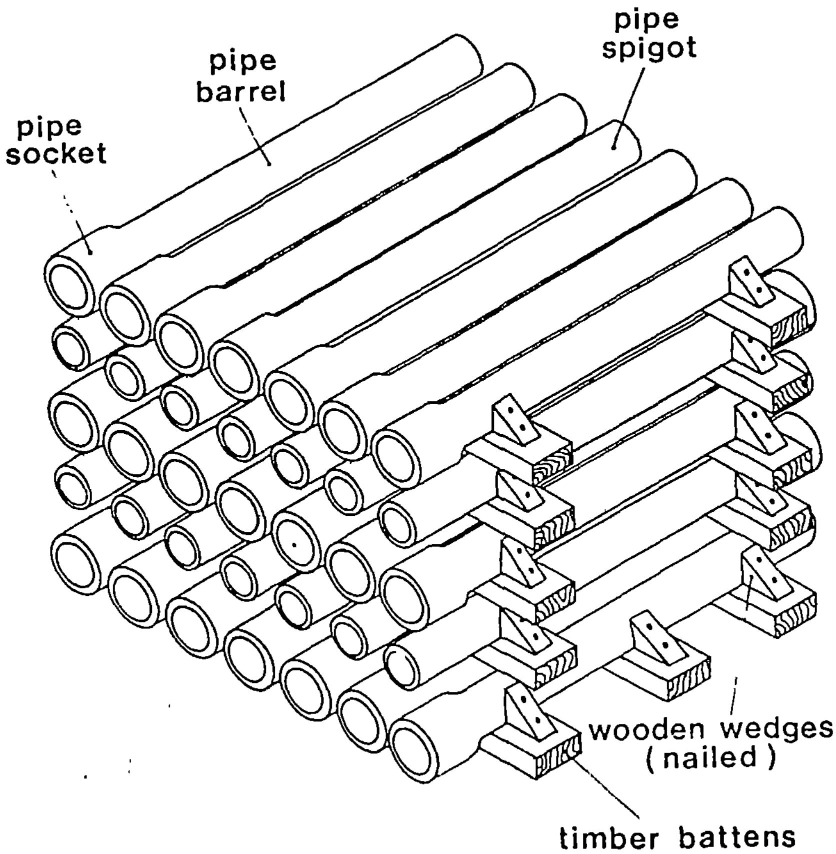


Fig. 3. Box stack.

6. HANDLING PIPES

Essentially pipes are handled in one of the following:
a. using mechanical equipment
b. manually.

However, both methods require pipe slings or ropes for lifting purposes. It is important to note the weight limits (safety limits) of any pipe slings or ropes used, particularly when hoisting with mechanical equipment to considerable heights above the ground.

In order to spread the lifting forces more equally over the pipes, spreader beams may be used.
Manufacturers will supply details of the weight per pipe length, and of any special fittings.

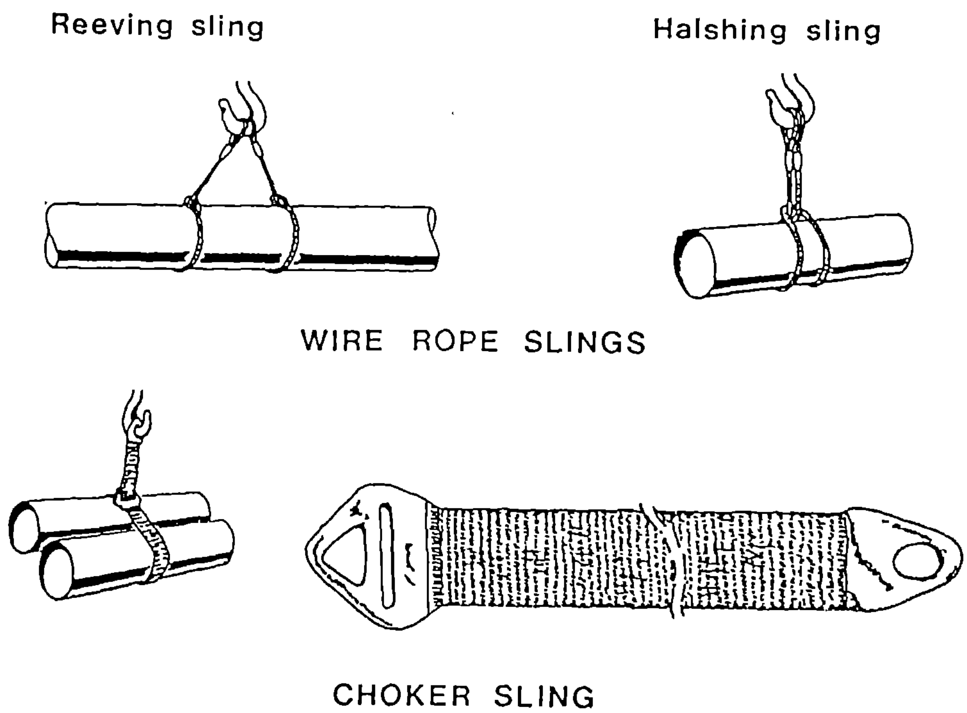


Fig. 4. Slings for handling pipes.

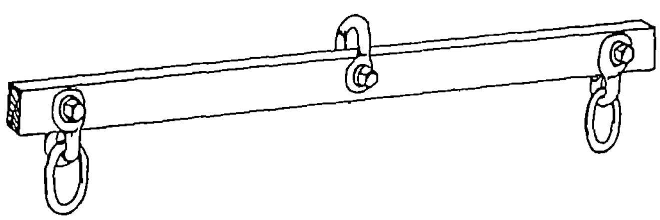


Fig. 5. Spreader beam.

7. SAFETY

One must always remember that pipes are bulky and heavy and, with the exception of uPVC pipes and small fittings, cannot normally be carried safely by one man. In fact, most metal and AC pipes normally require the use of mechanical equipment for off-loading and lowering into the trench. Gloves and safety shoes should always be worn when handling pipes.

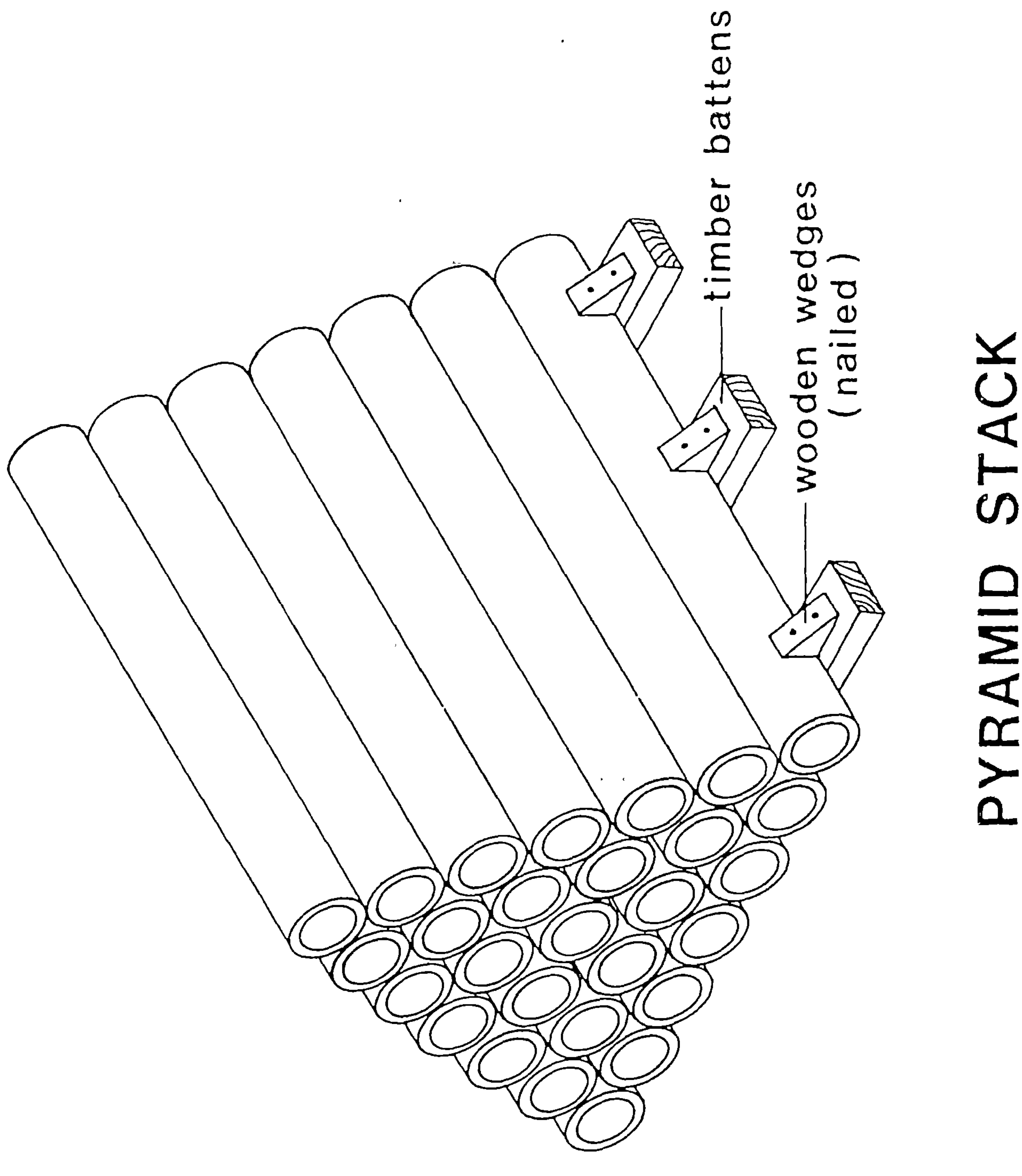
8. SUMMARY

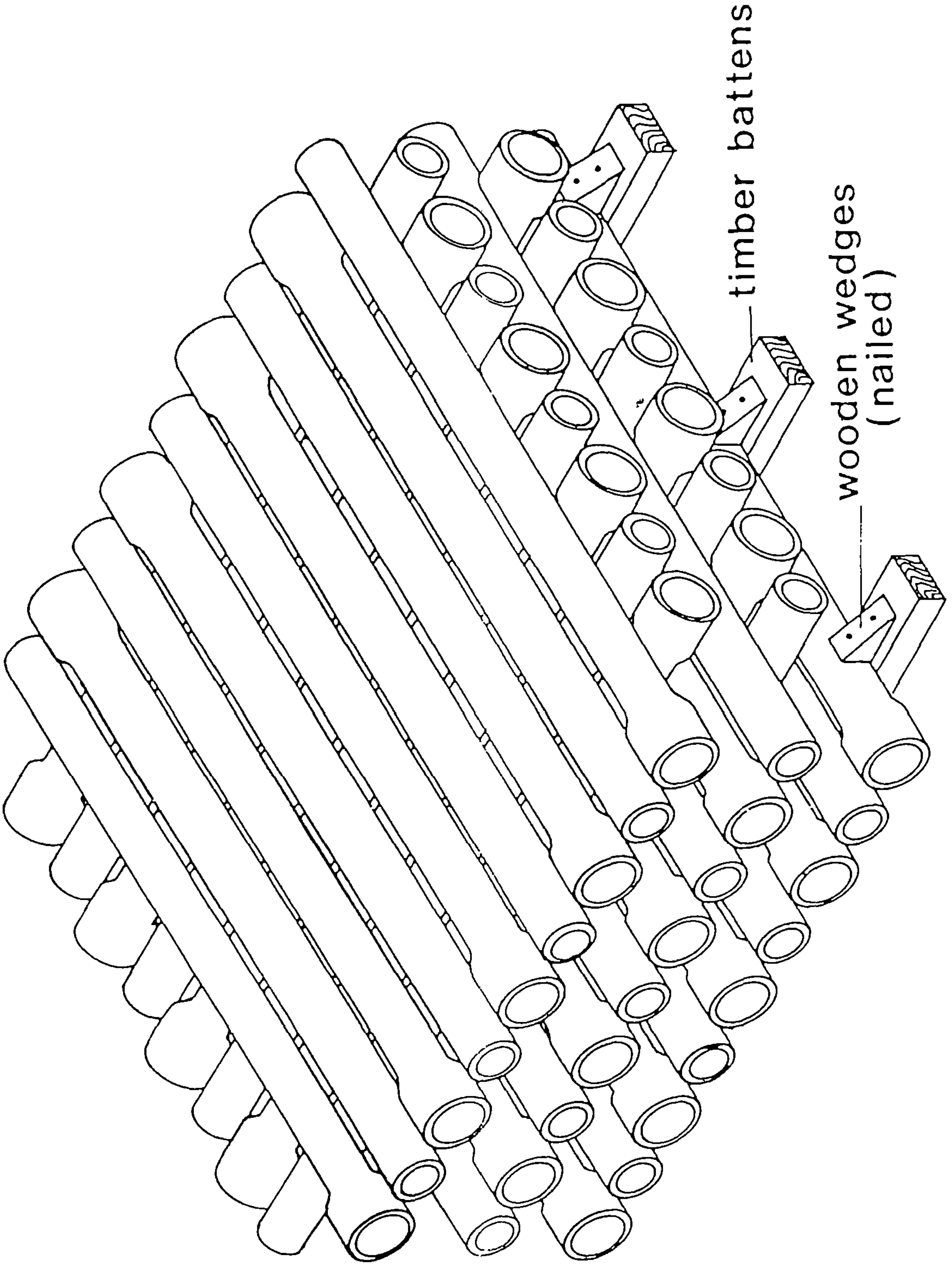
There are basically three types of pipe stack :

a. pyramid stack
b. cross stack
c. box stack.

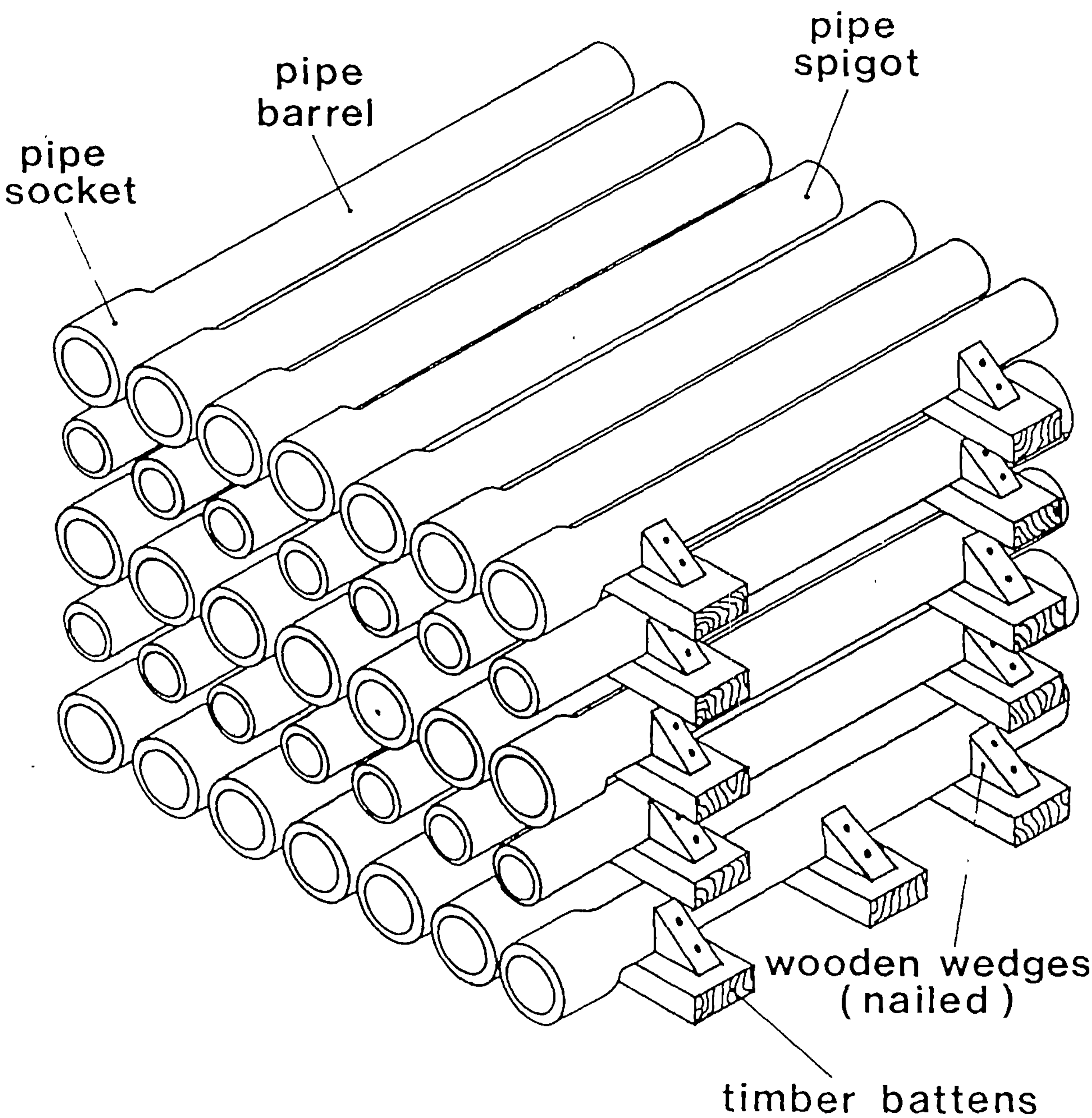
The pipes should be handled safely using slings or ropes.

* * *


timber battens
wooden wedges
(nailed)
PYRAMID STACK



CROSS STACK


pipe barrel
pipe spigot
pipe socket
wooden wedges (nailed)
timber battens

BOX STACK

Module : HYDROPHORE	Code : TEG 501
	Edition : 03-05-1985
Section 1 : I N F O R M A T I O N S H E E T	Page : 01 of 01/15

Duration :	45 minutes.
Training objectives :	After the session the trainees will be able to: - explain why hydrophores are used; - explain how hydrophores work; - explain which two main parameters influence the size of the pressure vessel; - calculate the required total pressure vessel capacity of a hydrophore.
Trainee selection :	- Head of Section Maintenance; - Head of Section Transmission-Distribution; - Junior Engineer; - Mechanics.
Training aids :	- Viewfoils : TEG 501/V 1-8; - Handout : TEG 501/H 1.
Special features :	-
Keywords :	Hydrophore/pressure vessel/pressure switch.

1. Introduction

Show V 1

- A hydrophore is used:
  - . to prevent sudden pressure changes;
  - . to maintain the water pressure automatically within certain values;
  - . to supply a certain amount of pressurized water between pumping periods.

2. How it works

- Pressure vessels in general contain water in the lower part, and air in the upper part.

Show V 2

- The pressure in the pressure vessel is kept between specific minimum and maximum values. When the pressure decreases below the minimum value, the pump will start automatically and when the pressure reaches the maximum value the pump will be switched off automatically.

Show V 3-5

- Volume of air and water in the vessel at each cycle of operation:
  - . the function of the air is to stabilize the pressure in the vessel and to enable withdrawal of a certain amount of pressurized water;
  - . the amount of water that can be withdrawn from the vessel between subsequent pumping periods depends on:
    - * the size of the vessel;
    - * ratio of water to air.

3. Size of pressure vessel

Show V 6

- The effective pressure vessel volume can be calculated from:

$$V_{required}\,[m^3] = 0.33\,K\,\frac{Q_{AV}\,(P_B + P_{OFF})}{(P_{OFF} - P_{ON})\,.\,S}$$

- The size of the pressure vessel is influenced by:
  a. difference in maxium and minimum pressure ($P_{OFF} - P_{ON}$);
  b. frequency of pump cycles (S).

4. **Control of air inside the pressure vessel**

   - If water and air are in contact under pressure, there is a tendency for the water to absorb the air. The water leaving the hydrophore will take some air along. If the air is not replaced, the vessel will gradually loose all air and be filled up with water ("water logged" condition). To prevent this, equipment is required to control the volume of air needed, and to replace the amount of air carried away by the water from the vessel. Normally compressors are applied for this purpose.
     In small installations a special arrangement of the pump in combination with an airvalve is often used to maintain the air supply in the vessel. Too much air will be released through the release valve. Small hydrophores (mostly made in Japan) use in principle the same system although there are differences in operation. — Show V 7-8

5. **Operation and maintenance**

   - After proper adjustment the vessel will function automatically.

   - Regular inspections must be made to check:
     . condition of the pressure regulator switch;
     . condition of the vessel (must be painted periodically).

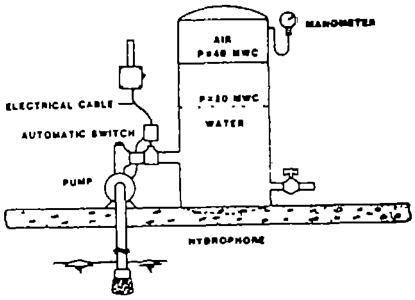
   - Other devices requiring maintenance are compressors, which need energy and are vurnerable to wear and tear. — Give H 1

Application of hydrophores — TEG 501/V 1

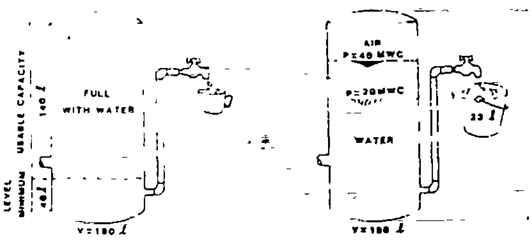
HYDROPHORES ARE USED .

- To level out pressure fluctuations
- To keep water pressure between certain values
- To supply a certain amount of pressurized water between two subsequent pumping periods

Hydrophore installation — TEG 501/V 2



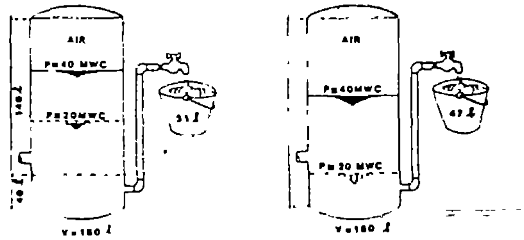
Functioning of pressure vessel (I) — TEG 501/V 3



NO COMPRESSED AIR CUSHION

1/4 OF VESSEL FILLED WITH COMPRESSED AIR (35 l)

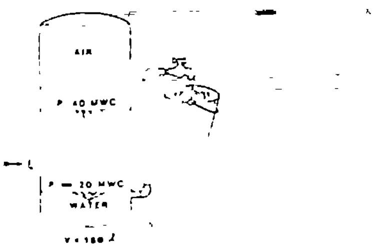
Functioning of pressure vessel (II) — TEG 501/V 4



1/3 OF VESSEL FILLED WITH COMPRESSED AIR (47 l)

1/2 OF VESSEL FILLED WITH COMPRESSED AIR (76 l)

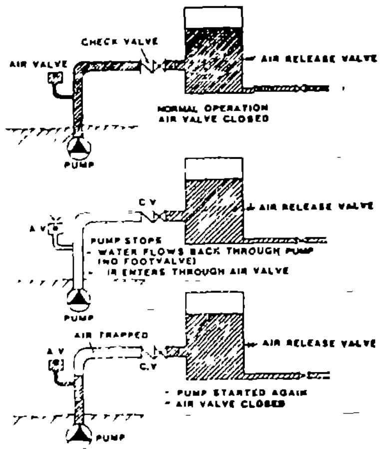
Operation pressure vessel — TEG 501/V 5



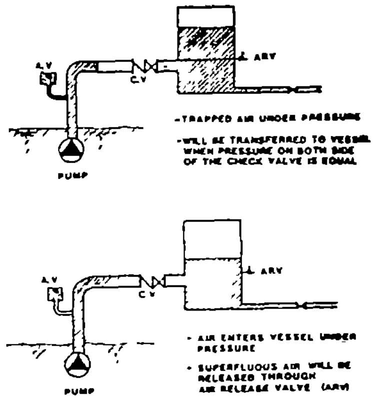
TOO MUCH AIR IN TANK

Tank measurements — TEG 501/V 6

Air pressure control (I) TEG 501/V 7



Air pressure control (II) TEG 501/V 8



Hydrophore TEG 501/H 1

1. INTRODUCTION

Hydrophores are usually much cheaper than water towers. Hydrophores are used for maintaining pressure in the distribution network in case:

- consumption is relatively small and the construction of a water tower is too expensive;
- water towers cannot be accepted due to aesthetic reasons;
- water towers cannot be constructed, for instance for high-rise apartment buildings.

A hydrophore consists of one or more pumps which keep a pressure vessel partially filled with water and partially filled with air between specific minimum and maximum pressures by automatically actuating the pump switch(es).

Hydrophores consist of the following components (see fig. 1):

- one or more pumps;
- pressure vessel;
- measuring gauge;
- pressure switches;
- manometer;
- drain;
- device to keep the vessel constantly partly filled with air (air-pumps connected with water pumps, one-way air-valve or compressors).

2. HOW HYDROPHORES WORK

Apart from the differences in design, the basic principles of the operation cycle of hydrophores are usually of comparable nature. Figure 1 shows that the pressure vessel is generally filled with water in the lower part and with air in the upper part. Water is pumped into the vessel near the bottom, thus compressing the air in the upper part. As an example we consider a hydrophore with a minimum pressure of 20 metres water column (= 20 mwc or 2 kg/cm^2) and a maximum pressure of 40 mwc (4 kg/cm^2). When the pressure in the vessel decreases to 20 mwc, the pump starts to operate and when the pressure reaches 40 mwc the pump is automatically switched off. The pressure range can be changed by adjusting the pressure regulator on the pressure switch.
Initiated by the minimum pressure of 20 mwc in the vessel the cycle of operation is as follows:

- At a pressure of 20 mwc, the water level inside the vessel is indicated by line-x in diagram 1. It is now necessary to pump water into the vessel; the pressure switch is closed, and the pump starts running.

- The pump supplies water from the source into the vessel. The water pushes the air upwards, while compressing it.

- When the water level has reached its level indicated by the line-y, the pressure will be sufficient to trigger the automatic switch and stop the pump.

- The compressed air above the water inside the vessel constantly compresses the water downwards like a large spring. This pressure will cause the water to flow out from the vessel through the outlet pipe when water is withdrawn by opening valves or taps.

- As water flows out of the vessel, the air will expand and this will cause a decrease in pressure. When the water level has dropped reaching the line-x, the pressure is reduced to 20 mwc and the switch will close to start the pump.

With this method, the automatic system maintains the pressure required, such that the water can be let out through the valve at any time.

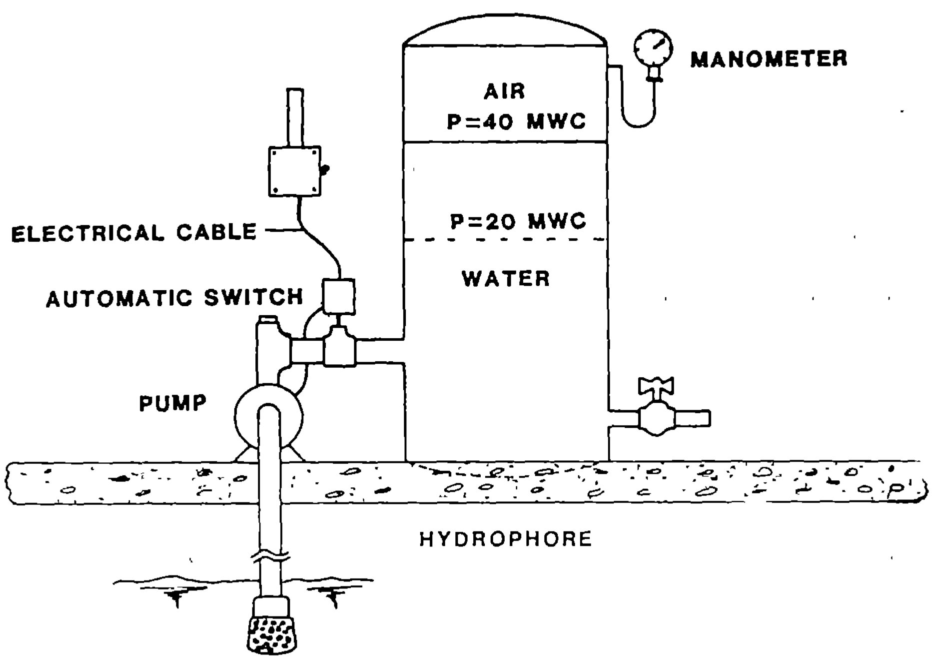


Fig. 1. Cycle of operation, .the pump starts at a pressure of 20 mwc and stops at a pressure of 40 mwc.

Volume of water available from vessel during every cycle of operation

The amount of water that can be withdrawn from the vessel between two pressure adjustments, depends on the amount and initial ratio between air and water inside the vessel. When there is no air, the pressure inside the vessel will increase rapidly when the pump is switched on, and decrease rapidly when water is withdrawn from the vessel. This is caused by the fact that water is hardly compressible. If air is absent in the vessel, the vessel is "water-logged".
Under water-logged conditions the pump starts to operate each time water is withdrawn from the vessel. The system will work as if there were no vessel. The pump almost never works at maximum efficiency, which means that this pumping system will be very expensive. Frequent starting and shutting off of the pump will use up too much electrical energy and can damage the motor quickly.

The amount of water which can be withdrawn from a pressure vessel under static conditions (i.e. pressure vessel is pressurized to a certain pressure and contains certain volumes of air and water; pump is not running) can be calculated with the Law of Boyle:

$$pV = C \quad \text{(at constant Temperature)} \quad \text{or} \quad p_1 V_1 = p_2 V_2 \quad \ldots\ldots \quad (1)$$

or: $$V_2 = \frac{p_1}{p_2} \cdot V_1 \quad \ldots\ldots \quad (2)$$

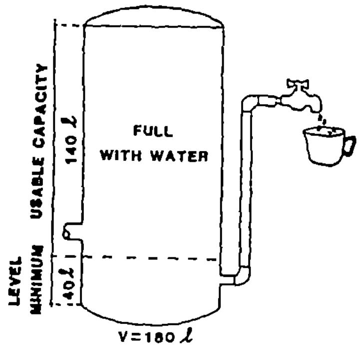
where: V_2 = air volume at p_2 (in m^3);
p_1 = absolute pressure before water withdrawal (in bar);
p_2 = absolute pressure after water withdrawal (in bar);
V_1 = air volume at p_1 (in m^3)

Note: absolute pressure = manometric pressure (in bar) + 1 bar.

From (2) the water volume withdrawn can be calculated as $V_2 - V_1$ (in m^3). For further details see fig. 2.

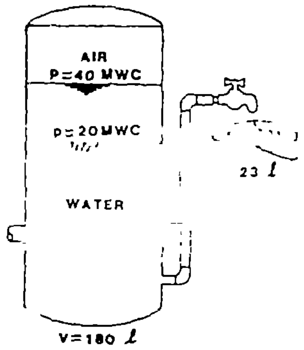
Previously, it was mentioned that the purpose of air inside the vessel is to supply a certain amount of pressurized water, during intervals between stopping and starting the pumping. However there is a limit to how much air should be left inside the vessel. If the volume of air is too large, the water level will drop to below the outlet pipe before the pressure drops to minimum value and air will pass out through the outlet. Larger installations are equipped with air release valves to prevent the above from happening.

a.



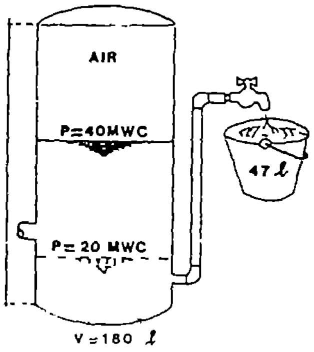
NO COMPRESSED AIR CUSHION

b.



1/4 OF VESSEL FILLED WITH COMPRESSED AIR (35 ℓ)

c.



1/2 OF VESSEL FILLED WITH COMPRESSED AIR (70 ℓ)

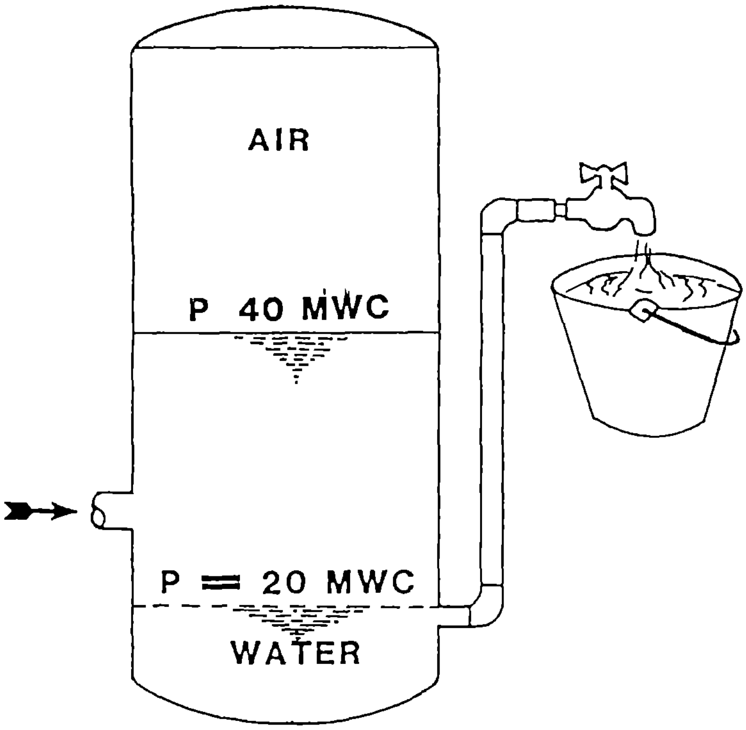
Fig. 2. The amount of water that can be withdrawn from the pressure vessel, between stopping and starting the pump, varies with the volume of air inside the tank.

Explanation of fig. 2. :

a. There is no air. The pressure drops rapidly from 40 mwc to 20 mwc while yielding a small amount of water. The vessel has hardly any function. The pump will start operating each time water is withdrawn, and most likely the pump runs and stops while the valve is opened.

b. 1/4 of the vessel is filled with air at a pressure of 40 mwc. 23 litres of water can be let out before the pump will be started again (at 20 mwc).

c. 1/2 of the tank (70 l) is filled with air at a pressure of 40 mwc. 47 litres of water can be withdrawn before the pump will be restarted (at 20 mwc).



V = 160 ℓ

TOO MUCH AIR IN TANK

Fig. 3.

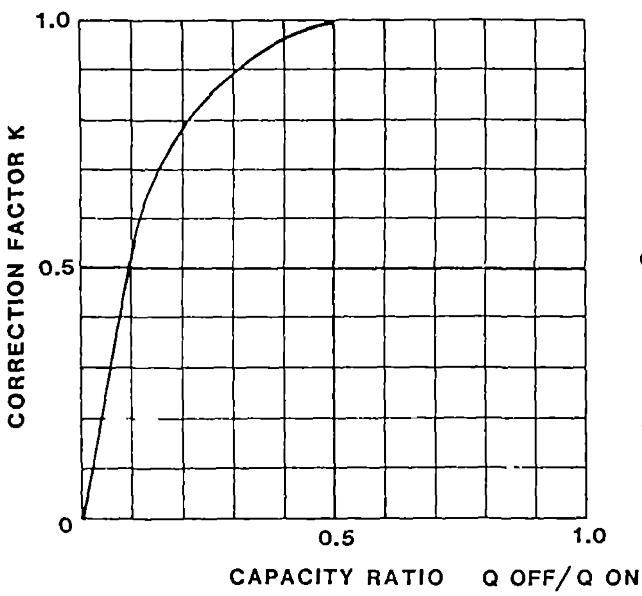
If there is a lot of air inside the tank, the air will flow out with the water, and the water will come out intermittently.

3. SIZE OF PRESSURE VESSEL

The required capacity of the vessel can be calculated from the formular below. For the design of pressure vessels the maximum allowable air volume at the minimum vessel pressure (P_{ON}) is set at 75% of $V_{required}$. In other words the total vessel volume (= $V_{required}$) is 25% larger than the effective vessel volume.

$$V_{required}\ [m^3] = 0.33\ K\ \frac{Q_{AV}\ (P_B + P_{OFF})}{(P_{OFF} - P_{ON})\ .\ S}$$

Where:



$V_{required}$ = Volume of pressure vessel required [m³].
K = correction factor if $Q_{OFF}/Q_{ON} < 0.5$ (See fig. 4)
Q_{AV} = average flow or $(Q_{ON}+Q_{OFF})/2$ of the largest pump in the installation (in m³/h)
Q_{ON} = capacity at switching on pressure (in m³/h)
Q_{OFF} = capacity at switching off pressure (in m³/h)
P_B = barometric pressure (in bar)
P_{ON} = pressure at the time the pump is switched on (in bar)
P_{OFF} = pressure at the time the pump is switched off (in bar)
S = number of cycles permitted per hour (in h^{-1}).

Fig. 4. Correction factor K.

The outlet pipe of the pressure vessel should be installed in such a way that the outlet is immersed (outlet below water level) at minimum water level (occuring at minimum pressure P_{ON}).

The formular shows that for certain values of Q_{AV} and P_{OFF} the size of the pressure vessel is influenced by:

a. The pressure difference $P_{ON}-P_{OFF}$.
   The smaller the pressure difference, the more uniform the pressure at the outlet, and the larger the volume required for the pressure vessel.

b. Frequency of cycles (S).
The lower the frequency, the lower the pressure at the couplings, control mechanism and motor, however the size of the motor has to be larger. To limit the wear and tear of components, the frequency of start-ups is to be limited to a maximum of 30 cycles/hr and should preferably be lower.

Generally, the number of start-ups permitted will decrease if the size of the pump is enlarged. The recommendations of the manufacturer have to be considered in each case.

4. CONTROL OF AIR VOLUME INSIDE THE PRESSURE VESSEL

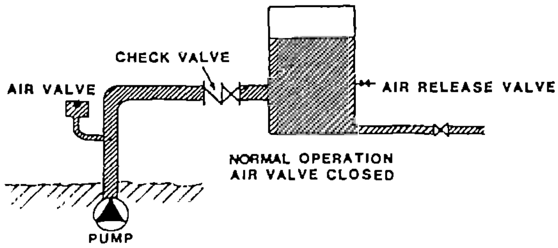
When water and air are in contact under pressure, there will be a tendency for the water to absorb the air. The result will be that the water withdrawn from the pressure vessel will carry the air along. If the air is not replaced, then the vessel will become "water-logged". To prevent this, the control device for the volume of air will work automatically to maintain the exact volume of air inside the vessel at anytime thereby replacing the amount of air carried away by the water:

- If there is too much air inside the the pressure vessel, then the air will escape through the air release valve.

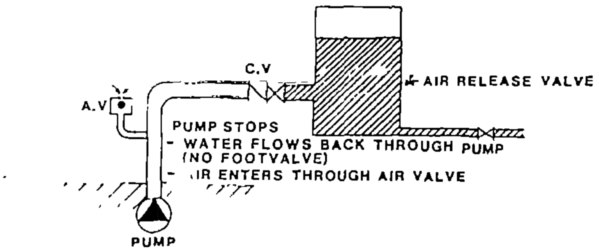
- If there is not enough air inside the pressure vessel, then it must be refilled. The easiest method is by using a compressor. The compressor can be switched on and off by hand, after observation of the air/water interface level, or it can also be done automatically by means of various switch levels inside the tank. The compressor represents a piece of the equipment requiring maintenance and energy, and moreover it is vulnerable to wear and tear.

In small installations the air supply to the pressure vessel may be maintained by means of a special arrangement of the pump in combination with an air-valve. Fig. 5 illustrates this procedure. By placing the air-valve near the one-way valve, the amount of air transferred to the vessel everytime the pump is started can be minimized. If the system does not function, this is generally caused by an improper functioning of the air-valve.

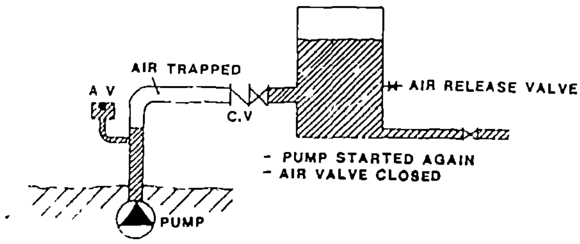
Small hydrophores, mostly made in Japan, use in principle the same system. However, there are some differences in operation. Problems are mostly caused by the air valves.



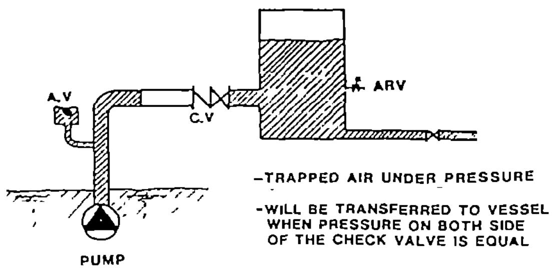
1. Normal operation. Air valve closed.



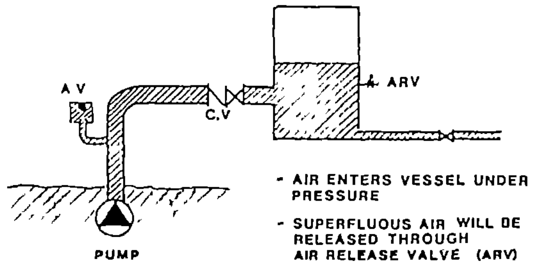
2. After the pump is switched off, air is let into the inlet pipe through the air-valve.



3. If the pump is switched on the air will be pushed out of the inlet pipe until the water level reaches the ball inside the air-valve which will be closed immediately.



4. The air trapped between the air-valve and the the one-way valve will cause the valves to be under gradually increasing pressure by the pump, until it reaches the same pressure as on the other side of the one-way valve.



5. Once this happens the air will enter the vessel and combine with the air already in it. If there is too much air in the vessel it will be released by the air release valve.

Fig. 5. Replenishment of air by means of air-valve + pump.

5. OPERATION AND MAINTENANCE

After proper adjustment, the hydrophore will function automatically. Only the pressure regulator switch has to be checked regularly to check whether its spring is functioning properly.

Apart from the pump, there is no special maintenance required. The pressure vessel shall be maintained in good condition, painted regularly and checked for leakages. For operation and maintenance of pumps refer to manufacturer's documentation or modules on pumps. Regular inspection of the frequency of operation of the pump is necessary.

6. REVIEW

The pressure vessel is used to:
- prevent sudden pressure changes;
- maintain the water pressure automatically within a certain pressure range;
- supply a certain amount of pressurized water between subsequent pumping periods.

How pressure vessels work

- The pressure vessel contains water in the lower part and air in the upper part.

- The pressure in the vessel is kept between specified minimum and maximum values:

. if the pressure drops to the minimum level the pump will be started automatically;
. if the pressure reaches the maximum level the pump will be switched off automatically.

- The amount of the pressurized water that can be obtained from the vessel depends on:
  . the size of the vessel;
  . the ratio of air and water volumes in the vessel.

- The function of air is to:
  . stabilize the pressure in the vessel and to enable withdrawal of pressurized water from the vessel.

Size of pressure vessel:

- The total vessel volume required can be calculated from:

$$V_{required}\,[m^3] = 0.33\,K\,\frac{Q_{AV}\,(P_B + P_{OFF})}{(P_{OFF} - P_{ON})\,.\,S}$$

- The size of the vessel is influenced by:
  . difference in maximum and minimum pressure (P_{OFF}-P_{ON});
  . frequency of pump cycles per hour (S).

Control of air inside the pressure vessel

If water and air are in contact under pressure the water will absorb the air. Each time water is withdrawn from the vessel it will take some air out. If the air is not replaced the vessel will eventually be full of water (water-logged). To prevent this, an automatic device to control and also to maintain always the correct volume of air inside the vessel is required. A conventional solution is the application of a compressor. A compressor is a piece of equipment which requires maintenance, and energy, and it is vulnerable too. In smaller installations the supply of air inside the vessel can be effectuated by a special arrangement of pump and air-valve.

Operation and maintenance

- Once the hydrophore is properly adjusted, it will function automatically.

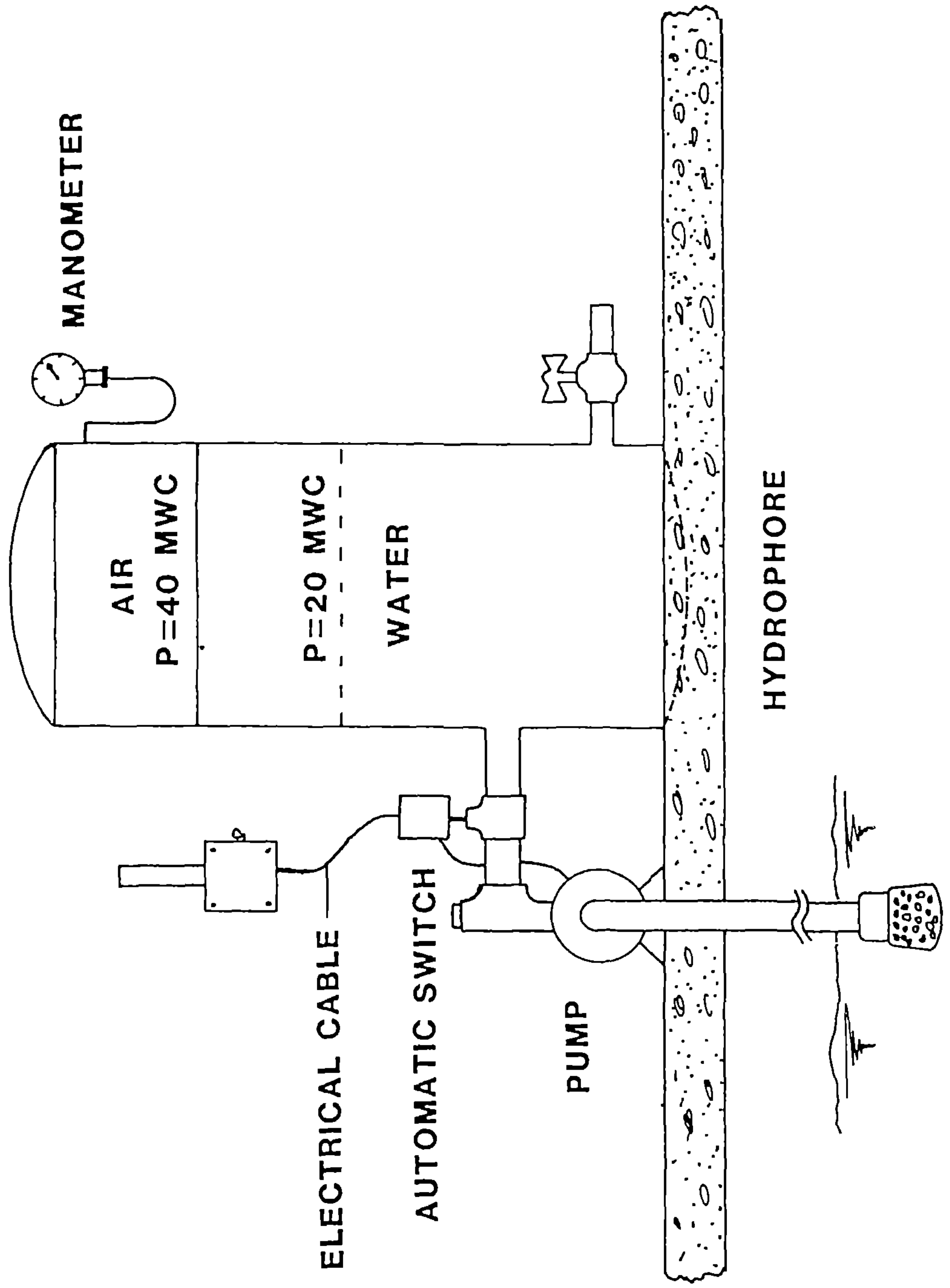
- Regular inspection must be made to check:
  . condition of switches;
  . frequency of start/stop functions of pumps;
  . condition of vessel (must be painted periodically).

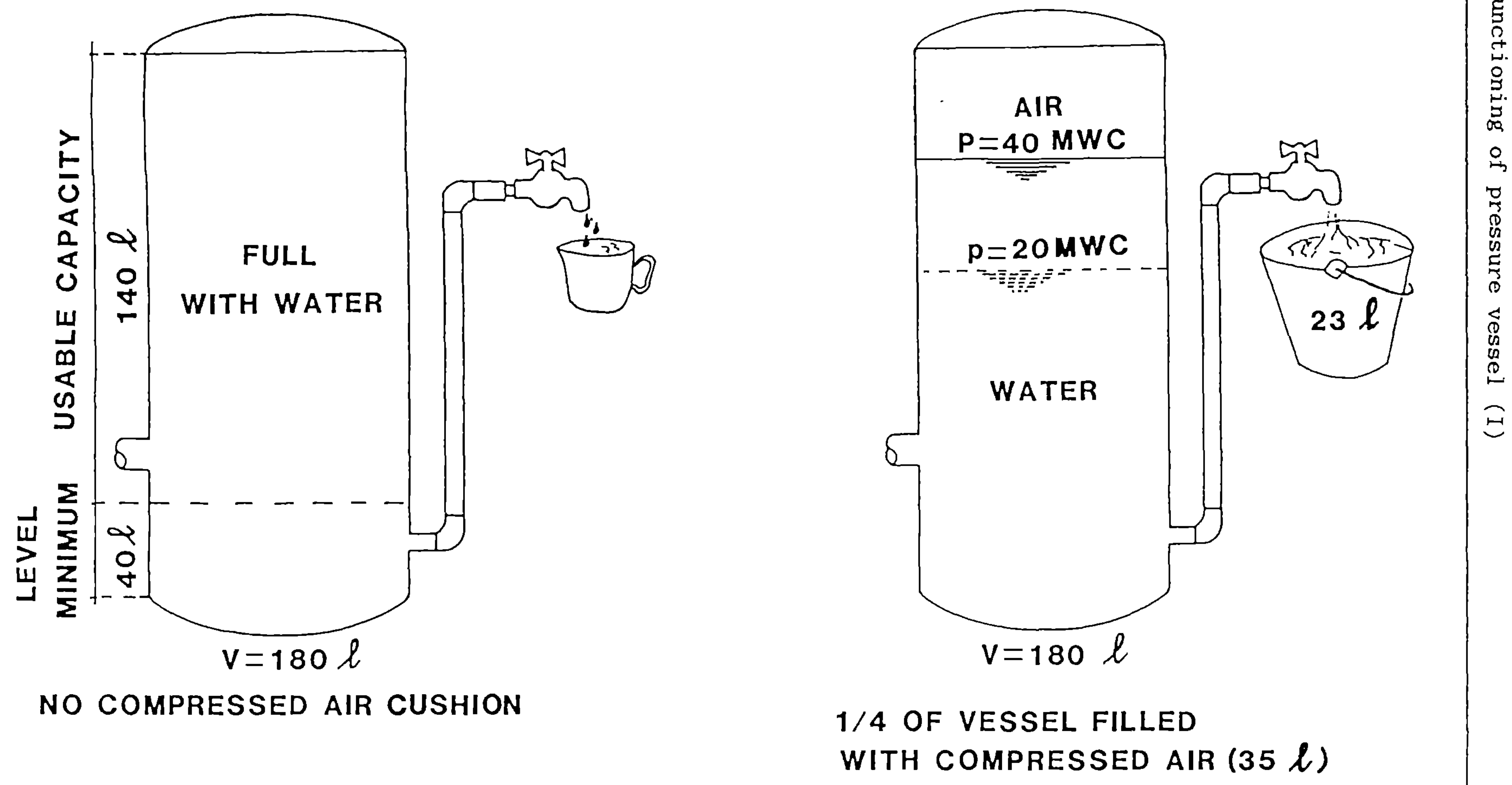
* * *

TITLE :	CODE :
1. Application of hydrophores	TEG 501/V 1
2. Hydrophore installation	TEG 501/V 2
3. Functioning of pressure vessel (I)	TEG 501/V 3
4. Functioning of pressure vessel (II)	TEG 501/V 4
5. Operation pressure vessel	TEG 501/V 5
6. Tank measurements	TEG 501/V 6
7. Air pressure control (I)	TEG 501/V 7
8. Air pressure control (II)	TEG 501/V 8

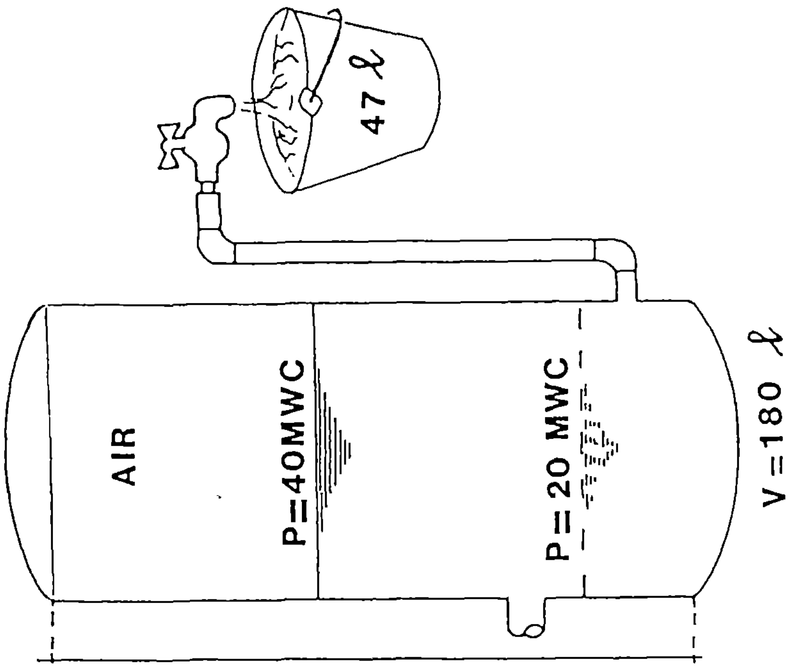
HYDROPHORES ARE USED :

- To level out pressure fluctuations
- To keep water pressure between certain values
- To supply a certain amount of pressurized water between two subsequent pumping periods

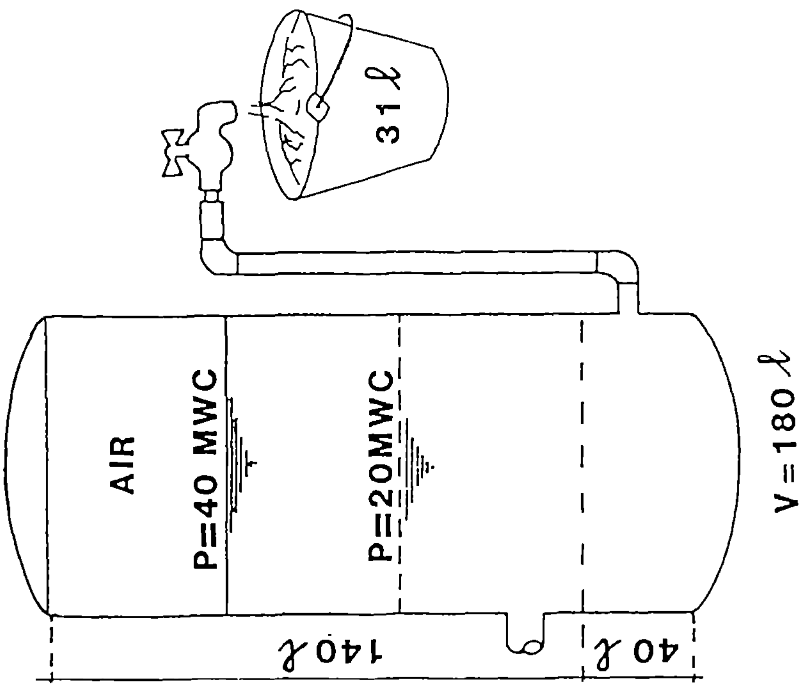

MANOMETER
AIR
P=40 MWC
P=20 MWC
WATER
HYDROPHORE
ELECTRICAL CABLE
AUTOMATIC SWITCH
PUMP



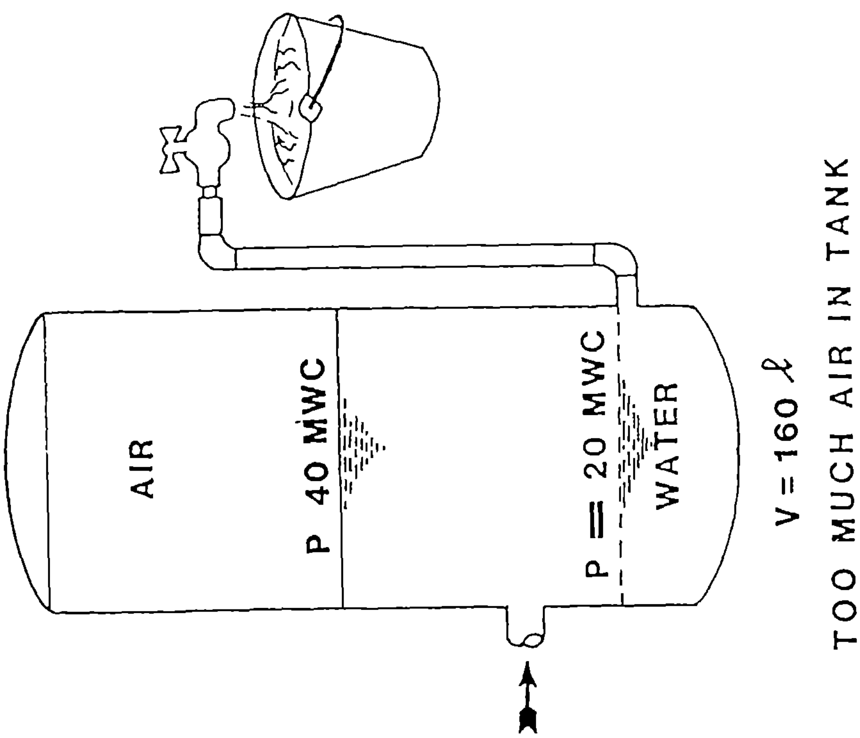
Functioning of pressure vessel (I)

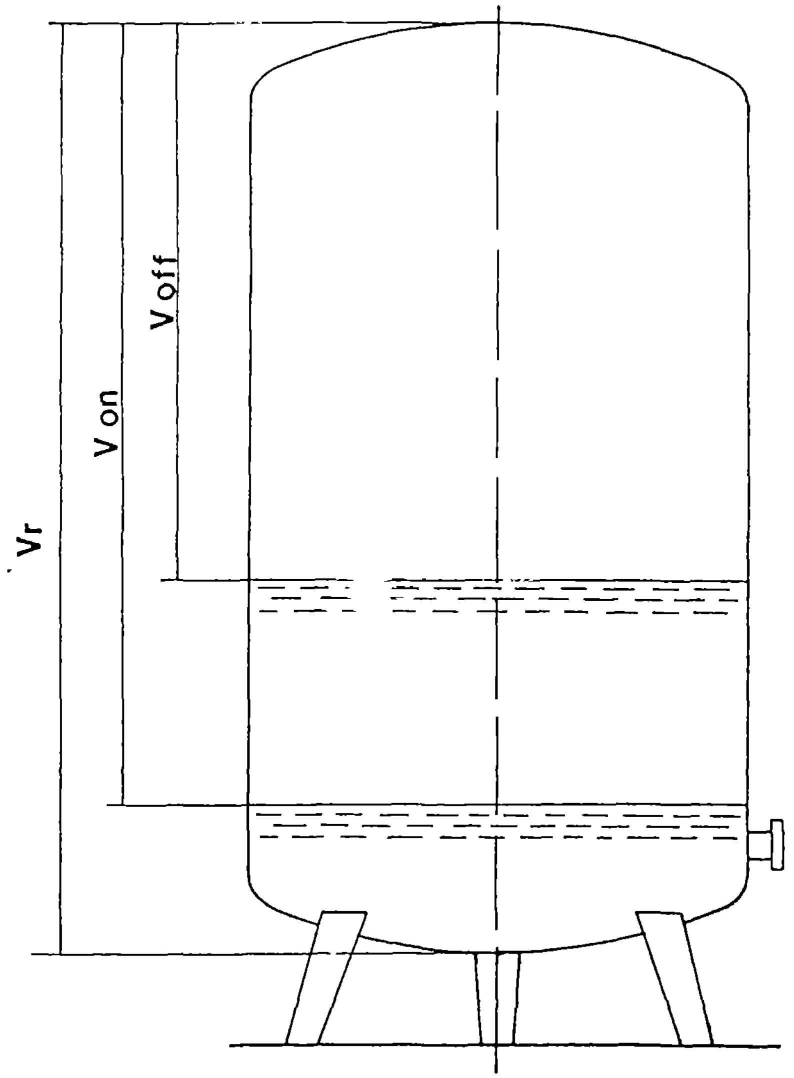


1/2 OF VESSEL FILLED WITH COMPRESSED AIR (70 ℓ)

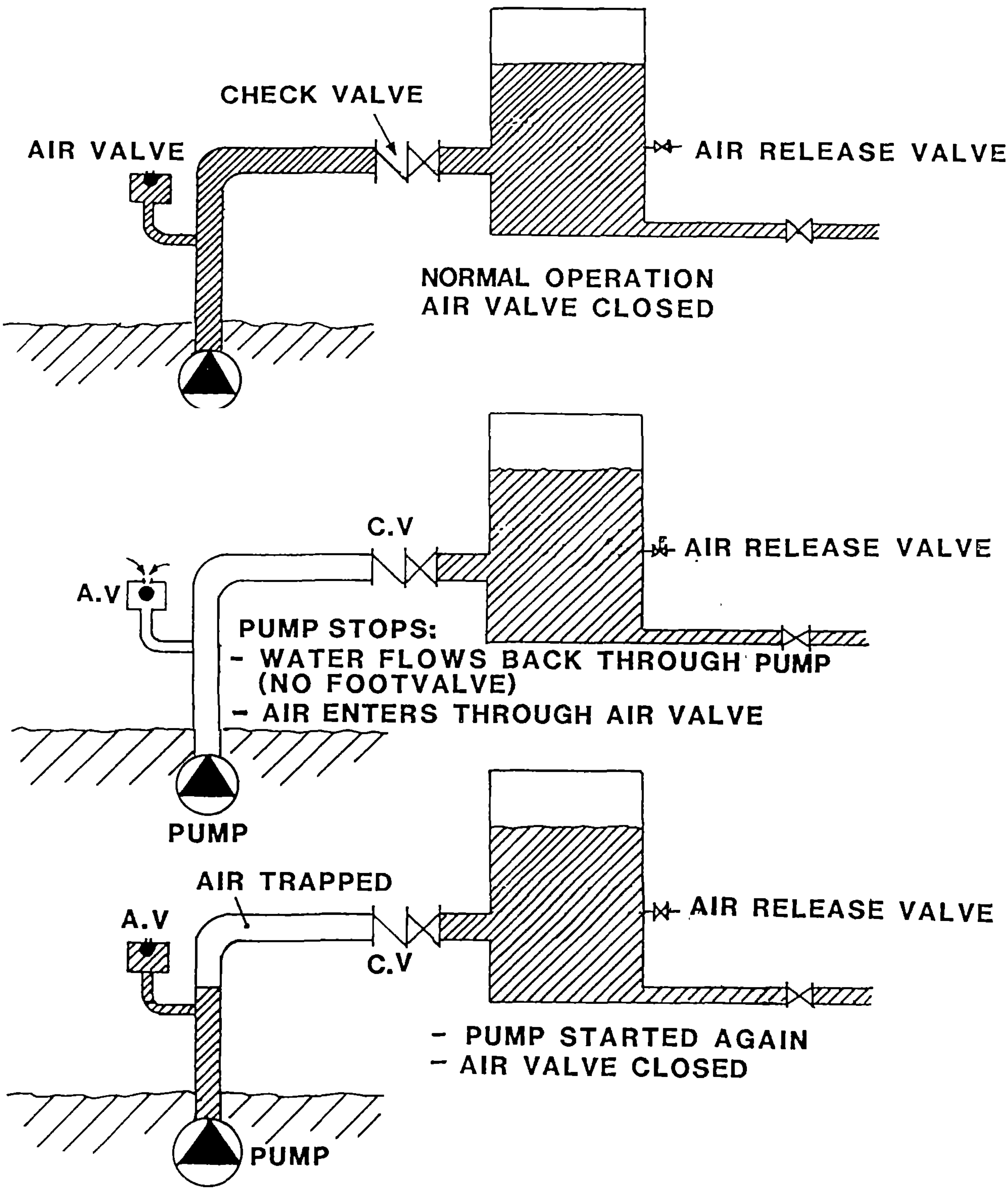


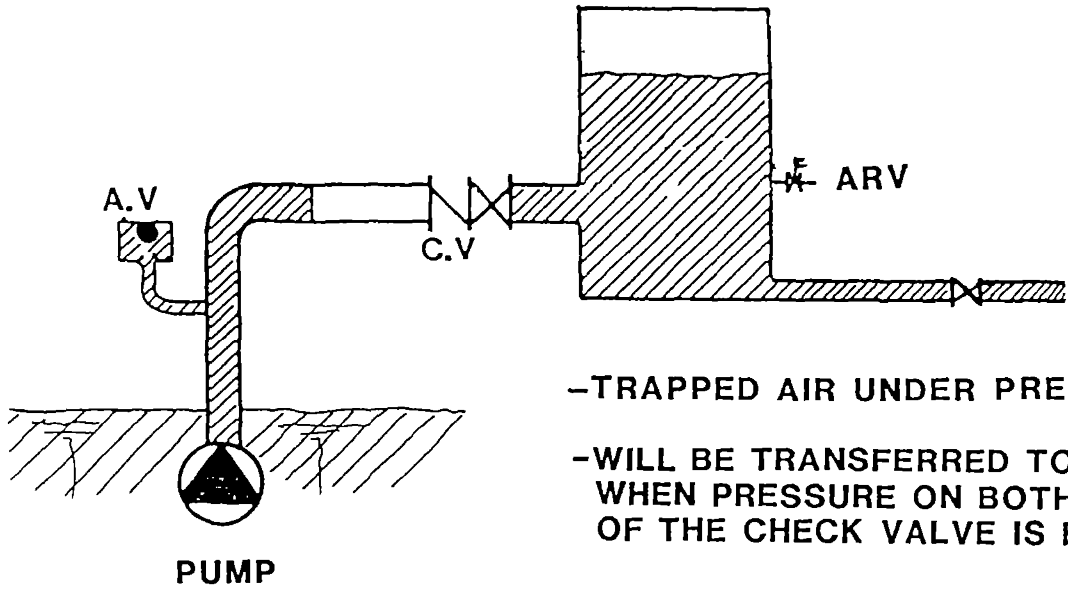
1/3 OF VESSEL FILLED WITH COMPRESSED AIR (47 ℓ)


AIR
P 40 MWC
P = 20 MWC
WATER
V = 160 ℓ
TOO MUCH AIR IN TANK

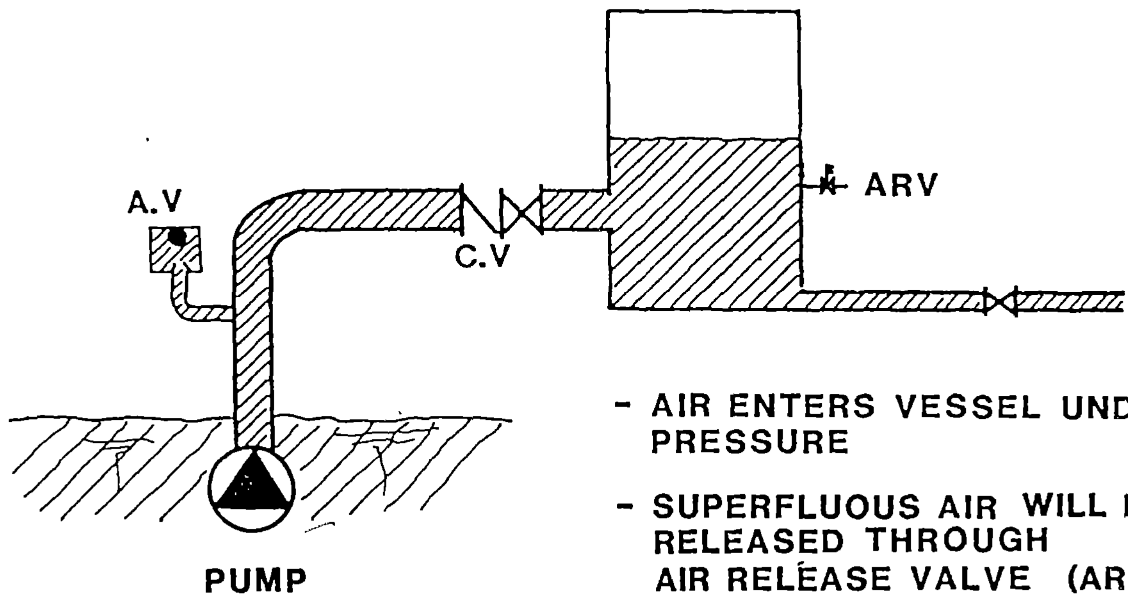


$$V_{req}\ (\text{in } m^3) = 0.33K \frac{Q_{av}(P_b + P_{off})}{(P_{off} - P_{on}) \cdot S}$$


CHECK VALVE
AIR VALVE
AIR RELEASE VALVE
NORMAL OPERATION
AIR VALVE CLOSED
C.V
A.V
AIR RELEASE VALVE
PUMP STOPS:
- WATER FLOWS BACK THROUGH PUMP
(NO FOOTVALVE)
- AIR ENTERS THROUGH AIR VALVE
PUMP
AIR TRAPPED
A.V
AIR RELEASE VALVE
C.V
- PUMP STARTED AGAIN
- AIR VALVE CLOSED
PUMP



- TRAPPED AIR UNDER PRESSURE
- WILL BE TRANSFERRED TO VESSEL WHEN PRESSURE ON BOTH SIDE OF THE CHECK VALVE IS EQUAL



- AIR ENTERS VESSEL UNDER PRESSURE
- SUPERFLUOUS AIR WILL BE RELEASED THROUGH AIR RELÉASE VALVE (ARV)

Module : **OPERATION OF GATE VALVE AND BUTTERFLY VALVE**	Code : TEO 222
	Edition : 20-03-1985
Section 1 : **I N F O R M A T I O N S H E E T**	Page : 01 of 01/08

Duration :	45 minutes.
Training objectives :	After the session the trainees will be able to : - explain the difference, in construction and application, between gate valves and butterfly valves; - operate (open and close) both types of valves.
Trainee selection :	- Water Treatment Plant Operator; - Plant Attendant; - Intake Attendant; - Pipeline Inspector; - Leakage Officer.
Training aids :	- Gate valve; - Butterfly valve; - Viewfoils : TEO 222/V 1-2 (a-b); - Handout : TEO 222/H 1.
Special features :	-
Keywords :	Gate valve/sluice valve/butterfly valve.

1. Introduction	
- Most common types of valves are: . gate (sluice) valves; . butterfly valves.	
- Gate valves when installed in water main stop the flow of water when closed, and allow water to pass when open.	Show gate valve Show V 1 (a-b)
- Butterfly valves can also regulate the flow of water	Show butterfly valve Show V 2 (a-b)
2. Operation	
a. Gate valves	
- Gate of valve is raised or lowered by turning a spindle.	Demonstrate
- Spindle is turned by : a. key and bar; b. wheel.	
- Direction of turning to open or close is marked on either : a. body of valve; b. on wheel if fitted.	
b. Butterfly valves	
- Disc of valve is rotated by turning spindle (with or without gearbox)	Demonstrate
General remarks	
- Valves should be opened or closed SLOWLY. - Caution should be excercised by turning spindle slowly during first 20% of opening and last 20% when closing.	

3. Protection

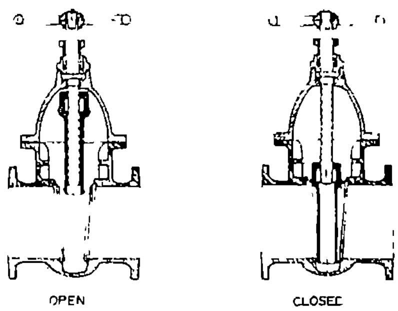
- Gate valves in underground pipelines should be installed in a vertical position.
- Underground valves have to be installed in protective chambers.

4. Summary

Give H 1

Module : OPERATION OF GATE VALVE AND BUTTERFLY VALVE	Code : TEO 222 Edition : 29-01-1985
Section 3 : T R A I N I N G A I D S	Page : 01 of 01

Operation of sluice valve — TEO 222/V 1 (a-b)



Butterfly valve — TEO 222/V 2

Operation of gate valve and butterfly valve — TEO 222/H 1

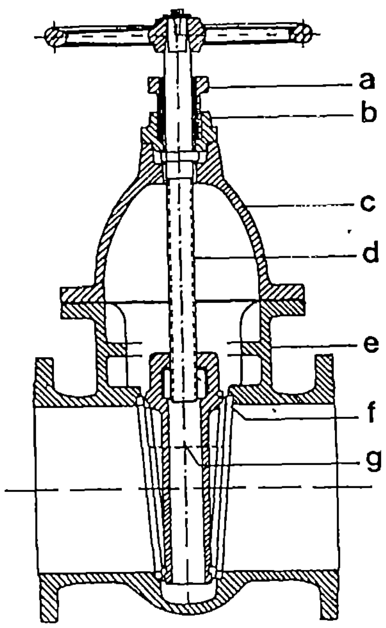
1. INTRODUCTION

The two most common types of valves used in water supply practice are
- gate valve (also called sluice valve);
- butterfly valve.

Gate valves (sluice valves) are installed on water mains to stop the flow of water when required. In distribution networks this is normally done in emergencies or when extension work is being carried out. In pumping stations, reservoirs, treatment plants, etc. gate valves are used to shut off pipe sections that are not in use at the time, e.g. backwash piping during normal operation of filters, bypasses around water meters, drain pipes, etc. They are not designed to regulate the flow of water by partially opening or closing the valve. Consequently, gate valves should always be left either in the fully open or in the fully closed position.

Butterfly valves, however, are very well suited to regulate the flow of water. Because this type of valve is more expensive than gate valves, they are rarely used as section valves in distribution systems, but especially in those cases where the flow of water has to be controlled, e.g. in treatment plants.

2. OPERATION



a. stuffing box nut
b. stuffing box
c. housing (upper part)
d. threaded spindle
e. housing (lower part)
f. nut
g. gate / sluice

GATE VALVE WITH STUFFING BOX
AND NON-RISING SPINDLE

a. Gate valves

The gate or sluice of the valve is raised or lowered by turning a threaded spindle which is attached to it. The spindle is turned by means of a key (which fits on the top) and a turning bar.

Alternatively a wheel is fixed to the top of the spindle and used for turning.
The direction of turning for opening or closing is specified at the time of purchase and may be in either direction. The direction of closure is normally marked on the body of the valve or on the wheel, if fitted.

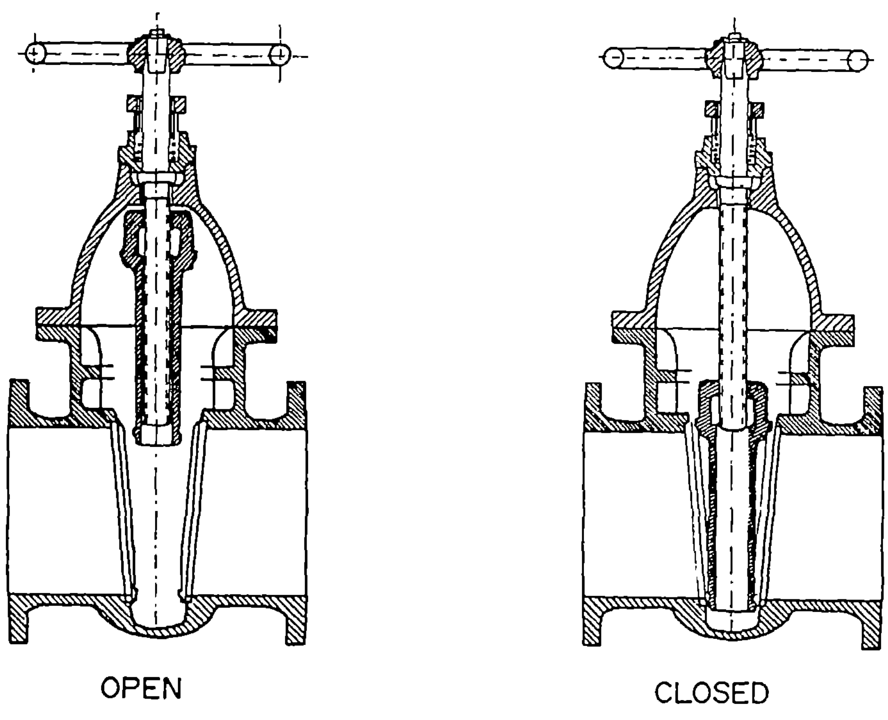
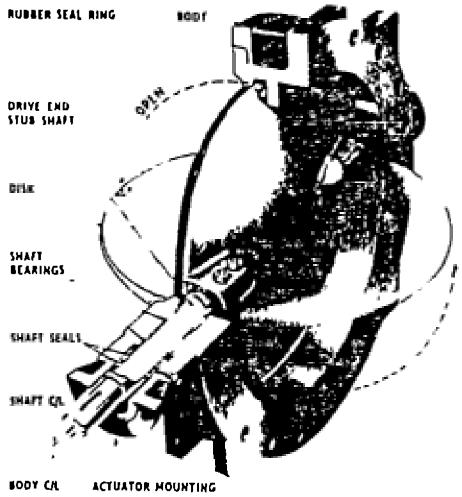


Fig. 2.

b. Butterfly valves

Figure 3



The disc of the valve is operated by turning a threaded spindle, which drives a reduction gear. Only very small butterfly valves are operated by turning a handwheel that is directly connected to the disc's shaft.

This type of valves offers a fairly high resistance to flow, even in fully open state, because the thickness of the disc obstructs the flow also in fully open position.

General

Valves should always be opened or closed SLOWLY as water hammer problems may occur if this is done too quickly. It is important, for hydraulic reasons, to be even slower during the first 20% of opening and the last 20% when closing.

3. PROTECTION

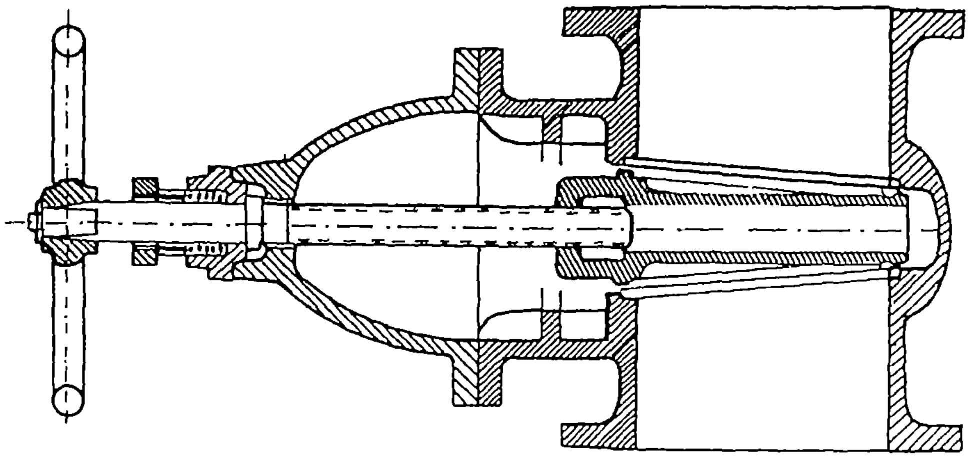
Gate valves in distribution systems should normally be installed in the vertical position for ease of operation. A protective chamber must be built around gate valves and butterfly valves when installed underground.

4. SUMMARY

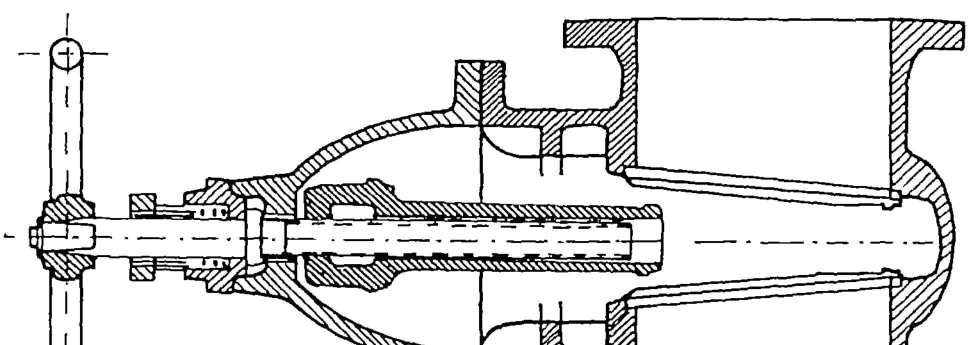
The most common types of valves in water practice are gate valves (also called sluice valves), which should be used only in the fully open or closed position, and butterfly valves, which can also be used for regulating flows.
Both types must be operated carefully, to prevent water hammer.

* * *

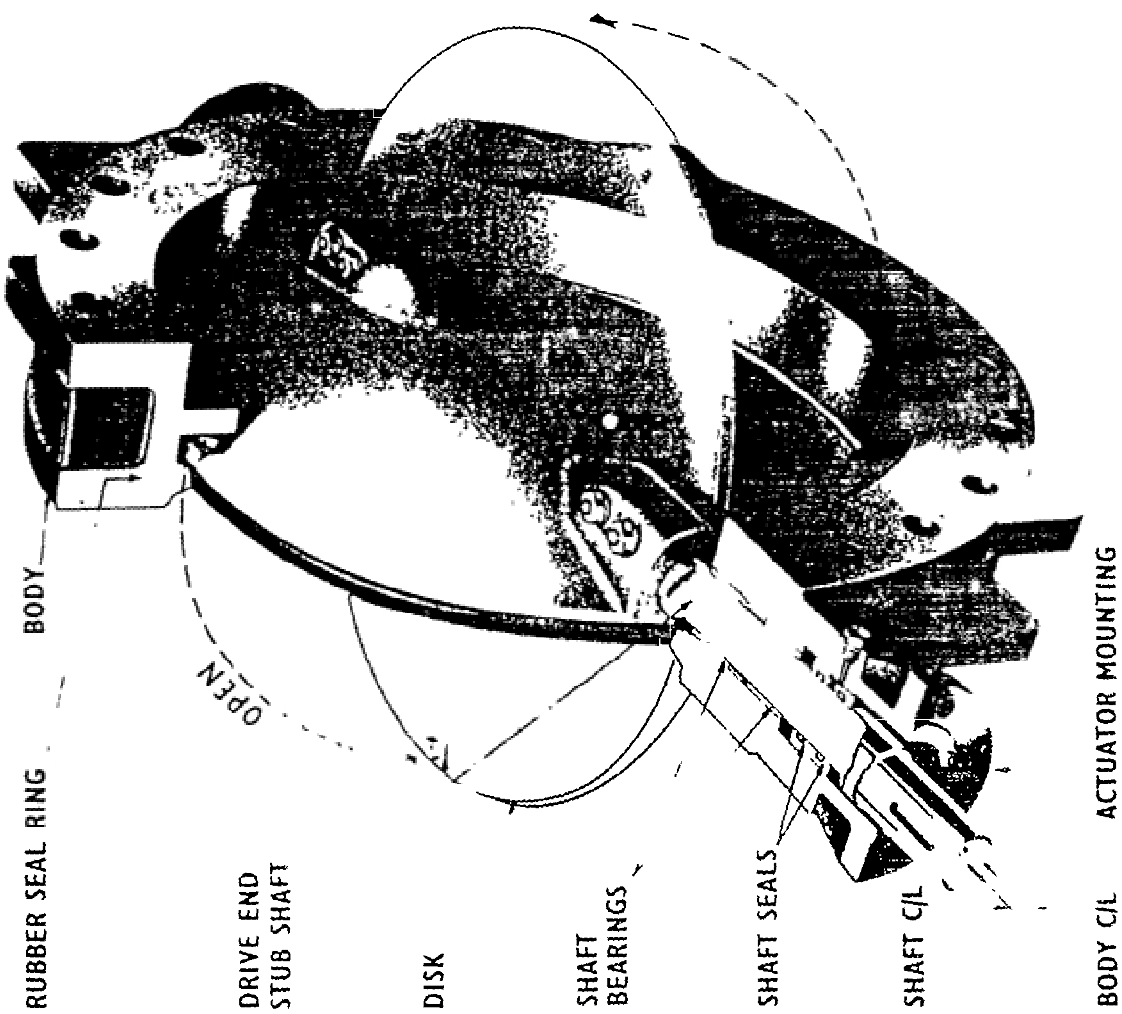
TITLE :	CODE :
1. Operation of sluice valve	TEO 222/V 1 (a-b)
2. Butterfly valve	TEO 222/V 2



CLOSED



OPEN

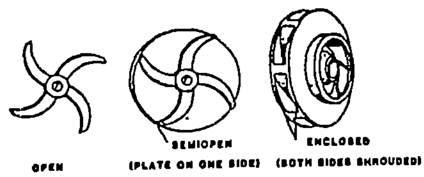

RUBBER SEAL RING
BODY
OPEN
DRIVE END
STUB SHAFT
DISK
SHAFT
BEARINGS
SHAFT SEALS
SHAFT C/L
BODY C/L
ACTUATOR MOUNTING

Duration :	45 minutes.
Training objectives :	After the session the trainees will be able to: - explain operational procedures for centrifugal pumps; - state three causes of pump failure; - state 3 types of important preventative maintenance; - state remedial actions for particular faults.
Trainee selection :	- Head of Section Production; - Head of Section Maintenance; - Head of Section Planning & Supervision; - Plant Attendant.
Training aids :	- Viewfoils : TEO 320/V 1-16; - Handout : TEO 320/H 1.
Special features :	-
Keywords :	Centrifugal pump operation/repairs of centrifugal pumps/maintenance of centrifugal pumps.

1. Introduction	
- Explain the basic principles of a centrifugal pump.	Show V 1
- The factors that are crucial for proper operation and maintenance are: the accuracy of <u>installation</u> and <u>assembly</u> of pumps.	Show V 2
- Explain the pump characteristics regarding shaft, leaks and vibrations.	Show V 3
2. Operating centrifugal pumps	
- Inspect before initial starting: . cleanliness of pipes; . accuracy of shaft centre line; . rotation; . bearings; . gasket.	Show V 4-7
- Start-up of pump: . open the inlet valve; . open the vent-valve and discharge valve; . fill the pump and suction line with water; . close the pressure-valve again; . start pump, and after nominal flow is reached, open the discharge valve gradually.	Show V 8-9
- Note: . note the type of impeller; . system of water supply operations; . power supply, and types of prime movers.	
3. Faults and remedial actions	
- Pump failures are often caused by <u>air inside the system</u>.	Show V 10-11

- Other possible causes: . valves, are closed or blocked; . motor failure; . foot valve is damaged; . pipe connection is leaking; . excess load; . blockages; . wear and tear of pump parts.	
4. **Preventative maintenance**	
- Explain that damages to pumps often occur due to: . damage of the pump shaft; . damage of the gear; . damage of the inner parts.	Show V 12-16
- Causes are: . the shaft is not centre-lined; . vibrations; . wrong or dirty lubricant; . foreign bodies entered the pump; . cavitation.	
- Preventative maintenance: . check the gasket; . check the accuracy and condition of coupling; . check the prime mover; . check the installation equipment.	Show models of pumps and the parts that need maintenance
5. **Summary**	Distribute H 1

Types of impellers in centrifugal pumps — TEO 320/V 1



Crucial factors for operation and maintenance — TEO 320/V 2

CRUCIAL FACTORS FOR SUCCESSFULL OPERATION AND MAINTENANCE OF PUMPS

Accuracy of :

- Installation
- Assembly

Characteristics of correct pump installation — TEO 320/V 3

CHARACTERISTICS OF A WELL INSTALLED PUMP

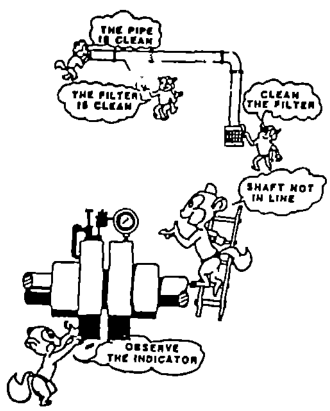
- Shaft center line constant
- No or minor leakages
- No or minor vibrations

Preparations for pump operation — TEO 320/V 4

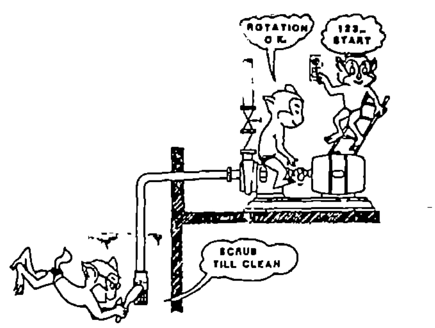
CHECK BEFORE FIRST START

- Cleanliness of pipes
- Accuracy of shaft centre
- Rotation
- Bearings
- Gasket

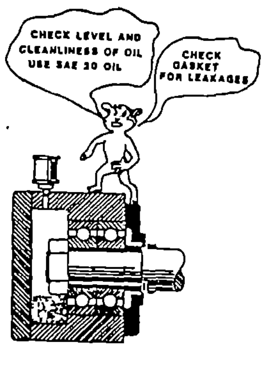
Checking pump installation — TEO 320/V 5



Testing the pump (I) — TEO 320/V 6



Testing the pump (II) TEO 320/V 7

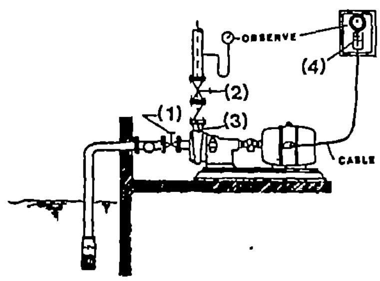


Starting the pump (I) TEO 320/V 8

START-UP OF CENTRIFUGAL PUMP

- OPEN THE SUCTION VALVE (1)
- OPEN THE PRESSURE VALVE (2) AND VENT CAP (3)
- FILL THE PUMP WITH WATER THROUGH THE VENT HOLE (3)
- CLOSE THE PRESSURE VALVE (2)
- START THE PUMP (4)
- OPEN THE PRESSURE VALVE SLOWLY (2)

Starting the pump (II) TEO 320/V 9



Failures and remedial actions TEO 320/V 10

FAULTS AND REMEDIAL ACTIONS

Main cause of malfunctioning :

- AIR IN THE SYSTEM

Other causes :

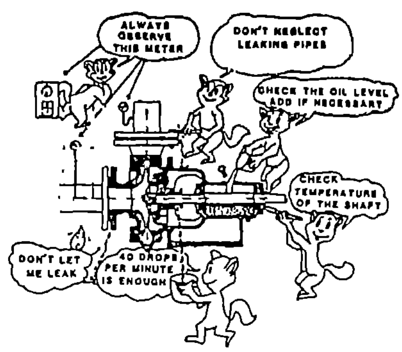
- VALVE IS NOT OPENED
- MOTOR FAILURE
- FOOT VALVE
- CONNECTIONS
- OVER LOAD
- FOREIGN MATTER
- WEAR

Causes of pump damages TEO 320/V 11

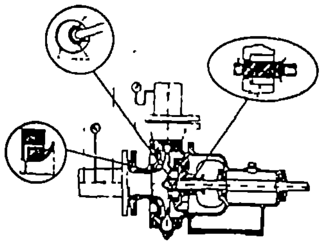
PUMP DEFECTS

Type of defect	Cause of defect
Shaft	– SHAFT NOT CENTRE LINED
	– CRACKS D[illegible] TO VIBRATIONS
	– FOREIGN MATTER
Cranks	– LACK OF LUBRICATION
	– DIRTY OIL
	– CAVITATION
	– SHAFT NOT CENTRE LINED
	– BAD QUALITY CRANK
Inner parts	– CAVITATION
	– FOREIGN MATTER

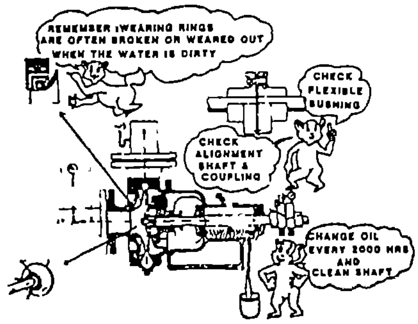
Pump maintenance TEO 320/V 12



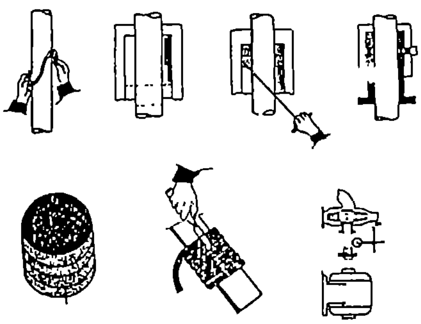
Easily damaged parts (I) TEO 320/V 13



Easily damaged parts (II) TEO 320/V 14



Installation of gaskets TEO 320/V 15



Maintenance of centrifugal pumps TEO 320/V 16

PUMP MAINTENANCE

- CHECK GASKET FOR LEAKAGES AND CLOSE LEAKS
- CHECK BEARINGS
  - TEMPERATURE
  - CLEAN EVERY 3000 HRS
- CHECK LUBRICATION
  - CHANGE EVERY 3000 HRS
  - ADD OIL IF NECESSARY
- SHAFT & COUPLING
  - ACCURACY
    FLEXIBLE BUSHING
- CHECK ACCESSORIES & PIPES
- CHECK MOTOR

Centrifugal pump operation and maintenance TEO 320/H 1

1. INTRODUCTION

Centrifugal pumps operate by way of a number of impellers which operate from a hub. The impeller operates in a close-fitted housing adapted to the particular forms of the vanes used. The water enters the impeller from one or both sides of the hub, and is thrown out by centrifugal force. The casing has a volute (snail-like) passage extending around the impellers. The passage begins very small and increases in cross sectional area to the discharge. Water moving out through the impeller creates a vacuum at the center which in turn will draw water from the suction line to the impeller.

The most effective factor in the operation and maintenance of a centrifugal pump is the accuracy of installation or pump assembly. Characteristics of correctly installed pumps are:
- accurate centre-line of shaft and stable position of shaft;
- no or minor leaks on the pump casing and flange;
- no or minor vibrations.

Under such circumstances overhaul will be rarely necessary.

Good installation can prolong the time of operation whereas bad installation will shorten the life time of the pump.

Besides good installation, good operation and maintenance according procedures and specifications set out in the manufacturer's documentation are essential.

2. OPERATING CENTRIFUGAL PUMPS

Initial starting

When operating the pump for the first time, faults may occur if no checking has been made during and after its installation.

Before initial operation attention should be paid to:

- Cleanliness of the suction pipe (if using clear water pumps). Dust entering the pump will damage the pump.

- Accuracy of shaft centre-line
  Rotate the pump shaft by hand. The pump must rotate freely without friction, and without twisting of the shaft.

- Rotation of motor
  Start the pump motor for a while and observe its rotation. The direction of rotation must be similar to the arrow on the pump.

- Checking the bearings
  Bearings must be clean and lubricated. Sleeve-bearings have to be cleaned with cerosene first, then with oil. Lubrication must be in accordance with the manufacturer's instructions.

- Check the gasket clamp
  The gasket clamp must not be too tight as this will cause the moving shaft to become hot and will damage the shaft.

Initial starting can be carried out after inspection and completion of possibly necessary repairs and adjustments.

Follow the procedures below for the initial starting:

a. Open the suction valve.

b. Open the vent cap and discharge valve.

c. Fill the pump including the suction pipe (for pumps having high negative suction) with water through the vent hole so that the air escapes through the inlet hole.

d. Close discharge valve fully or partly, depending on the manufacturer's instructions.

e. Start the pump and after reaching the nominal rotation speed open the discharge valve. Increase pressure slowly until the required pressure is reached.

f. Observe the electrical current (Amps) used. If power consumption is too high, close the valve partly until it is below the maximum allowable current load and check the cause.

Note:

- For centrifugal pumps with vanes of the gear-propeller type with axial flow, the discharge valve is left open at the start of operation, because more energy would be needed when the valve is closed.

- To operate the pump, the following has to be considered:
  . The type of the pump motor:
  induction motor of the slipping type has greater torque compared to squirrel cage motor type; thus the discharge valve needs to be closed during the initial starting;
  . The available power supply, and type of prime mover.

- If the pump fails to lift any water, possible causes could be that there is air in the system or other types of blockages. To overcome this act as follows:
  . check foot valve;
  . check for any leaks in the suction pipes;
  . check the pipe installation for possible air pockets;
  . check the gasket clamp, possibly it is not tight enough;
  . check the discharge valve for possible blockages due to foreign objects.

3. OPERATION CONTROL

Every pump needs to be controlled during operation.
The following aspects have to be observed regularly:
- the pump has to run smoothly, quietly and without any significant vibration;
- pressure in the suction line;
- load/capacity of the pump vs pressure of the pump;
- the electric current used (shall be less than the full current load of the motor);
- water leaks at the gasket casing;
- the tightness of the gasket, the shaft has to be able to rotate freely;
- the accuracy of the shaft centre-line;
- working hours of the pump;
- oil level in the reservoir.

4. FAULTS FINDING AND REMEDIAL ACTIONS

If the centrifugal pump does not work properly (i.e. no water comes out), the following aspects have to be inspected:

a. Have all relevant valves been opened?
If not, open them all.

b. Has the prime mover reached its normal rotation speed?
If not, the problem may be caused by the prime mover.

c. Is there any air present in the system?
If so, release all the air by filling the system with water.
If it is not possible to fill the system completely check the foot valve on malfunctioning.

d. If the pump functions only for a short period and then stops, check the pipe joints for leaks, tighten all joints, tighten gasket clamp, or check the overload protection for possible wrong adjustments, or damages.

e. If normal capacity can not be reached, check the pipe joints.

f. If there is no external disturbance found, open the pump and check for wear of or blockages at the pump vanes.

5. PREVENTATIVE MAINTENANCE

In general, damages often occurring in pumps are located at:
- pump shaft;
- bearings;
- inner parts.

These damages are mainly caused by:
- the centre-line of shaft not set accurately;
- high vibrations;
- lack of lubrication;
- foreign matter blocking the pump;
- not enough positive suction pressure.

To overcome and prevent these damages, good inspection, operation control and preventative as well as curative maintenance are needed.

Preventative maintenance shall be focussed on:

- Checking the gasket for leaks; if there are leakages, adjust the gasket clamp or change the gasket if leaks cannot be stopped.

- Checking the pump bearings. Do not let the temperature become too high. Check the lubrication oil level, add more oil if necessary.

- After approximately 2000 working hours, clean the bearings with cerosene and fill them with new oil.

- If the bearings are lubricated with grease, after a certain time, according to the manufacturer's instruction or after approximately 2 years with 8 working hours a day, open, inspect and clean them together with the shaft and then apply the grease according to the manufacturer's instructions.

- Check the alignment of the coupling, and check the flexible membrane for any signs of wear and tear. Replace if necessary.

- Check the prime mover according to the manufacturer's instructions.

- Check the pump installation equipment for leaks, damages at the valves, manometer, and other parts.

6. SUMMARY

a. Introduction:

Proper assembly and installation of pumps are of crucial importance for their functioning and live span.
Good pumps have:
- an accurate shaft centre-line;
- no or minor leaks;
- no or minor vibration.

b. Pump operation:

- Inspection before initial starting:
  . cleanliness of pipes;
  . accurate shaft centre-line;
  . rotation of motor;
  . bearings
  . gasket clamps.

- Initial start up of centrifugal pumps:
  . open suction valve;
  . open vent cap and discharge valve;
  . fill pump and suction line with water;
  . close the discharge valve;
  . start the pump and open the discharge valve gradually.

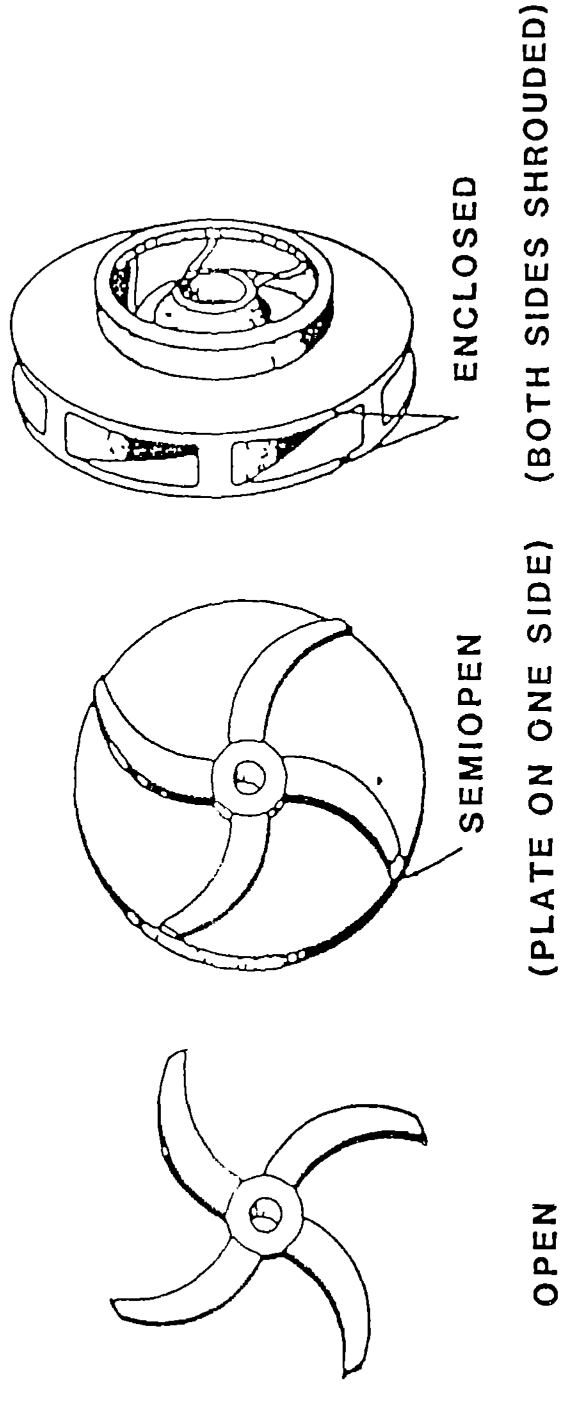
c. Faults:

Running pump does not deliver water; likely causes:
- presence air inside the pump and/or system;
- pump cannot be primed due to malfunctioning of the foot valve;
- suction and/or pressure lines are dirty.

d. Preventative maintenance is required for:
- gasket (no or minor leaks);
- lubrication of bearings;
- coupling;
- motor;
- pump equipment/accessories.

* * *

Module : CENTRIFUGAL PUMP OPERATION AND MAINTENANCE	Code : TEO 320
	Edition : 02-05-1985
Annex : V I E W F O I L S	Page : 01 of 17


ENCLOSED
(BOTH SIDES SHROUDED)
SEMIOPEN
(PLATE ON ONE SIDE)
OPEN

CRUCIAL FACTORS FOR SUCCESSFULL OPERATION AND MAINTENANCE OF PUMPS

Accuracy of :

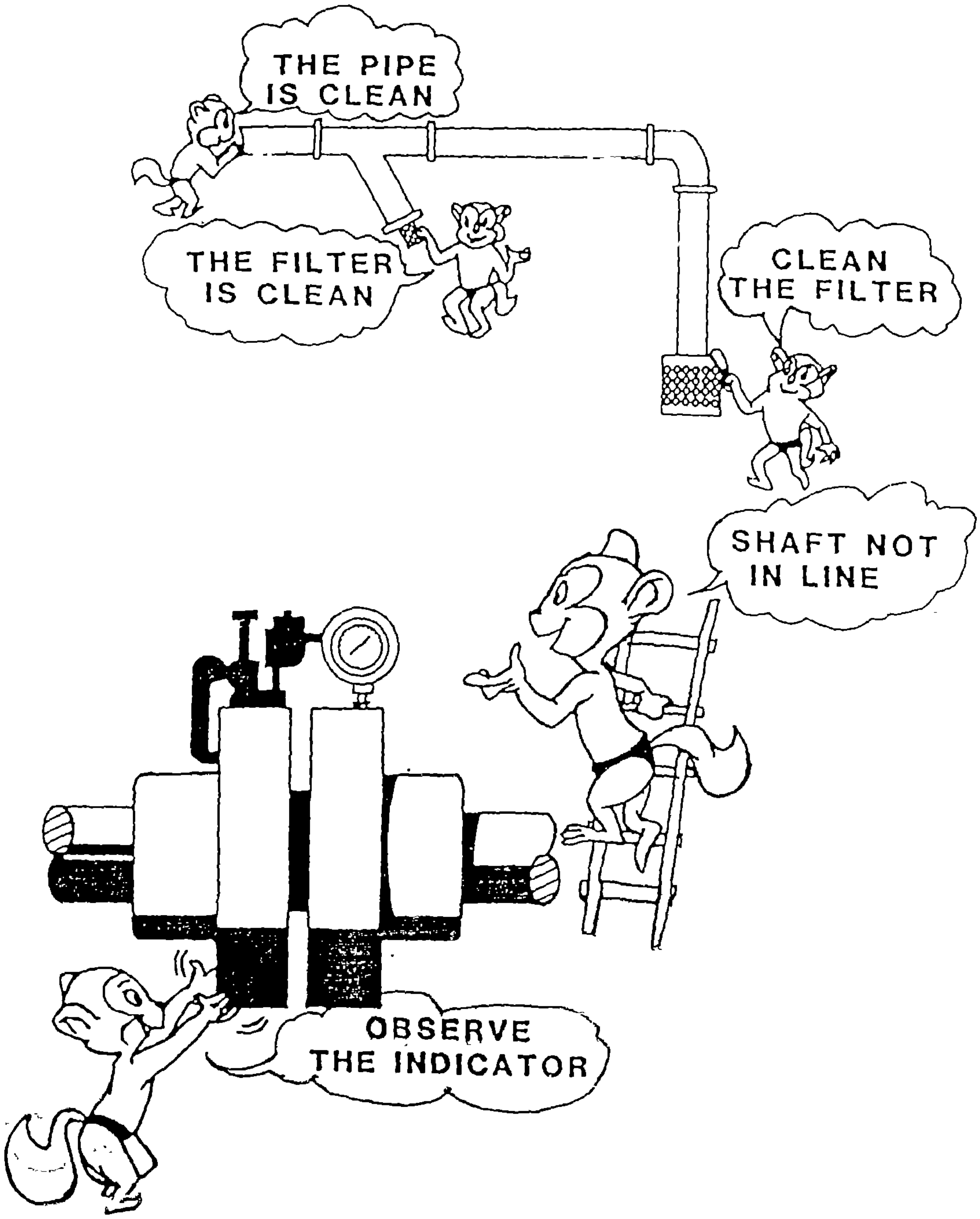
- Installation
- Assembly

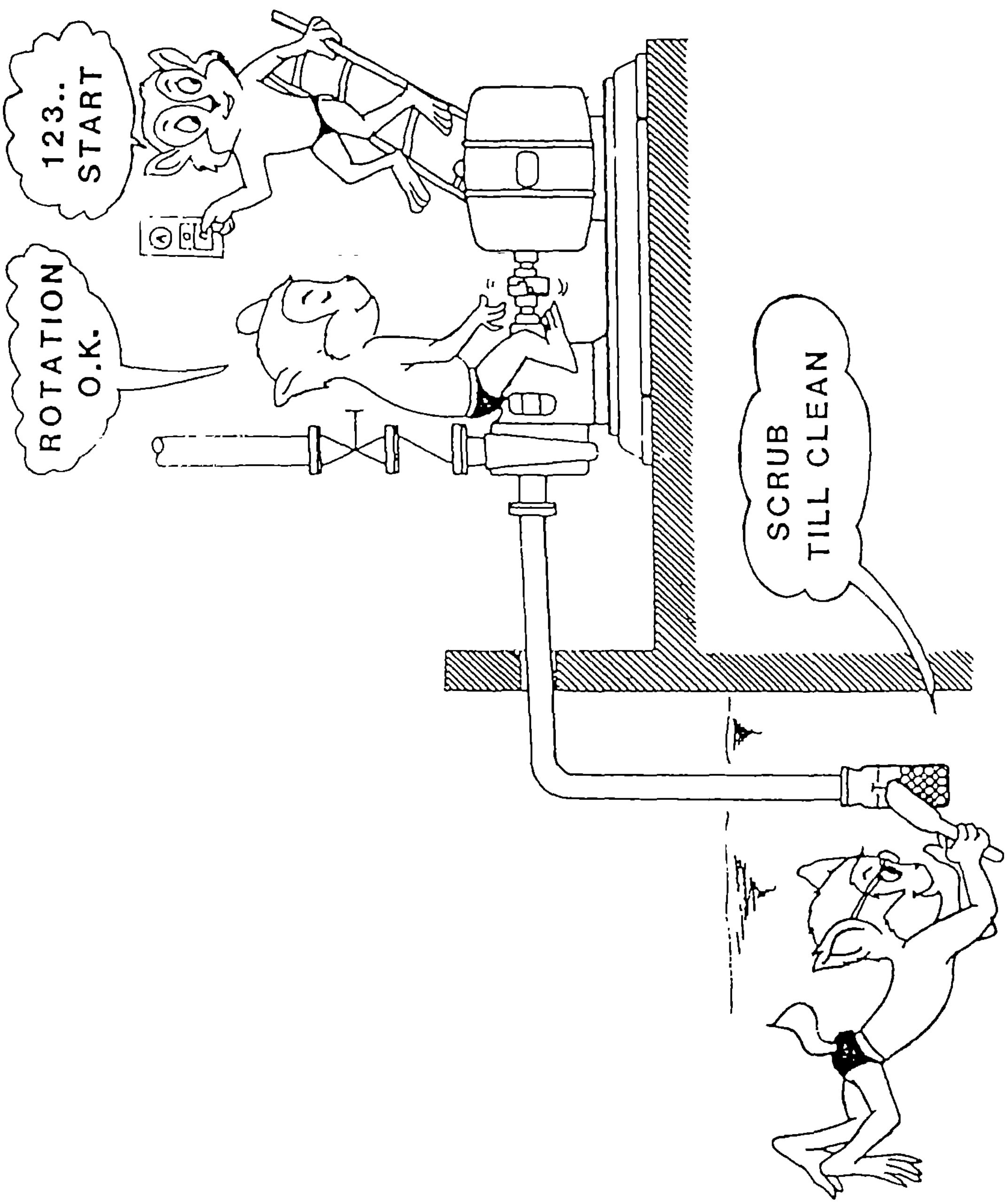
CHARACTERISTICS OF A WELL INSTALLED PUMP

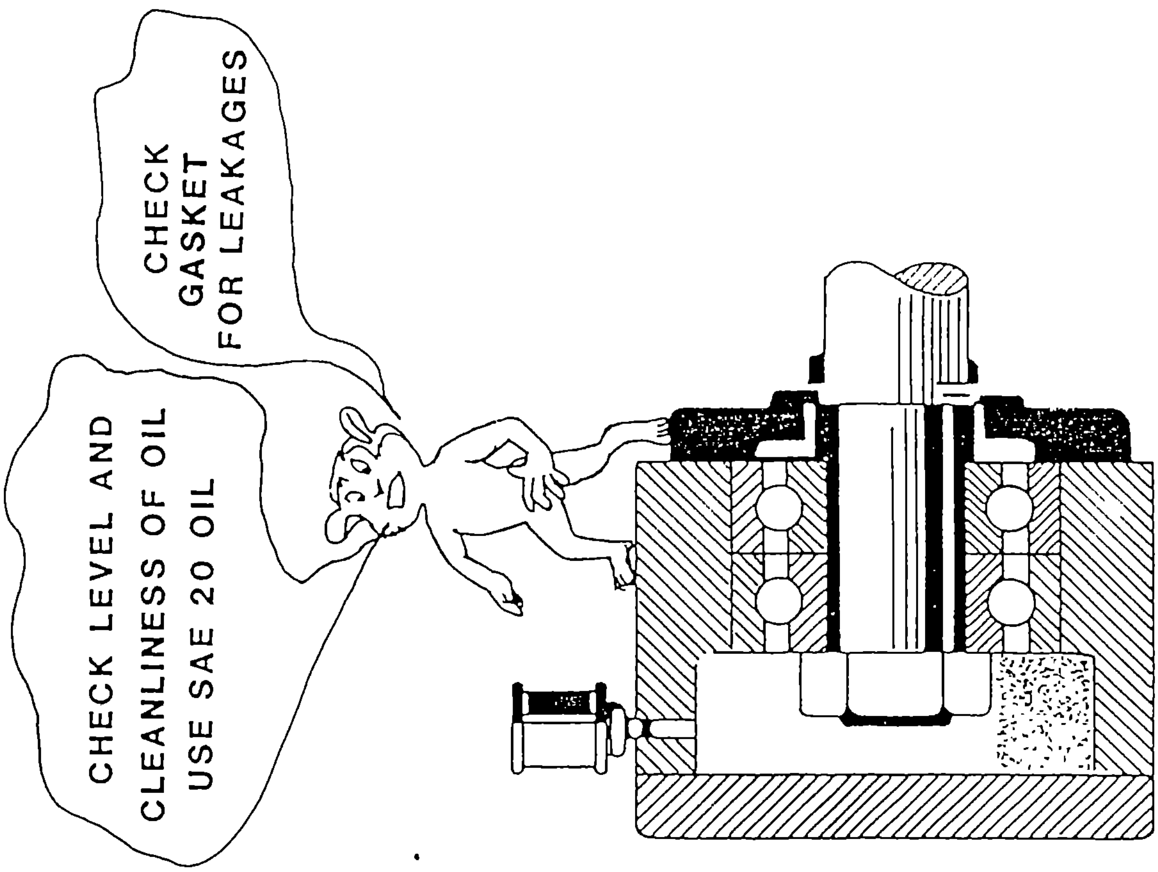
- Shaft center line constant
- No or minor leakages
- No or minor vibrations

CHECK BEFORE FIRST START

- Cleanliness of pipes
- Accuracy of shaft centre
- Rotation
- Bearings
- Gasket


THE PIPE
IS CLEAN
THE FILTER
IS CLEAN
CLEAN
THE FILTER
SHAFT NOT
IN LINE
OBSERVE
THE INDICATOR


123..
START
ROTATION
O.K.
SCRUB
TILL CLEAN


CHECK
GASKET
FOR LEAKAGES
CHECK LEVEL AND
CLEANLINESS OF OIL
USE SAE 20 OIL

START-UP OF CENTRIFUGAL PUMP

— OPEN THE SUCTION VALVE (1)

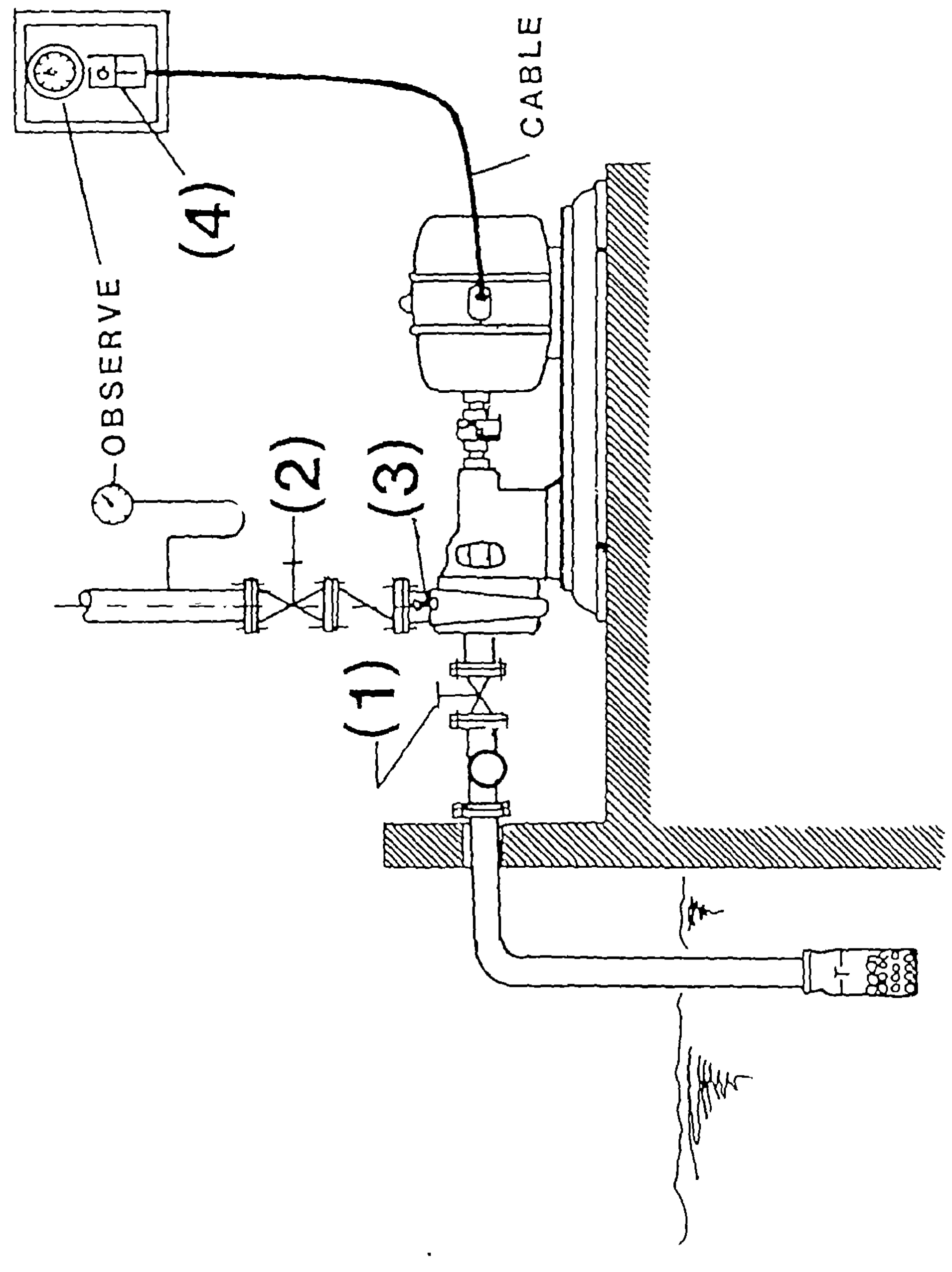
— OPEN THE DISCHARGE VALVE (2) AND VENT CAP (3)

— FILL THE PUMP WITH WATER THROUGH THE VENT HOLE (3)

— CLOSE THE DISCHARGE VALVE (2)

— START THE PUMP (4)

— OPEN THE DISCHARGE VALVE SLOWLY (3)


OBSERVE
(1)
(2)
(3)
(4)
CABLE

FAULTS AND REMEDIAL ACTIONS

Main cause of malfunctioning :

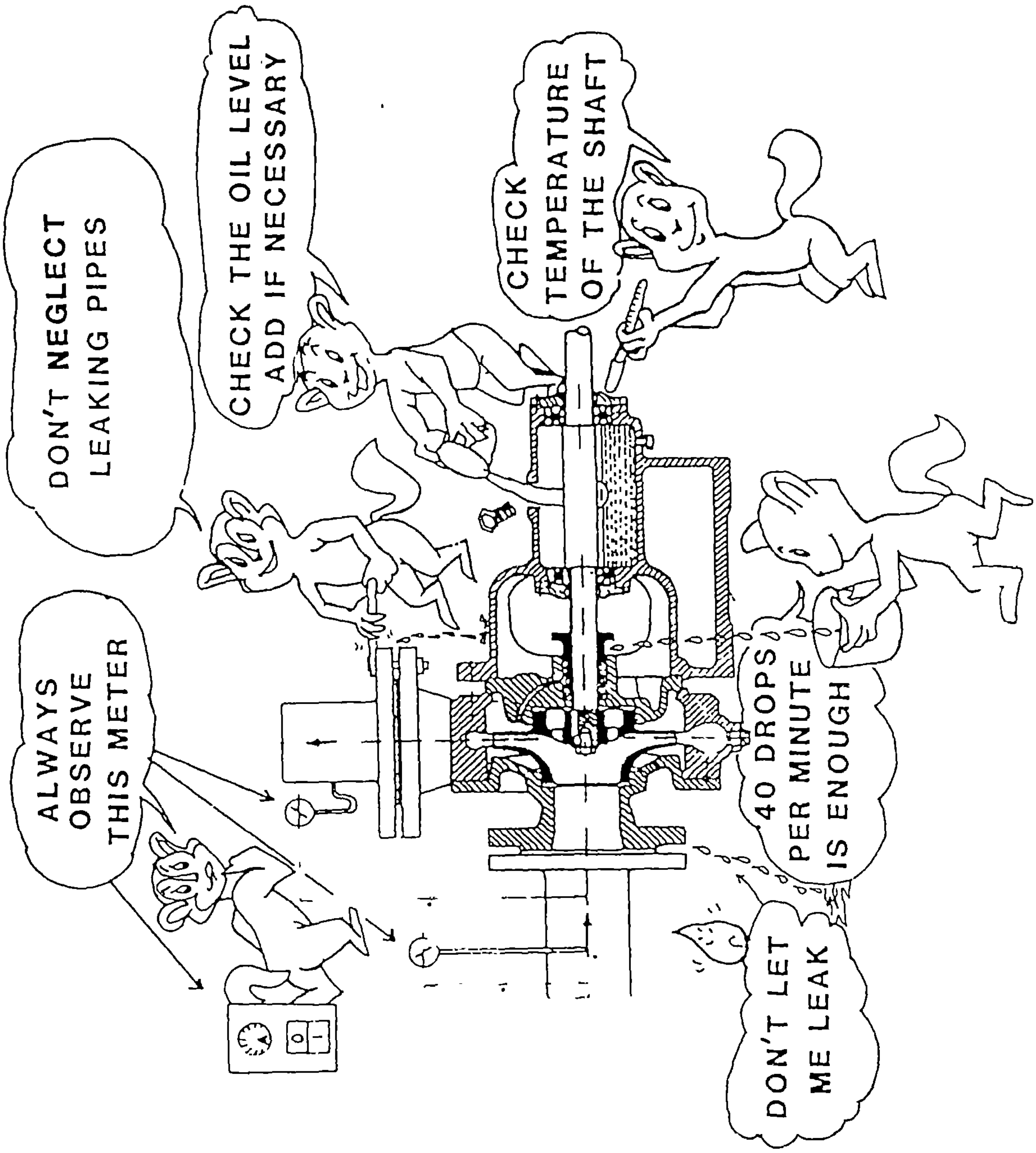
- AIR IN THE SYSTEM

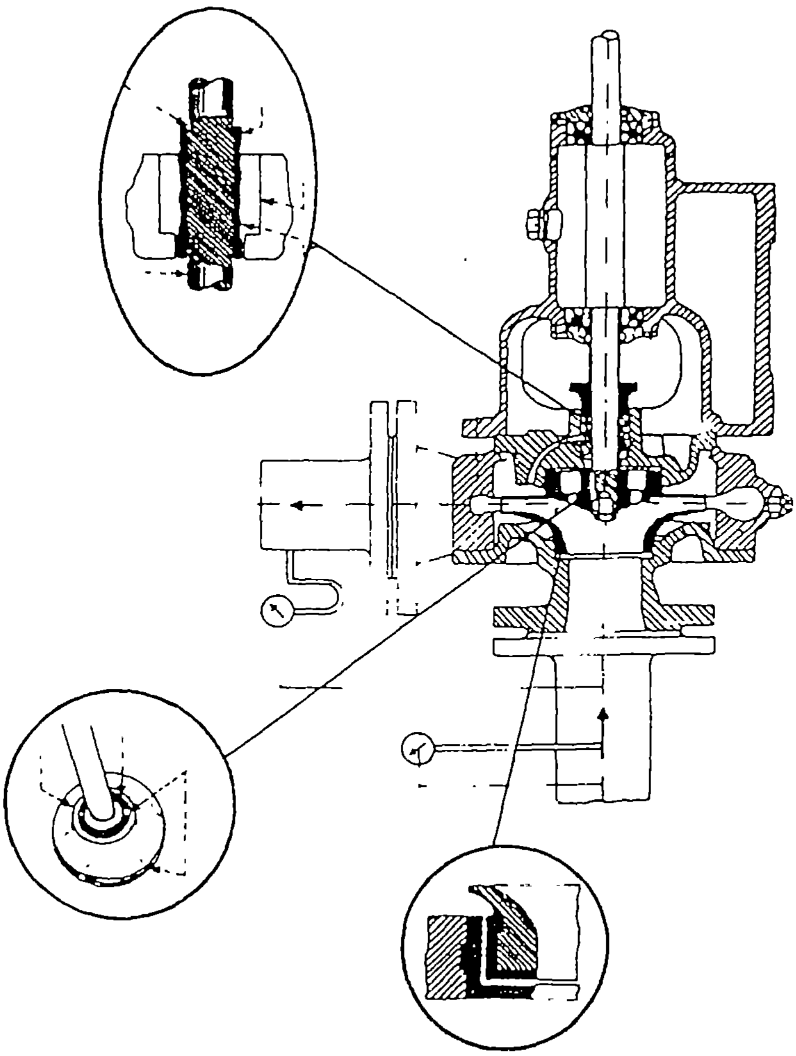
Other causes :

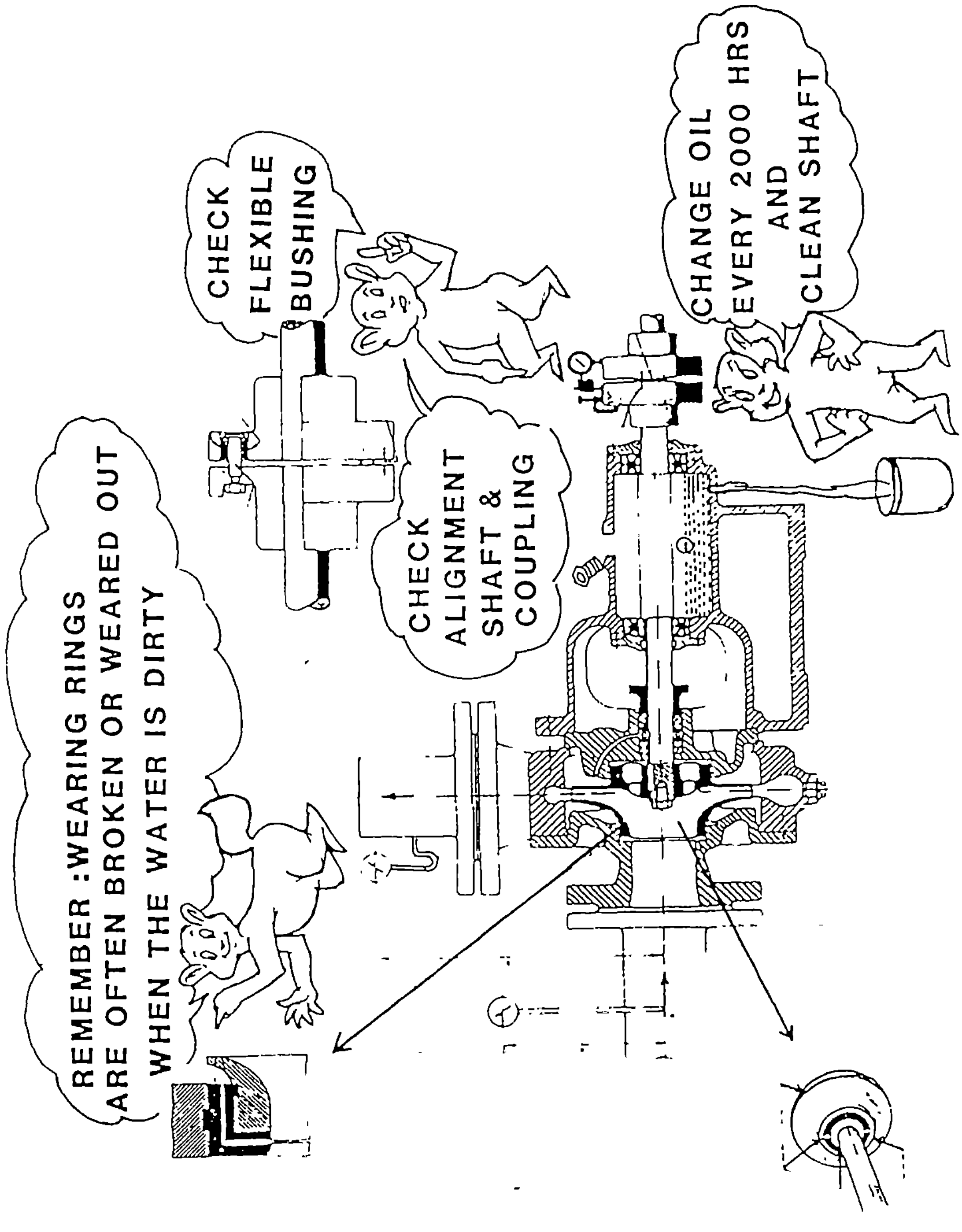
- VALVE IS NOT OPENED
- MOTOR FAILURE
- FOOT VALVE
- CONNECTIONS
- OVER LOAD
- FOREIGN MATTER
- WEAR

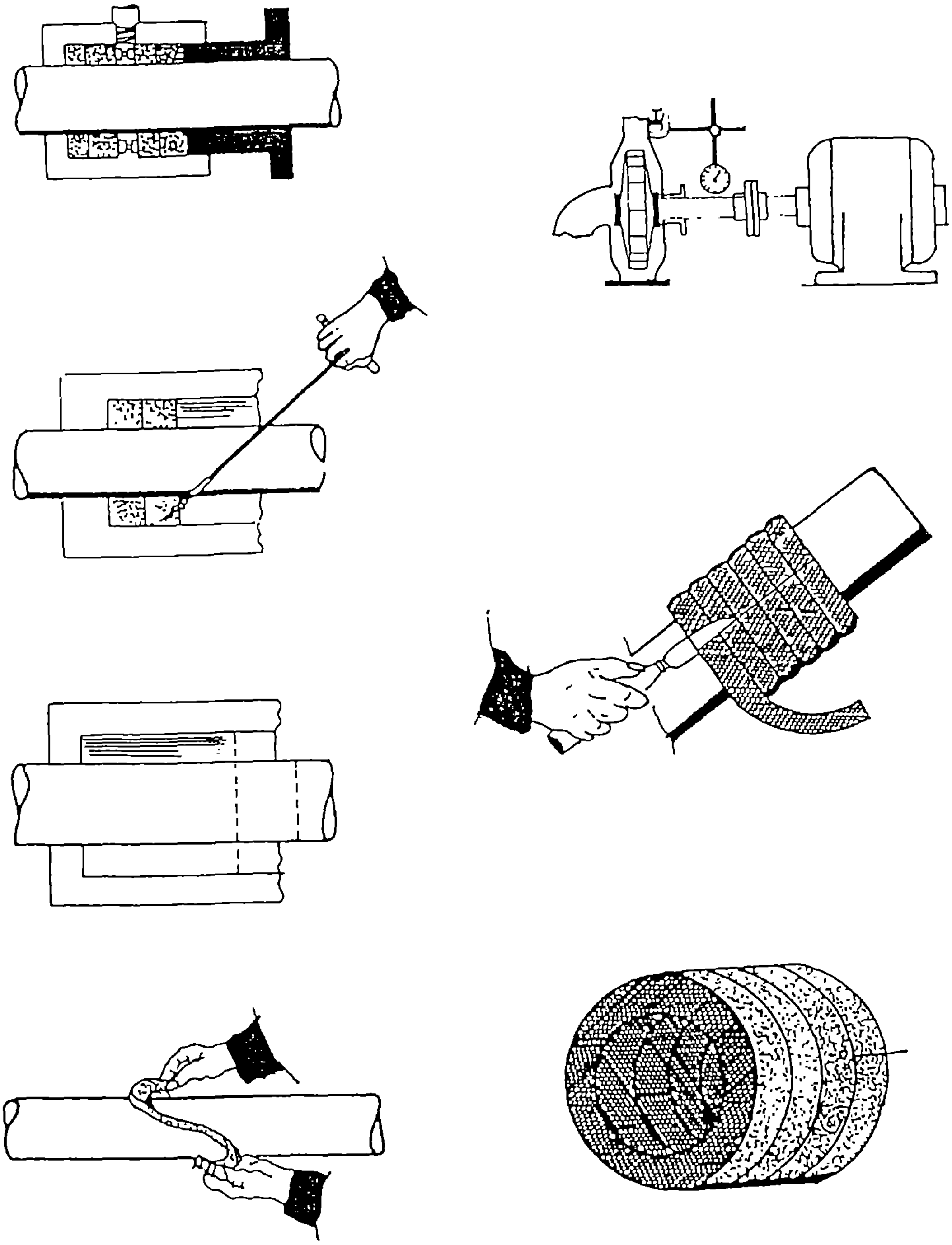
PUMP DEFECTS

Type of defect	Cause of defect
Shaft	SHAFT NOT CENTRE LINED
	CRACKS DUE TO VIBRATIONS
	FOREIGN MATTER
Cranks	LACK OF LUBRICATION
	DIRTY OIL
	CAVITATION
	SHAFT NOT CENTRE LINED
	BAD QUALITY CRANK
Inner parts	CAVITATION
	FOREIGN MATTER


ALWAYS OBSERVE THIS METER
DON'T NEGLECT LEAKING PIPES
CHECK THE OIL LEVEL ADD IF NECESSARY
CHECK TEMPERATURE OF THE SHAFT
40 DROPS PER MINUTE IS ENOUGH
DON'T LET ME LEAK




REMEMBER :WEARING RINGS ARE OFTEN BROKEN OR WEARED OUT WHEN THE WATER IS DIRTY
CHECK FLEXIBLE BUSHING
CHECK ALIGNMENT SHAFT & COUPLING
CHANGE OIL EVERY 2000 HRS AND CLEAN SHAFT



PUMP MAINTENANCE

- CHECK GASKET FOR LEAKAGES AND CLOSE LEAKS

- CHECK BEARINGS

  . TEMPERATURE
  . CLEAN EVERY 2000 HRS

- CHECK LUBRICATION

  . CHANGE EVERY 2000 HRS
  . ADD OIL IF NECESSARY

- SHAFT & COUPLING

  . ACCURACY
  . FLEXIBLE BUSHING

- CHECK ACCESSORIES & PIPES

- CHECK MOTOR

Module : SUBMERSIBLE PUMP OPERATION AND MAINTENANCE	Code : TEO 330
	Edition : 06-05-1985
Section 1 : INFORMATION SHEET	Page : 01 of 01/14

Duration :	45 minutes.
Training objectives :	After the session the trainees will be able to: - recite three important factors regarding operation and maintenance of submersible pumps; - state four important aspects in operating the pump; - state three important activities in the maintenance of every type of pump.
Trainee selection :	- Head of Section Maintenance; - Head of Section Production; - Head of Section Planning & Supervision; - Plant Attendant.
Training aids :	- Viewfoils : TEO 330/V 1-16; - Handout : TEO 330/H 1.
Special features :	-
Keywords :	Initial operation of submersible pumps/submersible pump trial test/submersible pump maintenance/submersible pump faults.

1. Introduction	
- Explain the basic characteristics of a submersible pump.	
- Operation and maintenance depend on the following factors: . installation; . piping system; . pump selection; . conditions of the surroundings; . control and observation.	Show V 1-5
- Good operation and maintenance prolongs the life-span of a pump.	
2. Operating the pump	
- General: . explain the possibility of start-up of the pump with the discharge valve fully open; . continuous running is better than intermittent operation.	
- Before initial start-up: . adjust the overload current protection relay to 58% of Amps on the name plate; . measure the resistance of the insulation; . check the water level.	
- Run a trial test: . open discharge valve one half up to one rotation; . push the ON-OFF switch a few times; alow 3 (three) minutes between switching;	Show V 6-7
. check the rotational direction of the pump; . run it again after 10 (ten) minutes; . check the water level control equipment.	Show V 8
- Operating the submersible pump: After the trial test, operate the pump while taking note of: . open valve one half up to one direction (open it fully if permitted);	Show V 9-10

- open the valve gradually after the nominal rotational speed has been reached;
- period between switch-on and shut-off should be at least three minutes;
- voltage changes not more than 5%;
- current changes not more than 10%;
- pressure vs. capacity.

3. **Maintenance**

Explain that, apart from lubricating, the maintenance of pumps should also involve control and inspection.

Show V 11

<u>Raw water submersible pump</u>

- Daily: (Show V 12)
  - clean the surroundings;
  - check the electric current;
  - check the voltage (deviation <5%).
- Monthly: (Show V 13)
  - measure the resistance of the insulation (> 1 mega Ohm);
  - check the characteristics of the pump.
- Yearly: (Show V 15)
  - change the oil;
  - change the mechanical seal, gasket, O-rings;
  - check and maintain the electrical cable.
- Note:
  - check the leaks on the motor casing;
  - overhaul every five years.

<u>Well submersible pump</u>

- The maintenance is the same as for raw water submersible pumps.
- Other maintenance activities that are to be done periodically:
  - check water level;
  - measure the resistance of the insulation;
  - check the characteristics of the pump;
  - check the water level control equipment.

4. How to overcome faults	
- Faults of the pump installation are normally caused by: . faults at the pump; . faults at the piping system; . faults due to installation; . inproper selection of pump type; . faults in electrical installation.	Show V 16
- Causes of faults or malfunctions of the pump: . foreign matters blocking the pumps; . electric current too high; . unstable electricity source; . controls damaged.	
5. Summary.	Distribute H 1

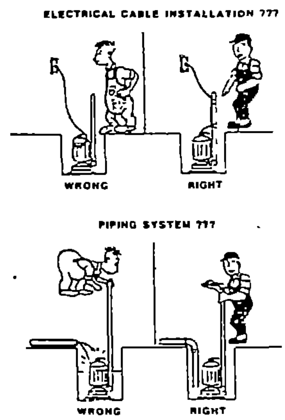
Module	: SUBMERSIBLE PUMP OPERATION AND MAINTENANCE	Code	: TEO 330
		Edition :	06-05-1985
Section 3 :	T R A I N I N G A I D S	Page	: 01 of 03

Operation and maintenance of submersible pump — TEO 330/V 1

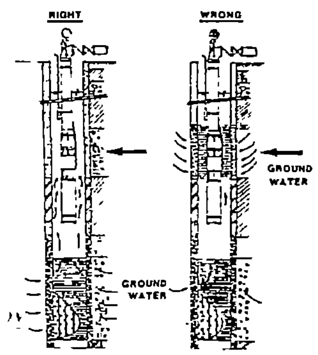
OPERATION & MAINTENANCE DEPEND ON :

- Installation
- Piping system
- Selection of pump
- Surroundings
- Controlling

Installation of submersible pump — TEO 330/V 2

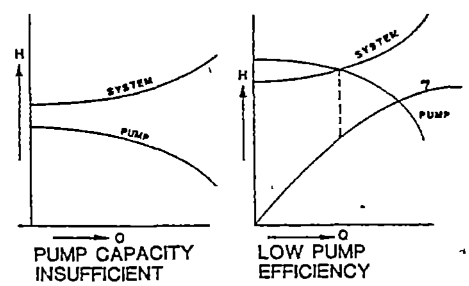


Pump installation — TEO 330/V 3

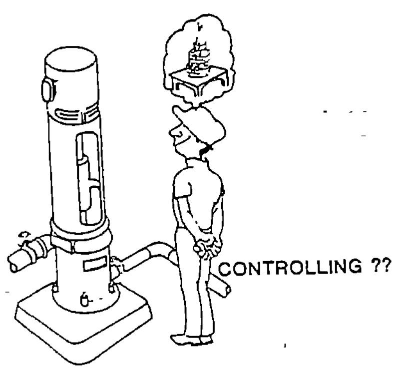


Pump installation

Wrong selection of pump — TEO 330/V 4



Pump control — TEO 330/V 5



Preparation before start-up of the pump — TEO 330/V 6

BEFORE START-UP OF THE PUMP :

- Set overload protection relay
- Measure insulation resistance
- Check water level

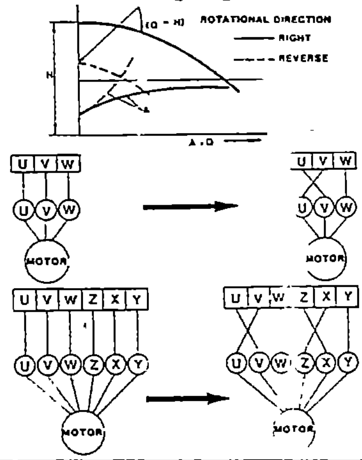
Module : SUBMERSIBLE PUMP OPERATION AND MAINTENANCE	Code : TEO 330
	Edition : 06-05-1985
Section 3 : T R A I N I N G A I D S	Page : 02 of 03

Trial testing the pump — TEO 330/V 7

PUMP TRIAL TEST

- Open the discharge valve one rotation
- Switch on & off (time lag > 3 minutes)
- Check rotational direction
- Start - up
- Check water level control instruments

Checking the rotational direction of the pump — TEO 330/V 8



Operation of submersible pump — TEO 330/V 9

STARTING THE PUMP

1. Open the valve one rotation (Open completely if permitted)
2. After nominal speed is reached :
   - Open the valve slowly
   - For submersible pumps in wells valve is fully opened when the water is clear

Observations during pump operation — TEO 330/V 10

TAKE NOTE OF THE FOLLOWING :

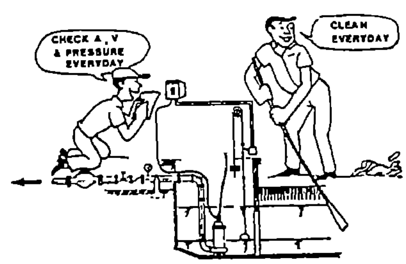
- PREVENT FREQUENT STARTING-STOPPING OF THE PUMP (WAIT AT LEAST 3 MINUTES BEFORE RESTARTING)
- CONTINUOUS RATHER THAN INTERMITTENT OPERATION SHOULD BE OBSERVED
- DON'T STOP THE PUMP WHEN THE SPRING/ WELL WATER IS STILL DIRTY
- OBSERVE FLUCTUATIONS IN ELECTRICITY SUPPLY
  $\Delta V < \pm 5\%$
  $\Delta A < \pm 10\%$
- OBSERVE CAPACITY VERSUS PRESSURE

Maintenance of submersible pumps — TEO 330/V 11

MAINTENANCE

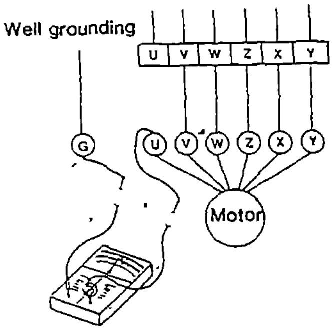
- Lubrication
- Controlling
  - . Checking
  - . Observations

Checking submersible pumps — TEO 330/V 12



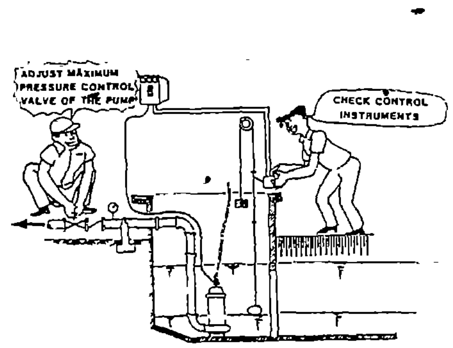
Module : SUBMERSIBLE PUMP OPERATION AND MAINTENANCE	Code : TEO 330
	Edition : 06-05-1985
Section 3 : T R A I N I N G A I D S	Page : 03 of 03

Checking motor insulation resistance — TEO 330/V 13

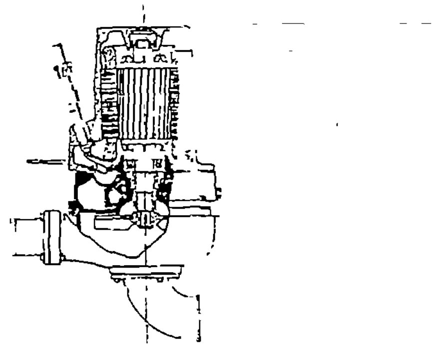


Measuring motor insulation resistance

Maintenance of submersible pump — TEO 330/V 14



Large diameter submersible pump — TEO 330/V 15



Faults pump installations — TEO 330/V 16

FAULTS PUMP INSTALLATIONS :

FAULT . - Pump
- Piping system
- Incorrect installation
- Inproper pump selection
- Power supply

Submersible pump operation and maintenance — TEO 330/H 1

1. INTRODUCTION

The entire pumping unit of submersible pumps is submerged in the water in the well. Submersible pumps are designed for deep-well installations and consist essentially of a pump and motor built together into a long slender unit. The motor is placed directly below the pumping unit, and a water-proof electric cable furnishes power to the motor.

It should be kept in mind that a submersible pump requires an ample supply of water, and that the well must be free from sand in suspension. In common with other centrifugal pumping systems, a quantity of sand will quickly ruin both the pump and the motor. The submersible pump is somewhat more sensitive to sand and grit, mainly because of the great precision necessary in its construction.

The success in operating and maintenance of submersible pump depends on various factors such as:
- installation meeting the requirements and work regulations (support and proper location);
- piping system meeting the requirements (installation of air-valve, water hammer protection device, etc.);
- selection of correct model (output in accordance with requirements);
- condition of the well (sandy or dirty water).

The life time of the pump will be prolonged with good operation and maintenance whereas bad operation and maintenance may seriously reduce the life span of the pump.

2. OPERATING SUBMERSIBLE PUMPS

a. General

- Submersible pumps are generally coupled with an induction motor (squirrel cage type), and can be started-up with the discharge valve completely open. If the power of the motor is relatively high, then the discharge valve should be virtually closed during start-up.

- Operating the pump continuously is better than frequent start-ups and shut-downs. For wells with small diameters, dirt, sand, and clay may get into the well through the well filters, due to fluctuation flows. This can shorten the life of the pump.

b. Before the initial start-up

- Overload current protection relay is adjusted to 58% of permissible current (Apms) specified on motor plate.

- Before operating the pump, measure again the motor insulation resistance. For the permitted insulation resistance see the specifications from the manufacturer. Carry out further measurements periodically.

- Check whether the water level is high enough.

c. Trial testing

- Open the discharge valve between one half and one full rotation.

- Push the ON and OFF switch a few times to check whether the pump runs normally. Time between switching OFF and ON shall be minimally 3 minutes.

- Check the rotational direction of the pump. The rotation is correct if the pressure on the closed valve is at its specified maximum. If the rotation is in the wrong direction, the electrical current will suddenly increase when the valve is gradually opened (see fig. 1). Carry out the exchange of cables on the terminal as shown in fig. 2.

- Start the pump again after a 10 minutes stop and open the valve slowly when the water has become clear. Sand may block the pump if the valve is opened quickly.

- Lift the low water level control equipment upwards (electrical or mechanical float) that will stop the pump if the electrodes are not submerged in the water, or if the mechanical floater descends over a certain distance.

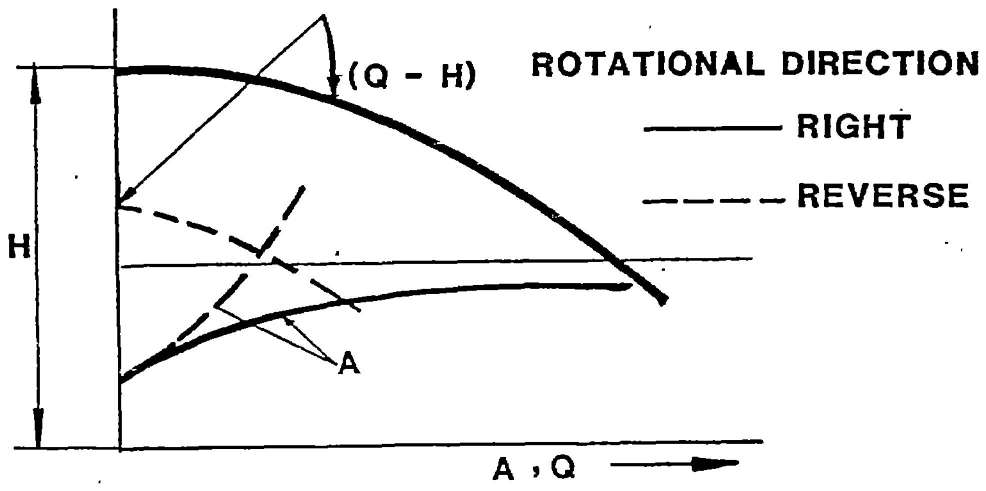


Fig. 1. Characteristics of pumps and level of current consumption.

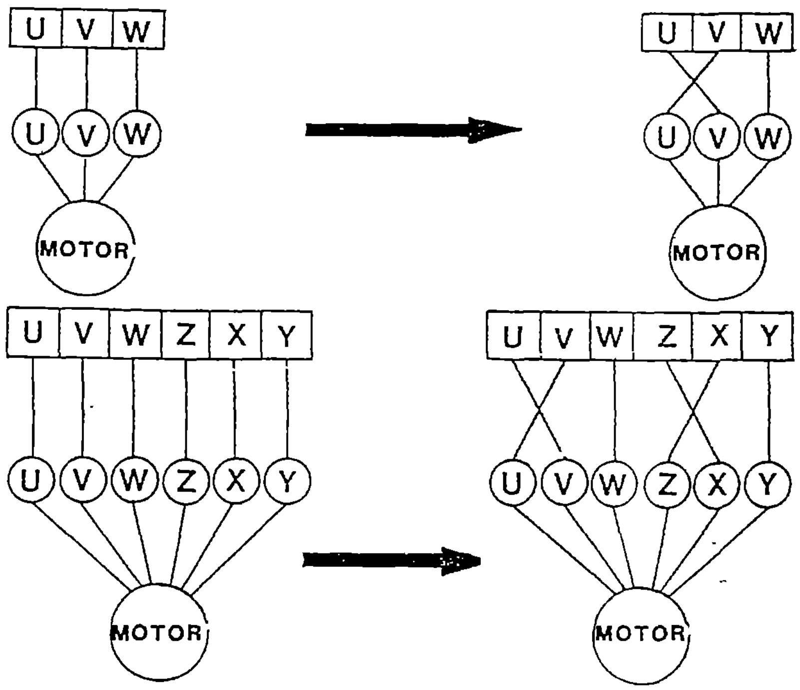


Fig. 2. Exchange the cables on the terminals when the rotation is in the wrong direction.

d. **Operating the submersible pump**

After the trial test is carried out, the pump can be operated normally while taking note of the following:

- During start-up the valve shall be virtually closed and be opened slowly after the pump has been reached its nominal rotational speed. Dirt may be pumped up when the valve is opened too quickly, which may damage or block the pump.

- Avoid opening and closing the adjusted valve under normal operating conditions.

- Period between shut-off and re-starting should be minimally 3 minutes (frequency of switching on/off should not be more than 20 times per hour).

- Check regularly the electricity supply: voltage shall not deviate more than 5%, and electric current variations shall not be more than 10%.

3. MAINTENANCE

Except for lubrication purposes, the pump needs very little maintenance. Normally only minor control and inspection is required. Necessary control and inspection activities are explained below:

a. **Raw water submersible pumps**

DAILY:

- Keep the are around the pump clean so that it remains free from sediments and dirt, that can block the pipes.

- Check the electric current on the ammeter. If the fluctuations are quite high, the pump may be blocked. If the water output suddenly decreases, a possible cause is blockage by foreign matters in the inner parts of the pump.

- Check the voltage of the electricity supply. Contact the electricity company or genset operator if the voltage deviates more than 5%.

MONTHLY:

- Measure the isolation resistance. Usually it must be over and above 1 mega Ohm (see manufacturer's specifications). If there is a sudden decrease of the resistance, even when it is still above 1 mega Ohm, there is a problem at the pump.

- Check the characteristics of the pump, pressure vs. capacity.

YEARLY:

- Change the oil of the pump. To do this, pull the pump out and tilt it. Open the oil cap and change the oil.

- Change the mechanical seal (when the oil becomes black in the seal chamber), and gasket of oil cap; change O-rings according to the manufacturer's instructions.

- Check the electric cable for damaged insulation, and repair it using the insulation tape.

Note:

- From time to time it is necessary to check for water and oil leaks entering the motor casing with raw water submersible pumps.

- After 5 working years it is advised to overhaul the pump.

b. **Well submersible pumps**

Maintenance is almost the same as for the large diameter pumps mentioned above.

Activities to be carried out include:

- Check the water level periodically. The well needs to be cleaned if during pumping the water level gradually drops (unless other reasons cause the drop of the water table; e.g. water mining).

- Measure the insulation resistance of the motor.

- Measure the capability and characteristics of the pump (power, capacity, pressure).

- Check the functioning of the water level control equipment.

4. FAULTS AND REMEDIAL ACTIONS

Faults occurring in pumping installations may have various causes.

In general, faults can be summarized as follows:
- faults on pumps;
- faults in the piping system;
- faults due to inaccurate selection of pumps;
- faults in the electrical power supply.

Faults or malfunctioning of the pump itself are generally caused by foreign matters clogging the pump.

By observing the electrical current used, the wear of the vanes and capability of the pump, faults and their causes can be identified.

Other possible causes for malfunctioning of pump installations are: inadequate electricity supply, damage of the control equipment, air or blockages in the pipes.

5. SUMMARY

a. Introduction:

Operation and maintenance of submersible pumps are influenced by the following factors:
- installation;
- piping system;
- selection of pumps;
- surroundings;
- inspection/control.

b. Operating the pump:

- General:
  . if coupled with the rotor of the induction motor, the discharge valve can be opened during start-up (except for larger motors where the discharge valve should be virtually closed);
  . continuous operation is better than frequent starting and stopping.

- Before initial start-up:
  . adjust the overload current protection relay to 58% of permissible current;
  . measure the insulation resistance;
  . check the water level.

- Run the trial test:
  . open the discharge valve one half to one turn;
  . switch the ON and OFF switch a few times;
  . start it again after 10 minutes;
  . check the water level, and water pressure control equipment.

- Operating the submersible pump:
  . open the valve one turn (it can be opened fully when operation is normal);
  . operate it continuously, avoid frequent starting and stopping;
  . observe: V, A, Q, and P.

c. Maintenance:

Improtant aspects in maintenance:

DAILY:
- always maintain a clean environment around the pump;
- ensure a stable electric power supply (V, f).

MONTHLY:
- check the insulation resistance and characteristics of the pump.

YEARLY:
- change the oil;
- check the vanes/impellers;
- check electric cables and control equipment.

d. How to overcome faults:

Faults on pump installations are often caused by:
- pump itself;
- piping system;
- installation;
- pump selection;
- electrical system.

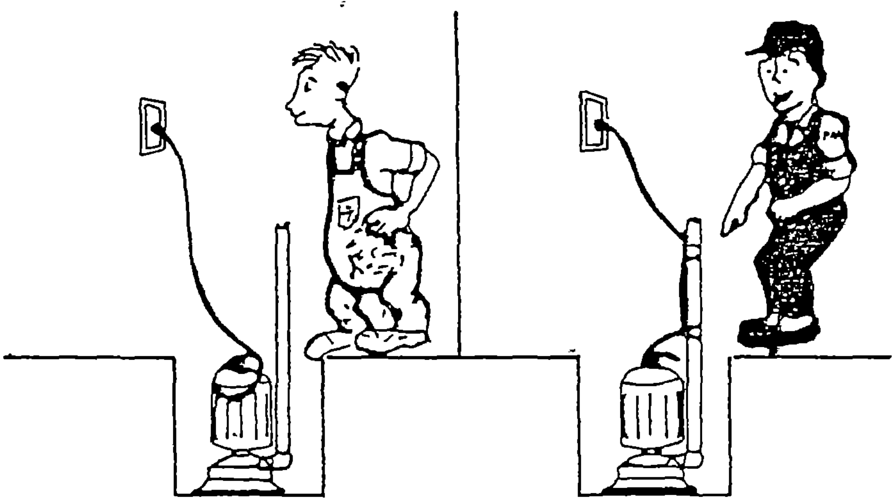
Frequently occurring faults are: instable electricity supply, air or blockages in pipes, damages to the control equipment.

* * *

OPERATION & MAINTENANCE DEPEND ON :

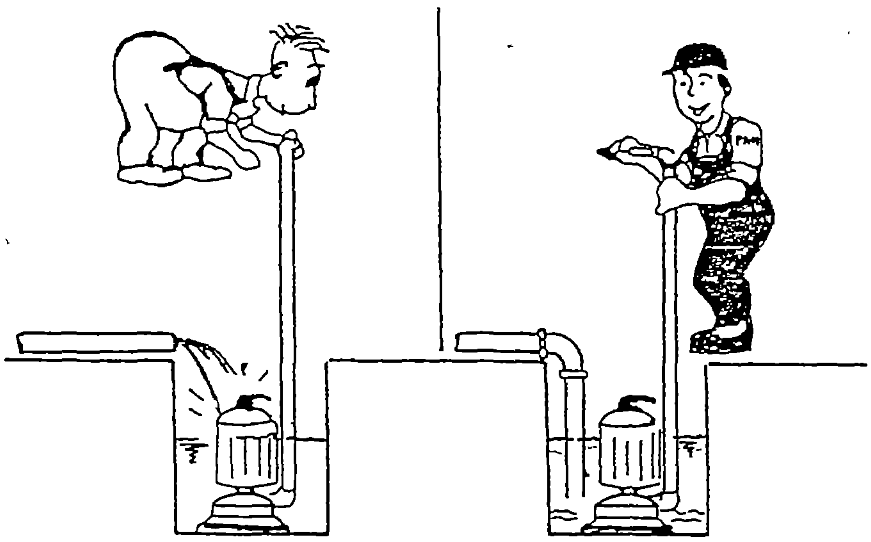
- Installation
- Piping system
- Selection of pump
- Surroundings
- Controlling

ELECTRICAL CABLE INSTALLATION ???

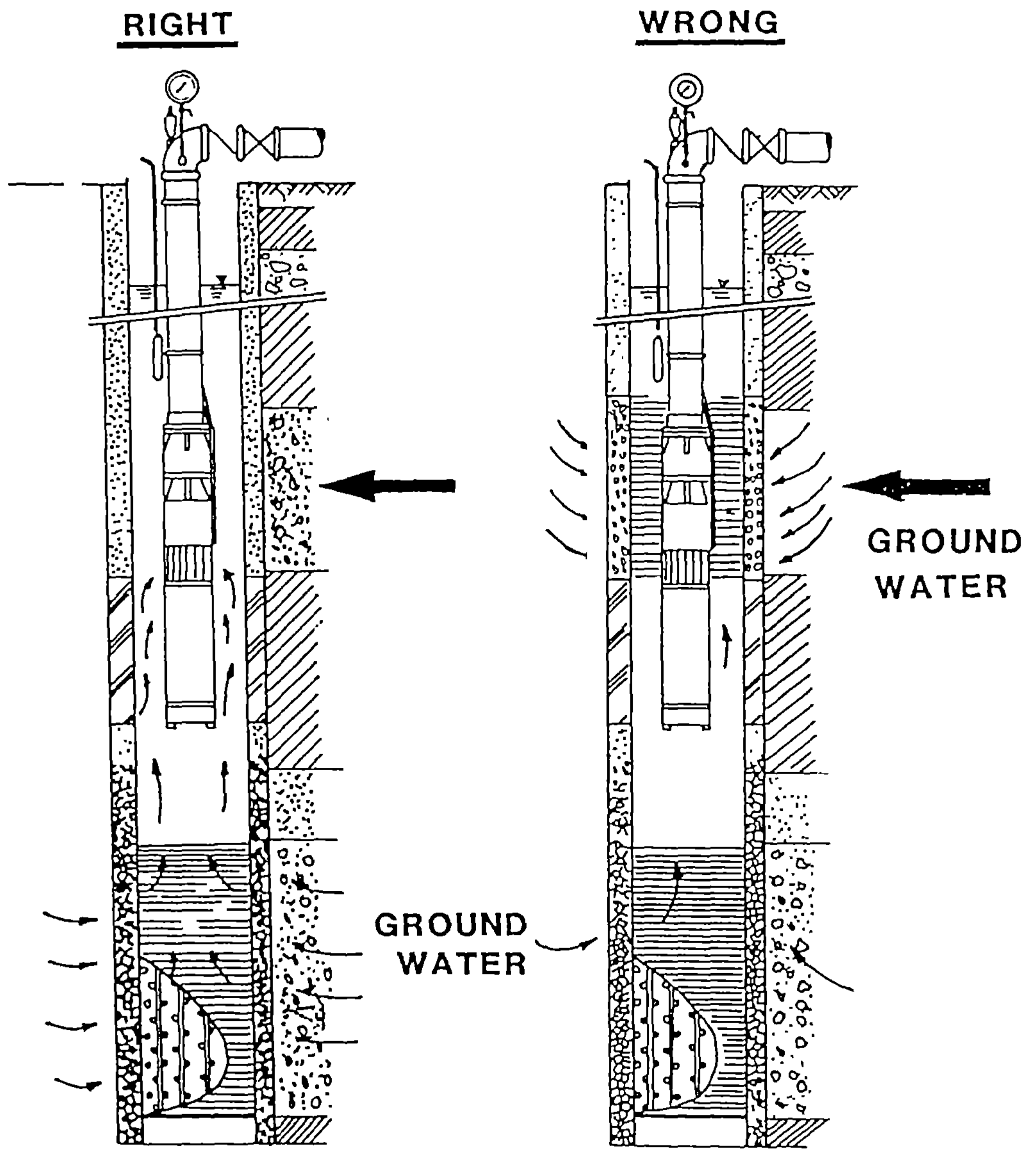


WRONG RIGHT

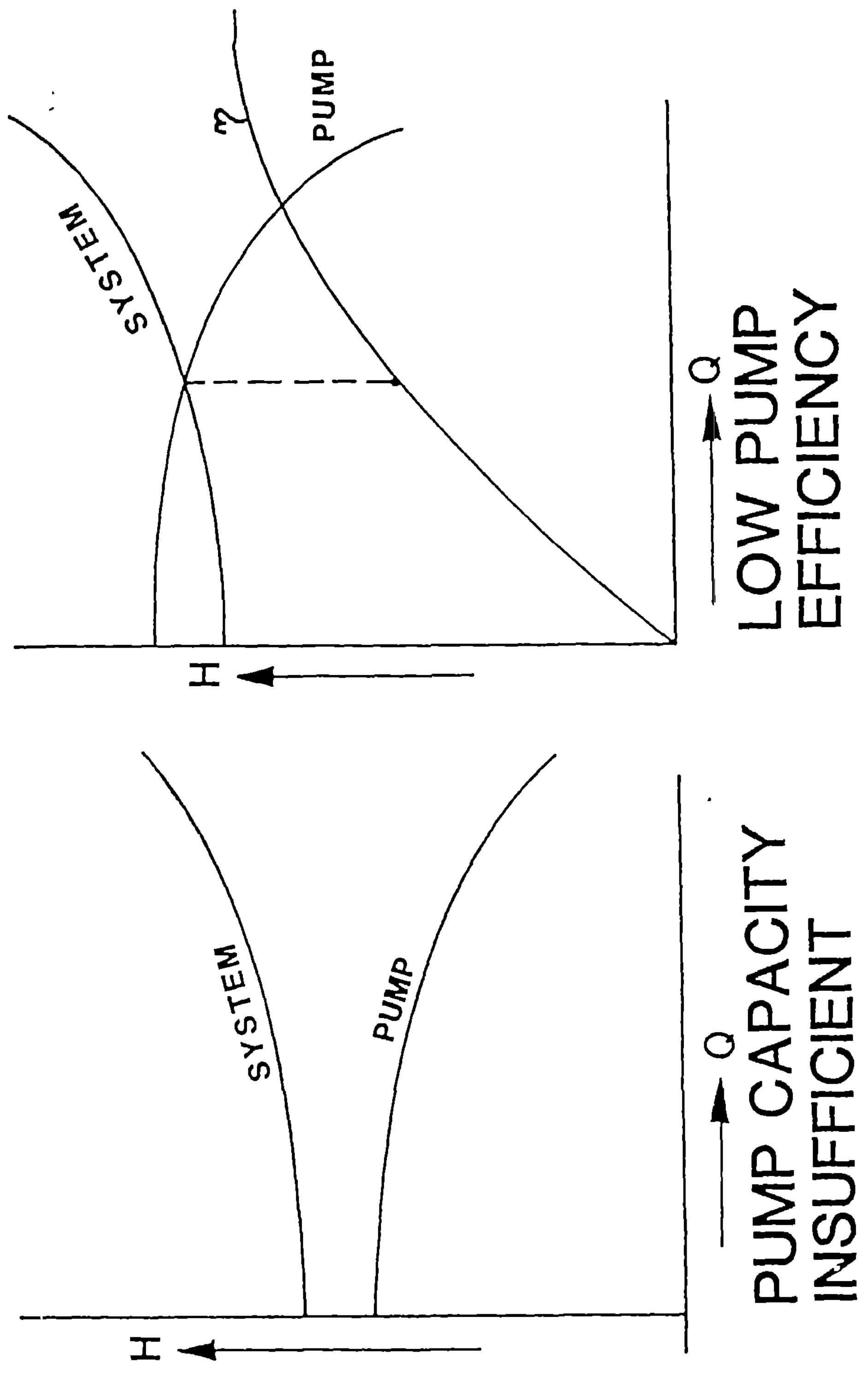
PIPING SYSTEM ???



WRONG RIGHT



Pump installation


SYSTEM
PUMP
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Q
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EFFICIENCY
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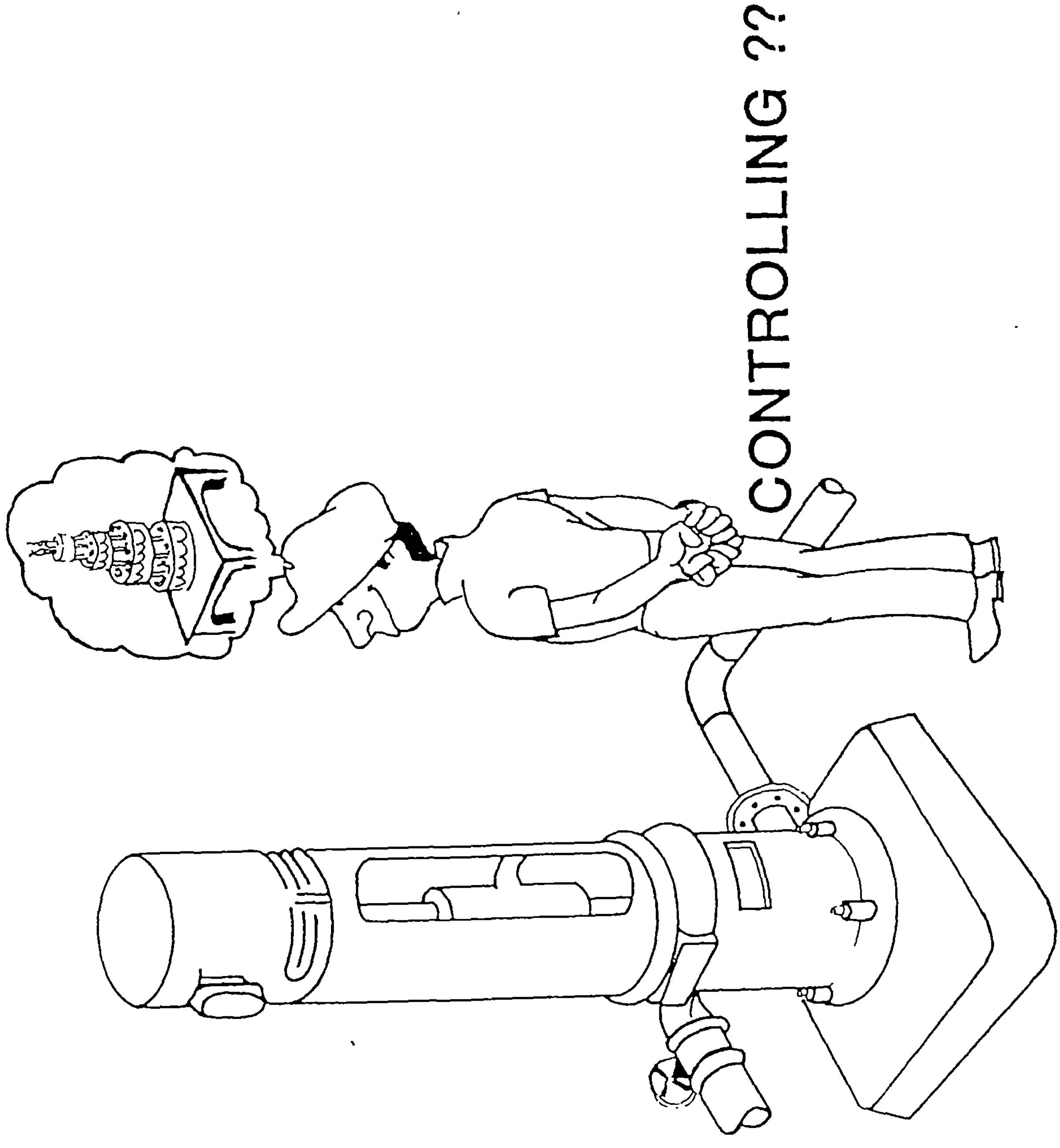
PUMP CAPACITY
INSUFFICIENT


CONTROLLING ??

BEFORE START-UP OF THE PUMP :

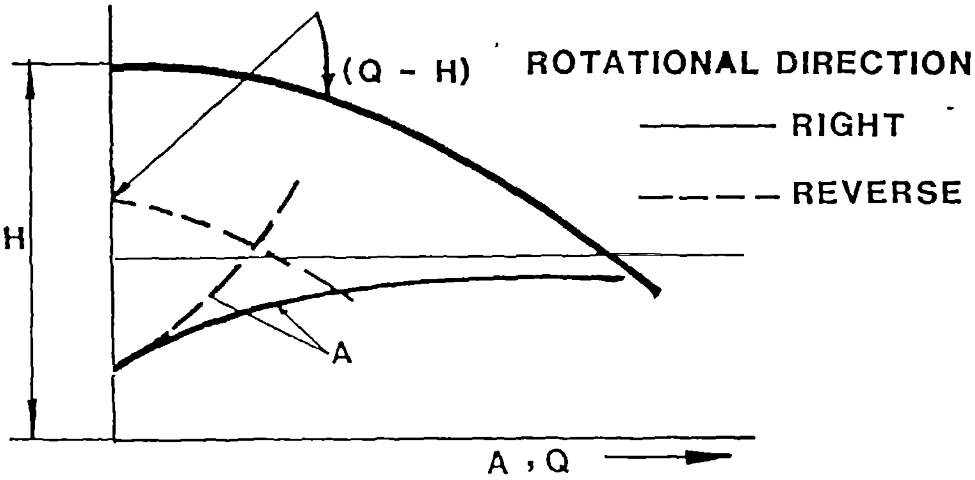
- Set overload protection relay

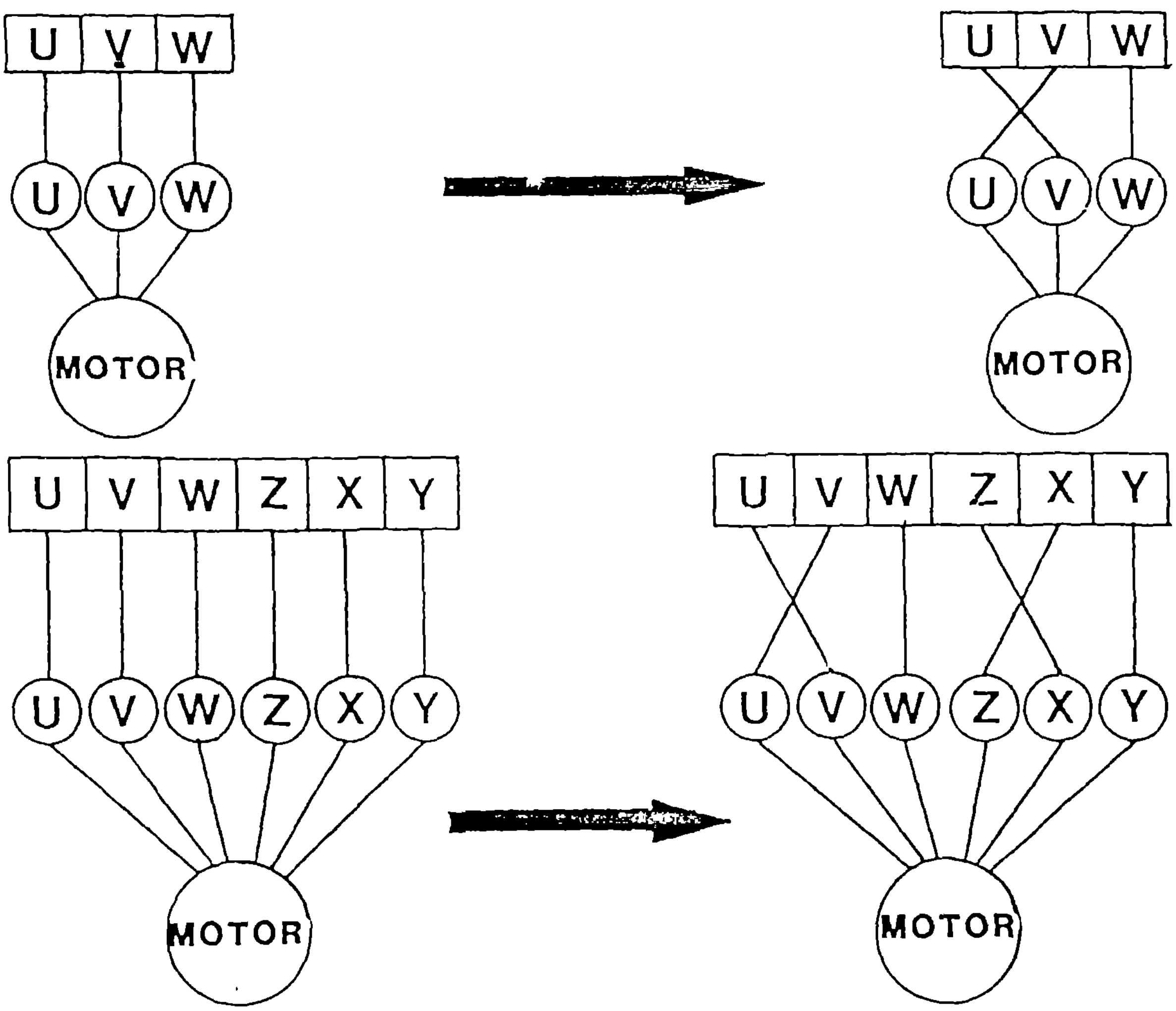
- Measure insulation resistance

- Check water level

PUMP TRIAL TEST

- Open the discharge valve one rotation
- Switch on & off (time lag > 3 minutes)
- Check rotational direction
- Start - up
- Check water level control instruments


(Q - H)
ROTATIONAL DIRECTION
RIGHT
REVERSE
H
A
A , Q


U V W
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U V W Z X Y
MOTOR
U V W Z X Y
U V W Z X Y
MOTOR

STARTING THE PUMP

1. Open the valve one rotation
   (Open completely if permitted)

2. After nominal speed is reached :

   - Open the valve slowly

   - For submersible pumps in wells:
     valve is fully opened
     when the water is clear

TAKE NOTE OF THE FOLLOWING :

- PREVENT FREQUENT STARTING-STOPPING OF THE PUMP (WAIT AT LEAST 3 MINUTES BEFORE RESTARTING)

- CONTINUOUS RATHER THAN INTERMITTENT OPERATION SHOULD BE OBSERVED

- DON'T STOP THE PUMP WHEN THE SPRING/ WELL WATER IS STILL DIRTY

- OBSERVE FLUCTUATIONS IN ELECTRICITY SUPPLY :

  $\Delta V < \pm 5\%$

  $\Delta A < \pm 10\%$

- OBSERVE CAPACITY VERSUS PRESSURE

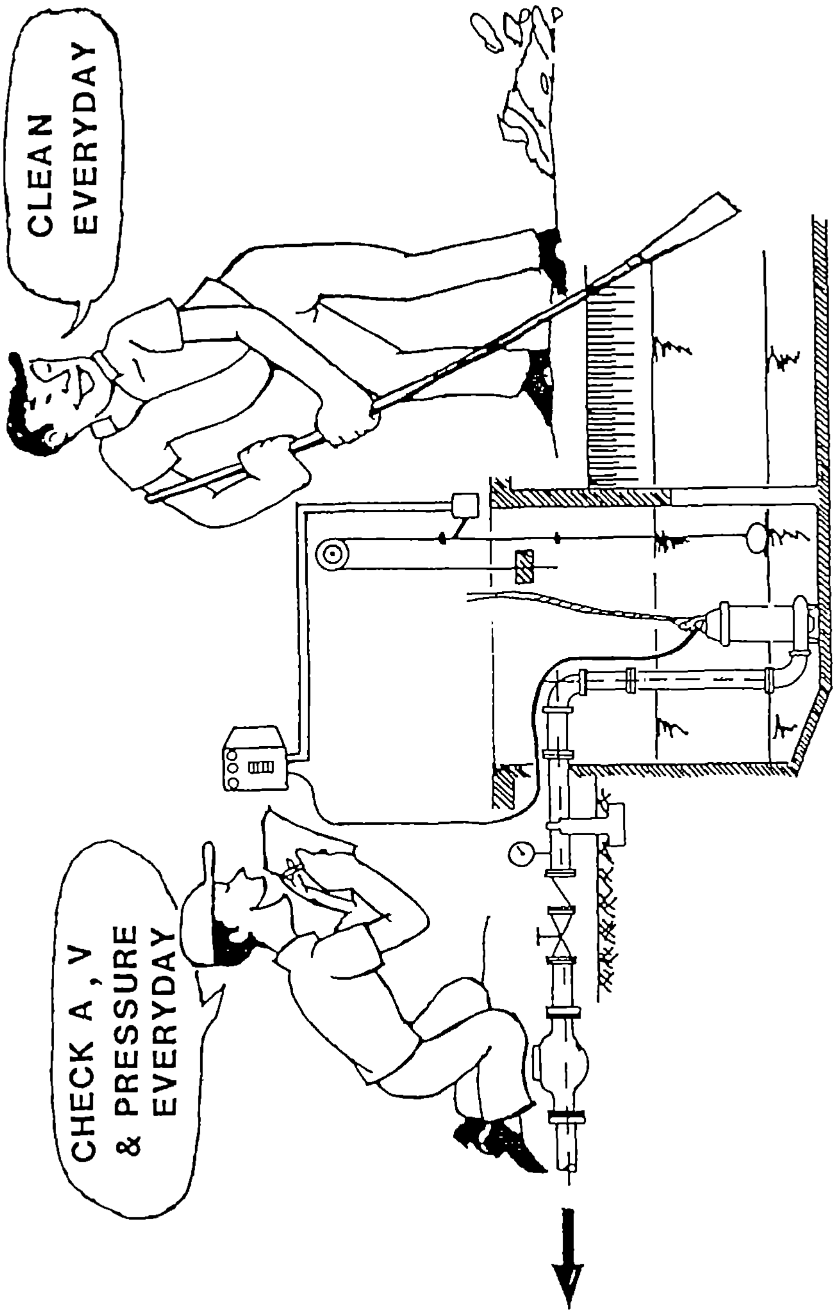
MAINTENANCE

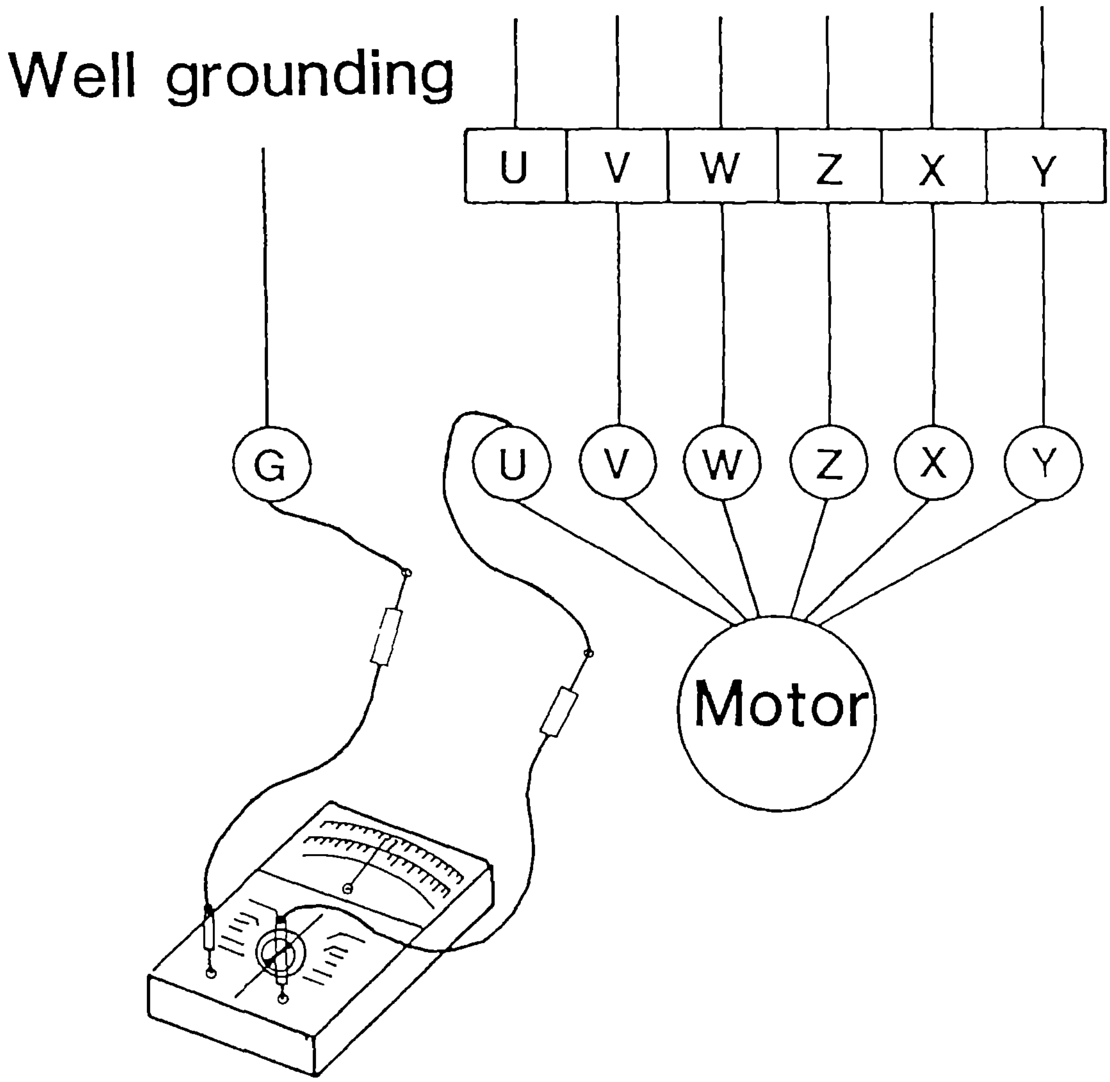
- Lubrication

- Controlling

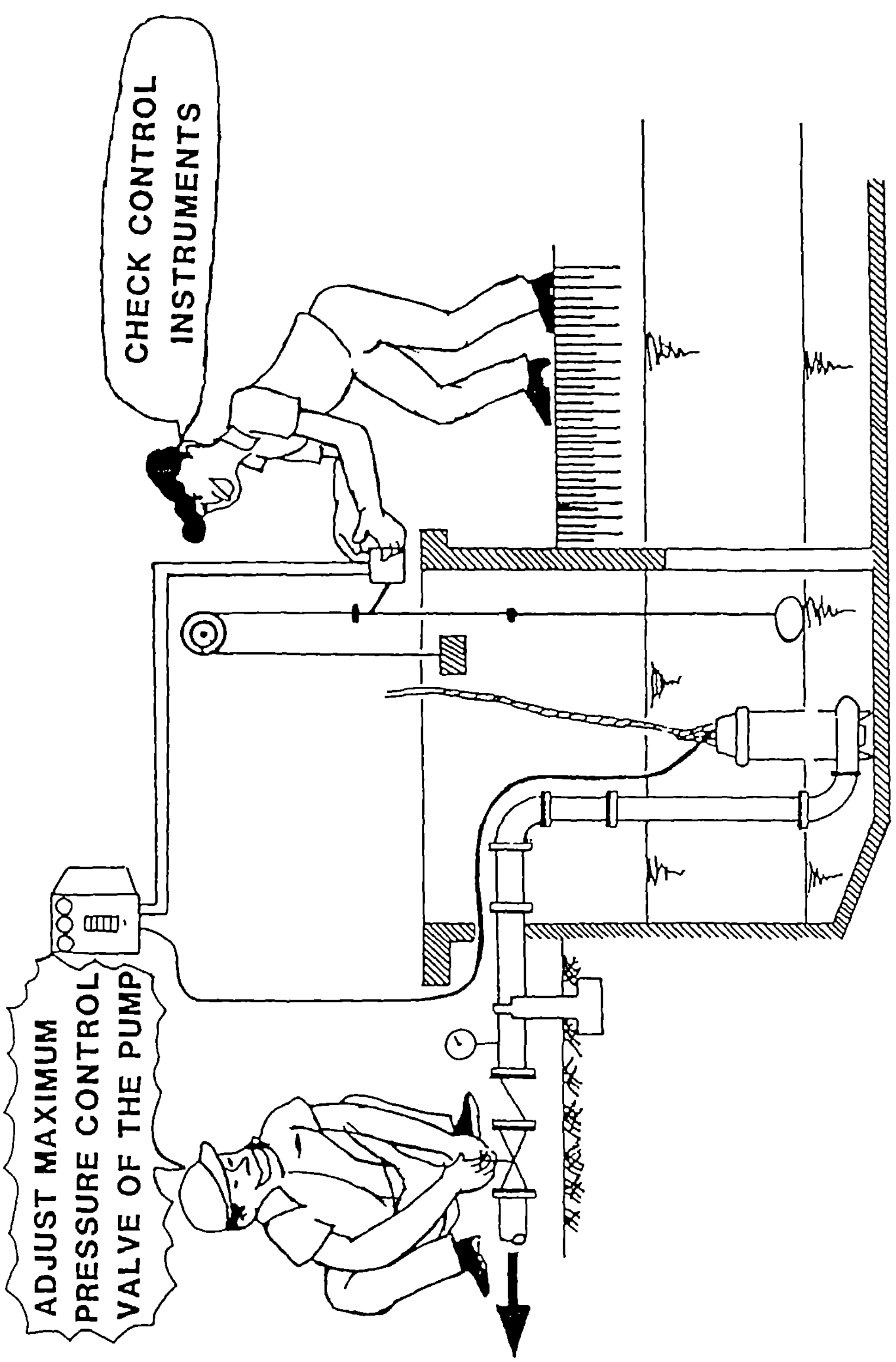
  . Checking

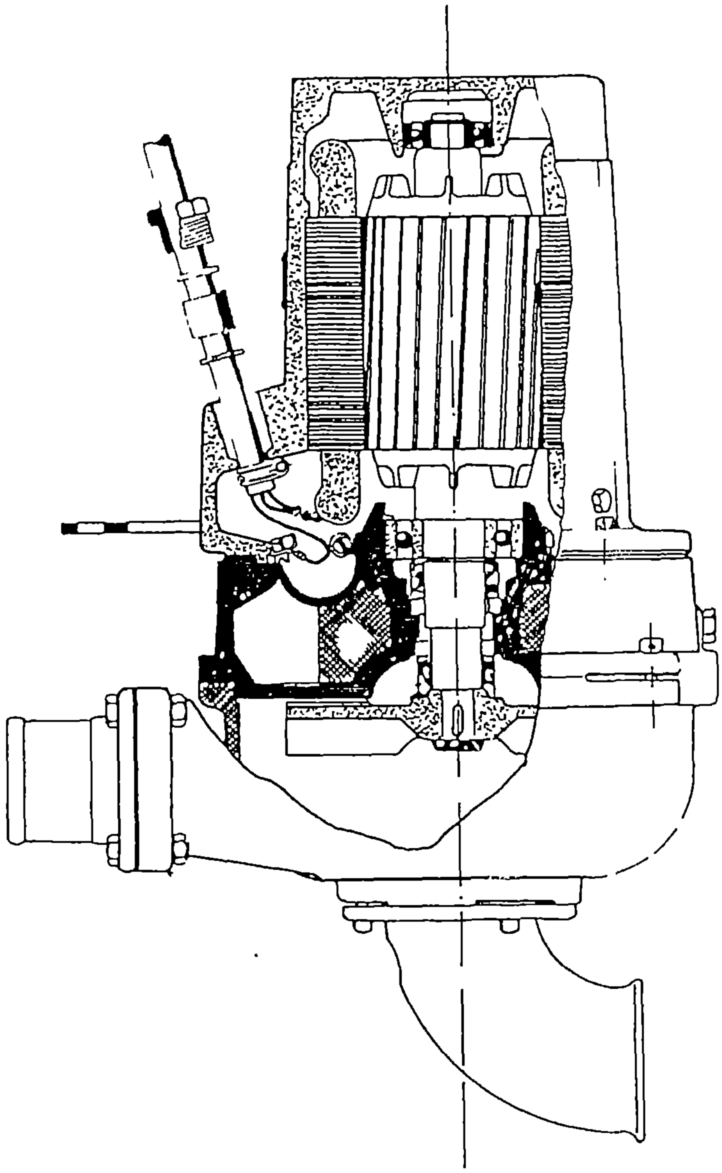
  . Observations


CLEAN EVERYDAY
CHECK A, V & PRESSURE EVERYDAY



Measuring motor insulation resistance


CHECK CONTROL INSTRUMENTS
ADJUST MAXIMUM PRESSURE CONTROL VALVE OF THE PUMP



FAULTS PUMP INSTALLATIONS :

FAULT : - Pump

- Piping system

- Incorrect installation

- Inproper pump selection

- Power supply

Module : COMPRESSOR OPERATION AND MAINTENANCE	Code : TEO 620
	Edition : 03-05-1985
Section 1 : INFORMATION SHEET	Page : 01 of 01/16

Duration :	45 minutes.
Training objectives :	After the session the trainees will be able to: - explain how to make an inspection before starting the compressor; - explain how to operate piston and rotary compressors; - list the important maintenance activities for piston and rotary compressors.
Trainee selection :	- Head of Section Maintenance; - Head of Section Production; - Head of Section Planning & Supervision; - Plant Attendant; - Mechanic.
Training aids :	- Viewfoils : TEO 620/V 1-8; - Handout : TEO 620/H 1.
Special features :	-
Keywords :	Compressor inspection/compressor operation/compressor maintenance/compressor lubrication.

1. Introduction	
- The following inspection has to be made before start-up of a compressor: . lubrication; . belt; . load free condition; . voltage.	Use whiteboard
- Factors which influence correct operation: . maintenance; . proper installation.	
- Maintenance schedules have to be followed.	
2. Compressor operation and maintenance	
<u>Piston compressor</u>	
- Inspection before operating: . bolts, nuts; . pulleys and belts; . air filters; . lubricating oil; . bearing grease.	Show V 1-4
- Operation: . disengage load; . rotate by hand; . check the direction of the rotation; . when the rotation is correct switch on and add the load gradually; . observe: * V, A and pressure; * oil (> 1 atm); * temperature.	Show V 5-6
- Maintenance: . driving belt and pulley; . for lubrication the following greasing materials are used: * lithium based grease for bearings; * oil (free from wax and containing naphtalene) for the piston, cylinder and rings; . oil filters;	

. note:

a. the viscosity of the oil is very important due to the high friction, pressure and high temperatures:
   - too viscous --> the temperature increases and destroys the oil film;
   - too thin --> parts wear out quickly;
   - too much or too little oil will cause the temperature to rise --> parts will wear out quickly;
   - possibility of scaling and formation of sediments of oil in the cylinder.

b. oil pressure may drop because of: — Show V 7-8
   - clogged oil filter;
   - worn-out crank shaft bearing and piston;
   - open by-pass.

<u>Rotary compressor</u> — Use whiteboard

a. The inspection is the same as for the piston compressor except for:
   . inspection of bearing lubrication and gears;
   . correct arrangement of the rotor blades;
   . oil seal.

   - Operation:
     . disengage the load;
     . rotate by hand;
     . check the rotation;
     . operate when the rotation is correct for approx. 30 minutes;
     . gradually increase the load;
     . observe:
       - temperature (< 70°C);
       - noise;
       - pressure;
       - voltage.

b. Maintenance:
Maintenance is the same as for the piston compressor. The important aspects are:
- gear lubrication (SAE 90, 140);
- bearings lubrication, lithium based grease;
- the addition of oil is not recommended; change oil completely;
- change: after first 200 hours;
  every 500 hours regularly.

3. **Summary** — Distribute H 1

Inspection before start-up of compressor — TEO 620/V 1

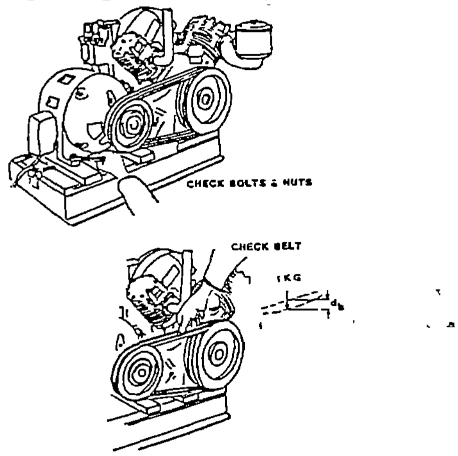
START-UP PROCEDURE :

- PREPARATION/INSPECTION

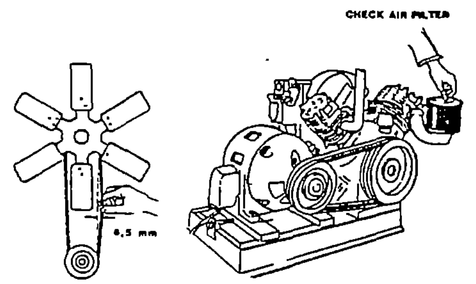
  CHECK :
  - . Bolts & nuts
  - . Belt
  - . Air filter
  - . Oil level

- START-UP
  - . Disengage load
  - . Rotate by hand
  - . Check direction of rotation
  - . Start & gradually increase load
  - . Observe voltage, temperature, pressure

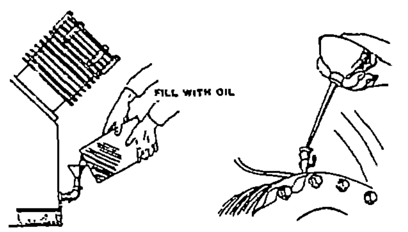
Preparation for operating compressor (I) — TEO 620/V 2



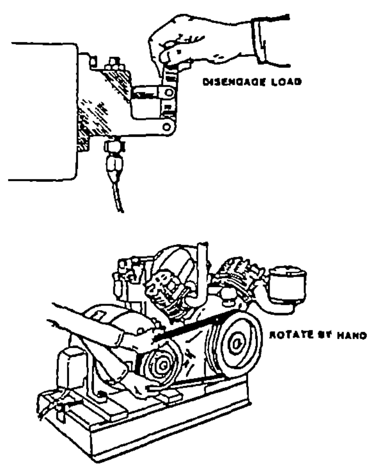
Preparation for operating compressor (II) — TEO 620/V 3



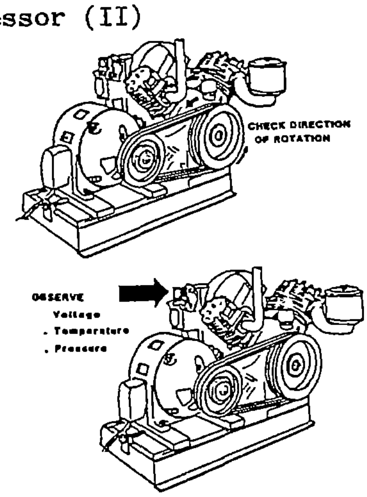
Preparation for operating compressor (III) — TEO 620/V 4



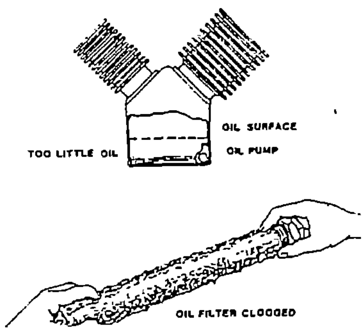
Operating the compressor (I) — TEO 620/V 5



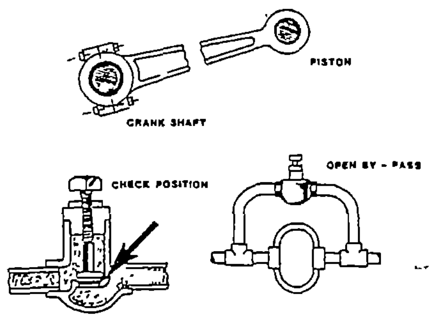
Operating the compressor (II) — TEO 620/V 6



Causes of low oil pressure (I) TEO 620/V 7



Causes of low oil pressure (II) TEO 620/V 8



Compressor operation and maintenance TEO 620/H 1

1. INTRODUCTION

A compressor is a machine which delivers air or gas under pressure higher than 2.4 kg/cm² (machines delivering air under pressures between 0.7 and 2.4 kg/cm² are called blowers).

In principle a compressor operates in the same way as a pump.

Compressors are used in Water Enterprises for:
- water hammer reducing tanks;
- pneumatic valves;
- water aeration;
- jet pumps;
- cleaning of filters;
- cleaning of equipment.

The types of compressors commonly used in Water Enterprises are pressure compressors (vs. dynamic compressors), either using a piston or rotors to compress the air.

To ensure the correct operation of compressors the following matters must always be remembered before starting the compressor:
- check level of lubricating oil;
- check tension of the belt;
- set the compressor free from any load;
- check power supply.

Good maintenance is needed to guarantee a long life lime of compressor. Operation and maintenance of the compressor are greatly facilitated by proper installation.

In a water supply system the compressor is not operated continuously because it is mainly used for water hammer protection devices, hydrophores, filter washing, operation of pneumatic equipment, and cleaning of the equipment for maintenance purposes. The maintenance schedule depends very much on the number of working hours of the compressor, which is relatively small compared to other mechanical equipment.

2. OPERATION AND MAINTENANCE OF THE COMPRESSOR

Piston compressor

a. Inspection before operating

- Check all bolts and nuts. If any are loose, then tighten them.
- Check that pulley and belt are accurately placed.
- Check the tension of the belt by pushing the belt downwards with a force of 1 kgf.
  The distance the belt may be pushed downwards is the same as the thickness of the belt.
- Check the air filter, fill it with the appropriate oil according to the manufacturer's instructions.
- Fill the casing with oil according to the manufacturer's instructions. Also the oil bowl in the compressor has to be filled before operating the compressor.

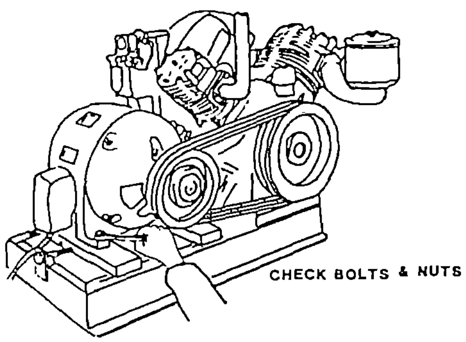


Fig. 1. Check and tighten bolts.

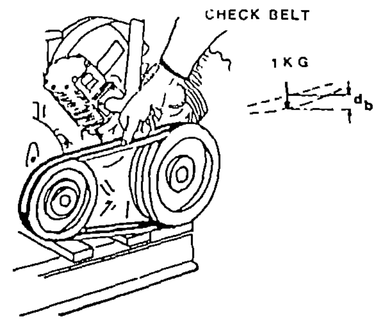
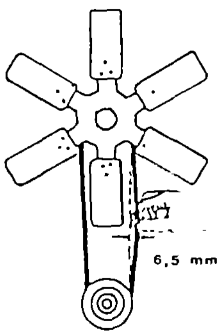


Fig. 2. Check the tension of the belt.



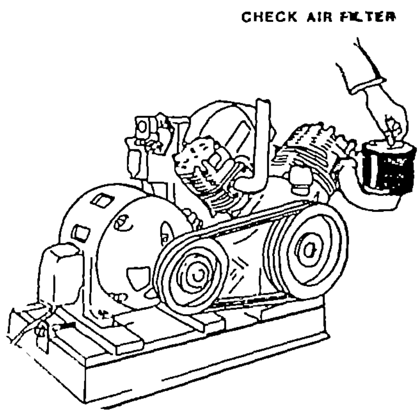


Fig. 3. Check the air filter and fill it with oil.

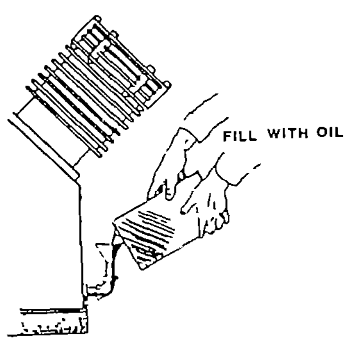


Fig. 4. Fill the casing with oil.

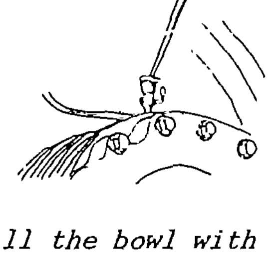


Fig. 5. Fill the bowl with oil.

b. Starting the compressor

- Free the compressor of any load before starting by using the load-free release, or if using load-free release switch gear, change the switch to the OFF position.

- Turn the compressor by hand a few times before start-up, to ensure that the compressor is free to rotate and can lubricate the inner parts properly.

- Try to start-up and observe the direction of the rotation. The rotation is indicated by the arrows. If the rotation is not right, the oil pump will not work properly and will burn out quickly.

- When the rotation is correct, switch on the compressor and observe the oil pressure. The pressure is at first above 2,4 kg/m² due to the oil still being cold. If the oil pressure is less than 1 kg/cm² switch-off and check the compressor.
  The causes of low oil pressure may be:
  . the oil level inside the casing is too low;;
  . the oil filter is clogged;
  . worn out crankshaft bearings and pistons;
  . by-pass valves are opened.

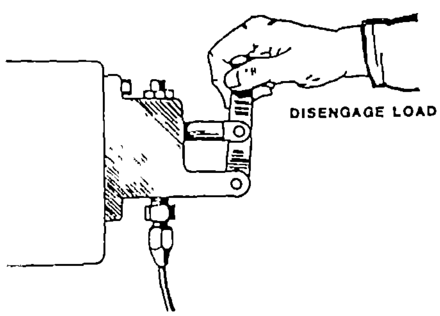


Fig. 6. Free the compressor from load.

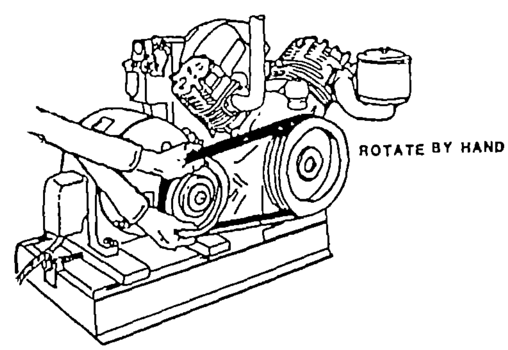


Fig. 7. Rotate by hand before start-up.

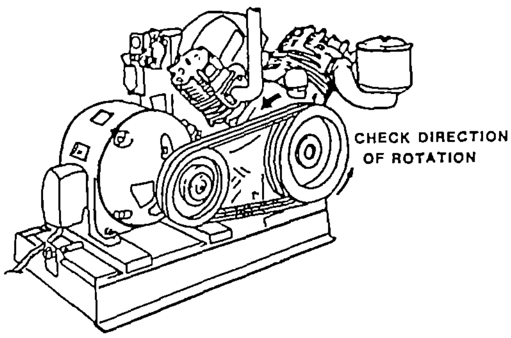


Fig. 8. Check direction of rotation.

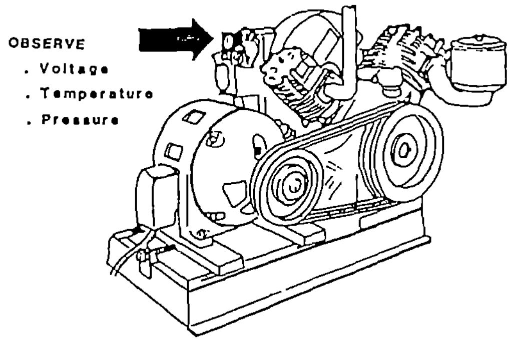


Fig. 9. Check oil pressure (pressure > 1 atm).

c. Maintenance

- DRIVING BELT

The condition of the driving belt needs to be checked periodically. The tension of the belt needs to be checked, because if it is too tight it will increase the load on the motor as well as on the compressor and thus damage the bearings, burn the motor and make abnormal sounds. If the belt is too slack, the belt will vibrate and cause a great friction loss. This will reduce the amount of compression.

- LUBRICATION

. The bearings need to be lubricated with grease or oil in accordance with the instructions from the manufacturer (lithium based grease can be used). The amount of lubricating grease used should not be excessive. If there is an excess of grease, the bearings become hot which reduces the quality of the grease. It will also damage the bearings. Open the bearing caps which are usually under the bearing casing and let the excess grease out.
If the amount of grease is not sufficient, the temperature will increase.
Remember that the life time of the bearings depends on appropriate lubrication and cleanliness from dust and sand.

. Pistons, rings, and cylinders need lubrication to reduce friction, wear and air leaks.

- LUBRICATING OIL

  . The type of lubricating oil is the wax-free type containing napthalene;
  . The amount and quantity of the lubricating oil is very important (look at the manufacturer's instructions);
  . Check the oil level of the lubricating oil periodically. It must be between the maximum and minimum level;
  . Change the lubricating oil after the first 200 hours of operation and thereafter change it regularly every 300-400 hours of operation.

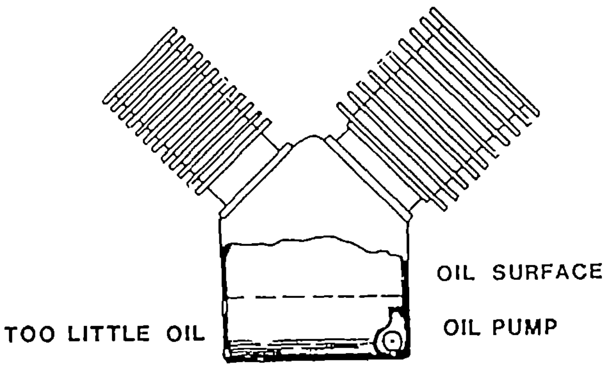


Fig. 10.
Fill in the oil up to the specified level.

- OIL FILTERS

  . Clean the oil filters periodically, so that the filter will not get clogged. If the filter is clogged the oil pressure will decrease. This causes a lack of lubrication, quickly damaging the parts lacking lubrication.
  A decrease in pressure is an indication that dirt is clogging the filter.

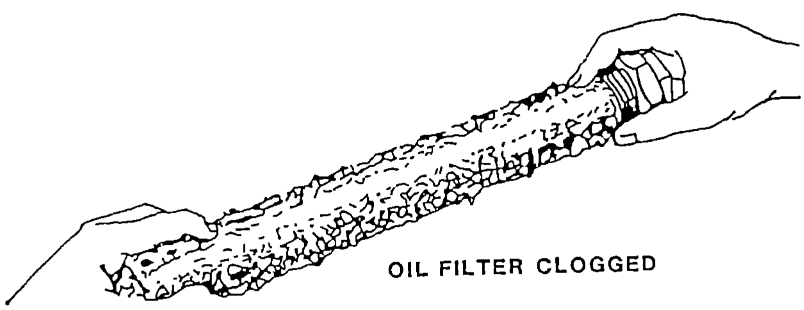


Fig. 11.
Clean the oil filter regularly.

. Note:
The oil viscosity used is very important as the friction and temperature of the compressor air are quite high.

- oil which is too viscous will cause the temperature to rise and will destroy the thin film of oil and also damage the parts being lubricated;
- oil which is too thin, causes damage to the parts being lubricated;
- not enough or too much oil will cause the temperature to rise and will damage the parts being lubricated;
- if the lubricating oil is used to lubricate the piston, there is a possibility of scales appearing and sediments of oil forming;
- the oil pressure may drop due to:
  . clogged filters;
  . piston and crankshaft worn out;
  . open by-pass.

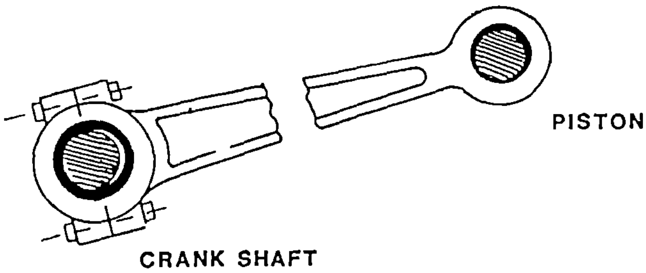


Fig. 12.
Piston and crankshaft bearings wearing out.

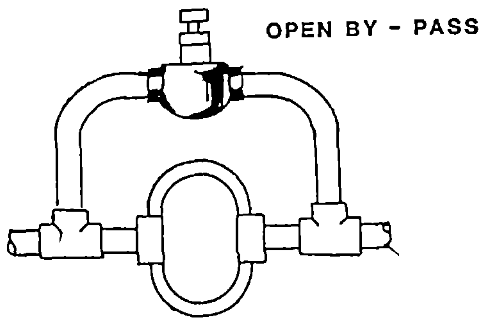


Fig. 13.
By-pass oil pipe.

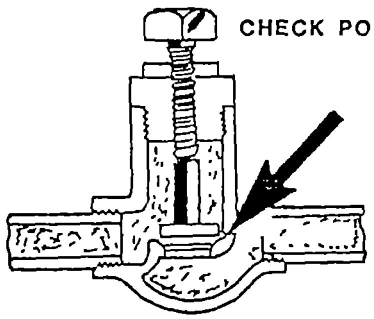


Fig. 14.
Check dirt sticking to the valve seating.

Rotary compressor

The inspection to be made before initial start-up of the rotary compressor is the same as the inspection mentioned above, except for the following:
- lubrication of bearings and gears. Ensure that the right lubrication grease is used and no dirt has entered the casings;
- ensure that the bearings and gears are not worn-out and that the rotor blades are correctly arranged;
- ensure that the oil seal is normal and that there are no worn-out parts on the shaft.

a. <u>Operation of rotary compressor</u>

- Free the compressor of any load before start-up. Use the load-free release or change the switch to the OFF position.

- Turn it by hand a few times before start-up to ensure that the compressor is free to rotate.

- Start the compressor and observe the direction of rotation. If the rotation is not correct, adjust rotational direction in accordance with manufacturer's instructions.

- When the rotation is correct, operate the compressor without any load for approx. 30 minutes. If there are no problems, normal operation can be started by adding the load gradually using the load regulator.

- Observe and check the following:
  . electrical voltage, ampere;
  . temperature of compressor parts (max. 70°C);
  . noise;
  . pressure of output.

During normal operation regularly check the above mentioned. If there are any abnormal noises, high temperatures or abnormal measurement read-outs, stop the compressor immediately and look for the cause.

b. Maintenance

Maintenance is generally the same as for the maintenance of piston compressor except for the following:

LUBRICATION:

- For lubrication of gears to drive the rotor blades, use gear oil (see manufacturer's instructions or use SAE 90, 140, etc.).

- For lubrication of bearings use lithium based grease or others of the same standard.

- It is not recommended to add more oil, all oil should be changed at once.

- Change the lubricating oil for the gears after the first 200 hours of operation and thereafter every 500 hours of operation.

3. SUMMARY

a. Introduction:

- Before start-up of compressor, check:
  . lubrication;
  . belt;
  . load set free;
  . voltage.

- Factors effecting the compressor's operation:
  . maintenance;
  . good installation.

b. Piston compressor:

- Inspection before start-up:
  . bolts, nuts;
  . pulleys and belts;
  . air filters;
  . piston lubricating oil, cylinder;
  . bearing lubricating grease.

- Operating the compressor:
  . free the load;
  . rotate by hand;
  . start compressor;
  . check the direction of rotation;
  . when the rotation is correct increase the load gradually;
  . observe: voltage, air pressure, oil pressure, temperature.

- Maintenance:
  . check pulleys and belts;
  . for lubrication use:
    - lithium based grease for bearings;
    - wax-free oil containing napthalene for pistons, cylinders and rings;
  . SAE 90, 140, oil for gears.

NOTE:

- Viscosity of the lubrication is very important.
- Lubricating oil should be carefully applied.

* * *

Module : COMPRESSOR OPERATION AND MAINTENANCE	Code : TEO 620
	Edition : 03-05-1985
Annex : V I E W F O I L S	Page : 01 of 09

TITLE :	CODE :
1. Inspection before start-up of compressor	TEO 620/V 1
2. Preparation for operating compressor (I)	TEO 620/V 2
3. Preparation for operating compressor (II)	TEO 620/V 3
4. Preparation for operating compressor (III)	TEO 620/V 4
5. Operating the compressor (I)	TEO 620/V 5
6. Operating the compressor (II)	TEO 620/V 6
7. Causes of low oil pressure (I)	TEO 620/V 7
8. Causes of low oil pressure (II)	TEO 620/V 8

START-UP PROCEDURE :

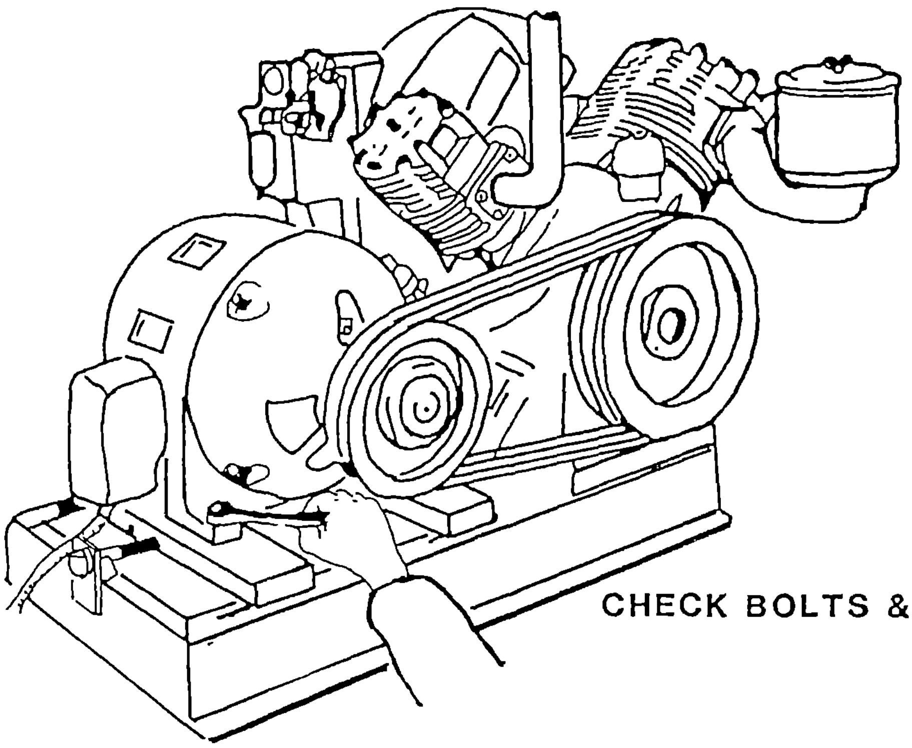
- PREPARATION/INSPECTION

CHECK :

. Bolts & nuts
. Belt
. Air filter
. Oil level

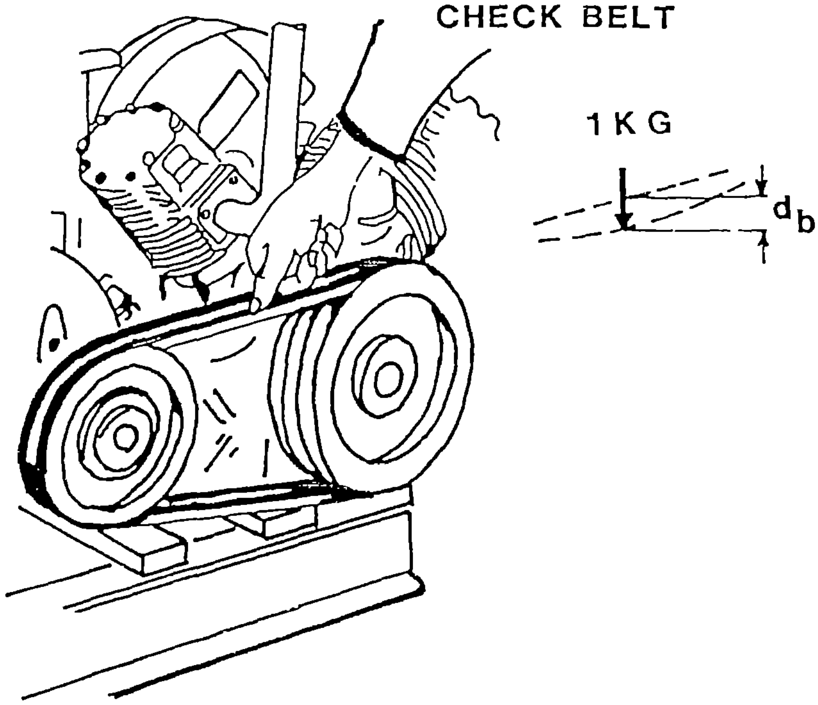
- START-UP

. Disengage load
. Rotate by hand
. Check direction of rotation
. Start & gradually increase load
. Observe voltage, temperature, pressure

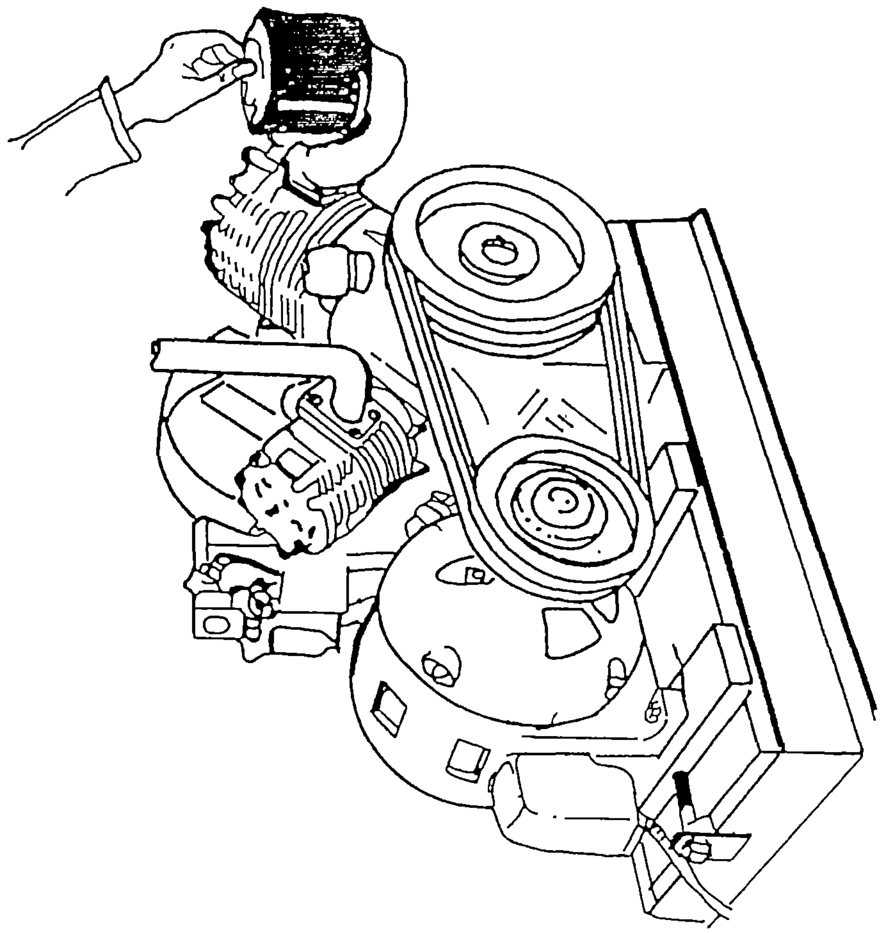


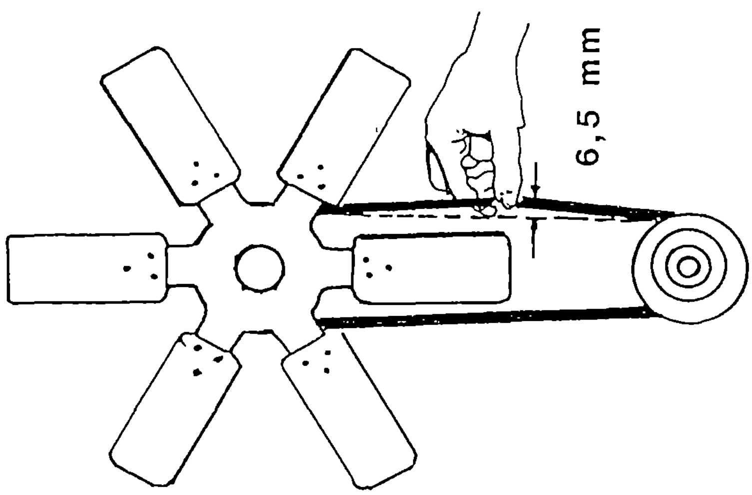
CHECK BOLTS & NUTS

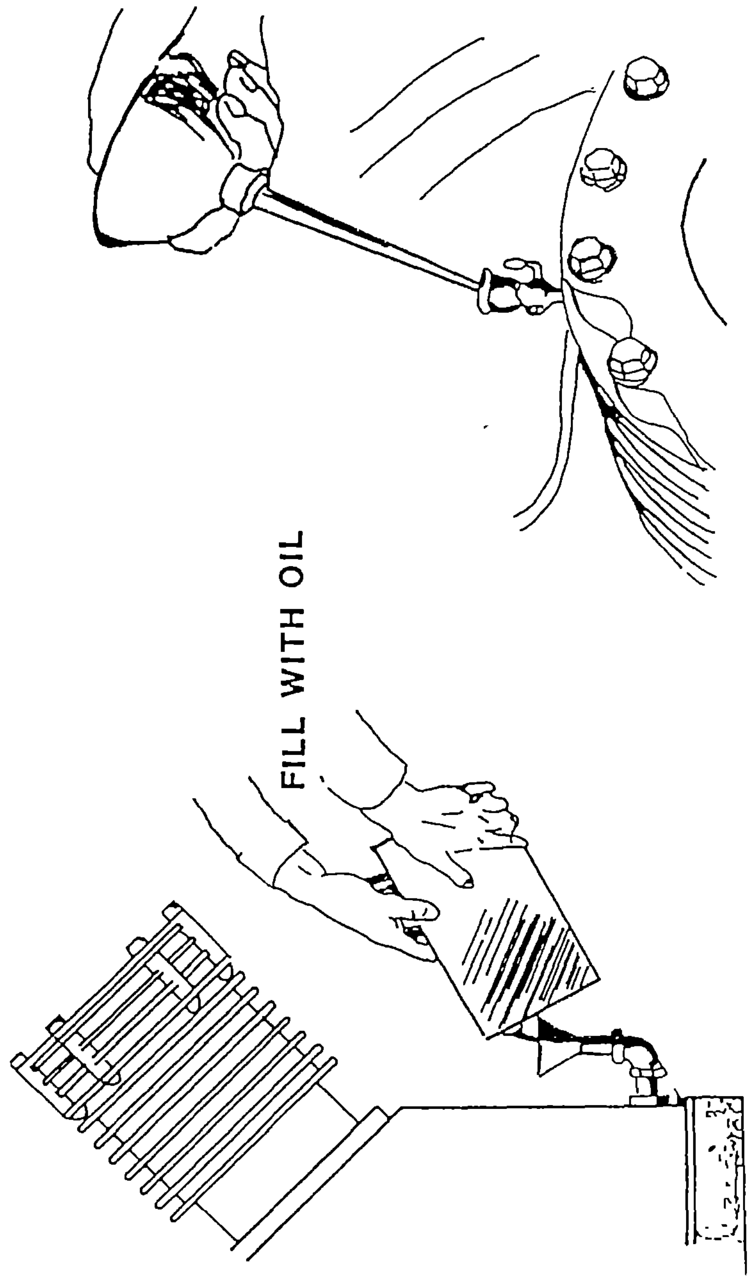
CHECK BELT

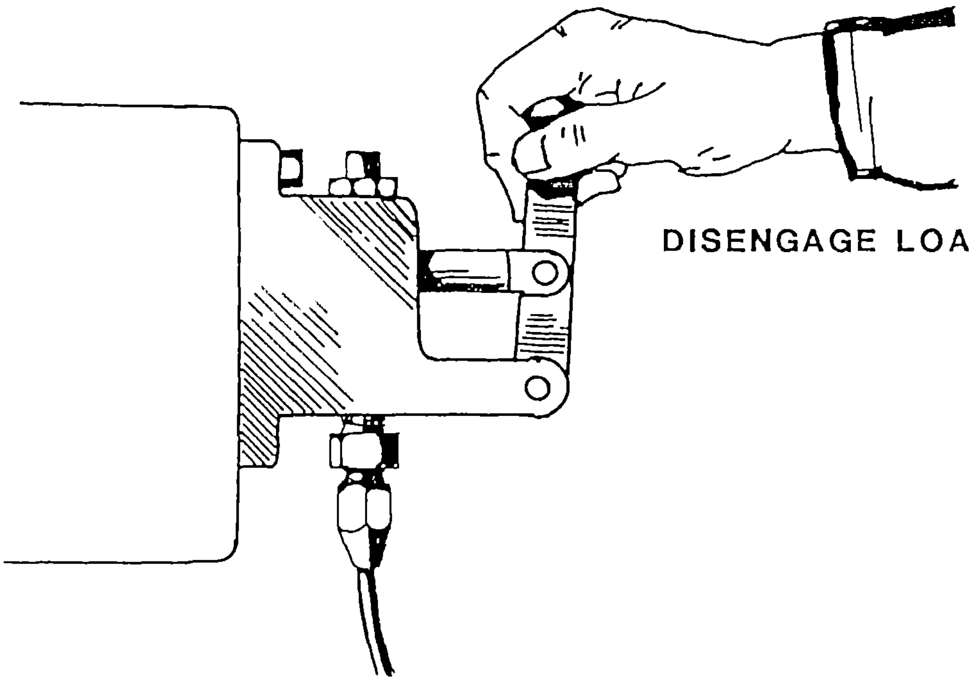


CHECK AIR FILTER

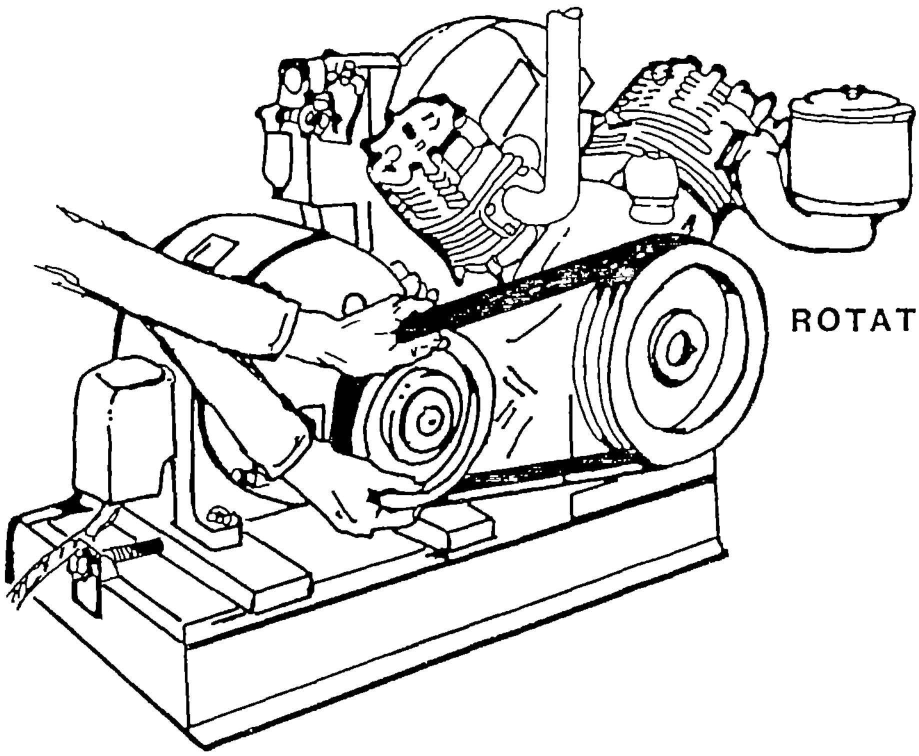




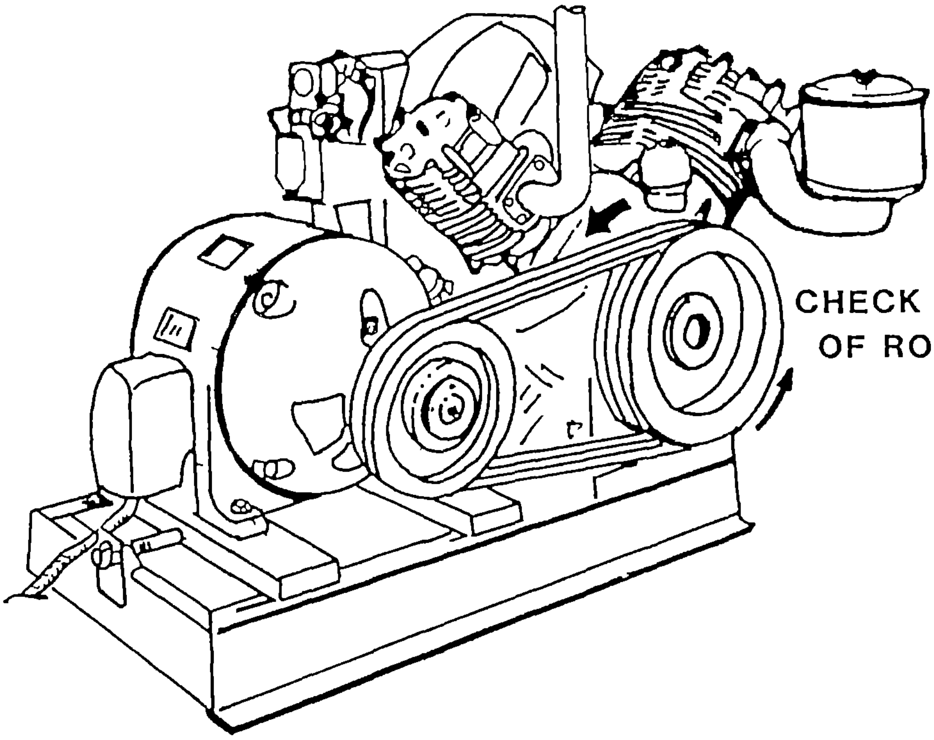

FILL WITH OIL

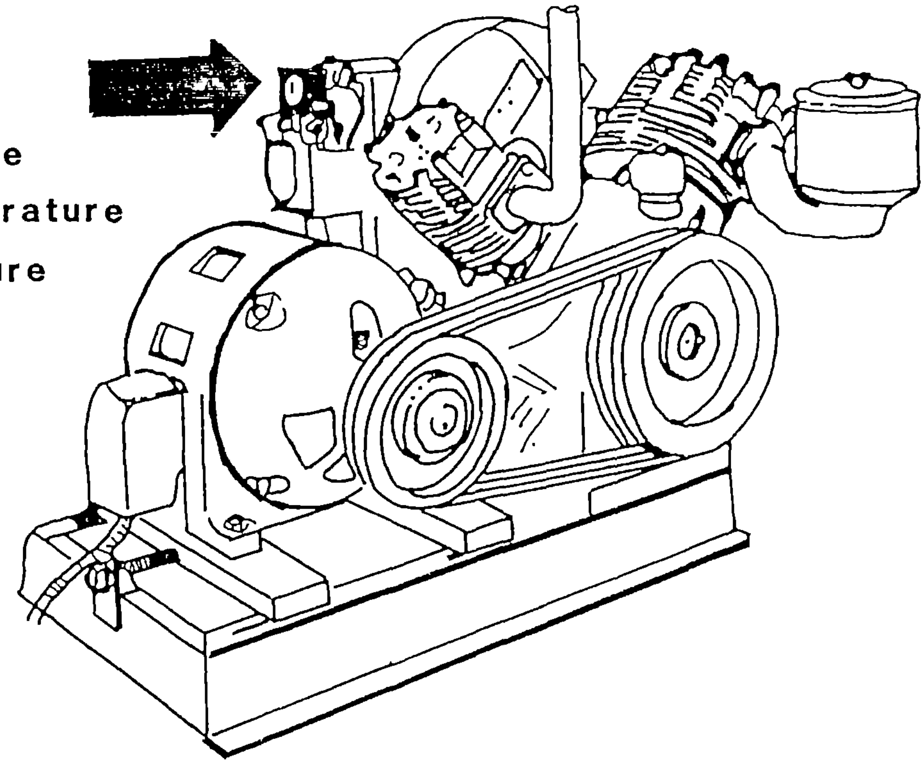


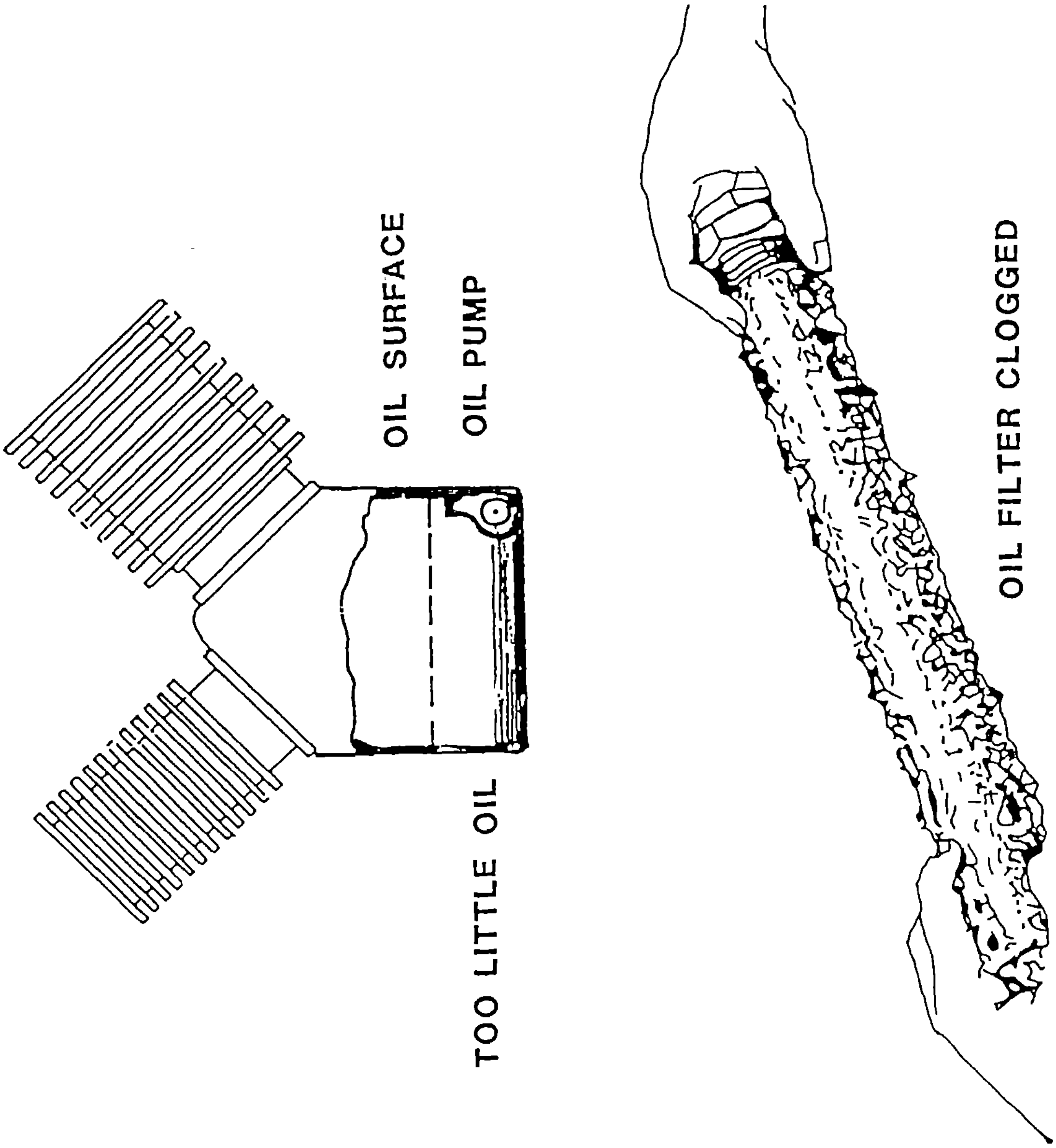
DISENGAGE LOAD

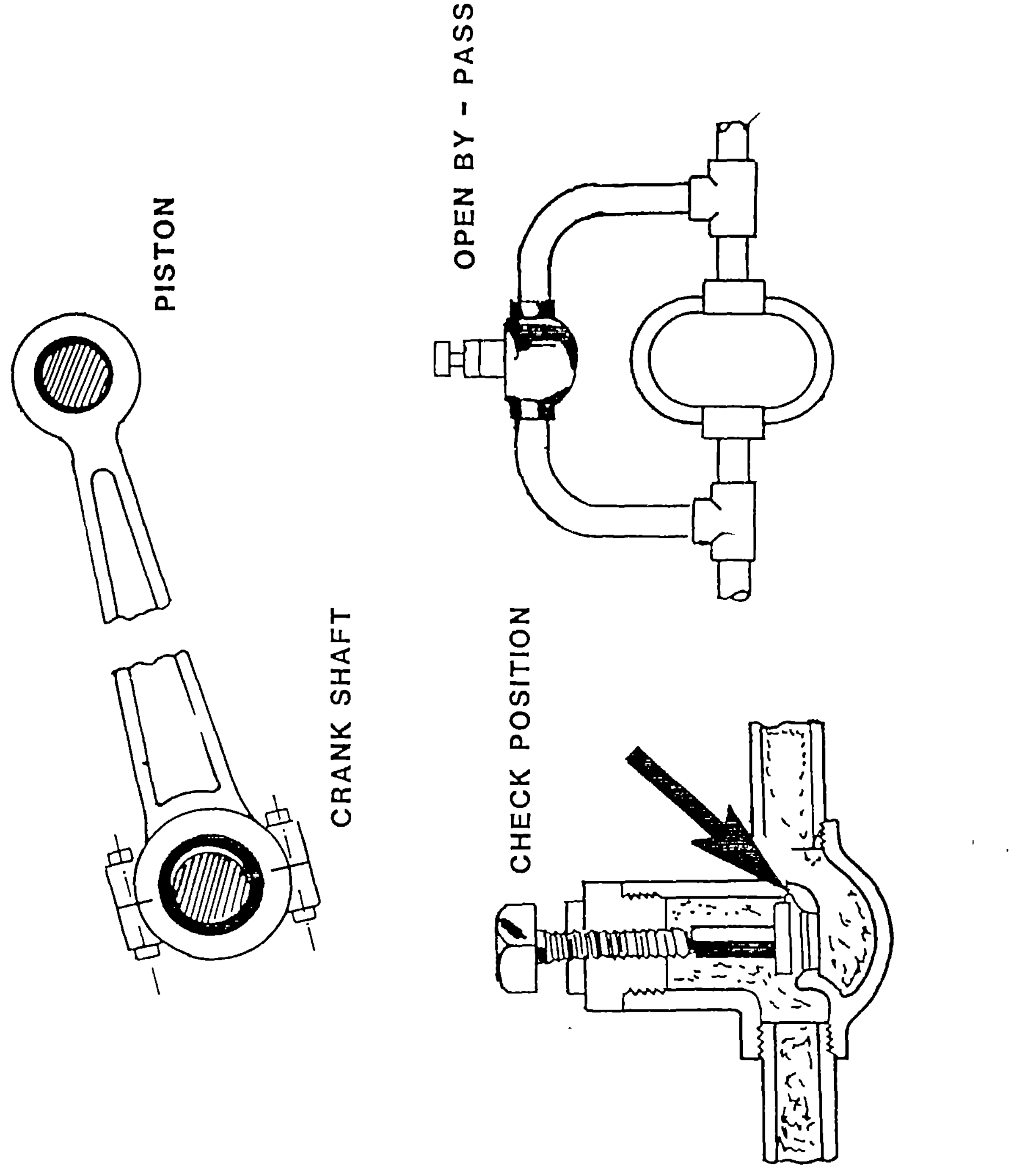


ROTATE BY HAND


CHECK DIRECTION
OF ROTATION


OBSERVE
. Voltage
. Temperature
. Pressure


OIL SURFACE
OIL PUMP
TOO LITTLE OIL
OIL FILTER CLOGGED


PISTON
CRANK SHAFT
OPEN BY - PASS
CHECK POSITION

Module : **MAINTENANCE OF GATE VALVES**	Code : TEM 222
	Edition : 20-03-1985
Section 1 : I N F O R M A T I O N S H E E T	Page : 01 of 01/05

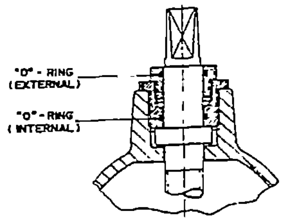
Duration :	90 minutes.
Training objectives :	After the session the trainees will be able to: - seal leaking glands on gate valves; - replace stuffing on gate valves; - replase "O" rings on gate valves.
Trainee selection :	- Head of Sub-section Distribution & Connections; - Pipelayer; - Pipeline Inspector.
Training aids :	- Sluice valves : . with stuffing box, . with "O" ring; - Packing material; - Tools; - "O" rings; - Spanners; - Viewfoils : TEM 222/V 1-2; - Handout : TEM 222/H 1.
Special features :	-
Keywords :	Gate valves/sluice valves/gate valve maintenance/sluice valve maintenance.

Module : MAINTENANCE OF GATE VALVES	Code : TEM 222 Edition : 20-03-1985
Section 2 : S E S S I O N N O T E S	Page : 01 of 01

1. Introduction	
- Maintenance is normally only carried out on leaking glands at spindle; - Glands are sealed either with : a. stuffing box, or b. "O" rings.	Use whiteboard
2. Stuffing Box	
- If stuffing gland is leaking it can be repaired in two ways : . tightening the bolts fixing the stuffing gland; . replacing the stuffing.	Show V 1
- Small leakages are normally repaired by tightening the bolts. - Larger leakages are normally repaired by replacing the stuffing.	Explain and demonstrate : - remove bolts from stuffing gland - remove gland - open stuffing box - replace gland - replace bolts and tighten Let trainees practice
3. "O" Ring	Show V 2
- "O" rings are rubber rings, which fit around the spindle and are used instead of stuffing.	- Replace by removing: a. bolts; b. gland cover; c. "O" rings; - then renew "O" rings and replace gland cover and bolts. Let trainees practice
4. Summary	Give H 1

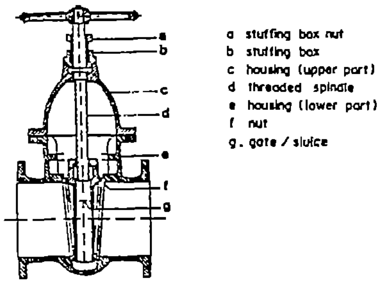
Module : MAINTENANCE OF GATE VALVES	Code : TEM 222
	Edition : 20-03-1985
Section 3 : T R A I N I N G A I D S	Page : 01 of 01

Gate valve with stuffing box — TEM 222/V 1



SPINDLE WITH "O" RINGS

Spindle with "O" rings — TEM 222/V 2



GATE VALVE WITH STUFFING BOX AND NON-RISING SPINDLE

Maintenance of gate valves — TEM 222/H 1

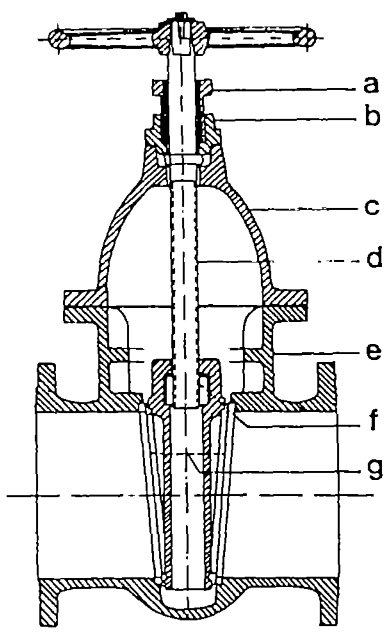
1. INTRODUCTION

Gate valves (also called "sluice valves") normally require very little maintenance. If problems arise, they are usually caused by leaking glands around the spindle.
These glands are sealed with stuffing within a stuffing box or with "O" rings around the spindle.

2. STUFFING BOX

The seal is formed around the spindle by compressing the stuffing or packing by means of a gland which is tightened down.
If the gland is leaking it can first be tightened, to check whether this will stop the leak. However, there is a limit to how often the gland can be tightened.
If, after tightening, the gland still leaks then the packing must be replaced.

This is done by removing the stuffing box nut, taking out the stuffing and replacing it with new stuffing material (see Fig. 1).



a. stuffing box nut
b. stuffing box
c. housing (upper part)
d. threaded spindle
e. housing (lower part)
f. nut
g. gate / sluice

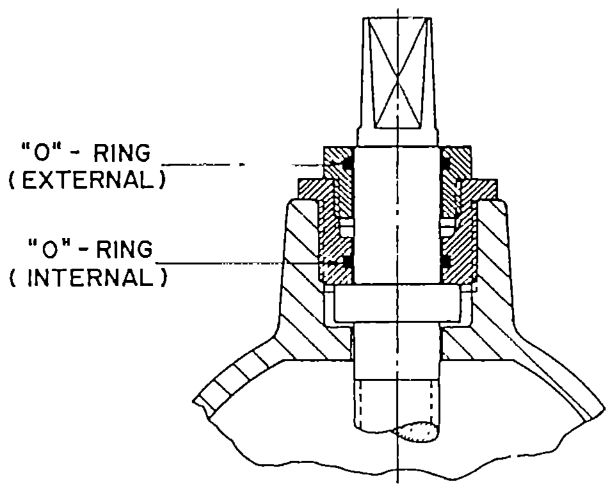
GATE VALVE WITH STUFFING BOX
AND NON-RISING SPINDLE

Fig. 1. Gate valve with stuffing box.

3. "O" RINGS

"O" rings are used in place of stuffing to avoid leaks from the spindle of gate valves. They are rubber rings, circular in cross section, which fit around the spindle.

To replace them, the gland cover must be removed, whereafter the "O" rings can be changed (See Fig. 2).



SPINDLE WITH "O" RINGS

Fig. 2. Detail of spindle with "O" rings.

4. SUMMARY

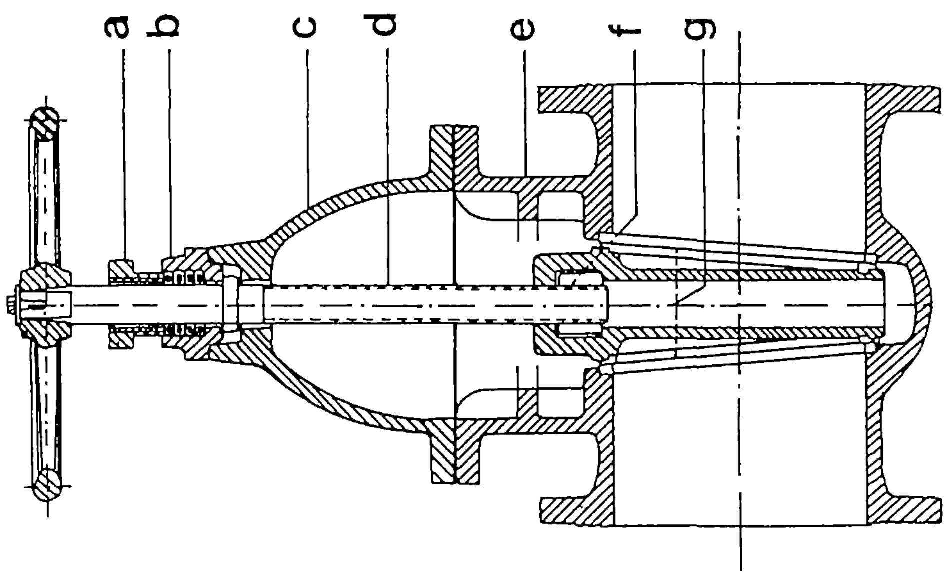
Maintenance is normally carried out to prevent or control the leaking of glands on a gate valve.

The glands are sealed using either a stuffing box or "O" rings.

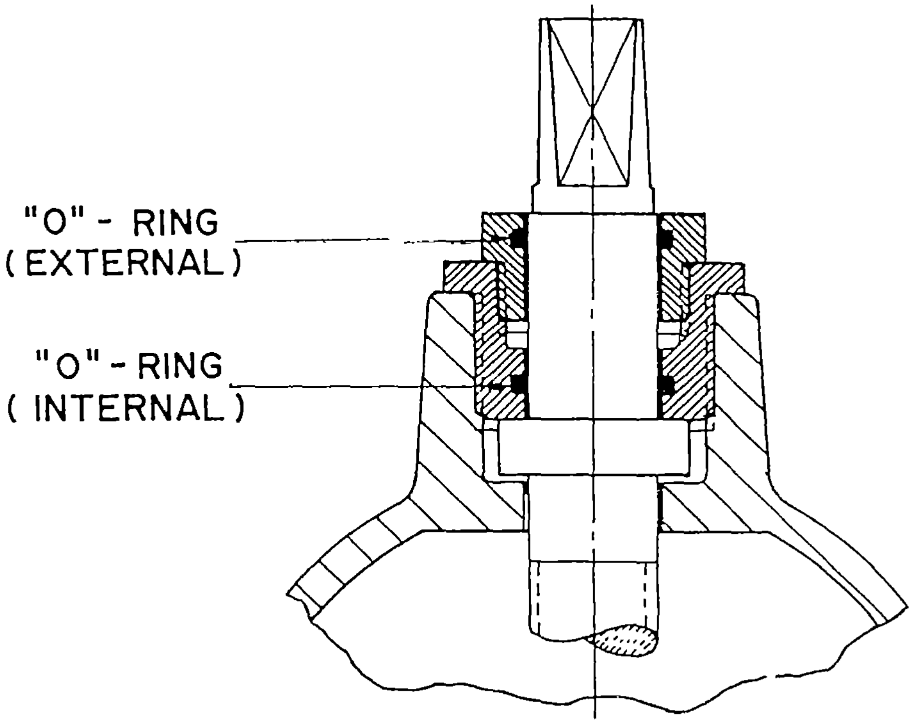
* * *

TITLE :	CODE :
1. Gate valve with stuffing box	TEM 222/V 1
2. Spindle with "O" rings	TEM 222/V 2

a. stuffing box nut
b. stuffing box
c. housing (upper part)
d. threaded spindle
e. housing (lower part)
f. nut
g. gate / sluice



GATE VALVE WITH STUFFING BOX
AND NON-RISING SPINDLE



SPINDLE WITH "O" RINGS