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 6B

	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

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MDP PRODUCTION TEAM

TRAINING MATERIALS FOR WATER ENTERPRISES

VOLUME 6B
TRAINING MODULES
TECHNICAL (Withdrawal + Treatment)

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

JÁKARTA
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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	

TABLE OF CONTENTS

TRAINING MODULES

Module : **RAPID GRAVITY SAND FILTRATION**	Code : TTG 311
	Edition : 18-03-1985
Section 1 : I N F O R M A T I O N S H E E T	Page : 01 of 01/19

Duration :	45 minutes.
Training objectives :	After this session the trainees will be able to: - explain the principles and characteristics of rapid gravity sand filtration; - recite the procedures for operation of rapid gravity sand filters; - recite the common faults in the operation of rapid gravity sand filters and list the corresponding remedies.
Trainee selection :	- Head of Technical Department; - Head of Section Production; - Head of Sub-section Water Treatment; - Water Treatment Plant Operator.
Training aids :	- Viewfoils : TTG 311/V 1-8; - Handout : TTG 311/H 1.
Special features :	-
Keywords :	Filter medium/filter run period/head loss/filtered water quality/filtration efficiency/constant rate filtration/declining rate filtration/break-through.

1. Principles	
<u>Introduction</u>	
- Rapid sand filtration is a purification process, suitable for the the removal of: . suspended solids; . colloidal matter; . bacteria.	Use whiteboard
- Sand is a suitable filter medium because of: . deep penetration without deterioration of filtered water quality; . availability; . low cost; . satisfactory experience.	Use whiteboard
- The filtering process leads to: . removal of impurities; . reduction of pore space; . increase of resistance against flow; . drop in efficiency; . nessecity of cleaning.	Use whiteboard
- Cleaning is accomplished by backwashing, involving: . reversed high-rate flow; . bed expansion; . scouring; . removal of impurities with backwash water	Use whiteboard
<u>Mechanisms of filtration</u>	
- Removal of impurities during the filtration is accomplished by : . straining; . sedimentation; . adsorption; . chemical reaction; . biological activity.	Show V 1

<u>Configuration of filter</u>	
- Filter configuration consists of: . box (concrete, steel, etc.); . filter bed (sand); . filter bottom (porous); . inlet; . outlet; . wash water provisions; . overflow gutter; . drain.	Show V 2
2. Characteristics of rapid sand filtration	
<u>Filter run period</u>	
- Filter run period depends on: . head loss; . filtered water quality.	Show V 3
- Termination of the filter run because of head loss is influenced by: . clogging of the pores; . increase of head loss; . rise of water level; . maximum allowable water level.	
- Termination of the filter run because of filtered water quality is influenced by: . standards : turbidity < 1 FTU; . initially slow increase; . suddenly steep increase : "break-through".	
- Normally the filter run as based on head loss is shorter than the filter run as based on turbidity of filtered water.	
- At end of the filter run the filter is backwashed.	
<u>Filtration efficiency</u>	
- Filtration efficiency depends on: . raw water quality; . filtration rate; . filter medium.	Use whiteboard

- Raw water quality:
  . higher raw water turbidity --> higher filtered water turbidity;
  . poor raw water quality --> pretreatment (sedimentation or coagulation/flocculation) required.

- Filtration rate:
  . influences penetration of impurities; — Show V 4
  . optimal rate 5-10 m/h.

- Filter medium:
  . dirt penetration depends also on grain sizes;
  . normal sizes 0.4-0.8 mm, 0.8-1.2 mm, 1-2 mm.

3. **Operation**

<u>Filter control</u>

- Basic formula:
  $v = \alpha (H_1 - H_2)$ — Show V 5
  . "α" depends on the degree of clogging of the filter bed and will decrease with time, unless a filter rate controller is used;
  . of the 3 remaining variables, 2 can be controlled with control devices;
  . the remaining parameter cannot be influenced directly, but will follow from the others.

- Constant rate filtration with constant clear water level: — Show V 6
  . filters fed individually and independently;
  . filters have different raw water levels.

- Constant rate filtration with fixed raw water level:
  . filters fed individually and independently;
  . filters have raw water level controllers
  . in outlet (also called : filter rate controllers).

- Declining rate filtration: . no rate controllers; . all filters are interconnected; . all filters have same water level.	Show V 7
Backwashing process	
- Backwashing: . reversed flow; . high velocity for bed expansion of approx. 10 %; . scouring by water; . additional scouring by air wash.	Show V 2
- Backwash water by pump or gravity.	Show V 8
- Stratification: . non-uniform filtering materials; . fine grains at top of filter; . increased resistance; . problems with backwashing (material loss or poor cleaning).	Use whiteboard
4. **Faults and remedies**	
Break-through	Show V 3
- Cause: . filter run too long; . impurities too fine.	
- Remedies: . backwashing; . optimizing coagulation/flocculation process if present.	
Filter cracks	
- Cause: . filter material too fine; . filter material coated with impurities.	
- Remedies: . backwashing for extended period; . additional air scour.	

Gas bubbles in filter bed

- Cause:
  . water pressure smäller than gas pressure, due to head loss.

- Remedies:
  . increase supernatant water level (water pressure);
  . remove part of filterbed.

Loss of filter material during backwashing

- Cause:
  . backwash rate too high;
  . non-uniform filter material.

- Remedies:
  . adjust backwash rate;
  . replace filter material by uniform material.

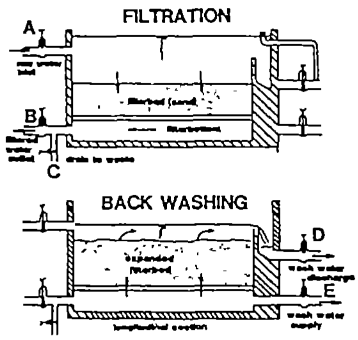
6. **Summary** — Give H 1

Module : RAPID GRAVITY SAND FILTRATION	Code : TTG 311
	Edition : 18-03-1985
Section 3 : T R A I N I N G A I D S	Page : 01 of 02

Filtration mechanisms — TTG 311/V 1

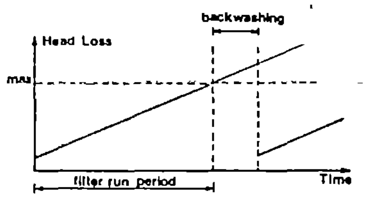
- STRAINING
- SEDIMENTATION
- ADSORPTION
- CHEMICAL REACTION
- BIOLOGICAL ACTIVITY

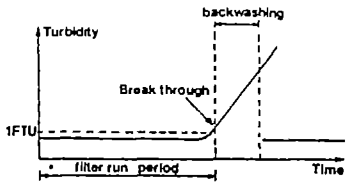
Sand filter construction — TTG 311/V 2



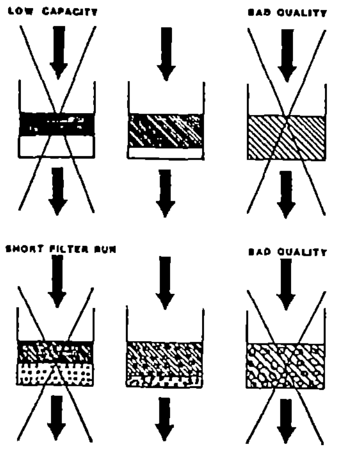
FREE-SURFACE RAPID GRAVITY FILTER

Filter run period — TTG 311/V 3

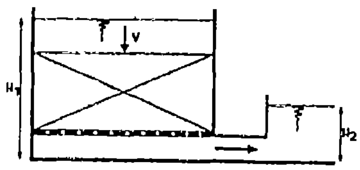




Penetration of impurities — TTG 311/V 4



Filtration variables — TTG 311/V 5

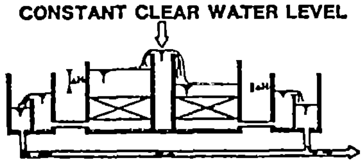


$$V = \alpha (H_1 - H_2)$$

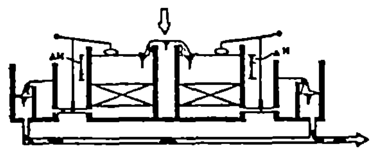
Fixed	Variable	Reaction during filterrun period
V and H_1	H_1	Decreasing
V and H_2	H_2	Increasing
H_1 and H_2	V	Decreasing (Declining)

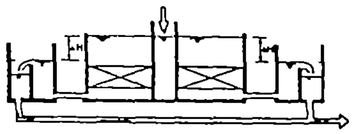
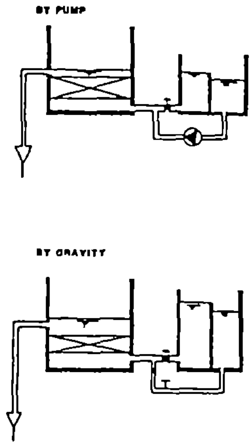
Constant rate filtration — TTG 311/V 6

CONSTANT CLEAR WATER LEVEL



CONSTANT RAW WATER LEVEL



Declining rate filtration — TTG 311/V 7 	Backwashing — TTG 311/V 8 
	Rapid gravity sand filtration — TTG 311/H 1

1. PRINCIPLES

Introduction

Rapid filtration is a purification process, whereby the water to be treated is passed through a porous medium at relatively high velocities. During the passage the water quality improves by partial removal of suspended and colloidal matter, by reduction of the number of bacteria and other organisms, and by changes in its chemical constituents. In the practice of water purification, the porous medium in principle may be any stable material.
In the field of public and larger private water supplies, however, granular beds of sand are used almost exclusively. Such beds allow for the penetration and accumulation of impurities from the raw water into the filter medium up to a certain period, before deterioration of filtered water quality will occur.
Sand as filtering material further has the advantages of availability, relatively low cost and the satisfactory experience gained with it over a long period of time.

During the process of filtration the impurities are removed from the water, and accumulated on the grains and in the pores between the grains of the filter bed. As a result, the effective pore space will be reduced and the resistance against the flow of water increased.
The filtration efficiency will gradually become lower. After some time the resistance (head loss) becomes so high, or the quality of the filtered water so poor, that cleaning of the filter becomes necessary.

Cleaning of rapid filters is accomplished by backwashing. Backwashing is performed by directing water at a high flow rate back through the filter bed, whereby the bed expands and is scoured. The backwash water carries the accumulated dirt out of the filter. The cleaning of a rapid filter can be carried out quickly; it normally takes not more than about half an hour.
It should be done as frequently as required in order to maintain favourable process conditions; normally once per 24-48 hours of operation.

Mechanisms of filtration

The removal of impurities during the filtration is brought about by:

- Straining:
  Particles larger than the openings between the grains of the filtering medium are retained.

- Sedimentation:
  Particles smaller than the openings between the grains but still large enough to settle will reach the surface of a grain sooner or later and are thus removed by sedimentation.

- Adsorption:
  Colloidal particles which cannot be removed by sedimentation may be adsorbed to the grains due to electrostatical forces.

- Chemical reaction:
  Dissolved impurities may be converted into insoluble compounds which are removed by straining, sedimentation or adsorption.

- Biological activity:
  Bacteria living on and in the filterbed, adsorbed to the filter grains, use inorganic and organic impurities as nutrients, in this way removing material by converting it into cell material.

Configuration of a rapid gravity sand filter

A rapid gravity sand filter consists of:

- A box (usually concrete) containing the filter bed and the water being treated.

- A filter bed consisting of the filtering material (sand of uniform size).

- A filter bottom supporting the filter bed and provided with small openings for the even discharge of filtered water and even distribution of wash water.

- Raw water inlet and filtered water outlet, provided with valves or float control devices.

- Wash water supply and wash water discharge (gutter) provided with valves or float control devices.

- Drain for draining the filter bed when it has to be taken out of operation.

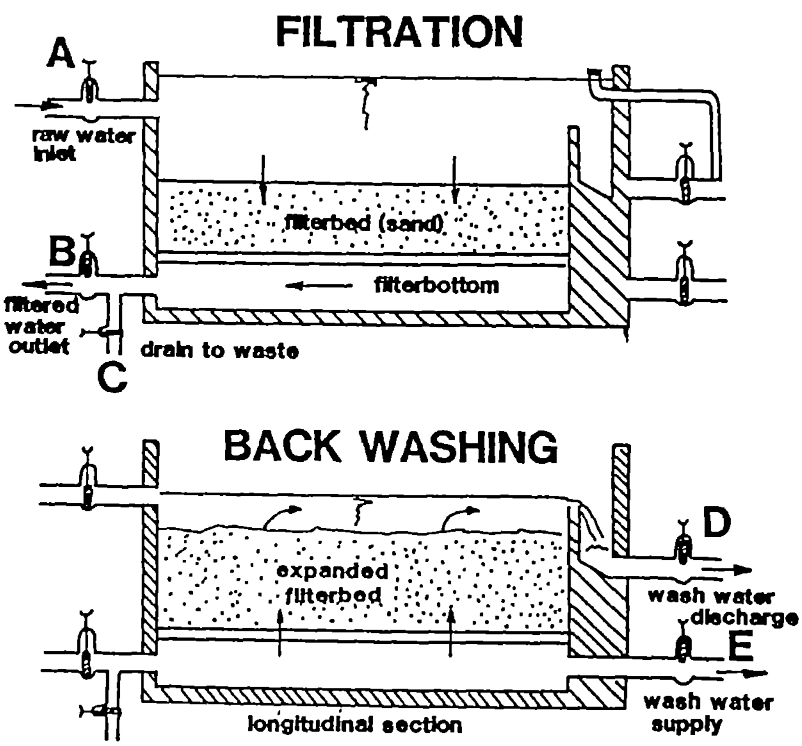


Fig. 1. Rapid sand filter construction.

2. CHARACTERISTICS OF RAPID GRAVITY SAND FILTRATION

Filter run period

The time between two successive cleanings of a filter bed is called the filter run period or length of filter run. The filter run period depends on two parameters: head loss and filtered water quality.

- Head loss

Head loss is a value for the resistance of the filter bed against water movement. During the filtration process the head loss (resistance) increases, caused by clogging of the pores between the grains. An increase of head loss will make the water level on top of the filter rise, so the maximum head loss which can be accepted

is limited by the maximum allowable water level (the overflow level of the filter bed). When this level is reached, backwashing must be carried out to restore the original head loss and lower the raw water level.
The filter run period is thus ended when the maximum designed head loss is reached (e.g. when the level of the water on the filter will reach its maximum allowable value).

- Filtered water quality

The filtered water quality can be measured as turbidity and its value must be lower than 1 FTU according to drinking water standards. When the filter run period is proceeding, the turbidity of the filtered water will only slightly increase with time. At a certain moment however, a steep increase in turbidity may occur rather suddenly. This is called the "break-through" of the filter. The impurities cannot be retained adequately anymore by the filter bed so backwashing must be performed. The filter run period is thus ended by a deteriorating filtered water quality.

In normal water treatment practice the filter run period is determined by the maximum allowable head loss, which should be reached before the filter bed water quality deteriorates by a "break-through" of the filter bed. The turbidity of the filtered water, should be measured regularly for control however, so in case "break-through" would happen before the maximum allowable head loss is reached, backwashing can be executed and the water quality is guaranteed.

Filtration efficiency

Filtration efficiency or the way in which the impurities are retained depends on three parameters: (i) raw water quality, (ii) filtration rate and (iii) filter medium.

- Raw water quality

The turbidity of the filtered water depends directly on that of the raw water. In other words, the lower the turbidity of the raw water, the lower the turbidity of the filtered water.
When the turbidity of the filtered water does not satisfy drinking water standards, due to high turbidity of the raw water, a pretreatment will be necessary.
This pretreatment can be:
Sedimentation: when the impurities are large enough to settle by gravity.

Coagulation/flocculation/sedimentation: when much colloidal matter is present.

- Filtration rate:

The filtration rate directly influences the penetration of impurities into the filter bed and thus the effluent quality. With a low filtration rate most impurities will be retained in the upper few centimeters of the filter bed, leading to a fast clogging of the filter bed. This will shorten filter run periods so that backwashing must be carried out rather often. Moreover, the production capacity of the filter will be limited.
When the filtration rate is too high, "break-through" will occur soon after the beginning of a new filter run period. Filter run periods will be short and backwashing must be performed too often.
The optimal filtration rate usually applied is about 5-10 m^3 water per hour for each m^2 of filter bed area (or : 5-10 m/h) whereby the impurities will be accumulated in the upper half of the filter bed.

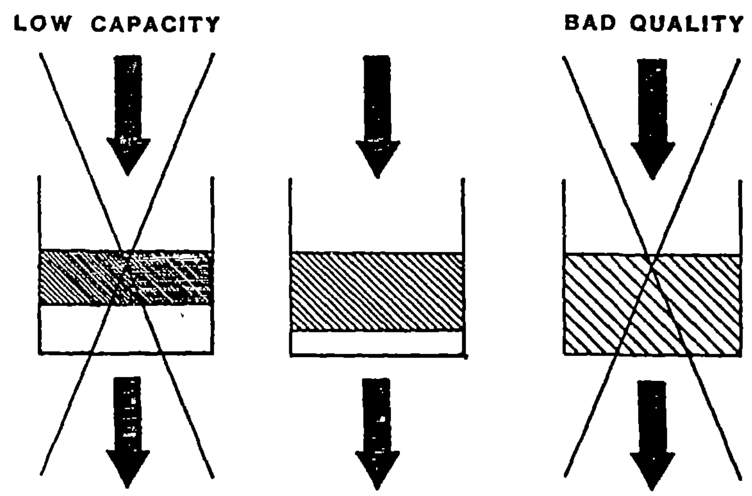


Fig. 2. Penetration of impurities (I).

- Filter medium:

The filtered water quality and the penetration of the impurities into the filter bed are directly related to the grain sizes of the filter sand used.
Fine sand will retain almost all impurities in the upper few centimetres of the filter bed, causing a fast increase in head loss and thus a short filter run. Coarse sand will not be able to retain the impurities, "break-through" occurs and backwashing must be performed too often.

Grain sizes of the sand layer should therefore be chosen carefully, and be as uniform as possible. Normally sizes used are 0.4-0.8 mm, 0.8-1.2 mm or 1-2 mm, depending on the raw water quality. The thickness of the filter bed should be 0.6-2 m. The filter bed is supported by an under drainage system or several gravel layers, graded in size between 2 mm and 60 mm and provided with a drain system.

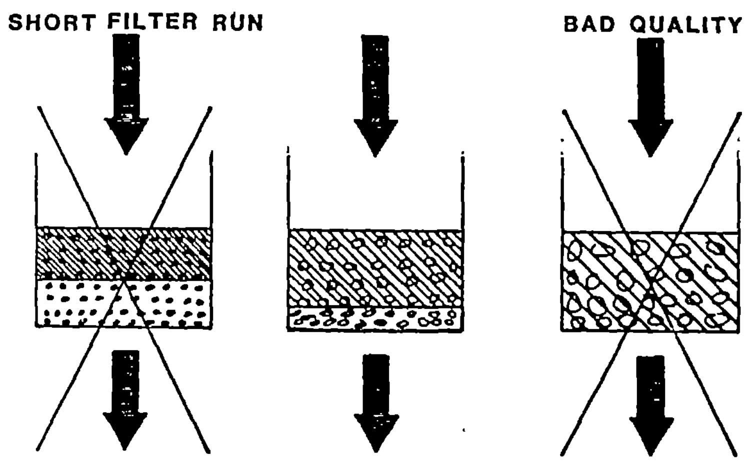


Fig. 3. Penetration of impurities (II).

3. OPERATION

Filter control

The most important relationship for understanding filter control is the proportionality between the head loss over a filter bed (H_1-H_2) and the filtration rate (v) at any moment.

In formula: $v = \alpha\ (H_1 - H_2)$

[illegible]

[illegible]

where v = filtration rate;
α = proportionality constant; decreasing during the filter run period because of clogging of the pores;
H_1 = water level on filter, above datum line;
H_2 = filtered water level above datum line.

By using filter control devices such as float-controlled valves and overflow weirs it is possible to choose two of the three variables v, H_1, H_2 at will. The remaining variable will then automatically be determined, as follows from the formula. This will lead to the following alternatives in filter control:

	Fixed	Variable	Change of variable parameter during filter run
1.	v and H_1	H_2	Decreasing
2.	v and H_2	H_1	Increasing
3.	H_1 and H_2	v	Decreasing (Declining)

A fourth possibility is to use a so-called filter rate controller in the filtered water pipeline. This is essentially a valve that is almost closed when the filter is clean, and automatically compensates for a growing resistance of the filter bed itself by adjusting its degree of opening. In this case all 3 values (v, H_1,H_2) can remain fixed.

Two of these alternatives will be discussed here because their use has found a wide application.

a. <u>Constant filtration rate with increasing raw water level</u>

The method of constant filtration rate is used when a set of filters are fed individually and independently of each other. When the head loss increases, the water level on the filter rises, up to a maximum level (overflow level), to maintain the constant flow rate in the filter bed. In such cases all the filters will have different water levels.

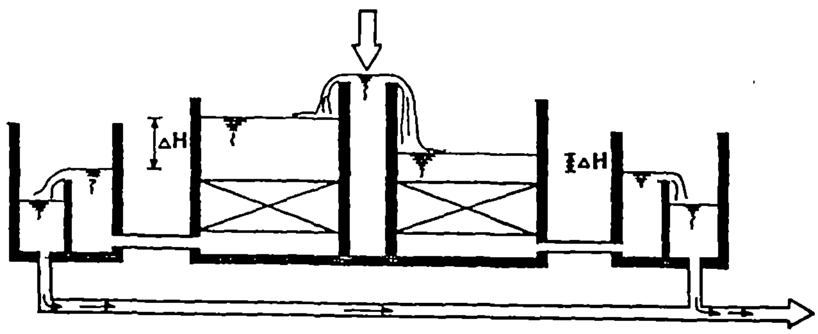


Fig. 4. Constant clear water level.

b. Declining rate filtration

When no filter rate controllers are used, filtration will take place at a declining rate. Declining-rate filters are less expensive than constant rate filters, as the constant water level on the filters allows the filter boxes to be lower.
All filters are in open connection with the raw water conduit, and discharging over weirs that have the same level for all. Consequently, all have the same raw water level and filtered water level so that all filters will operate under the same head. The filtration rate for the various filter units, however, will be different: highest in the filter just cleaned by backwashing and lowest for the one longest underway in its current filter run. For all filters jointly, the production will be determined by the supply of raw water which should be high enough to meet the demand for filtered water. During filtration the filter beds are gradually clogged and the raw water level in all filters will rise due to the increased resistance against water flow in the filter beds. The filter unit that has been in operation for the longest period of time will normally have the lowest output (as seen at the filtered water weir) and needs cleaning by backwashing first. After its cleaning this filter will have the lowest resistance against flow so that a considerable portion of the raw water supplied will pass this filter. The load on the other filters is temporarily reduced. These units will show a fall in filtered water production but later the further clogging of the cleanest filter bed will cause the distribution of water over the

filters to become more even. When in a second filter the output has reached its minimum allowable value this one will be back-washed, and so forth.

The high output of newly backwashed filters often results in a poorer quality of the water produced by that filter, which lowers the over-all filtered water quality temporarily. This is the main draw-back of declining rate filtration.

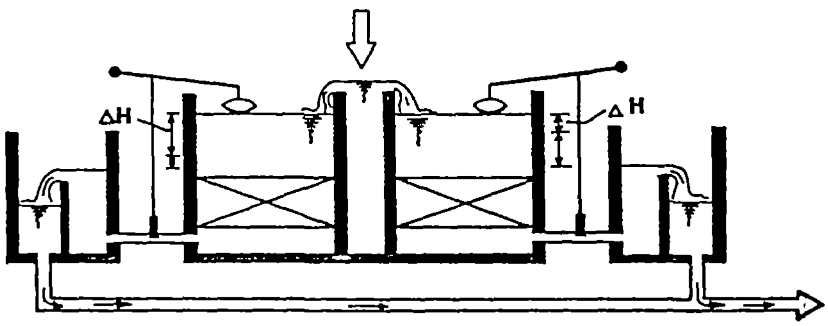


Fig. 5. Declining rate filtration.

Backwashing process

A rapid filter is cleaned by backwashing. Backwashing is accomplished by directing a flow of clean water at a specific flow rate upward through the filter bed for a period of several minutes. Filtered water from any storage reservoir or a special wash water reservoir can be used (by gravity or pumping), or the effluent from the other (operating) filter units of the filtration plant ('self-wash arrangements'). The velocity of the upward water flow should be high enough to produce an expansion of the filter bed so that the accumulated dirt can be carried away with the washwater after being loosened by the water scour. The expansion should be about 5-15% of the normal filter bed height.

Particularly when fine sand is used, the scouring force of the rising wash water may be inadequate to keep the filter grains clean in the long run. After some time they could become covered with a sticky layer of organic matter. This may cause problems such as mud balls and filter cracks.

This can be prevented by applying an additional scour through air wash. Filter cleaning now starts by backwashing with air, usually followed by a combined air and water backwashing and completed with water backwashing. This should remove the coatings from the filter grains and the loosened material is carried away by the following water wash. For backwashing with air a separate pipe system is used.

Backwashing is usually performed as follows:

a. with compressed air	5-10 minutes at	v(air) = 50 m/h;
b. with air and water	5-10 minutes at	v(air) = 50 m/h, v(water) = 25 m/h;
c. with water	5-10 minutes at	v(water) = 25 m/h.

With non-uniform filter materials, backwashing will result in a stratification, with the fine grains in the upper and the coarse grains in the lower part of the filter bed. Backwashing such beds at low rates will only expand the upper part, while in the lower part the grains remain stationary, thus hampering the removal of impurities accumulated here during the previous filter run. When for this reason the backwash rate is increased to provide an adequate expansion of the lower part of the bed, the expansion of the upper part may be so high that a serious loss of filter material could occur. These problems will be avoided by using a uniform filter material with upper and lower grain sizes not more than a factor 2 apart.

4. FAULTS AND REMEDIES

Break-through

When the filter reaches a certain degree of clogging, the turbidity of the filtered water might suddenly increase very steeply. This sudden increase of turbidity is called "break-through" and it is caused by dirt particles that are no longer adequately retained.
Usually this "break-through" will occur near the end of the filter run so a backwash cycle will restore filtrate quality.
In case coagulation/flocculation and sedimentation are preliminary steps in water treatment, break-through might occur in an early stage of the filter run, due to an improper functioning of the coagulation/flocculation process.
Filtrate quality must then be restored by optimizing the coagulation/flocculation process before backwashing.

Filter cracks

Filter cracks may develop when finely grained filter material is used. The fine grains may become coated with soft and compressible, often organic, material retained from the passing water. The dirt can be removed by backwashing for extended periods or with an air scour before a water scour is applied. If the problems cannot be solved by this method the fine grains must be replaced by coarser grains, which means that the filter has to be taken out of operation temporarily.

Gas bubbles in filter bed

Gases dissolved in the water will come out of solution when the water pressure is lower than the gas pressure. Gases may be released inside the filter bed when the water pressure in the filter bed is decreasing during the filter run due to an increasing loss of head while the gas pressure stays constant. The released gas bubbles will accumulate in the pores between the sand grains, hampering downward water movement, increasing filter resistance and prematurily ending filter runs. When this problem is of a more or less permanent nature the only remedy is to increase the filter water level and/or to remove part of the filter bed, resulting in a smaller bed height, combined with a thicker layer of water on top of the filter.

Loss of filter material during backwashing

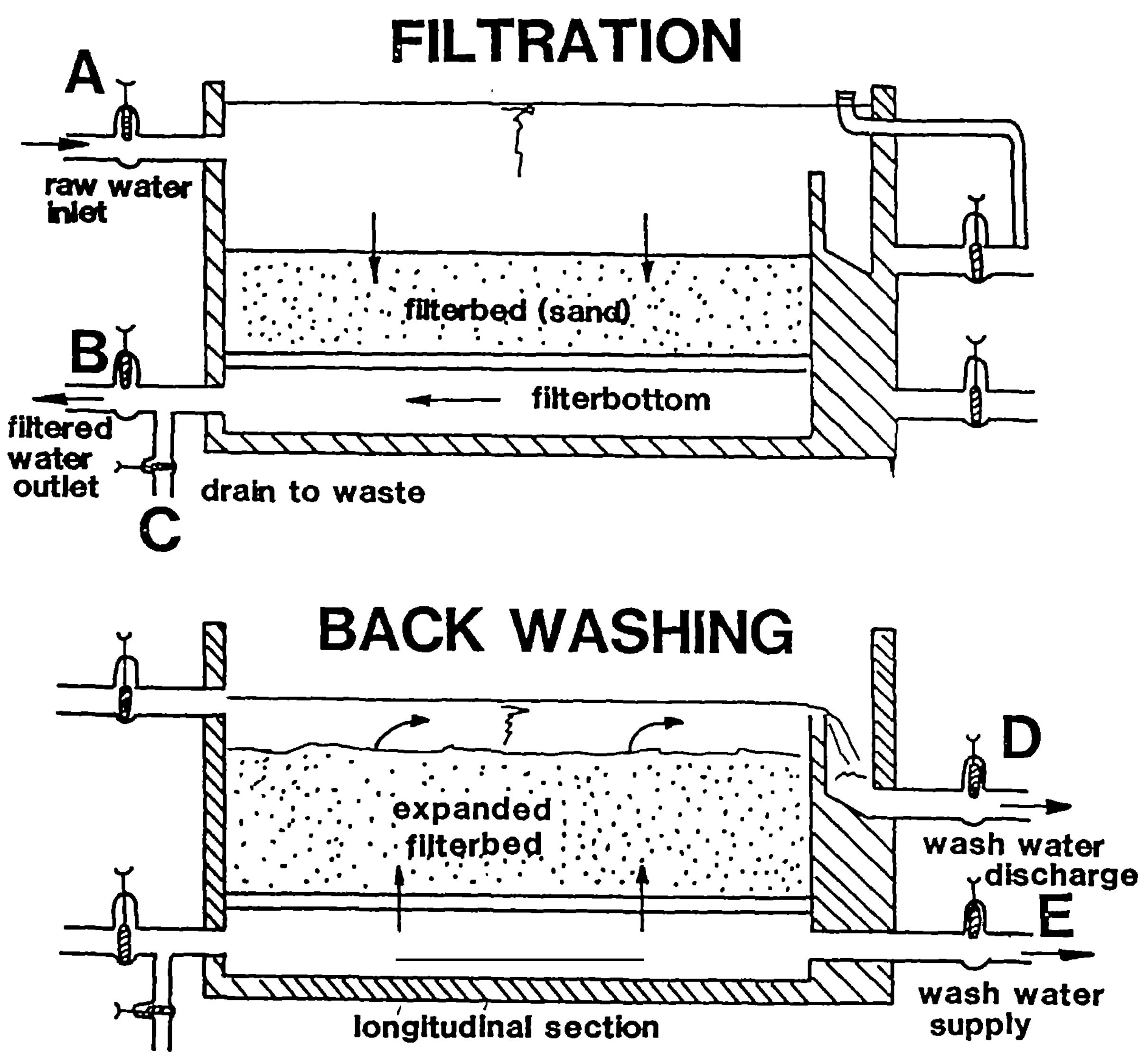
When filter material is lost during backwashing, too high a backwash rate is applied. This results in a bed expansion that will reach the backwash overflow gutter so the material is carried away with the backwash water in the gutter. The backwash rate should now be adjusted to a proper level by partly closing the backwash water valve until a proper bed expansion is obtained.

5. SUMMARY

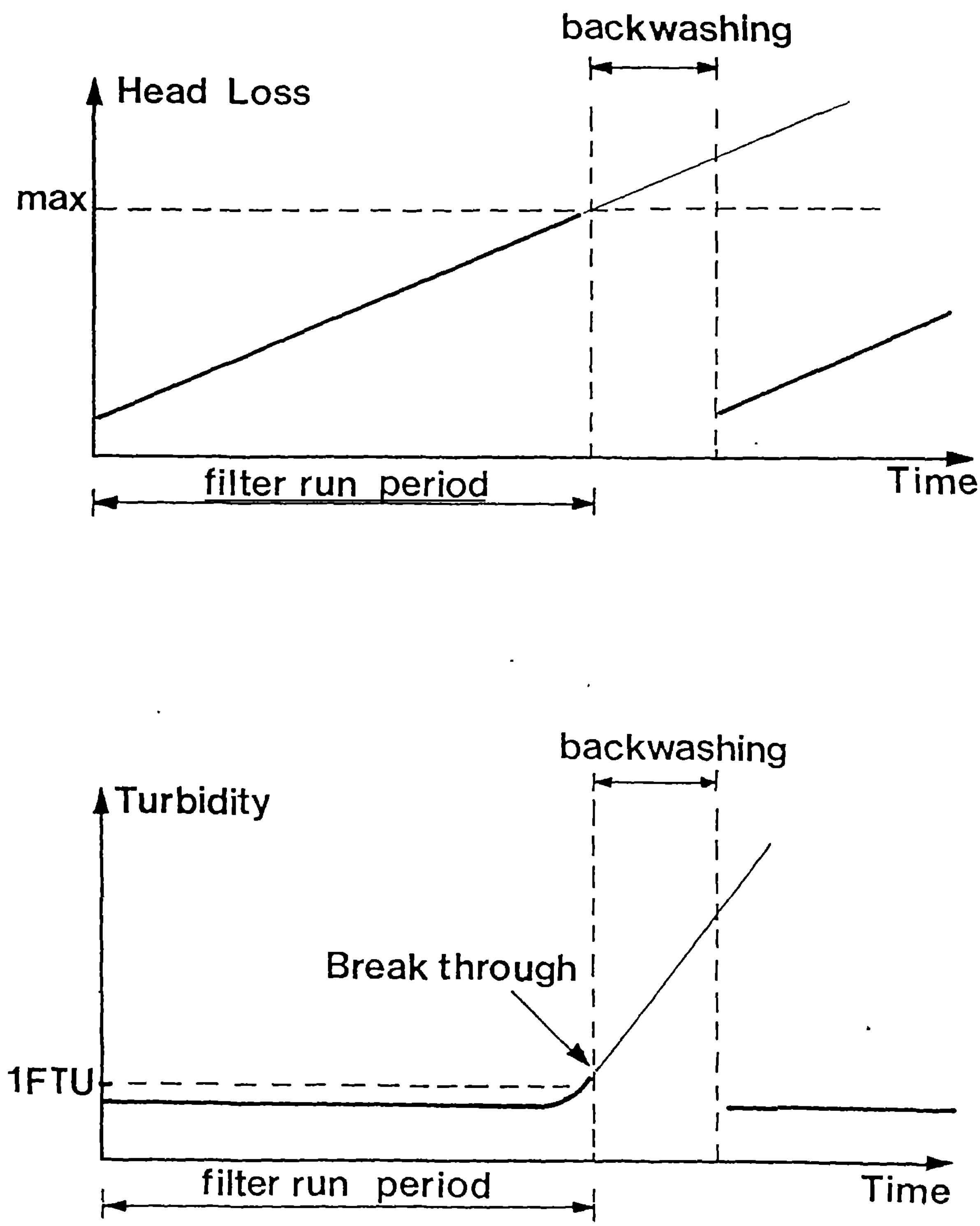
Rapid filtration is a purification process whereby the water to be treated is filtered through a filter bed containing sand. Due to the retaining of impurities the filter bed has to be cleaned regularly by backwashing. The period between two successive backwashings is called the filter run and depends on the head loss over the filter bed and the turbidity of the filtered water.
Two systems of rapid filtration are widely used : rapid filtration at a constant rate and at a declining rate. Rapid filtration is a reliable treatment process, that is easy to operate.

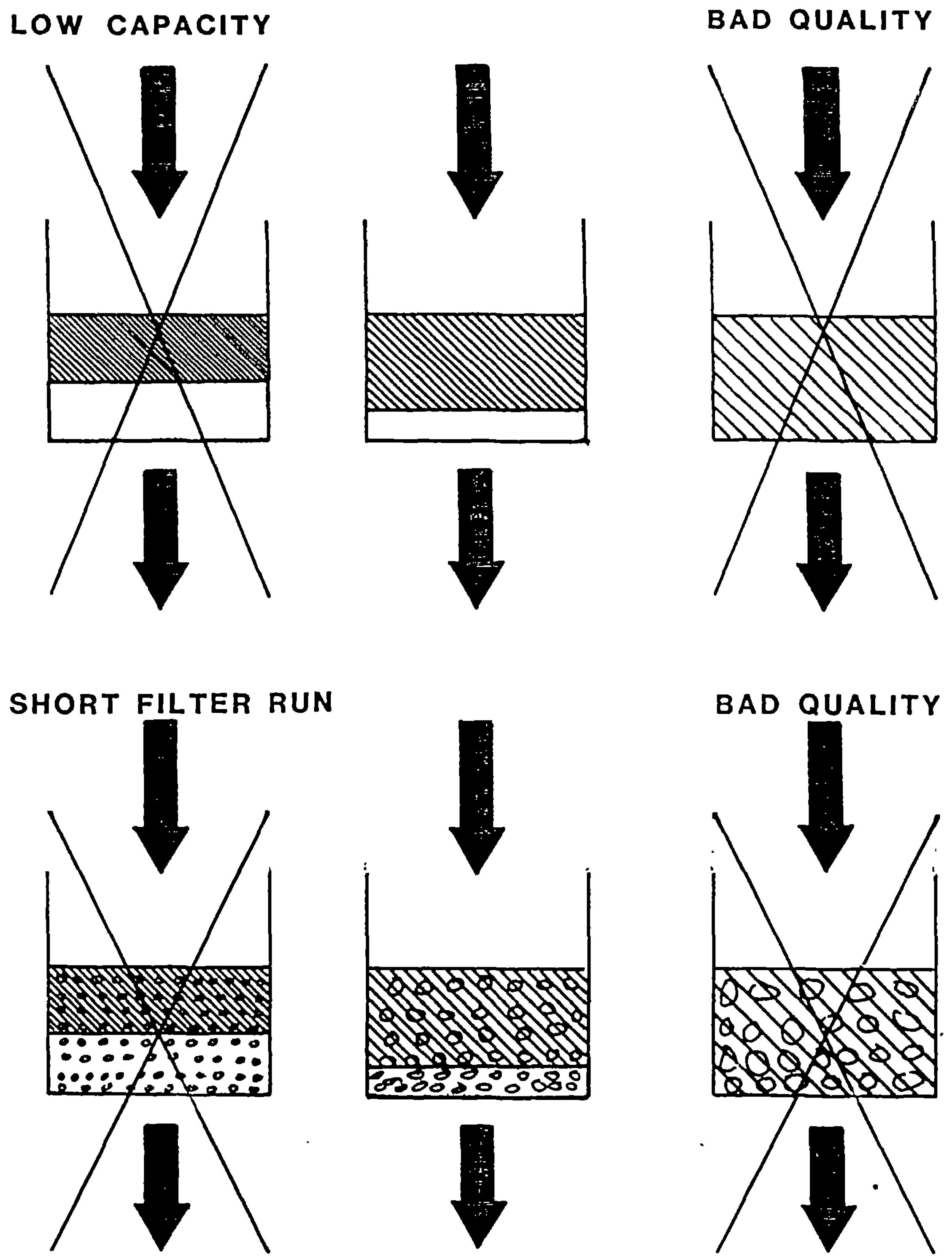
Module : RAPID GRAVITY SAND FILTRATION	Code : TTG 311
	Edition : 18-03-1985
Annex : V I E W F O I L S	Page : 01 of 09

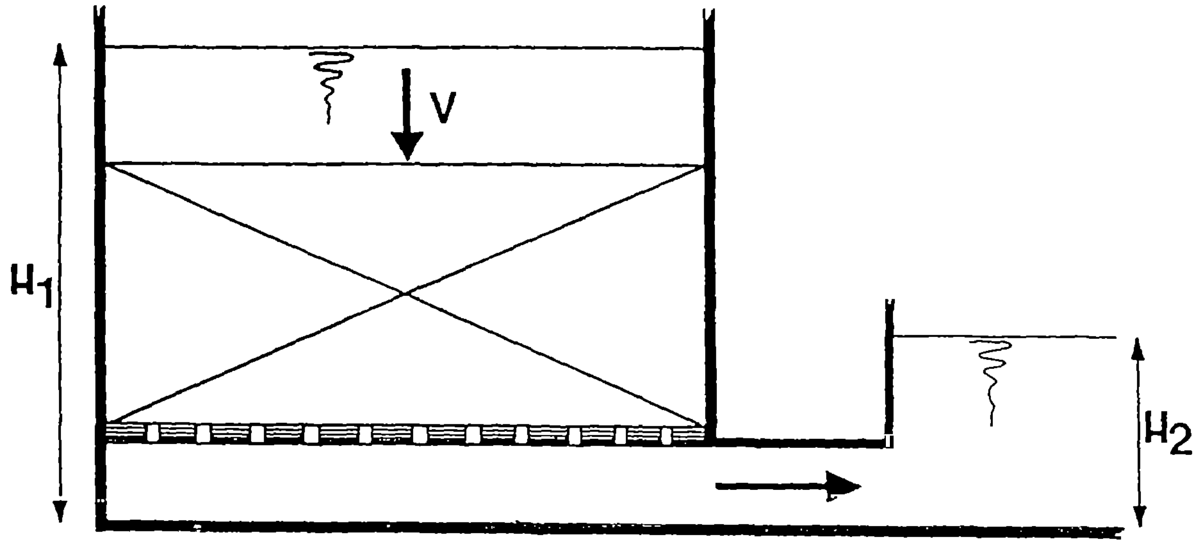
- STRAINING
- SEDIMENTATION
- ADSORPTION
- CHEMICAL REACTION
- BIOLOGICAL ACTIVITY



FREE-SURFACE RAPID GRAVITY FILTER


backwashing
Head Loss
max
filter run period
Time
backwashing
Turbidity
Break through
1FTU
filter run period
Time

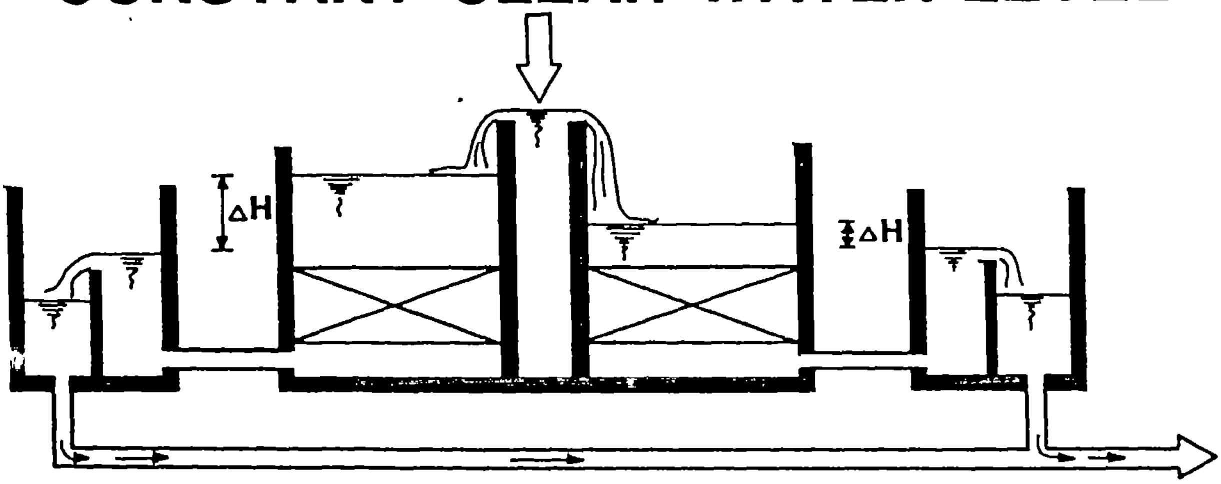

LOW CAPACITY
BAD QUALITY
SHORT FILTER RUN
BAD QUALITY



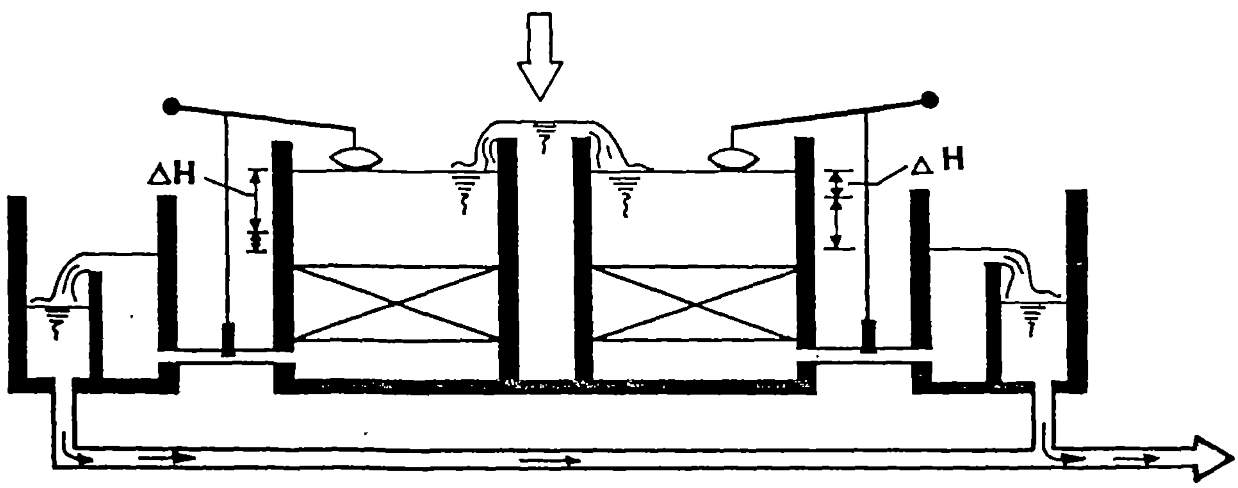
$$V = \alpha (H_1 - H_2)$$

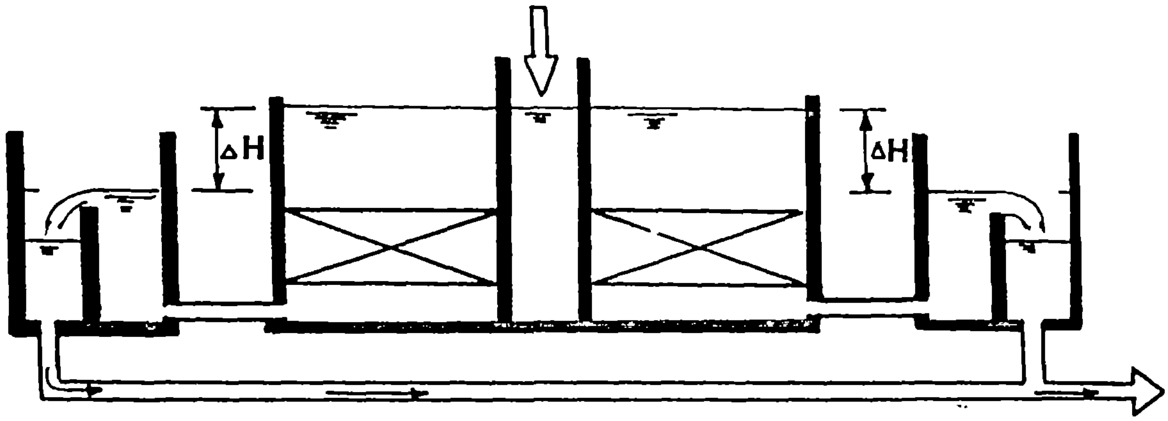
Fixed	Variable	Reaction during filterrun period
V and H_1	H_1	Decreasing
V and H_2	H_2	Increasing
H_1 and H_2	V	Decreasing (Declining)

CONSTANT CLEAR WATER LEVEL

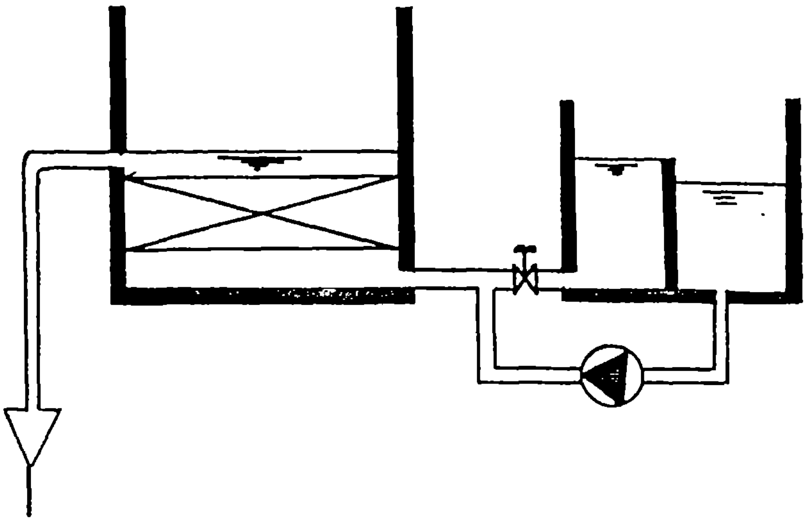


CONSTANT RAW WATER LEVEL

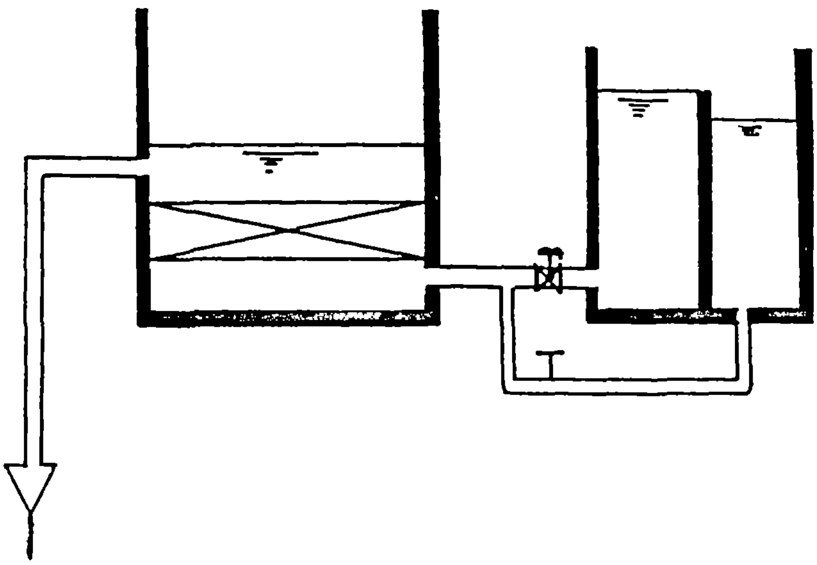



ΔH
ΔH

BY PUMP



BY GRAVITY



Module : **NEUTRALIZATION**	Code : TTG 400
	Edition : 18-03-1985
Section 1 : INFORMATION SHEET	Page : 01 of 01/10

Duration :	90 minutes.
Training objectives :	After the session the trainees will be able to: - recite the principles of neutralization or pH correction; - indicate neutralization.
Trainee selection :	- Head of Technical Department; - Head of Section Production; - Head of Sub-section Water Treatment; - Water Treatment Plant Operator; - Head of Sub Section Laboratory.
Training aids :	- Bottle of Sprite; - Viewfoils : TTG 400/V 1-4; - Handout : TTG 400/H 1.
Special features :	-
Keywords :	Neutralization/corrosiveness/scale forming/aggressive CO_2/saturation index/aeration/limestone filtration /lime saturator/ alkaline solutions.

1. Introduction

- Neutralization is the reduction of excessive carbon dioxide concentration in order to eliminate corrosiveness. — Use whiteboard

- Reduction of CO_2 content is done by:
  - aeration;
  - limestone filtration;
  - dosing of alkaline solutions.

2. Theory

- CO_2 can be found: — Use whiteboard
  a. in air;
  b. in breath;
  c. in Sprite (bubbles);
  d. in groundwater at high concentrations;
  e. in surface water at normal concentrations.

- CO_2 is not dangerous for health. — Demonstrate and drink Sprite

- If concentration of CO_2 in water is higher than 20 ppm, then: — Use whiteboard
  - it reacts with $CaCO_3$ in:
    - cement;
    - asbestos cement;
    - concrete;
  - as $CaCO_3$ dissolves, cement products will become porous, causing leakage and deterioration of water quality.

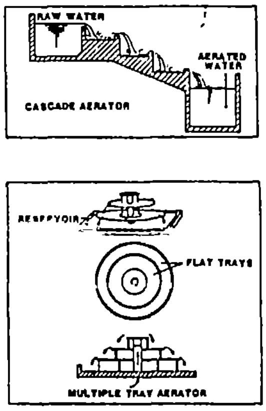
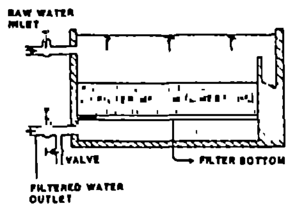
- In ground water the CO_2 content can be very high (> 100 ppm), giving a low pH: neutralization is necessary.

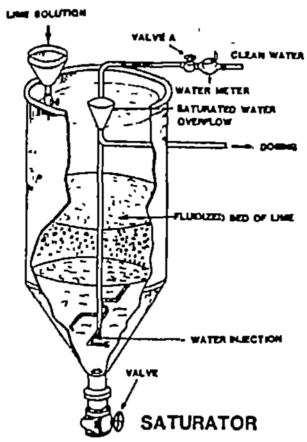
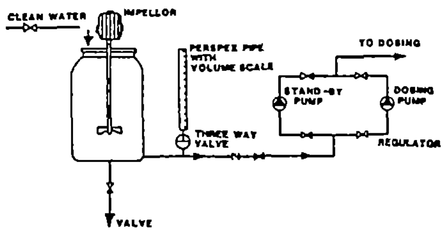
- In surface water the CO_2 concentration is normally very low because of the frequent and intensive contact of water with air.

- The corrosiveness of the water is expressed as the saturation index, SI.
  SI = pH − pH_s wherein:
  pH = the actual pH of the water,
  pH_s = the pH of the water when it is saturated with $CaCO_3$.

- Determination of SI can be done by: . water examination in a well organised laboratory; . practical test by adding 1 gram of $CaCO_3$ to 1 litre of water and measuring the pH_s after 24 hours of contact time.	Use whiteboard
- Values of SI can be: . negative, less than -0.3 : the water is corrosive and neutralization is necessary; . possitive, the water is scale forming or $CaCO_3$ will precipitate on pipe walls and valves.	
3. **Neutralization systems**	
- Aggressive CO_2 can be removed by: . aeration; . limestone filtration; . dosing of alkaline solutions: a. lime saturator ($Ca(OH)_2$); b. pump dosing systems (NaOH or Na_2CO_3).	Show V 1-4
4. **Summary**	Give H 1

Module : NEUTRALIZATION	Code : TTG 400
	Edition : 18-03-1985
Section 3 : T R A I N I N G A I D S	Page : 01 of 01

Aeration TTG 400/V 1	Limestone filtration TTG 400/V 2
	

Lime saturator TTG 400/V 3	Dosing system for soda ash TTG 400/V 4
	

	Neutralization TTG 400/H 1

1. INTRODUCTION

Neutralization, or pH correction, is the reduction of excessive carbon dioxyde, dissolved in water, to a concentration that is not corrosive to construction materials as used in water supply systems. Aggressive CO_2 can be removed by aeration or chemically bound by limestone filtration or by the addition of alkaline solutions.

2. THEORY

Carbon dioxyde (CO_2) is a very common gas. It can be found in the air (2%), in respired breath and in soft drinks (Sprite) at very high concentrations. It is also found in groundwater, usually in high concentrations and in surface water at normal concentrations.

Considering human health, carbon dioxyde is not dangerous, even at high concentrations. Water containing high concentrations of carbon dioxyde (CO_2), however, will corrode and dissolve respectively metallic and concrete parts of the system, causing leakage, damage to pumps and a deterioration of water quality.

In general, the content of corrosive carbon dioxyde is considered too high when there is more than 20 ppm of free carbon dioxyde in the water. Treatment is necessary for neutralization:
a. to avoid chemical reactions such as dissolution of calcium carbonate from the concrete and asbestos cement products, and
b. to avoid corrosion of the metal parts.

CO_2 present in water lowers the pH at increasing contents.
Concentrations in groundwater can be as high as 100 mg/l CO_2, resulting in a low pH of the water. In surface water the CO_2 content is normally low, due to the intimate contact with the air, giving a normal pH value (approx. 7) to the water.

The corrosiveness of water can be expressed by the saturation index; if this value is negative, the water is said to be corrosive, if the value is positive, the water is scale-forming. Scale forming is the deposition of insoluble $CaCO_3$ on pipe walls and valves.

The saturation index can be calculated with the following formula:

$$\text{Saturation index} = pH - pH_s \text{ ; wherein}$$

pH = the actual pH of the water;
pH_s = the theoretical pH when the water is saturated with respect to $CaCO_3$.

The pH_s can be calculated as follows:

$$pH_s = 9.3 - A\ value + B\ value - C\ value - D\ value$$

The A, B, C and D values are listed in the table below.
In this way, however, the index can only be determined by a well equipped water laboratory.
Without a laboratory, satisfactory results can be obtained by adding 1 gram of pure $CaCO_3$ to 1 litre of water. After 24 hours contact time the water is saturated with respect to $CaCO_3$, so the pH_s can be measured with a pH meter.

When the saturation index has shown to be less than -0.3, it is necessary to raise the pH of the water by neutralization in order to suppress corrosiveness. The water will not be corrosive when the pH value is in the range of 7.5 to 8.0.

Total Residue (ppm)	A Value
50 - 300	0.1
400 - 1000	0.2

Water Temperature (°C)	B Value
0 - 1	2.6
2 - 6	2.5
6 - 9	2.4
10 - 13	2.3
14 - 17	2.2
18 - 21	2.1
22 - 27	2.0
28 - 31	1.9
32 - 37	1.8
38 - 43	1.7
44 - 50	1.6
51 - 56	1.5
57 - 63	1.4
64 - 71	1.3
72 - 81	1.2

Calcium Hardness (ppm)	C Value	Total Alkalinity	D Value
10 - 11	0.6	10 - 11	0.1
12 - 13	0.7	12 - 13	1.1
14 - 17	0.8	14 - 17	1.2
18 - 22	0.9	18 - 22	1.3
23 - 27	1.0	23 - 27	1.4
28 - 34	1.1	28 - 35	1.5
35 - 43	1.2	36 - 44	1.6
44 - 55	1.3	45 - 55	1.7
56 - 69	1.4	56 - 69	1.8
70 - 87	1.5	70 - 88	1.9
88 - 110	1.6	89 - 110	2.0
111 - 138	1.7	111 - 139	2.1
139 - 174	1.8	140 - 176	2.2
175 - 220	1.9	177 - 220	2.3
230 - 270	2.0	230 - 270	2.4
280 - 340	2.1	280 - 350	2.5
350 - 430	2.2	360 - 440	2.6
440 - 550	2.3	450 - 550	2.7
560 - 690	2.4	560 - 690	2.8
700 - 870	2.5	700 - 880	2.9
800 - 1000	2.6	890 - 1000	3.0

3. NEUTRALIZATION SYSTEMS

Aggressive CO_2 can be removed by the following neutralization systems:
- aeration;
- limestone filtration;
- dosing of alkaline solutions.

Aeration

Aeration is a process whereby the water is brought into intimate contact with air, thus reducing the excessive CO_2 content. The intimate contact is obtained by creating an artificial waterfall such as the multiple tray aerator or the cascade aerator. The reduction of CO_2 by waterfall aerators can be considerable but is not sufficient when treating very corrosive water. In that case chemical neutralization is required.

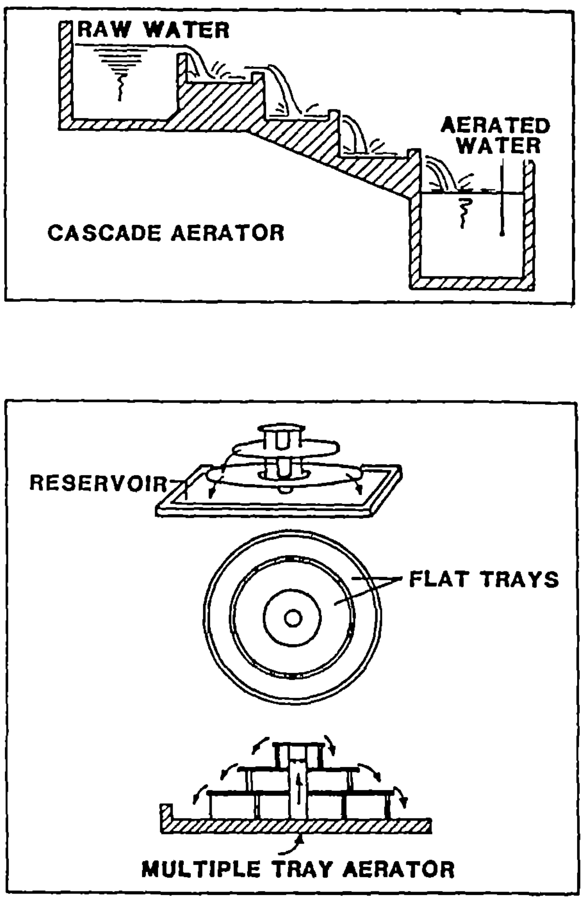


Fig. 1. Multiple tray and cascade aerators.

Limestone filtration

The aggressive CO_2 is chemically bound to limestone during its passage of a filter bed containing limestone grains (marble filter).

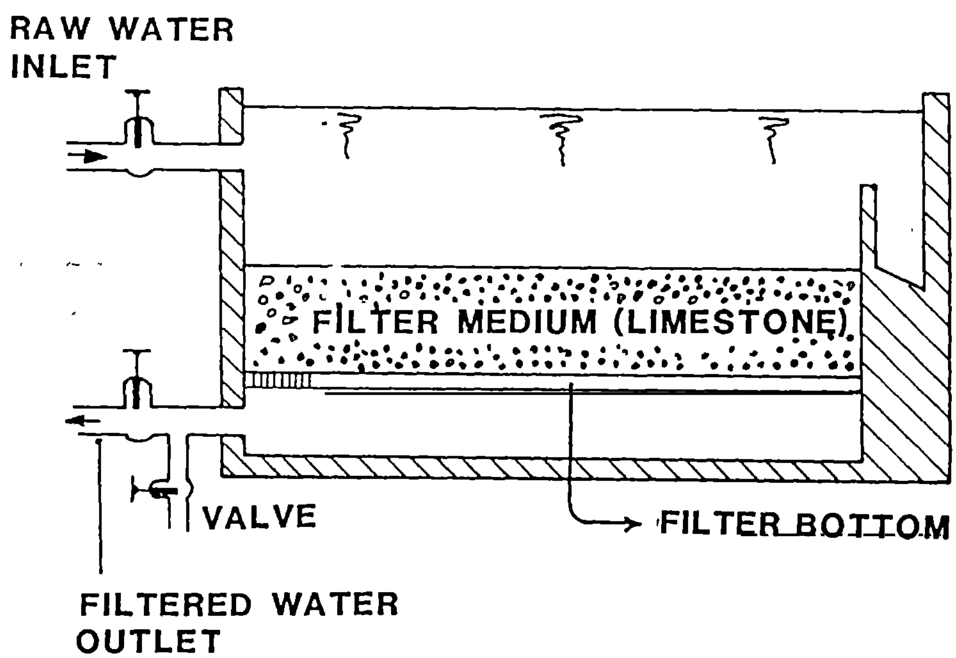


Fig. 2. Marble filter.

Dosing of alkaline solutions

a. Lime saturator

The lime saturator consists of a tank wherein the water to be treated passes a fluidized bed of lime ($Ca(OH)_2$) particles. The aggressive CO_2 is now chemically converted into bicarbonates, saturating the water.

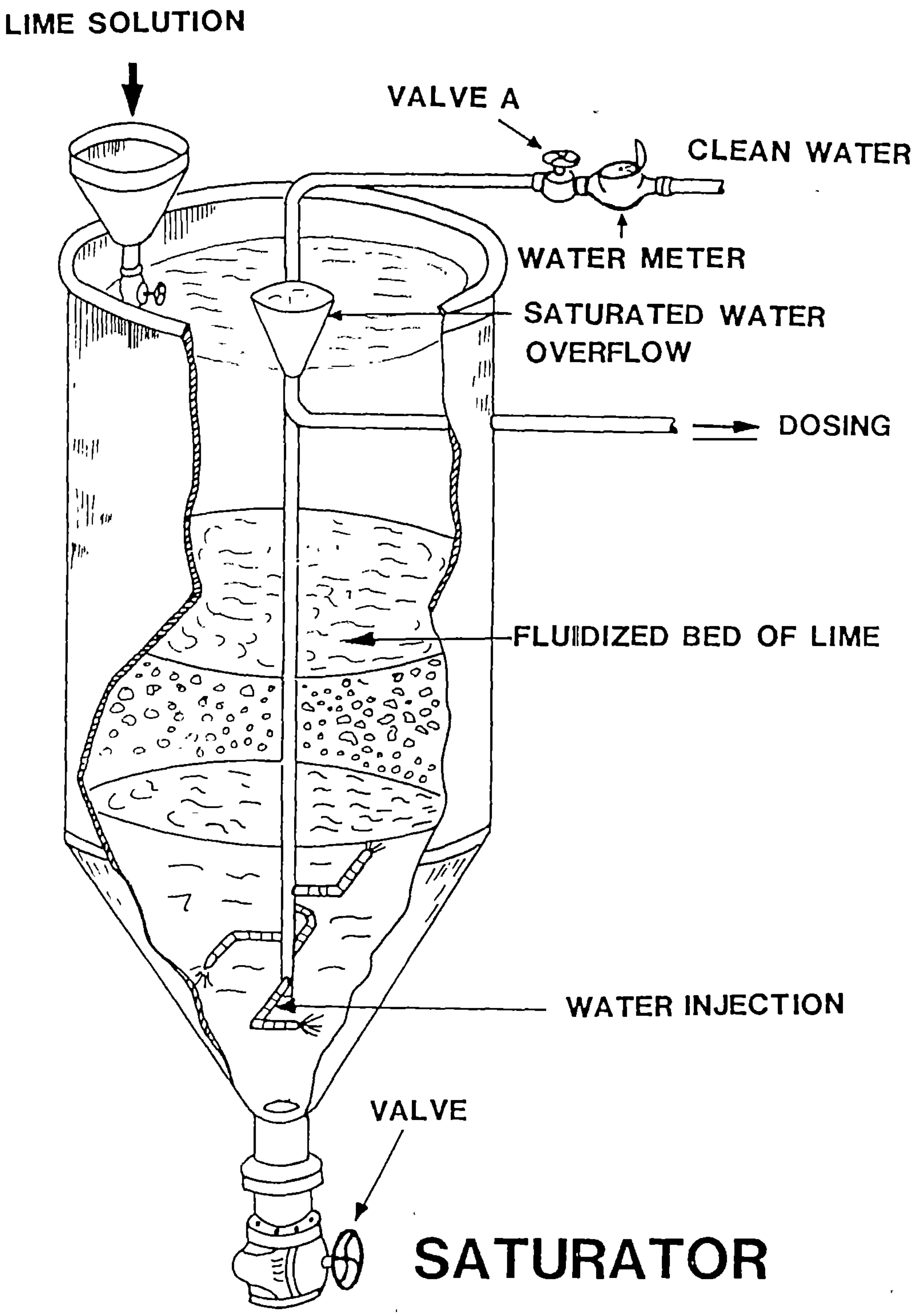


Fig. 3. Lime saturator.

b. Pump dosing systems

For pH correction an alkaline solution of soda ash or caustic soda can be added with the aid of a dosing pump. For a proper correction the rate of dosing flow must be calculated and adjusted correctly.

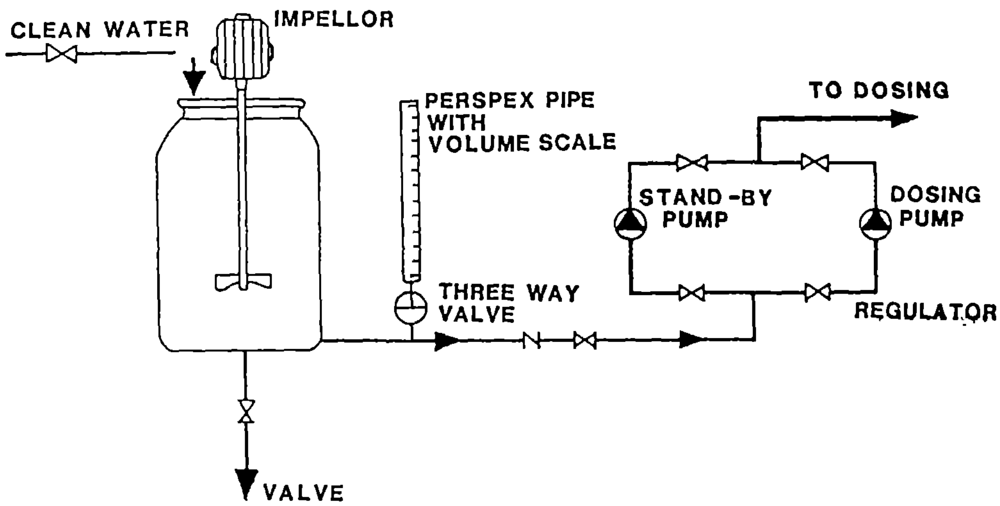
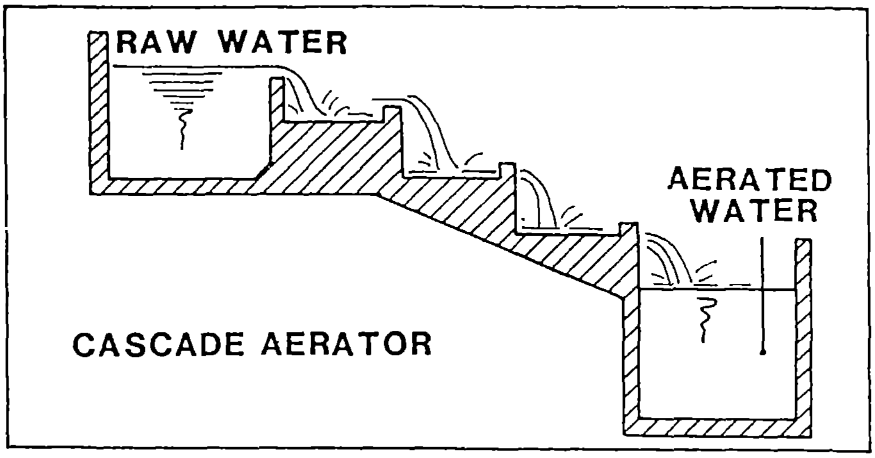


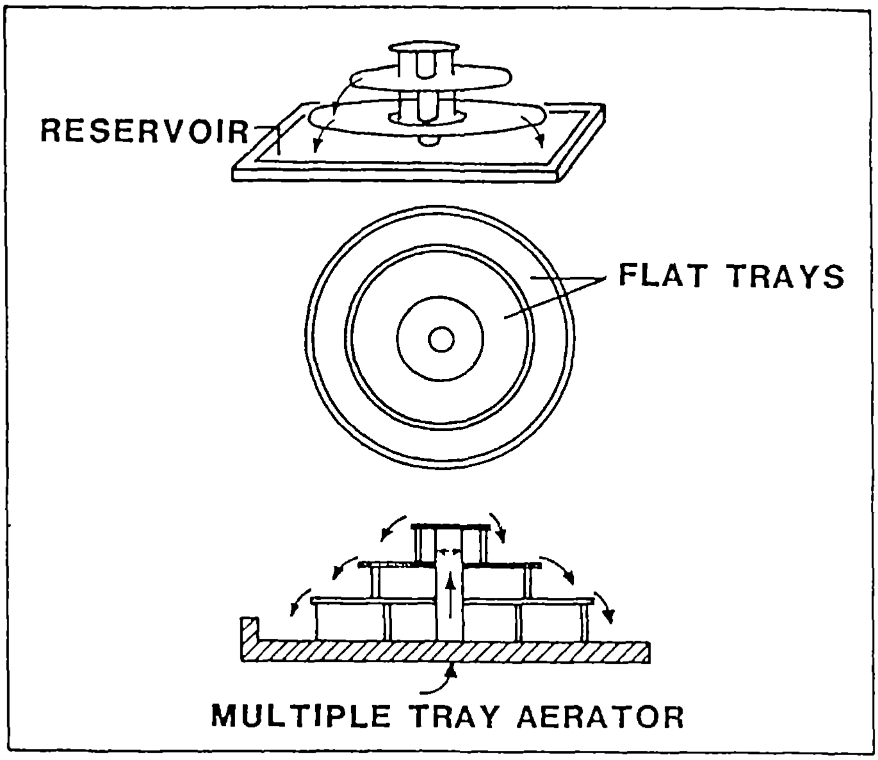
Fig. 4. Pump dosing systems.

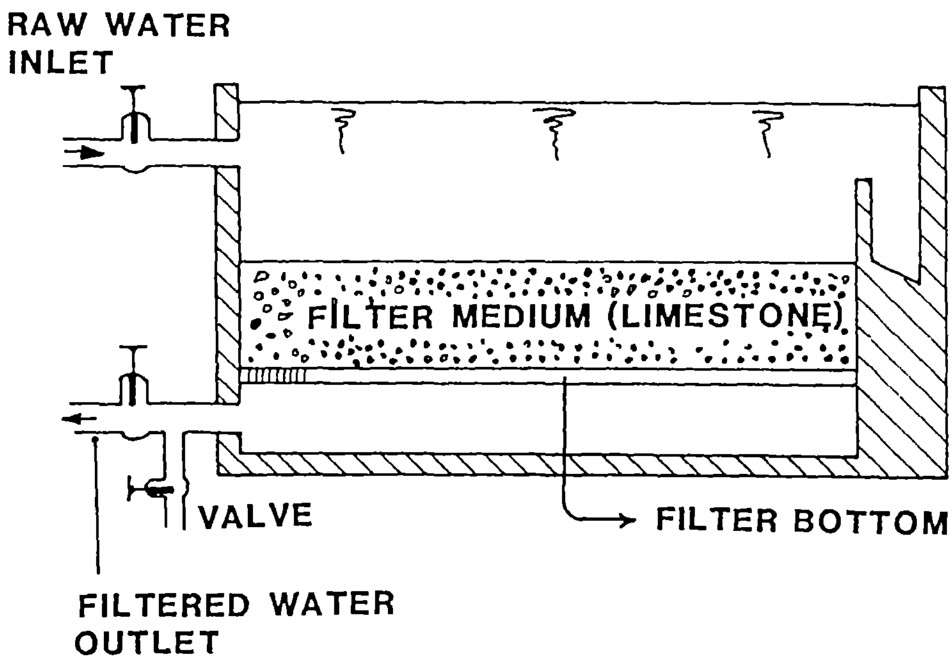
4. SUMMARY

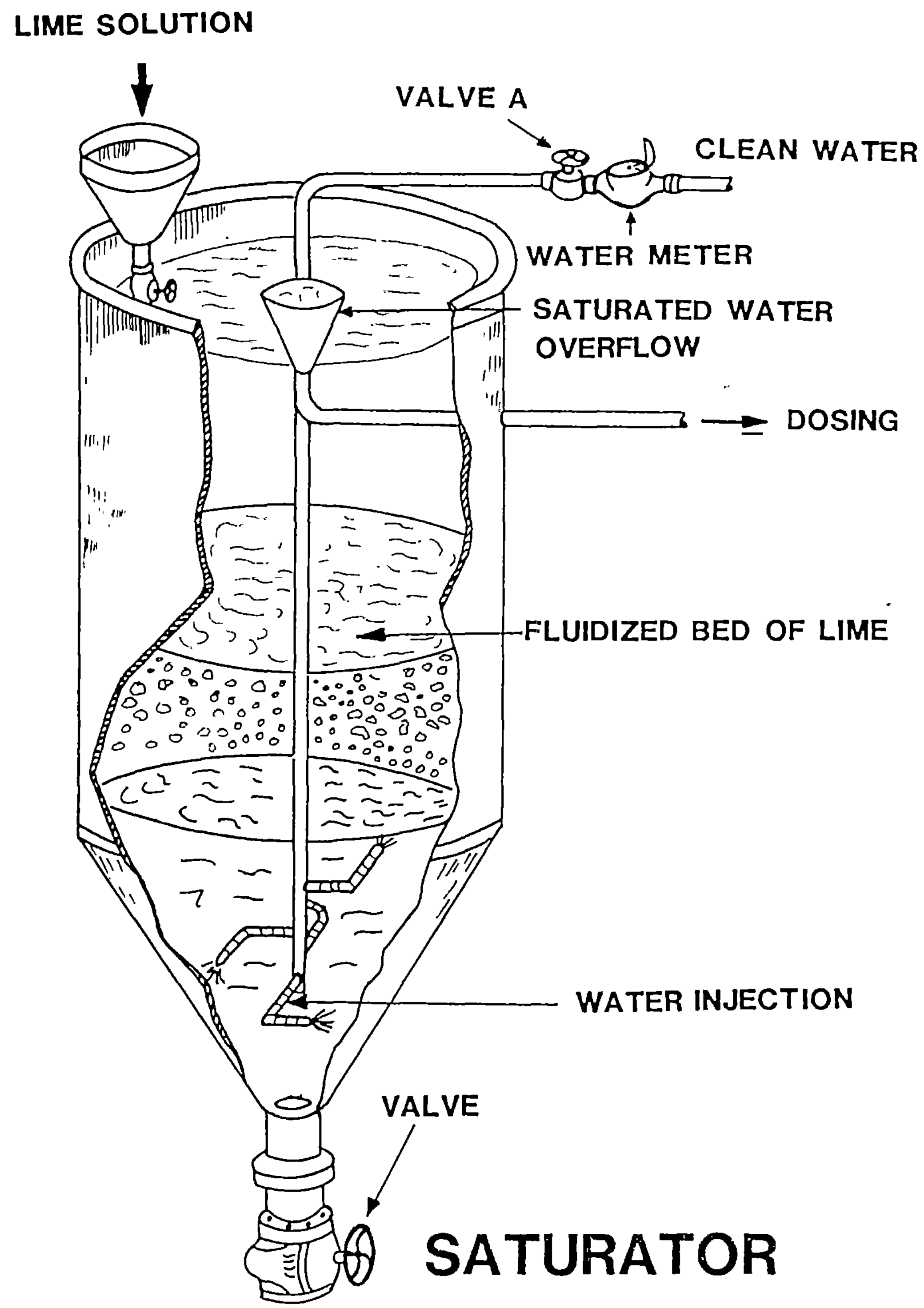
Neutralization is protecting construction materials of the water supply system against corrosion by adjusting the pH of the water to a normal level (7.5 to 8.0) with the aid of neutralization systems.

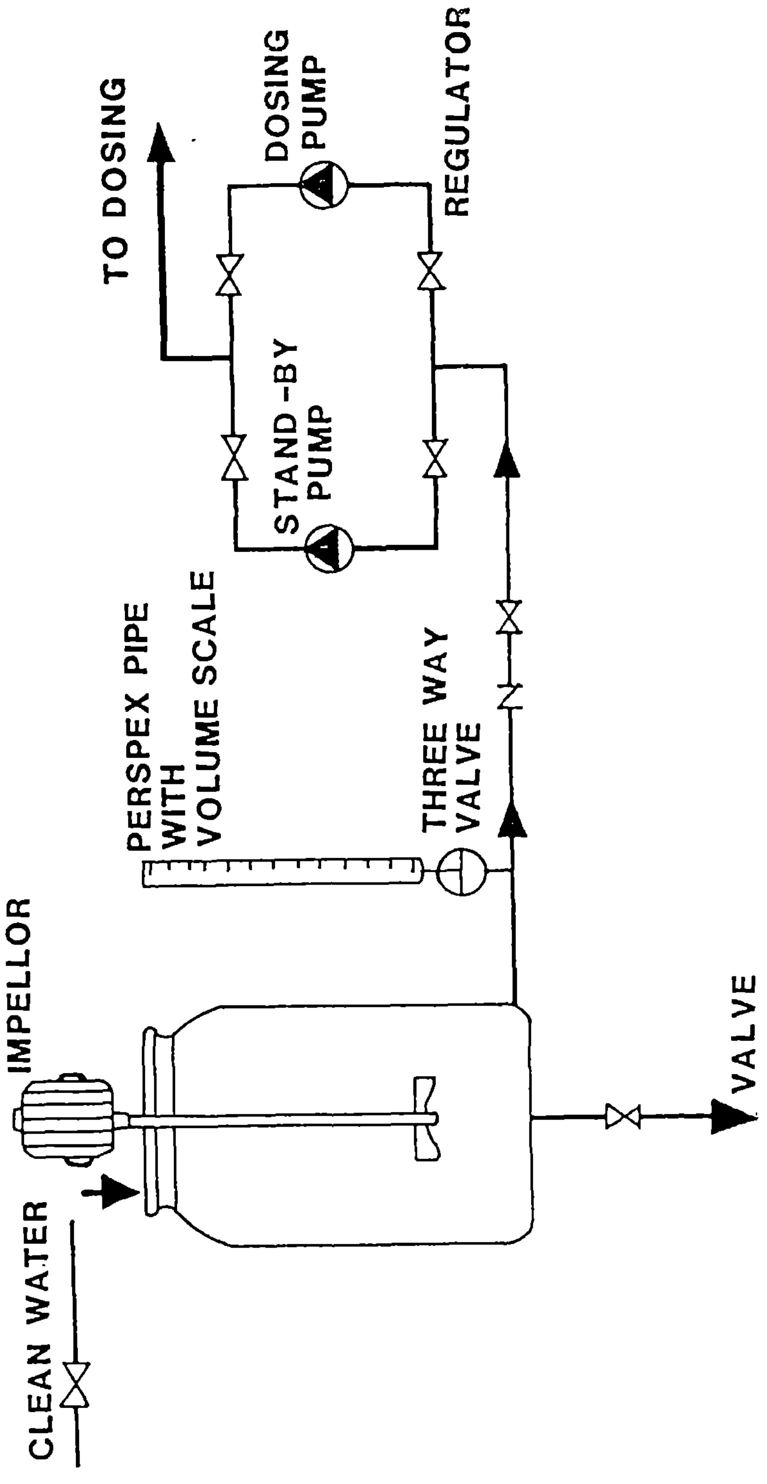
* * *


RAW WATER
AERATED WATER
CASCADE AERATOR


RESERVOIR
FLAT TRAYS
MULTIPLE TRAY AERATOR


RAW WATER
INLET
FILTER MEDIUM (LIMESTONE)
VALVE
FILTER BOTTOM
FILTERED WATER
OUTLET


LIME SOLUTION
VALVE A
CLEAN WATER
WATER METER
SATURATED WATER
OVERFLOW
DOSING
FLUIDIZED BED OF LIME
WATER INJECTION
VALVE
SATURATOR


TO DOSING
DOSING PUMP
REGULATOR
STAND-BY PUMP
PERSPEX PIPE WITH VOLUME SCALE
THREE WAY VALVE
IMPELLOR
VALVE
CLEAN WATER

Module : CHEMICALS HANDLING, DOSING AND MIXING	Code : TTG 500
	Edition : 18-03-1985
Section 1 : INFORMATION SHEET	Page : 01 of 01/21

Duration :	135 minutes.
Training objectives :	After the session the trainees will be able to: - prepare a chemical solution with a specified strength; - dose the chemicals at a specified dosing rate, give the solution strength and the rate of flow of the raw water.
Trainee selection :	- Head of Technical Department; - Head of Section Production; - Head of Sub-section Water Treatment; - Water Treatment Plant Operator; - Head of Sub-section Laboratory.
Training aids :	- Viewfoils : TTG 500/V 1-10; - Handout : TTG 500/H 1.
Special features :	-
Keywords :	Handling/dosing/mixing/commercial strength/solution strength/dosing tank/mixing tank/gravity/feed dosing systems/hydraulic mixers/mechanical mixers.

1. Introduction	
- The chemicals used most often in water treatment are: . alum for the coagulation/flocculation process; . soda ash or lime for neutralization and/or pH correction; . kaporit for disinfection.	Use whiteboard
- Chemicals are available in powder form, packed in bags or barrels.	
- Chemicals have to be stored: . to ensure continuity of the process.	
- The places where chemicals are dosed normally are: . alum and soda ash or lime at the coagulation/flocculation basin; . soda ash or lime at the neutralization at the end of the treatment process; . kaporit for disinfection just before clear water storage and distribution.	Show V 1
2. Properties	
- Chemicals have quite different appearances.	Show V 2
- Available forms are: . blocks; . powder; . crystals; . liquid.	
- The commercial strength indicates the amount of usable compound in the bulk of chemical (chemical in commercial form will never be pure but contain some foreign compounds).	
- Chemicals can be: . corrosive; . explosive; . poisonous.	

- The solution strength is the strength of the dosed solution.

3. Storage and handling

- Chemicals have to be imported.

- Handling and storage of chemicals asks for
  . mechanical equipment;
  . storage building with a large capacity.

4. Operation

- Operation activities can be divided into: — *Use whiteboard*
  . preparing a solution;
  . dosing the solution;
  . mixing of the solution with water.

Preparing solution

- Solution strength. — *Use whiteboard*
  . a 10% solution means 10 kg of chemical + 90 kg of water;
  . a 1% solution means 1 kg of chemical + 99 kg of water;
  . 1 kg of water equals 1 liter;
  . commercial strength of the chemicals has to be taken in account.

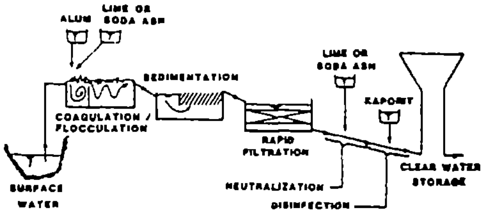
- Chemicals are prepared in a mixing tank. — *Show V 3*

- Preparation of a chemical solution is done by: — *Show V 4, Use whiteboard*
  . filling a tank with a known amount of water;
  . calculating the amount of chemical which must be added for obtaining the desired solution strength;
  . weighing out the desired amount of chemical;
  . mixing the chemical with the water.

Chemical dosing	
- Chemicals can be added to the water: . as a powder or slurry; . as a solution (the most common way).	
- Solution feeders consist of: . a dosing tank; . a dosing rate of flow controller.	Show V 3
- There are two kinds of dosers: . gravity feed; . displacement pumps or tippers.	Show V 5
Mixing	
- Basically there are two groups of mixers: . hydraulic mixers; . mechanical mixers.	
- Hydraulic mixers are: . baffled channels; . overflow weirs; . hydraulic jumps.	Show V 6-7
- Mechanical mixers need power for the agitation of the water by propellors or turbines.	Show V 8
Note: ALWAYS TAKE CARE WHEN HANDLING CHEMICALS. USE PLASTIC OR RUBBER HANDGLOVES. WEAR PROTECTIVE CLOTHES AND COVER NOSE AND MOUTH.	
5. Problems	
- The following problems may occur when handling chemicals: . the prepared solution doesn't have the correct strength; . the dosing rate is not correct; . not all the necessary chemicals are in store.	Use whiteboard

- The following measures have to be taken in order to avoid the above mentioned problems	Show V 9
. checking of the solution strength by using a Baumè meter;	
. checking the dosing rate with a calibrated cylinder and a stopwatch;	Show V 10
. record keeping of the chemical use and the chemicals still in store and ordering new chemicals when the time the quantity still in store will last, is only slightly more than the time needed for delivery.	
6. Summary	Give H 1

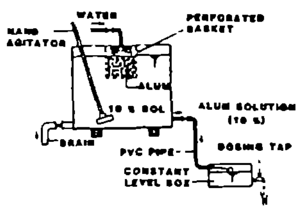
Chemical dosing points — TTG 500/V 1



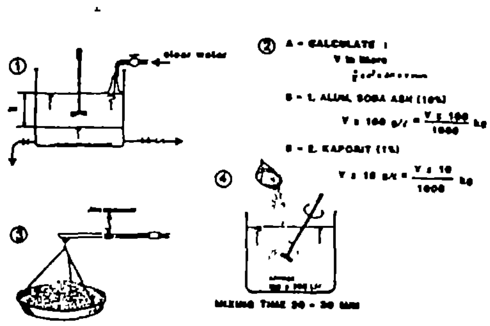
Properties of chemicals — TTG 500/V 2

CHEMICAL	AVAILABLE FORM	COMMERCIAL STRENGHT	PROPERTIES	SOLUTION STRENGTH
ALUM	CLOCKS STICKS GRANULAR POWDER	15 - 17 % Al_2O_3	GREY WHITE ACIDIC CORROSIVE	10 %
SODA ASH	POWDER CRYSTALS	98 - 99 % Na_2CO_3	WHITE CAUSTIC	10 %
KAPORIT	GRANULES POWDER TABLETS	60 - 70 % Cl_2	WHITE SMELLING OF CLORINE	1 %

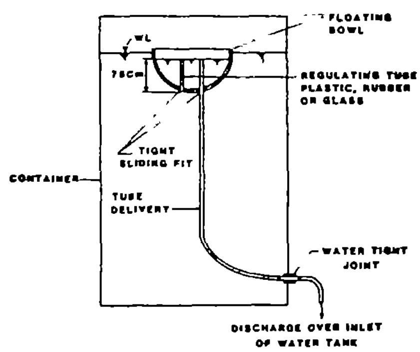
Mixing tank — TTG 500/V 3



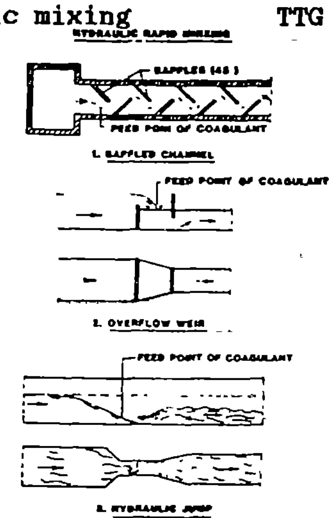
Preparation of solution — TTG 500/V 4



Gravity feed doser — TTG 500/V 5

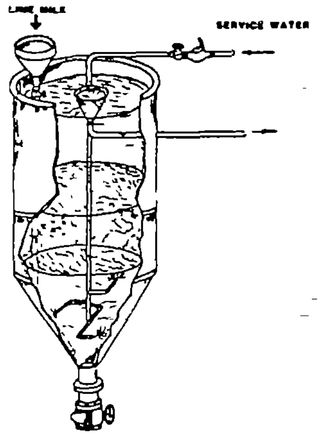


Hydraulic mixing — TTG 500/V 6

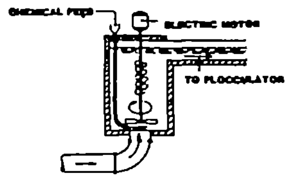


Module : CHEMICALS HANDLING, DOSING AND MIXING	Code : TTG 500
	Edition : 18-03-1985
Section 3 : T R A I N I N G A I D S	Page : 02 of 02

Hydraulic mixing (lime saturator) — TTG 500/V 7

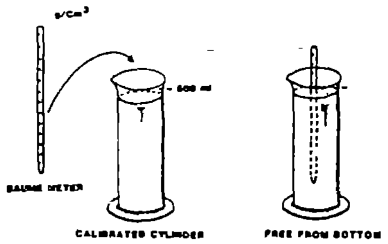


Mechanical rapid mixing — TTG 500/V 8

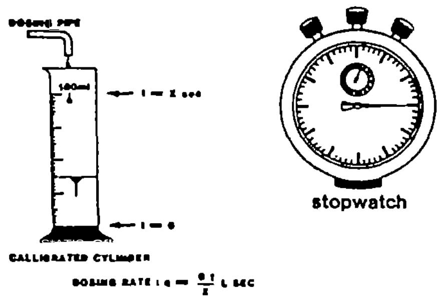


MECHANICAL RAPID MIXING

Baumè meter — TTG 500/V 9



Checking dosing rate — TTG 500/V10



Chemicals handling, dosing and mixing — TTG 500/H 1

1. INTRODUCTION

In water treatment practise several chemicals are used for various purposes. The chemicals used most often in Indonesia are:
- alum for the coagulation/flocculation process.
- soda ash or lime for neutralization and/or pH correction.
- kaporit for disinfection.

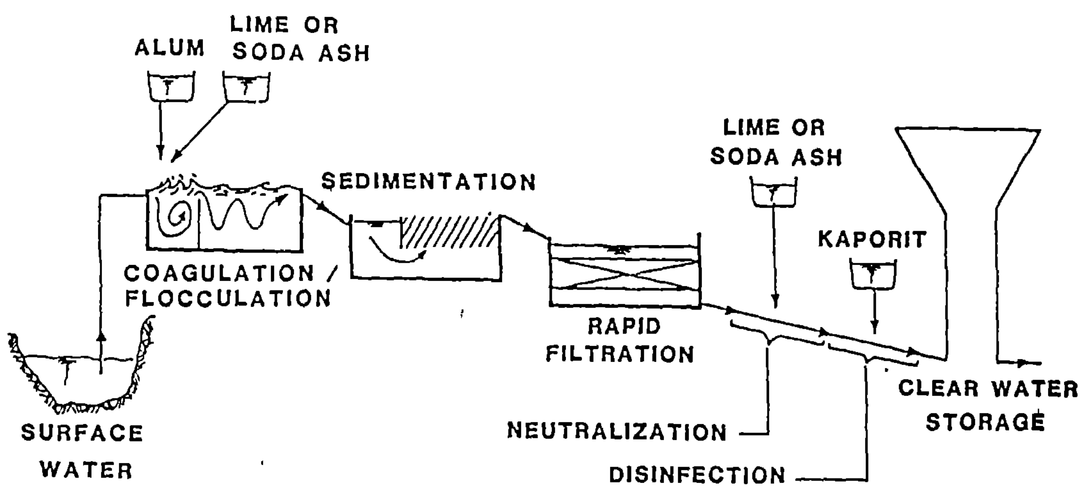


Fig. 1. Chemical dosing points.

The chemicals are mostly available as powder, packed in bags or barrels. Because of their important role in the water purification process storage of a large quantity is necessary in order to assure a continuous supply of treated water.

2. PROPERTIES

Chemicals used in water supply enterprises have quite different appearances and properties. Mostly they are available as powder packed in bags or barrels. The chemical is seldom pure but will contain impurities which are not active for the purpose the chemical is applied. For this reason, notice should be taken of the commercial strength of the chemical as indicated on the packing or in the specifications of the manufacturer. Special care has to be taken when a solution with a certain strength needs to prepared.
The following table summarizes the most important properties of the chemicals used in water treatment practice.

COMMON CHEMICALS USED IN WATER TREATMENT

Chemical name and formula	Common name	Use	Available forms	Commercial strength	Appear. and propert.	Usual solution strength
Aluminium sulphate $Al_2(SO_4)_3$	Alum	Coagulant	Blocks, sticks, lumps, granules powder	15-17% Al_2O_3	Grey-white to light brown, crystalline acidic, corrosive slightly hygroscopic	8-10%
Sodium carbonate Na_2CO_3	Soda ash	pH adjustment, neutralization	Powder or crystals	98-99% Na_2CO_3	White powder, caustic	1-10% solution
CaO	Burnt lime, chemical lime, unslaked lime	pH adjustment and neutralization	Lumps, pebbles, granules, powder	75-99%	White to light grey, caustic	1-5% solution
Calcium hydroxide $Ca(OH)_2$	Hydrated lime, slaked lime	pH adjustment and neutralization	Powder	80-95% $Ca(OH)_2$ 60-70% CaO	White powder, caustic	Saturated or 1-5% suspension
Calcium hypochlorite $Ca(OCl)_2$	Kaporit	Disinfection	Granules, powder, tablets	60-70% available chlorine Cl_2	White granules, smelling of chlorine, explosive	1-3% available chlorine solution

3. STORAGE AND HANDLING OF CHEMICALS

In many Asian countries chemicals have to be imported and arrive at the works in bags or drums. In larger cities it is increasingly likely that delivery will be made by bulk carriers designed to transport powders that may be unloaded pneumatically, or liquids which can be pumped.

On small-to-medium works in developing countries, however, occasionally large consignments of bags or drums carrying the chemicals have to be handled and stored. At typical dosage rates, even a moderately sized works of, say, 25.000 m^3/day output, would use over one tonne of chemicals daily. Thought should therefore be given to initial off-loading, storage and daily transportation to the solution tanks, particularly when these are at high level. At all but the smallest works in countries where labour is cheap and plentiful, some sort of mechanical equipment is necessary. In its simplest form this may merely comprise hand trolleys and a hoist, but in bigger installations highly sophisticated bulk handling machinery can be justified. Such machinery is rarely designed only for waterworks but is similar to that used in installations handling sugar, flour, lime or similar substances. The equipment is normally bought as a package either from waterworks plant manufacturers or from the makers of the individual items.

4. OPERATION

Operation activities can be subdivided into:
- preparing a solution of the chemical to be applied;
- dosing of the solution to the water to be treated;
- mixing the chemical solution with the water to be treated.

Preparing a solution

In preparing solutions of any chemical it should be noted that a 5% solution means that 5 parts of the chemical should be added to 95 parts of water (by weight) to get 100 parts of solution, and so on.
An 8% solution would contain 8 kg of chemical to 92 kg of water. (1 kg water equals 1 liter).
Percentages normally relate to the actual substance (e.g. alum, lime) being handled and not to any of the basic elements (e.g. calcium, aluminium) therein included.

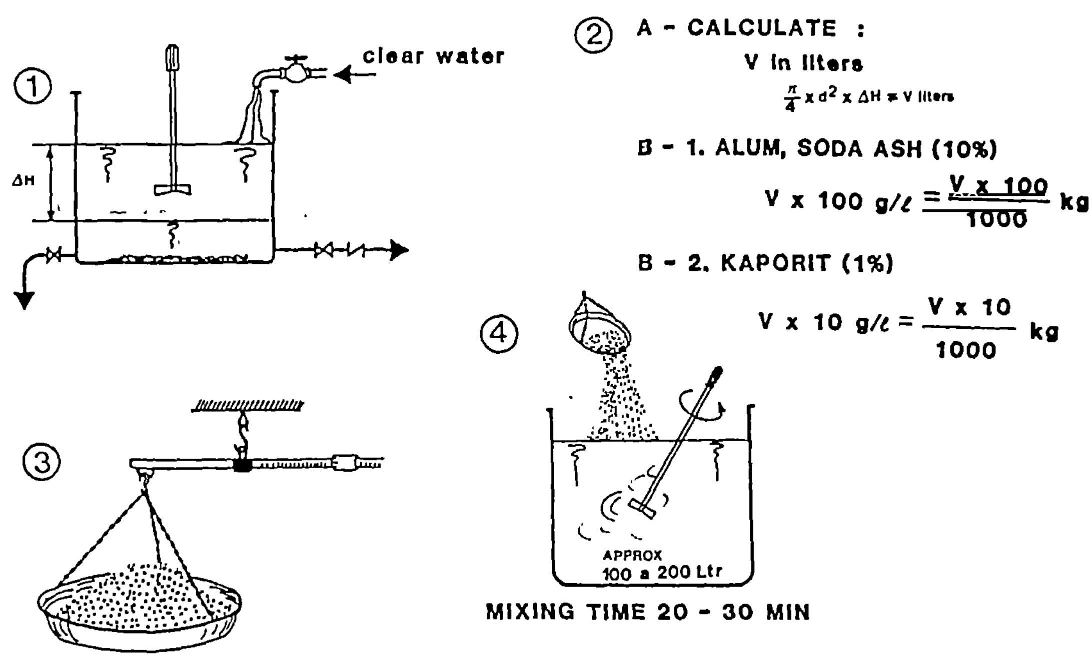


Fig. 2. Preparation of solution.

Chemicals are prepared in a special mixing tank which is suited to hold the chemical to be prepared.

The preparation of a solution can be done as follows:

- Fill the mixing tank with a certain amount of water.

- Calculate the amount of water by measuring the volume of water added to the tank. This volume is called V liters : 1 liter water equals 1 kg in weight.

- Calculate the amount of chemical required to obtain the correct solution strength (see table in par. 2).
  For instance : for a 10% solution (alum or soda ash) we have to add 0.1 * V kg of pure chemical.
  We have to take the commercial strength (s%) in account, so we have to add : (100/s) * 0.1 * V (kg) of the available powder.

- Enter the amount of weighed chemical.
  (Note : Some chemicals are toxic, explosive (kaporit) or cause violent reactions when added to the water (unslaked lime) so care must be taken).

- Mix during 20-30 min.

- Stop mixing and let solids settle. Normally the settled solids consist of impurities or $CaCO_3$, formed by the addition of the chemical. These do not influence the strength of the solution.

- Check the strength of the solution by using a Baumè meter.

Chemical dosing

Chemicals can be added to the water either as a solution, which is the most usual way, or in powder or slurry form. As treatment is a continuous process, dosing must also proceed in a continuous and controlled fashion.

Solution feed

The two essential parts of a solution feed system comprise a tank in which a solution of the correct strength may be stored, and a dosing rate-of-flow controller. The tank should hold 24 h supply and be duplicated so that one tank may be in service while the other is being replenished. There should be some sort of continuous stirring mechanism to obviate the risk of settlement after initial preparation. Many chemicals (particularly alum and kaporit) are corrosive and the tanks should be lined with acid-resisting material, commonly rubber, glass or special cement.

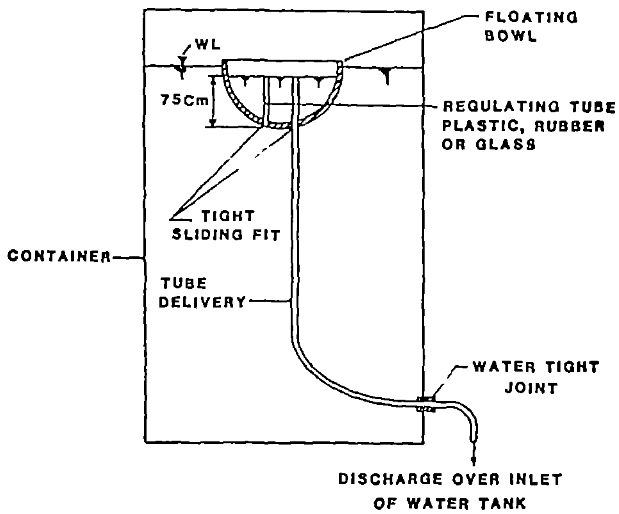


Fig. 3. Gravity feed doser.

The dosing mechanism should be capable of being controlled manually. There are two kinds of dosers : gravity-feed, and displacement pumps or tippers. The rate of flow can be altered in the former by adjusting the outlet valve in a constant-head tank, in the latter by altering the length of piston stroke of the specially made plunger pumps. The speed at which tippers operate can also be regulated. In big works of sophisticated design, dosing can be controlled automatically.

Dry feeders

A dry feeder incorporates a hopper which contains the powder and feeds a measuring device. This often takes the form of a revolving table from which a scraper of adjustable length deflects a greater or lesser amount of powder into the raw water. If the powder is not very soluble it may be mixed with water and fed as a slurry, like in the lime saturator that is used to neutralize the water by saturation when it passes a lime suspension. In humid, tropical conditions, trouble by 'caking' is sometimes experienced on dry feeders and for this reason solution feeders are preferred.

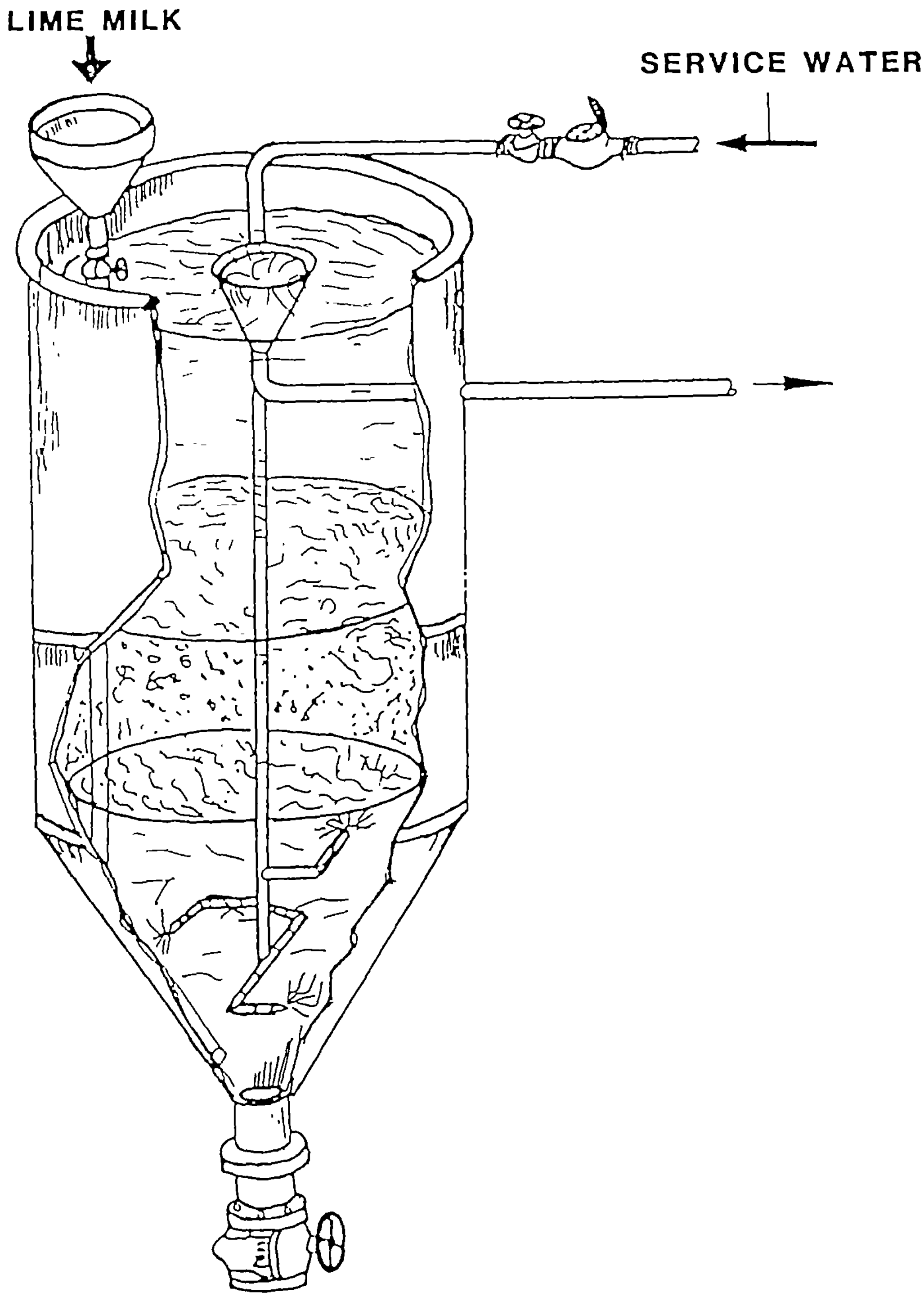


Fig. 4. Hydraulic mixing in lime saturator.

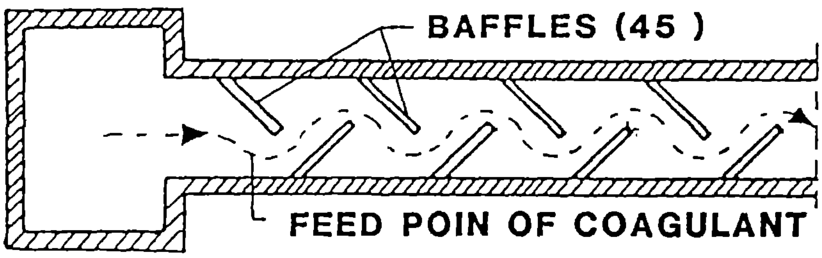
Most feeders lend themselves to automation, with the rate of flow of chemical dependent on the rate of flow of water through the works. On a small (or unsophisticated) works, where the rate of flow tends to be constant, the simplicity of manual regulation is much to be preferred.

Dosing appliances are mostly of proprietary make and they vary widely in detail, their mode of operation being described in the various makers' literature.

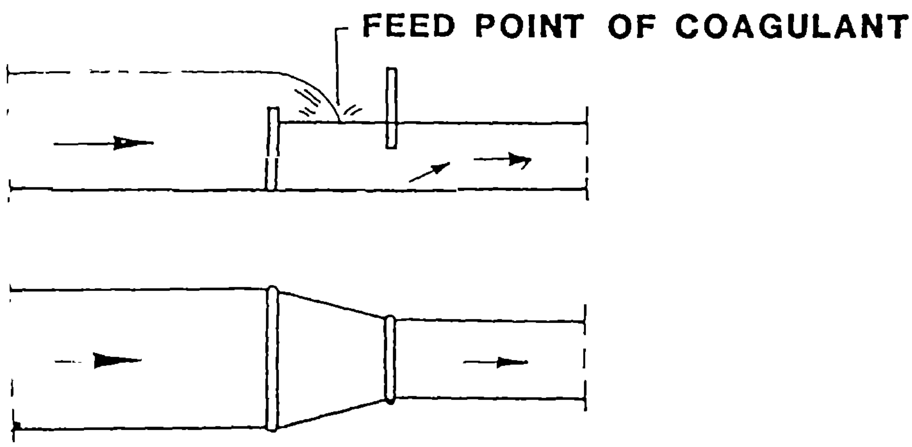
Mixing

Many devices are used to provide mixing for the dispersal of chemicals in water. Basically, there are two groups:
- hydraulic mixing;
- mechanical mixing.

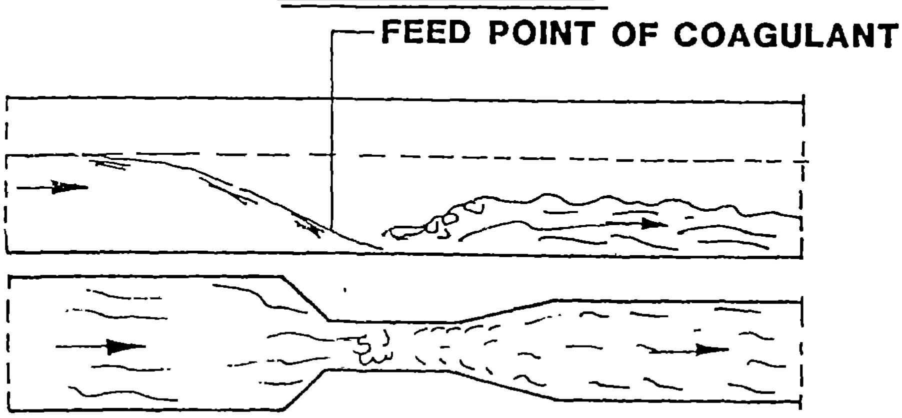
HYDRAULIC RAPID MIXING



1. BAFFLED CHANNEL



2. OVERFLOW WEIR



3. HYDRAULIC JUMP

Fig. 5. Hydraulic mixing devices.

Hydraulic mixing

For hydraulic mixing, arrangements are used such as : channels or chambers with baffles producing turbulent flow conditions, overflow weirs and hydraulic jumps. Mixing may also be achieved by feeding the chemicals at the suction side of pumps. With a good design, a hydraulic mixer can be as effective as a mechanical mixing device.

Mechanical mixing

With mechanical mixing the power required for agitation of the water is delivered by impellers, propellors or turbines.

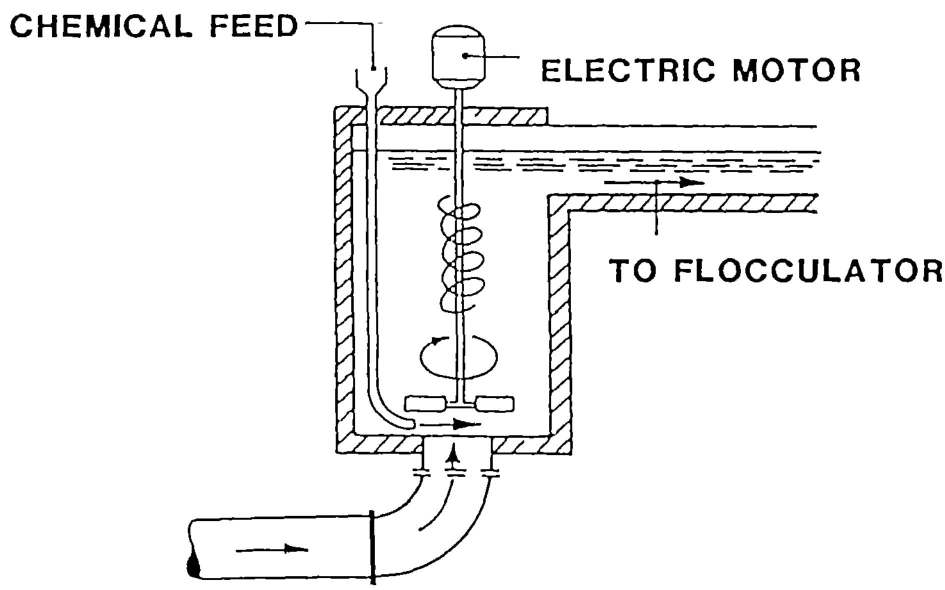


Fig. 6. Mechanical mixing device.

Generally, mechanical rapid mixers are less suitable for small treatment plants than hydraulic ones since they require a reliable and continuous supply of power.

Note:

ALWAYS TAKE CARE WHEN HANDLING CHEMICALS. USE PLÁSTIC OR RUBBER HANDGLOVES, WEAR PROTECTIVE CLOTHES AND COVER NOSE AND MOUTH.

5. PROBLEMS

The next problems can be experienced when handling chemicals:

Prepared solution doesn't have the correct strength.

When preparing a solution with a required strength, a certain amount of chemical must be added to a certain amount of water. The chemical must be obtained from a bulk source with a certain commercial strength which has to be taken in account. Improper calculation can easily lead to an incorrect strength of the solution prepared. To avoid mistakes, the strength of the solution can be checked by using a Baumè meter.

CHECKING THE SOLUTION STRENGTH WITH A BAUME METER:

- Fill a 500 ml calibrated cylinder with the prepared solution.
- Enter the Baumè meter. The meter will float more of less according to the density of the solution.
- Read the figure indicated on the meter at the liquid level accurately. The result is in Baumè degrees (see table).
- Convert the value into the density using the table.
- Convert the density into the solution strength using the table.

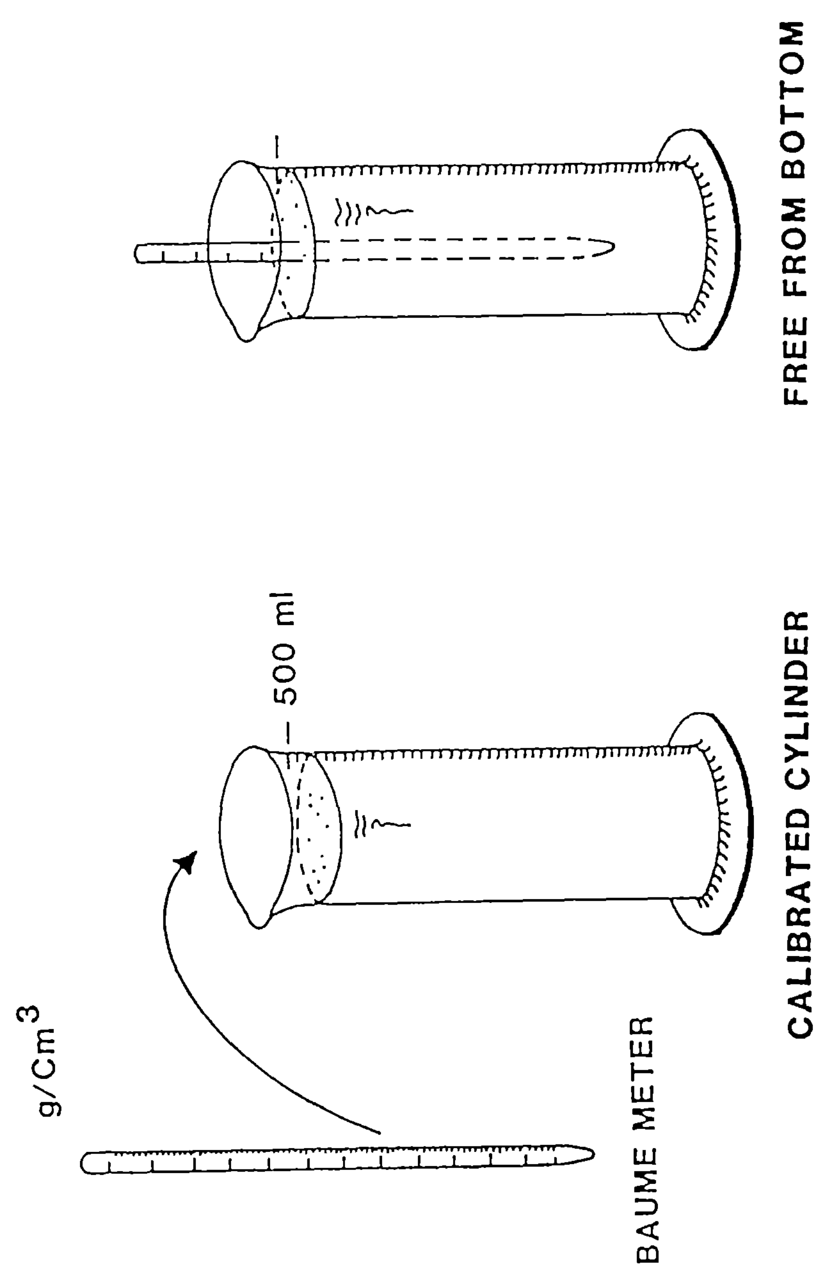


Fig. 7. Use of Baumé meter

Relation between the density and the concentration of solution of alum, soda ash, kaporit (grams of pure product per litre of solution at 15 °C).

Baume Degrees	Density kg/ltr.	Aluminium sulphate $Al_2(SO_4)_3$ 18 H_2O	Soda ash Na_2CO_3	Calcium hypochlorite $Ca(OCl)_2$
°Be	kg/liter	c (g/l)	c (g/l)	c (g/l)
1	1.007	14	6.3	2.8
2	1.014	28	13.1	5.5
3	1.021	42	19.5	8
4	1.028	57	29	10.5
5	1.036	73	35.4	13
6	1.044	89	41.1	16
7	1.051	103	50.8	18.5
8	1.059	119	58.8	21
9	1.067	135	67.9	23
10	1.075	152	76.1	25
11	1.083	168	85.0	27.5
12	1.091	184	93.5	30
13	1.099	200	101.2	32
14	1.108	218	110.6	34
15	1.116	235	122	36
16	1.125	255	131	38
17	1.134	274	141.5	40
18	1.143	293	150.5	-
19	1.152	312	162.5	-
20	1.161	332	-	-

The dosing rate is not correct

One should check the dosing rate regularly and adjust if necessary. The dosing rate should be in accordance with the dose required, which is:

- <u>for alum:</u>
  the optimal dose as determined by the jar test.
  Normally this dose will vary between 5 and 15 mg/l alum.

- for kaporit:
  a dose which will lead to a residual chlorine content in the distribution system of 0.2 - 0.5 ppm.

- for alkaline solutions:
  a dose which will lead to the pH value desired (as determined by the jar test).

The dosing rate can always be checked manually by filling a calibrated cylinder with the discharge of the prepared solution dosing pipe, and measuring the time that elapses for a 100 ml discharge.

For instance : a calibrated cylinder of 100 ml is filled in 20 seconds (use stopwatch) by the discharge of the dosing pipe).

The dosing rate : $\frac{100\ ml}{20\ sec} = 5\ ml/sec = 18\ l/hour$

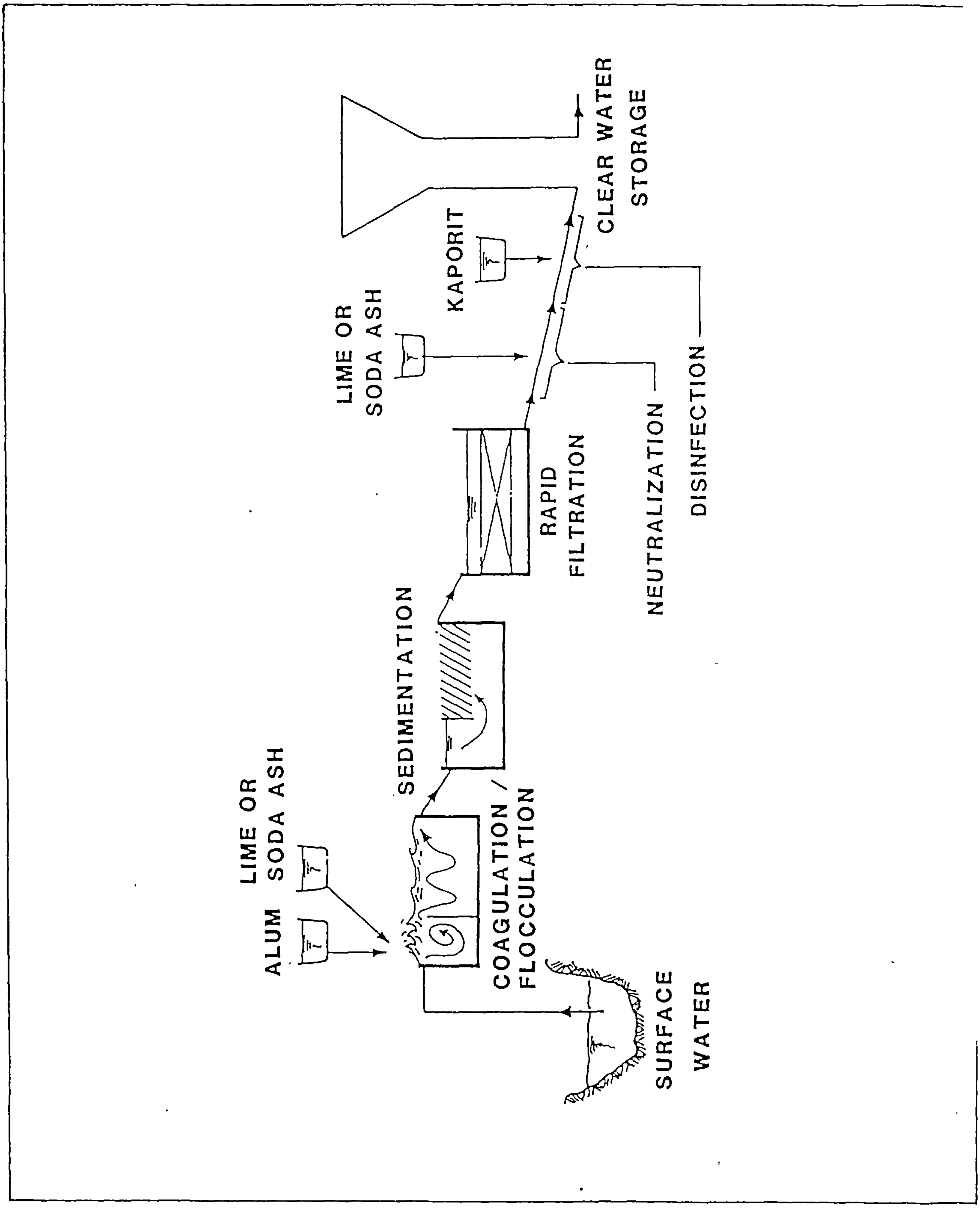
No chemicals in store

As treatment is a continuous process, dosing must also proceed in a continuous fashion, requiring an appropriate storage of a large quantity of chemicals. To avoid any problems of this type a proper record must be kept of the chemical use and the chemicals still in store. One should order new chemicals when the time for use of the quantity still in store equals the time which is needed for delivery.

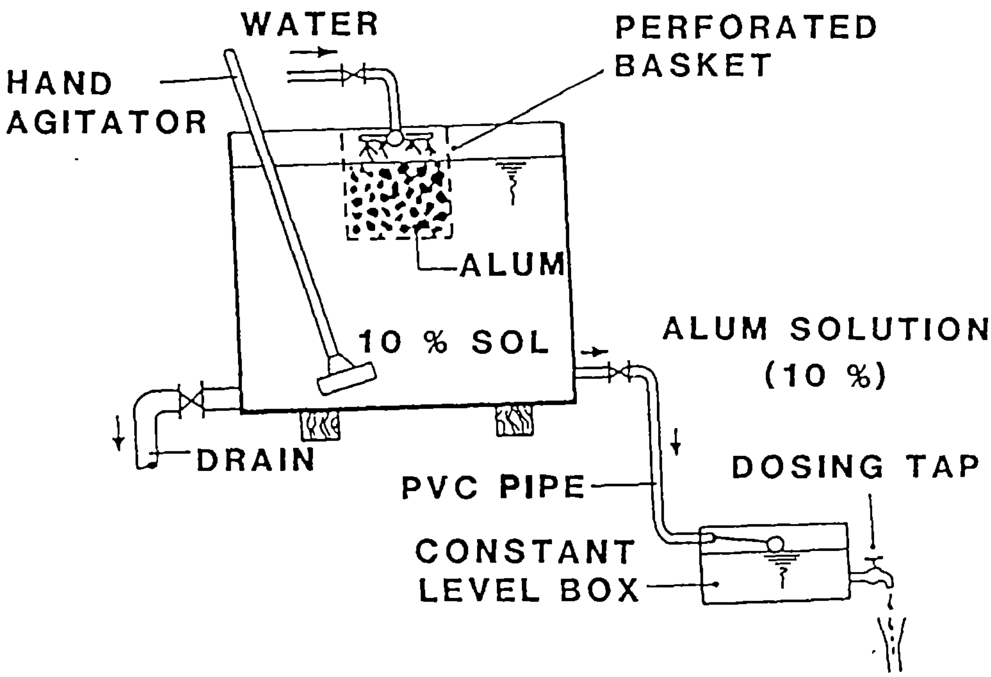
6. SUMMARY

Chemicals used most often in water treatment practise are alum, kaporit and lime or soda ash. Handling of chemicals must be done carefully since most chemicals have dangerous properties. Handling consists of preparing a solution, dosing the solution and mixing the solution with the water.

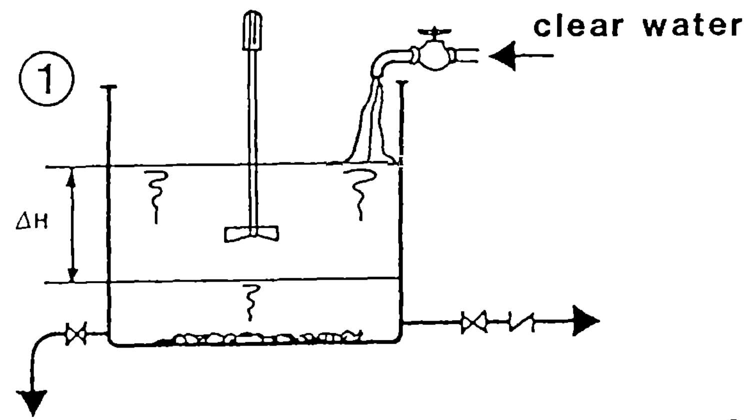
* * *


ALUM
LIME OR
SODA ASH
COAGULATION /
FLOCCULATION
SURFACE
WATER
SEDIMENTATION
RAPID
FILTRATION
LIME OR
SODA ASH
KAPORIT
NEUTRALIZATION
DISINFECTION
CLEAR WATER
STORAGE

CHEMICAL	AVAILABLE FORM	COMMERCIAL STRENGHT	PROPERTIES	SOLUTION STRENGTH
ALUM	CLOCKS STICKS GRANULAR POWDER	15 - 17 % Al_2O_3	GREY WHITE ACIDIC CORROSIVE	10 %
SODA ASH	POWDER CRYSTALS	98 - 99 % Na_2CO_3	WHITE CAUSTIC	10 %
KAPORIT	GRANULES POWDER TABLETS	60 - 70 % Cl_2	WHITE SMELLING OF CLORINE	1 %


WATER
PERFORATED BASKET
HAND AGITATOR
ALUM
10 % SOL
ALUM SOLUTION (10 %)
DRAIN
PVC PIPE
DOSING TAP
CONSTANT LEVEL BOX

(1)



(2) A - CALCULATE :

V in liters

$\frac{\pi}{4} \times d^2 \times \Delta H = V$ liters

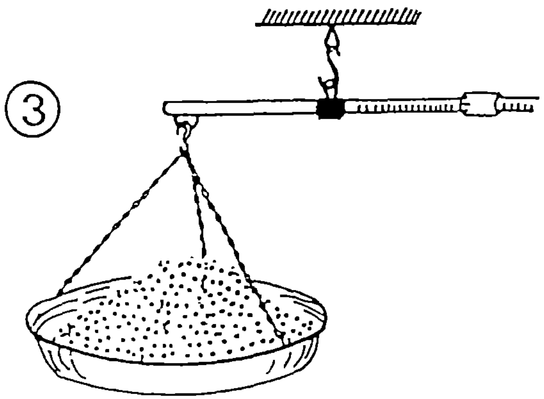
B - 1. ALUM, SODA ASH (10%)

$$V \times 100\ g/\ell = \frac{V \times 100}{1000}\ kg$$

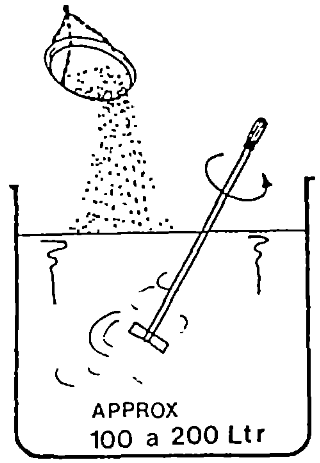
B - 2. KAPORIT (1%)

$$V \times 10\ g/\ell = \frac{V \times 10}{1000}\ kg$$

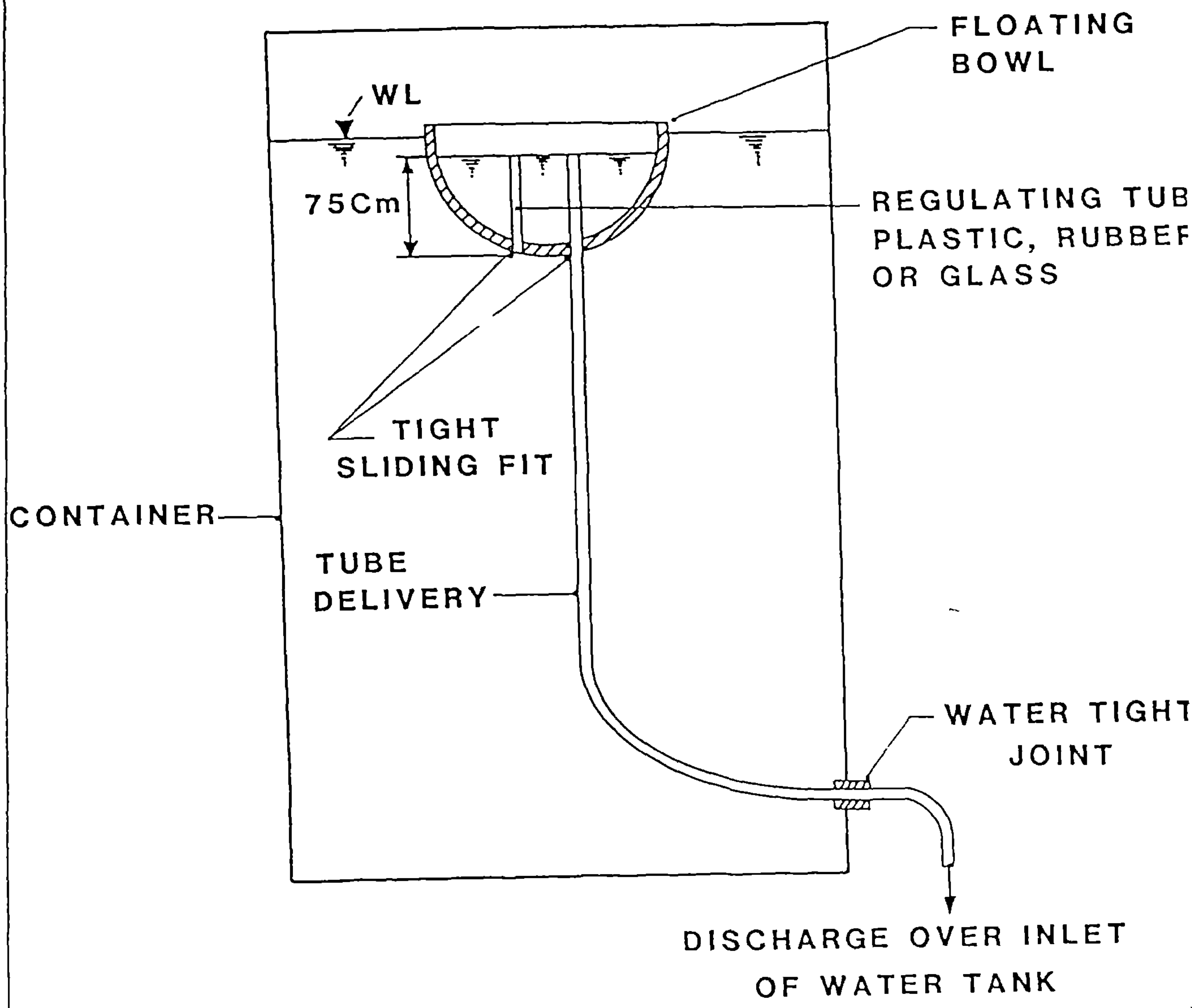
(3)



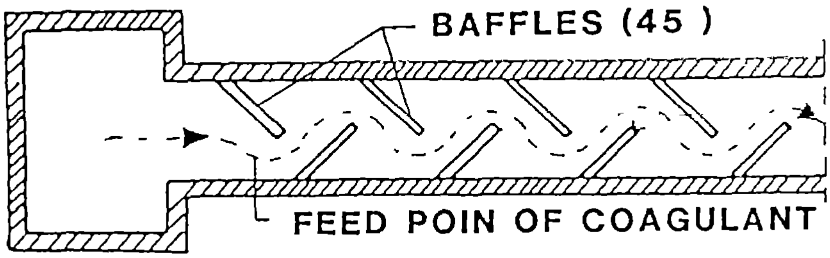
(4)



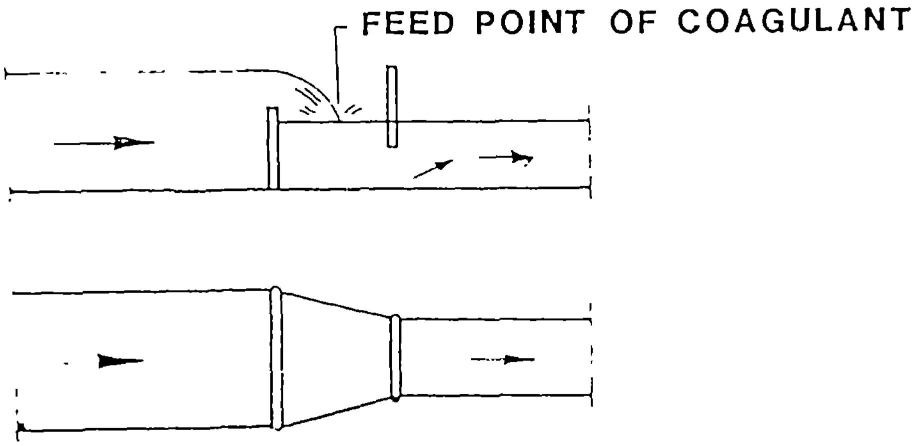
MIXING TIME 20 - 30 MIN


FLOATING BOWL
WL
75Cm
REGULATING TUB
PLASTIC, RUBBEF
OR GLASS
TIGHT SLIDING FIT
CONTAINER
TUBE DELIVERY
WATER TIGHT
JOINT
DISCHARGE OVER INLET
OF WATER TANK

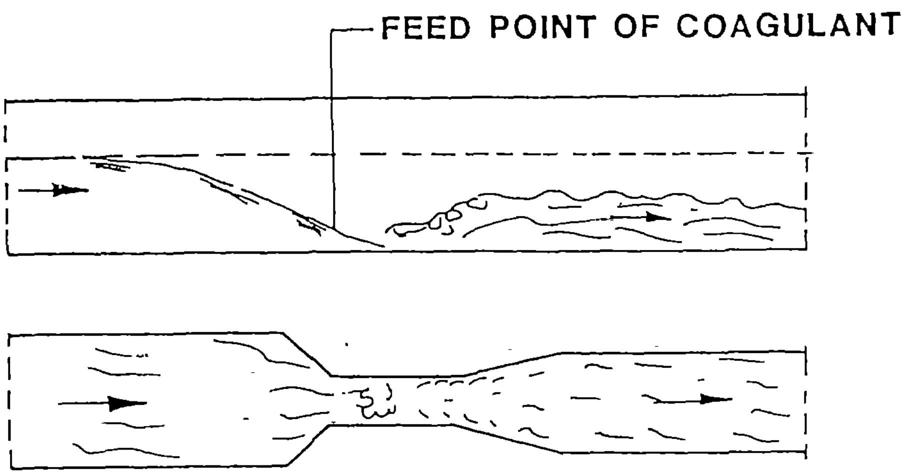
HYDRAULIC RAPID MIXING



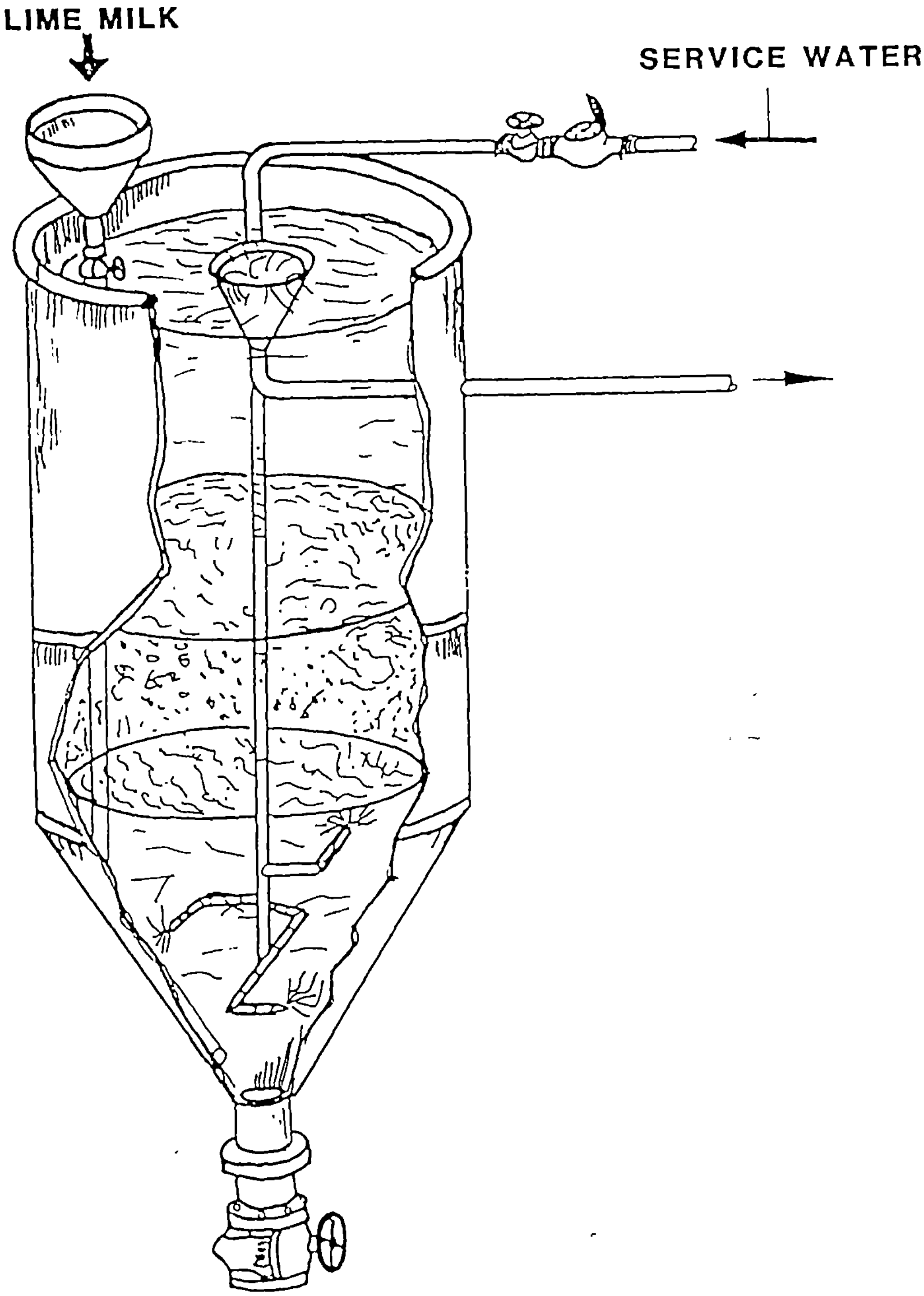
1. BAFFLED CHANNEL

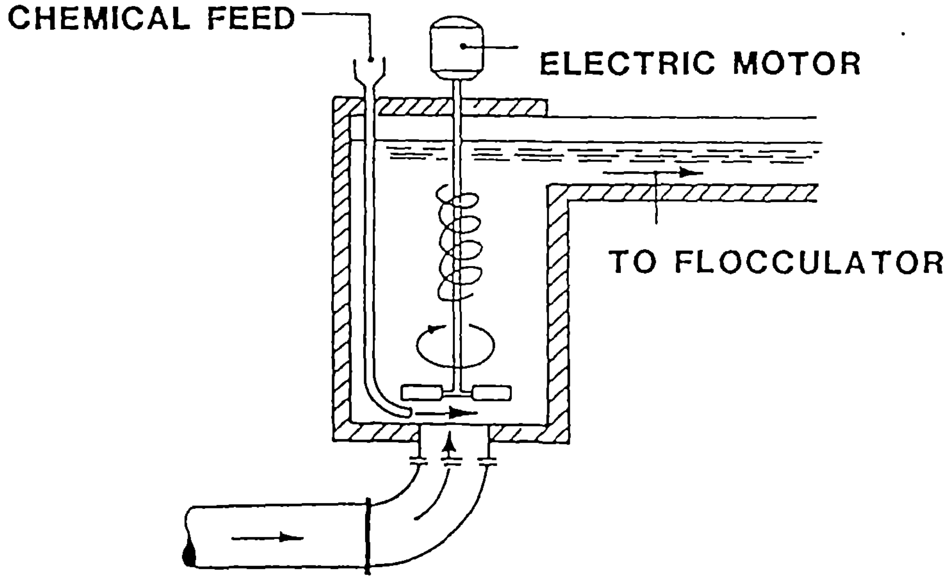


2. OVERFLOW WEIR

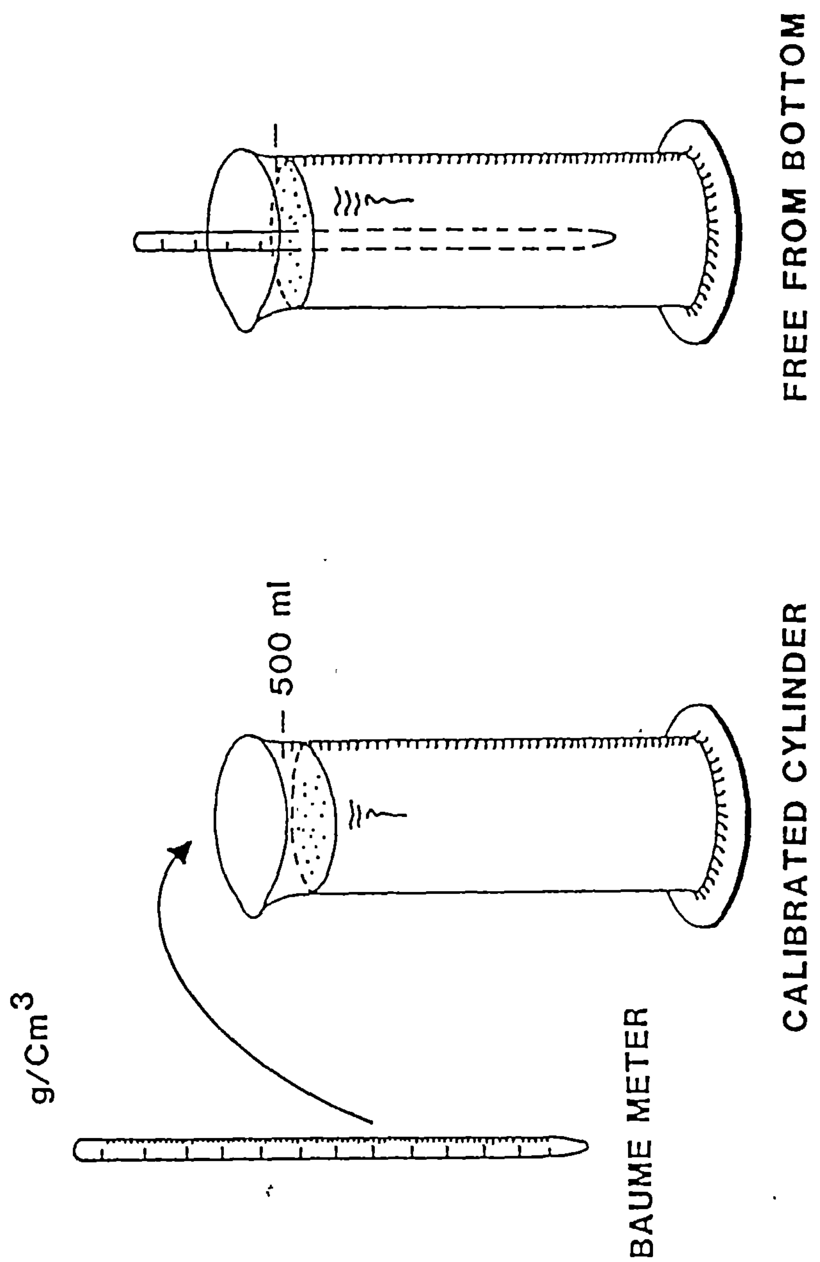


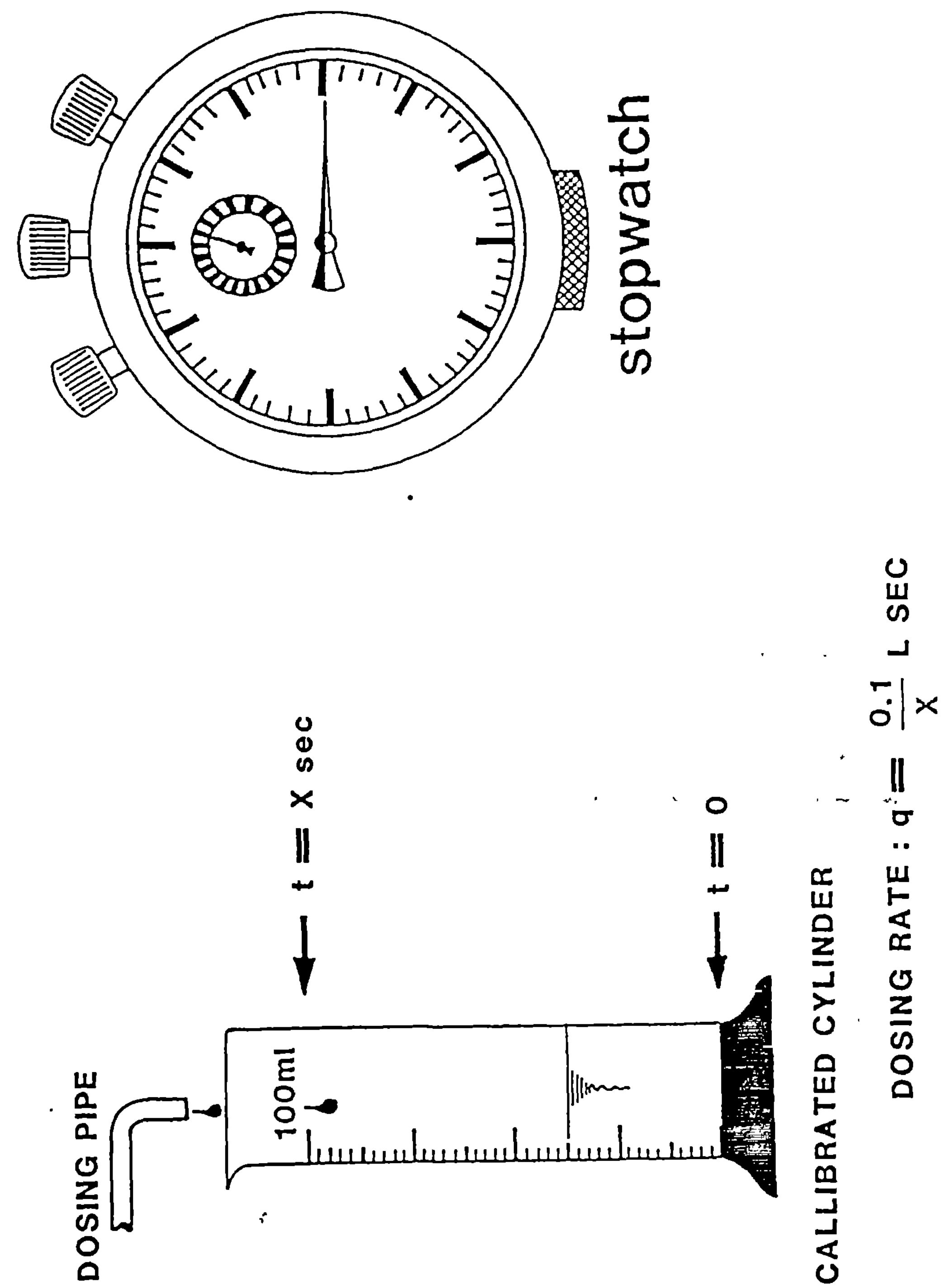
3. HYDRAULIC JUMP


LIME MILK
SERVICE WATER



MECHANICAL RAPID MIXING


FREE FROM BOTTOM
500 ml
CALIBRATED CYLINDER
g/Cm3
BAUME METER


stopwatch
DOSING PIPE
100ml
t = X sec
t = 0
CALLIBRATED CYLINDER
DOSING RATE : q = 0.1/X L SEC

Module : **OPERATION OF WATER TREATMENT FACILITIES - SURFACE WATER**	Code : TTO 051
	Edition : 18-03-1985
Section 1 : **INFORMATION SHEET**	Page : 01 of 01/15

Duration :	90 minutes.
Training objectives :	After the session the trainees will be able to: - construct a typical surface water treatment scheme; - recite the steps to be taken at the start and the shut down procedure; - mention four important operation procedures; - recite the observations to be made continuously by the operator.
Trainee selection :	- Head of Sub Section Water Treatment; - Water Treatment Plant Operator; - Plant attendant; - Intake attendant.
Training aids :	- Viewfoils : TTO 051/V 1-7; - Handout : TTO 051/H 1.
Special features :	-
Keywords :	Package plants/standard treatment plants/start procedure/water intake/chemical dosing/sludge withdrawl/backwashing/water treatment plant control/shut down procedure.

1. Introduction	
- In Indonesia there are two main types of surface water treatment plants. . package plants as built by: Sumber Tjipta Djaja (STD), Boma Stork (BS), Wijaya Kusuma (WK); . standard treatment plants as built by: Direktorat Air Bersih (DAB).	Use whiteboard
- All plants follow a typical purification scheme comprising : . surface water intake; . coagulation/flocculation; . sedimentation; . rapid filtration; . neutralization; . disinfection.	Show V 1
2. Main Characteristics	
- The main differences between package plants and standard treatment plants are: . the water intake is operated automatically or manually; . the chemical dosing is operated automatically or manually.	Show V 2
3. Starting Procedure	
- The start-up procedure comprises: . preparation of chemical solutions; . performance of the jar test; . calculation of chemical dosing and flow capacities; . start the intake pumps; . adjustment of raw water flow; . start chemical dosing; . checking and, if necessary, adjustment of chemical flows.	Use whiteboard

4. Operation Procedures

- Package plant STD: (Show V 3)
  - . alum is added for coagulation, in the inlet pipe;
  - . soda ash is added for pH correction;
  - . mechanical flocculators are used;
  - . sedimentation takes place in a tray settler unit;
  - . the backwash water of the filter takes the impurities at the filter and tray settler to the sludge outlet;
  - . surface washing can be applied to loosen the impurities at the top of the filter-bed;
  - . kaporit is added to the clear water for disinfection.

- Package plant BS: (Show V 4)
  - . alum is dosed for coagulation, in the inlet pipe;
  - . flocculation is favoured by corrugated plates;
  - . sedimentation takes place in tube settlers;
  - . rapid filtration is at a constant rate;
  - . backwashing is performed by an additional air scour;
  - . soda ash is dosed for neutralization;
  - . kaporit is dosed for disinfection.

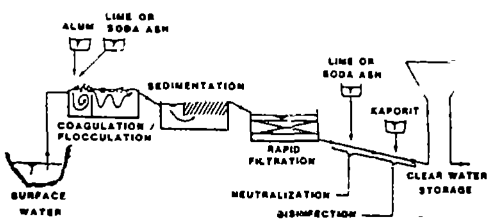
- Package plant WK: (Show V 5)
  - . alum is dosed for coagulation, in the inlet pipe;
  - . flocculation and sedimentation are combined in a sludge blanket unit;
  - . rapid filtration takes place at a constant rate;
  - . backwashing is performed by an additional air scour;
  - . soda ash is dosed for neutralization;
  - . kaporit is dosed for disinfection.

- Concrete water treatment plant DAB: . alum is dosed for coagulation, at an overflow weir; . flocculation is obtained by hydraulic chambers; . sedimentation takes place at tilted plates; . rapid filtration takes place at a declining rate; . filters are backwashed one by one with the product water of the other filters; . lime is dosed for neutralization; . kaporit is dosed for disinfection.	Show V 6
- Steel water treatment plant DAB: . alum is dosed for coagulation, at an overflow weir; . flocculation is obtained by hydraulic chambers; . sedimentation takes place at tilted plates; . rapid filtration takes place at a declining rate; . filters are backwashed one by one with the product water of the other filters; . lime is dosed for neutralization; . kaporit is dosed for disinfection.	Show V 7
5. **Water Treatment Plant Control**	
During operation:	Use whiteboard
- The following observations have to be made continuously by the operator: . raw water is flowing to the intake; . raw water is flowing into the plant; . chemical solutions are dosed; . flocs occur in the flocculator; . sediment is accumulating in the settler; . sludge withdrawal occurs properly; . water level in the filters is rising slowly.	Show V 1 Point at the places that require observation

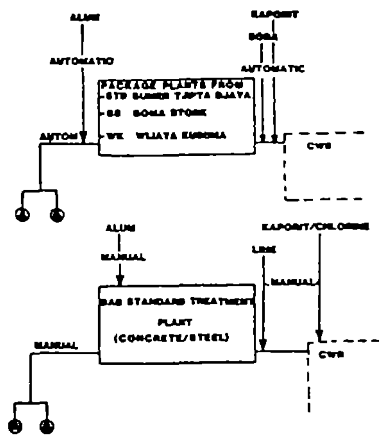
- The following figures must be obtained several times per day by the operator: . raw water flow Q; . alum dosing flow q1; . alkaline dosing flow q2; . kaporit dosing flow q3; . water level in clear water reservoir; . pH and turbidity of raw water, settled water, filtered water and clear water; . free and total chlorine in distributed water; . amounts of chemicals used; . amounts of chemicals in stock.	Use whiteboard Show V 1 Point at the places where figures must be obtained
- The following daily activities are required for proper operation : . execute the jar test and adjust the coagulant dose if necessary; . prepare chemical solutions; . execute sludge withdrawal if not done automatically; . execute backwashing if not done automatically; . remove sediments from the dosing tanks and flocculators; . write any action in the logbook.	Use whiteboard
6. **Shut Down Procedure**	
- The shut down procedure comprises the following steps: . stop the intake pumps; . stop the dosing of chemicals if not done automatically.	
- Shut Down Procedure is required when: . the clear water reservoir is filled; . new chemical solutions have to be prepared; . the intake pumps are not able to abstract water; . repair of one treatment unit is necessary; . cleaning of the plant is necessary.	Use whiteboard
7. **Summary**	Give H 1

Module :	OPERATION OF WATER TREATMENT FACILITIES - SURFACE WATER	Code :	TTO 051
		Edition :	18-03-1985
Section 3 :	T R A I N I N G A I D S	Page :	01 of 02

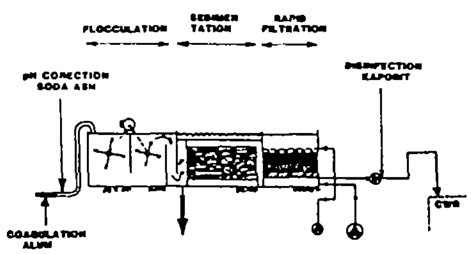
Surface water treatment — TTO 051/V 1



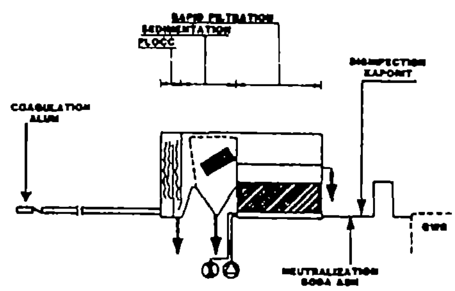
Operation of water treatment plant — TTO 051/V 2



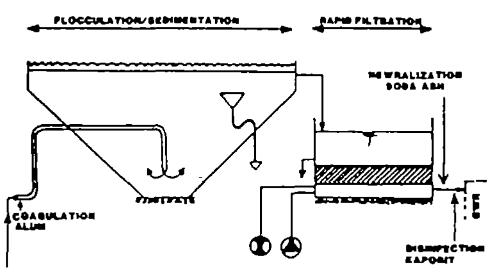
Package plant "STD" — TTO 051/V 3



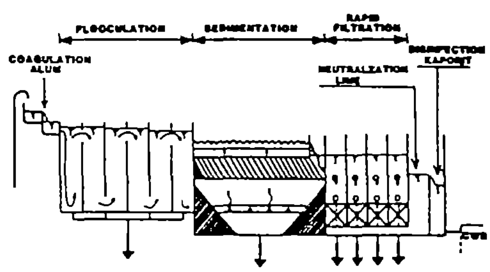
Package plant "BS" — TTO 051/V 4



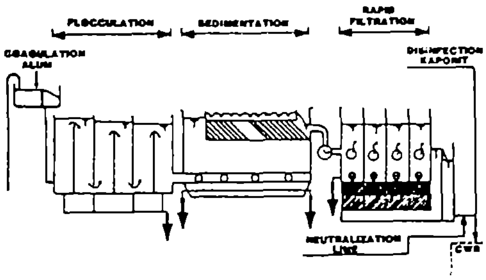
Package plant "WK" — TTO 051/V 5



Concrete water treatment plant (DAB) — TTO 051/V 6



Steel water treatment plant (DAB) TTO 051/V 7



Operation of surface water treatment plants TTO 051/H 1

1. INTRODUCTION

This module deals with the main characteristics of 2 types of surface water treatment plants namely:

- Package plants as built by contractors like:
  - . Sumber Tjipta Djaja (STD plant);
  - . Boma Stork (BS plant);
  - . Wijaya Kusuma (WK plant).
- Standard treatment plants in concrete or steel as built by the Direktorat Air Bersih (DAB plants).

For all plants the purification process follows a typical scheme for surface water treatment containing Coagulation - Flocculation - Sedimentation - Rapid Filtration - Neutralization and Disinfection processes.

2. MAIN CHARACTERISTICS

The next table summarizes the main characteristics of the various plants.

Table

Plant	STD	BS	WK	DAB
Coagulant	Alum	Alum	Alum	Alum
Rapid mixing	Pipe injection	Pipe injection	Pipe injecton	Overflow weir
pH correction	Soda ash	-	-	-
Flocculator	Mechanical rakes	Corru-gated plates	Sludge blanket unit	Hydraulic chambers
Settler	Trays	Tilted plates	Sludge blanket unit	Tilted plates
Rapid filtration	Constant rate	Constant rate	Constant rate	De-clining rate
Neutr. agent	-	Soda ash	Soda ash	Lime
Disinfectant	Kaporit	Kaporit	Kaporit	Kaporit

3. STARTING PROCEDURE

For any surface water treatment plant the start procedure comprises the following steps:

- Preparation of chemical solutions.
- Performance of the jar test in order to determine the optimal dose of coagulant and optimal pH for flocculation.
- Calculation of chemical dosing and flow capacity.
- Start of the intake pumps.
- Adjustment of raw water flow.
- Start of chemical dosing : coagulation, neutralization, disinfection.
- Checking and if necessary adjustment of the chemical flows.

4. OPERATION PROCEDURES

Water Intake

The water intake pumps which transport the water from the surface water intake to the plant are automatically controlled at the package plants STD, BS and WK. At the DAB standard treatment plants the intake pumps have to be started manually.

Chemical Dosing

At the package plants the chemical dosing is started automatically when the intake pumps start working i.e. when water is flowing through the plant. At the standard treatment plant the chemical dosing must be started manually after starting the intake pumps.

Sludge Withdrawal

At all types of plants mentioned, certain amounts of sludge accumulating in the settler unit, have to be removed regularly. The withdrawal is quite different for the various plants and will be discussed separately :

STD : Backwash water from the filters is flowing with high velocities in reversed direction through the settling compartment, taking the settled sludge from the trays to the drain outlet. In this way, filtered impurities and settled sludge are removed at the same time during backwashing (See Fig. 1)

BS : Sludge settled on the tilted plates will move by gravity into the sludge cone. Hydraulically operating valves perform the regular sludge withdrawal from the cone (See Fig. 2).

WK : Sludge will be retained in a sludge blanket near the top of the clarifier. From this blanket a continuous flow of water is taking the retained flocs to the drain. This flow amounts to approximately 2.5% of the incoming main flow (See Fig. 3).

DAB : Sludge settled on the tilted plates will move by gravity to the bottom of the settler unit. Sludge withdrawal is performed from here by manual operation of the drain valves (See Fig. 4 and 5).

Backwashing

Due to an increasing resistance against water moving through the filterbed during the filter run period, the filters have to be backwashed. Backwashing procedures are quite different for the various plants and will be discussed seperately:

STD : In addition to backwashing, surface washing is performed. Both procedures are controlled automatically.
The surface washing is performed in order to loosen impurities that stick to the relatively fine sand grains in the top of the filter bed.

BS/WK : Backwashing is performed with an additional air scour, by manual operating pump and blower. The backwash procedure must be started when the maximum water level in the filters is reached.

Note:
During backwashing of the package plants, the water intake and chemical dosing is automatically out of operation.

DAB : Backwashing of the filters is performed one by one by closing the inlet valve and opening the drain valve of the filter to be backwashed. In this situation, the filtered water from the remaining filters is flowing through the filter that is backwashed.
Contrary to the package plants the water intake is continued, in order to provide a sufficient amount of backwash water.

5. WATER TREATMENT PLANT CONTROL

During operation:

- The following observations have to be made by the operator continuously:
  . raw water is flowing to the intake;
  . raw water is flowing into the plant;
  . chemical solutions are dosed;
  . flocs are formed in the flocculator;
  . sediment is accumulating in the settler;
  . sludge withdrawal occurs properly;
  . water level in the filters is rising slowly.

- The following figures must regularly be obtained by the operator (many times per day):
  . raw water flow Q;
  . alum dosing flow q1;
  . alkaline dosing flow q2;
  . kaporit dosing flow q3;
  . water level in clear water reservoir;
  . pH and turbidity of raw water, settled water, filtered water and clear water;
  . free and total chlorine in distributed water;
  . amounts of chemicals used;
  . amounts of chemicals present.

- The following daily activities are required for proper operation:
  . execute the jar test and adjust the alum dose if necessary;
  . prepare chemical solutions;
  . execute sludge withdrawal if not done automatically;
  . execute backwashing if not done automatically;
  . remove sediments from the dosing tanks and flocculators;
  . write any action in the log book.

6. SHUT DOWN PROCEDURE

The shut down procedure comprises the following steps:
- Stop the intake pumps;
- Stop the dosing of chemicals if not done automatically.

The shut down procedure is required when:
- The clear water reservoir is filled;
- New chemical solutions have to be prepared;
- The intake pumps are not able to abstract water;
- Repair of one unit is necessary;
- Cleaning of the plant is necessary.

7. SUMMARY

The operation of surface water treatment plants is discussed for package plants and standard treatment plants. All plants require certain start-up and shut-down procedures and main operation procedures like water intake, chemical dosing, sludge withdrawal and backwashing. Water treatment control must be carried out to control the purification process.

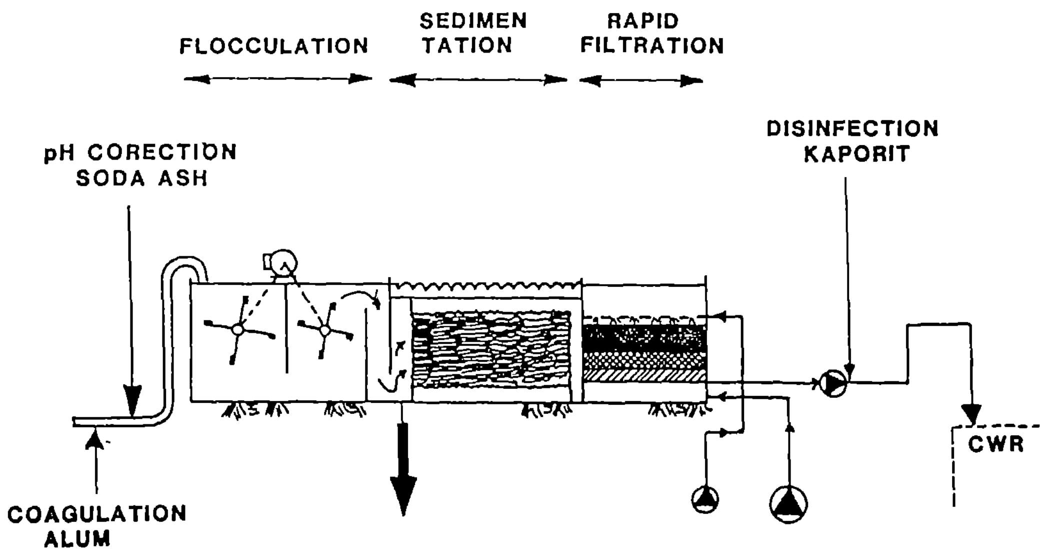


Fig. 1. Principles of STD plant.

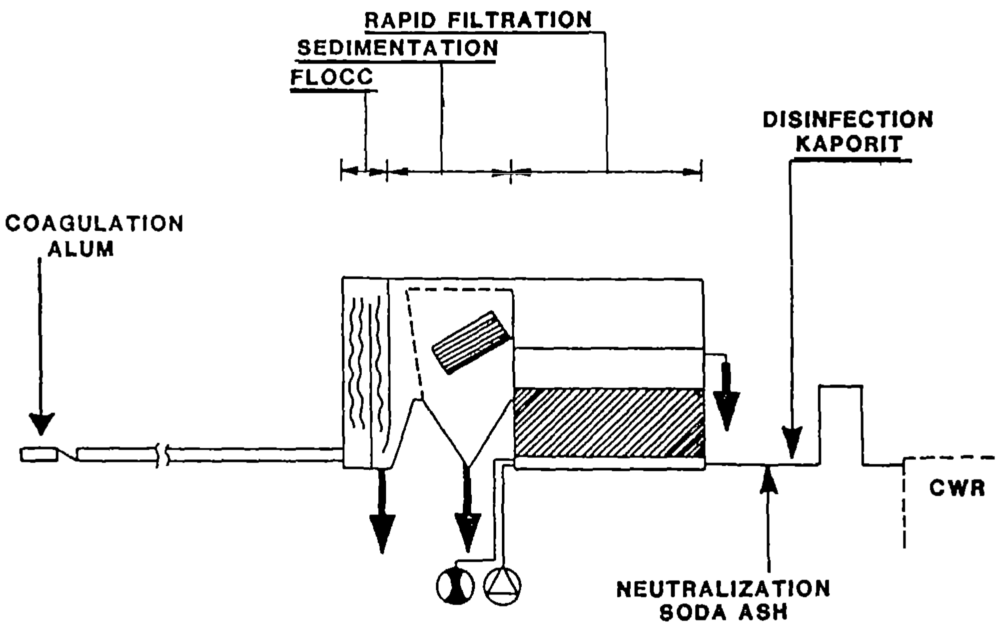


Fig. 2. Principles of BS plant.

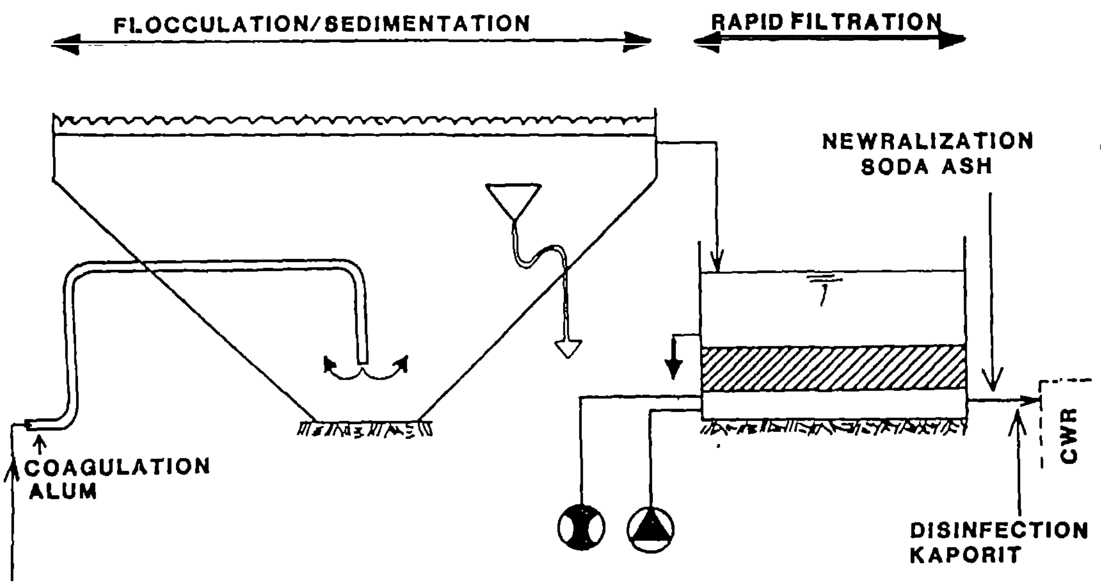


Fig. 3. Principles of WK plant.

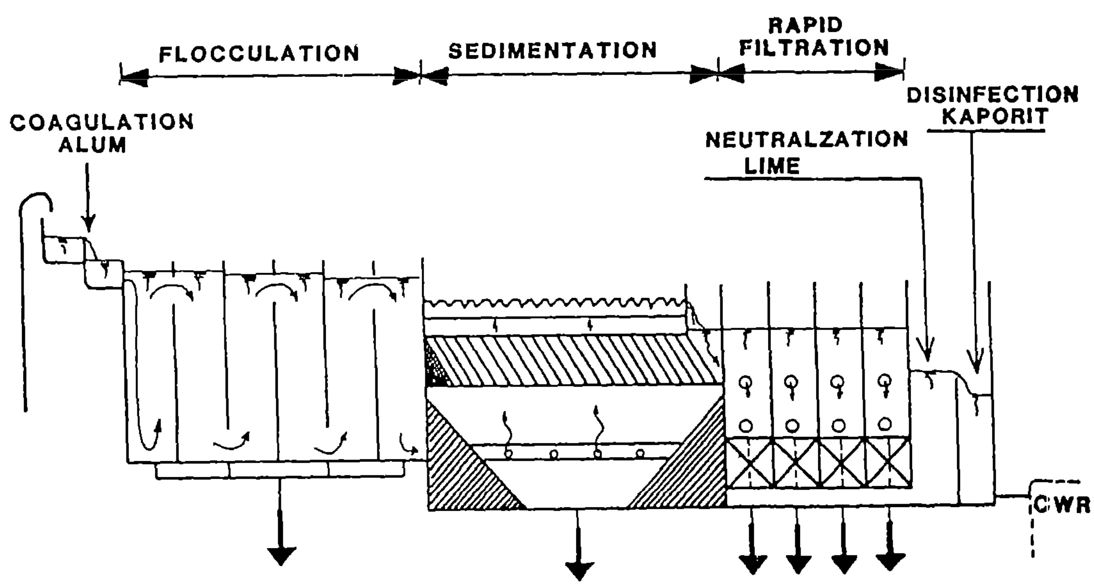


Fig. 4. Principles of DAB plant (concrete).

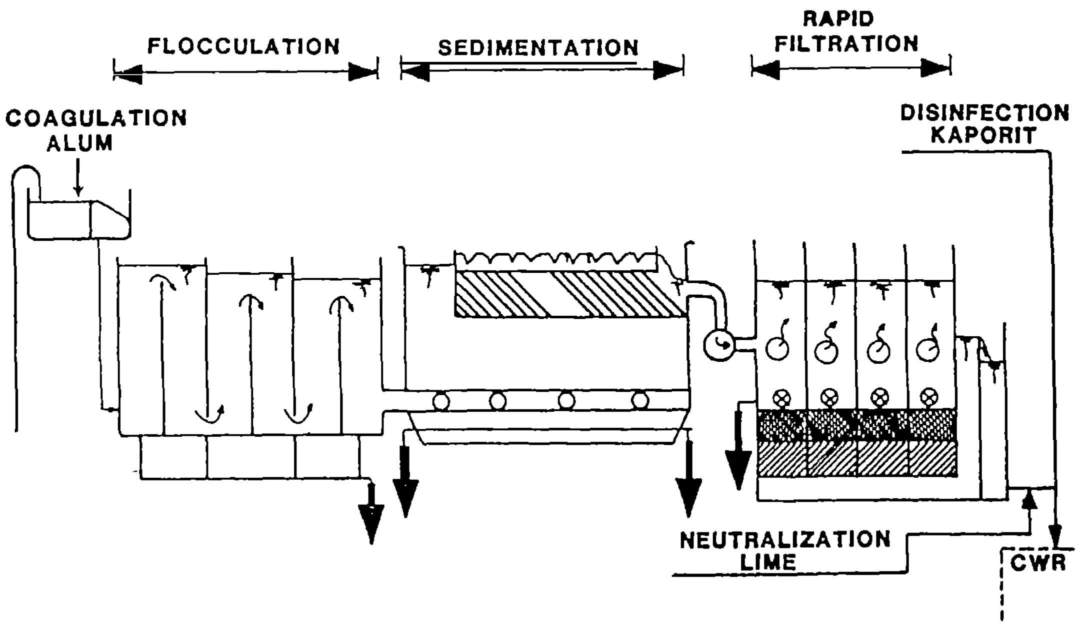
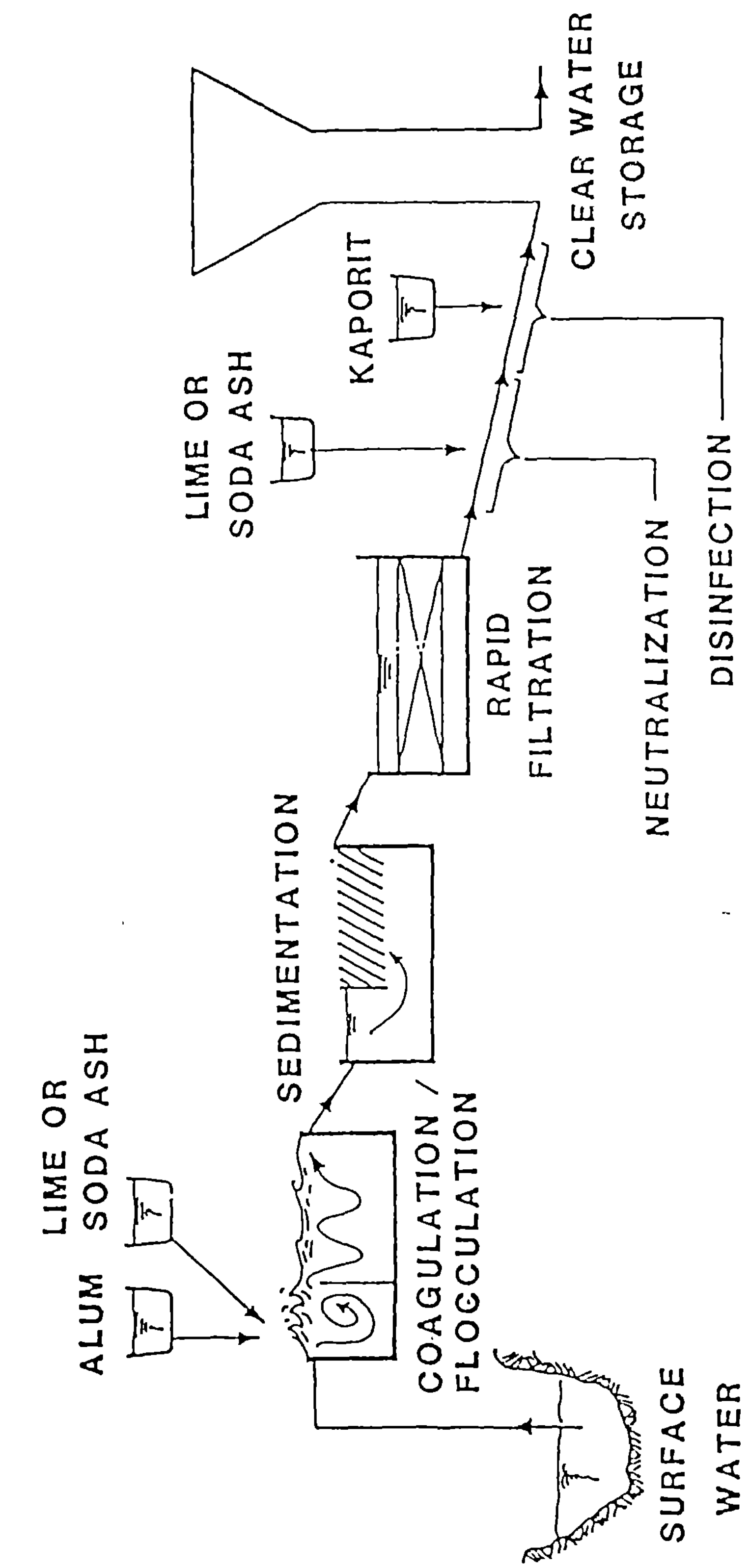
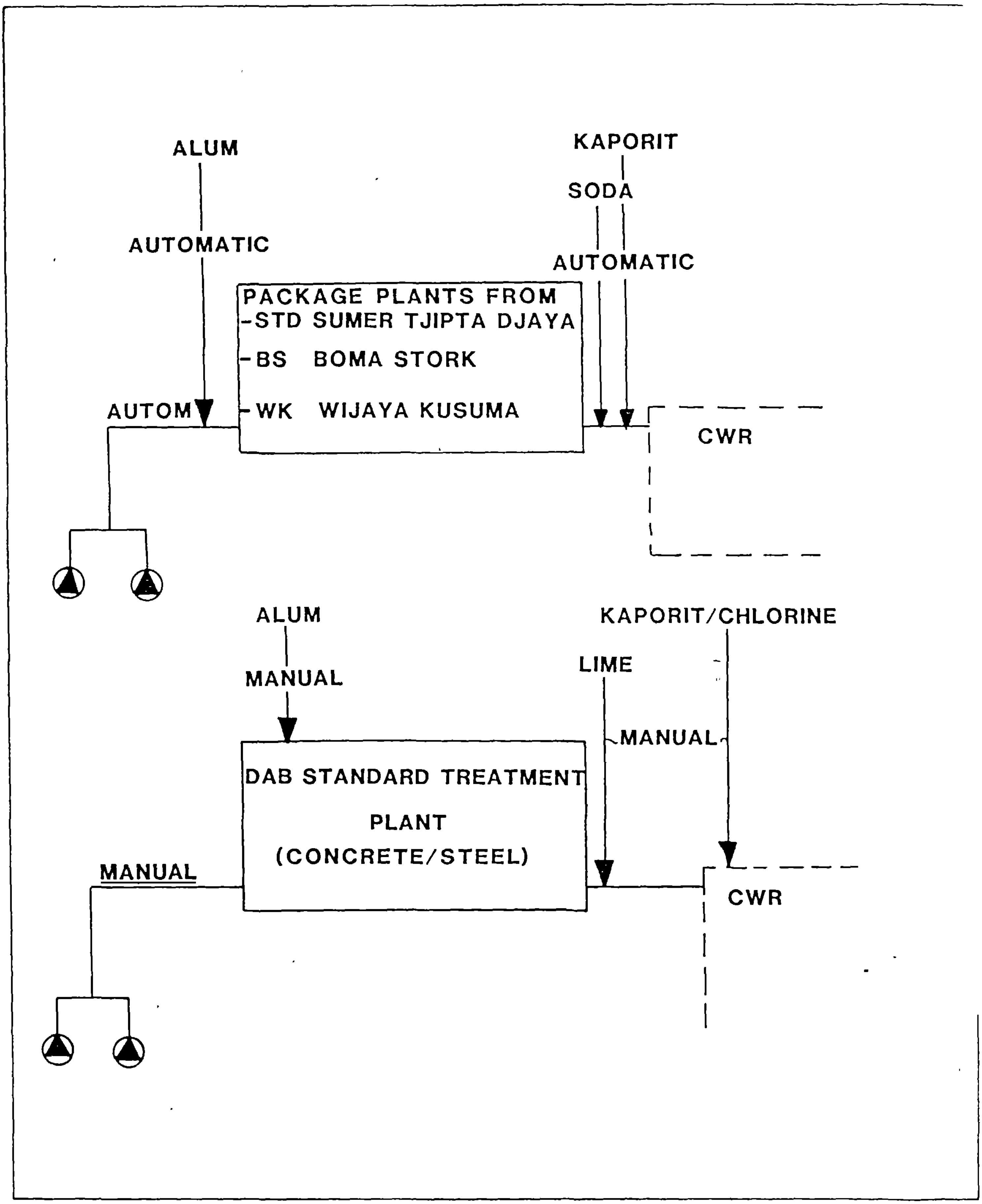


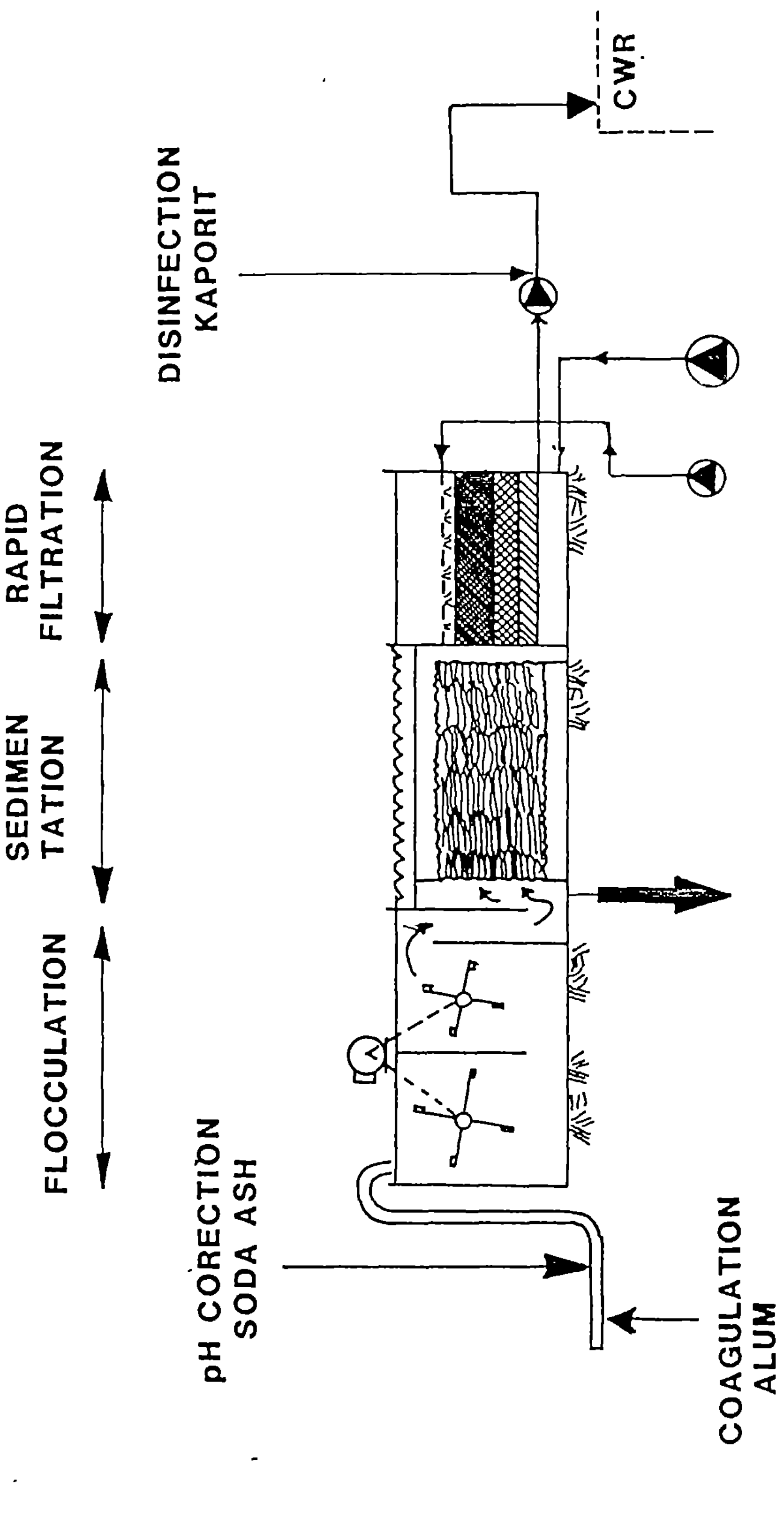
Fig. 5. Principles of DAB plant (steel).

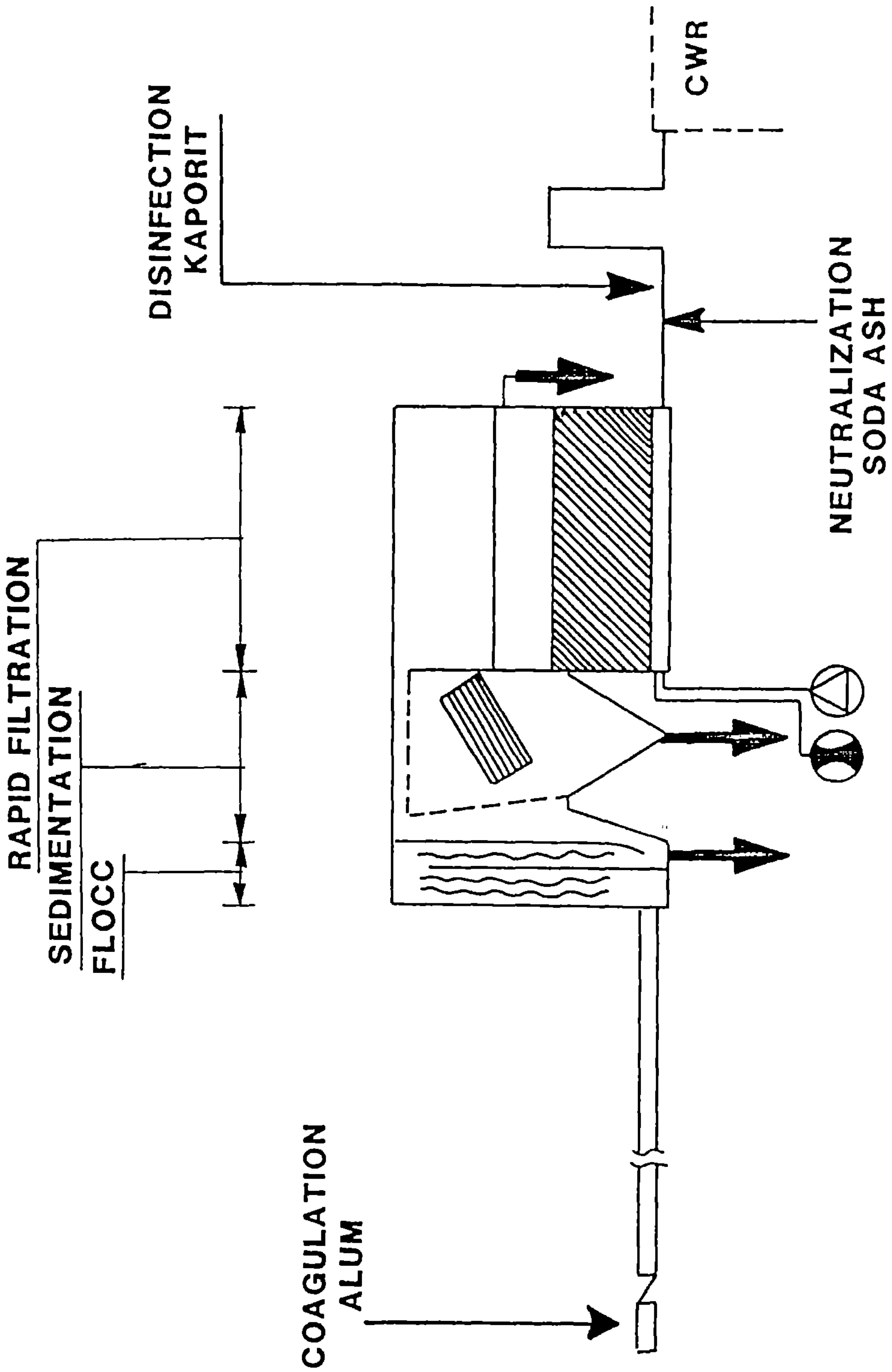
* * *

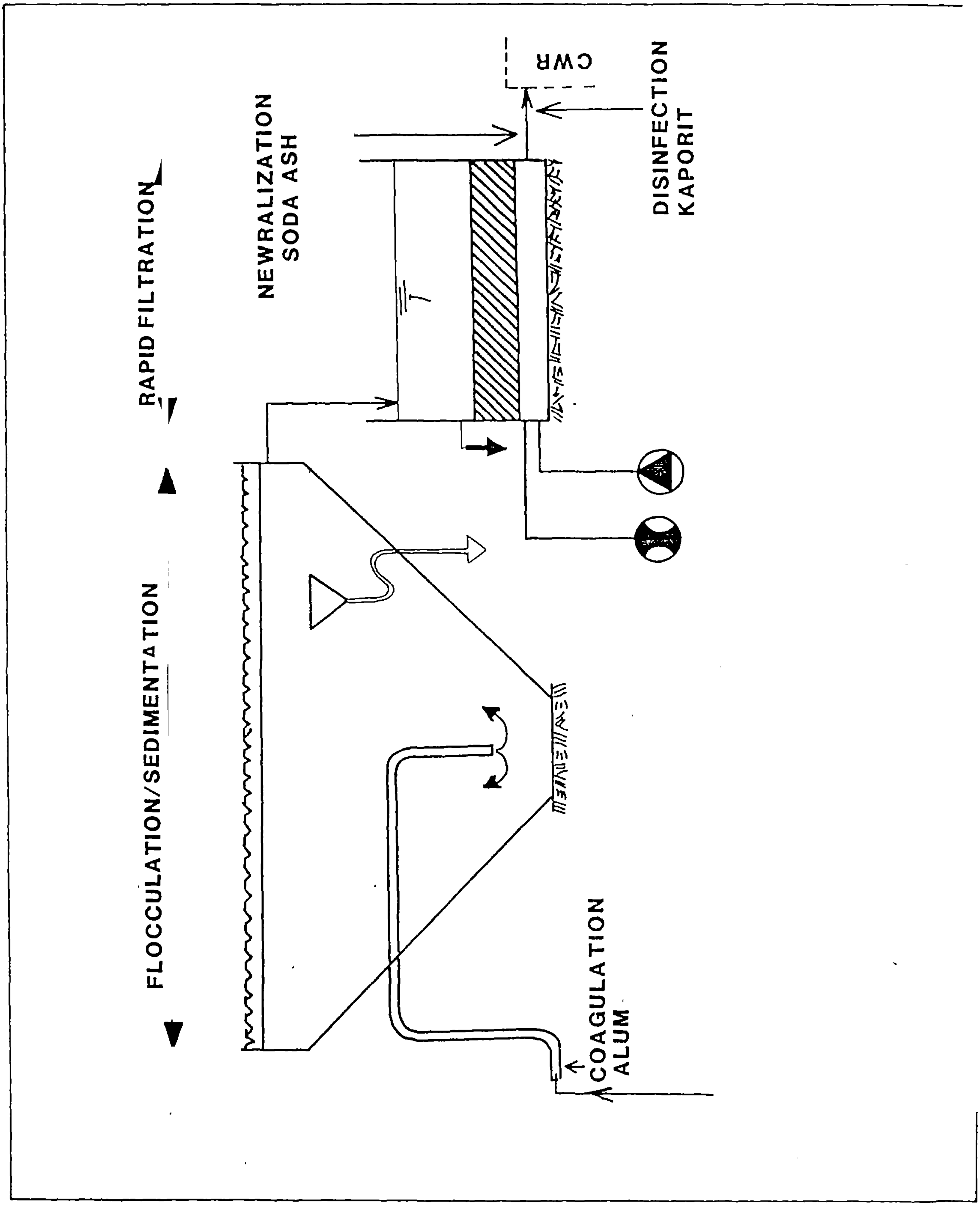
TITLE :	CODE :
1. Surface water treatment	TTO 051/V 1
2. Operation of water treatment plants	TTO 051/V 2
3. Package plant "STD"	TTO 051/V 3
4. Package plant "BS"	TTO 051/V 4
5. Package plant "WK"	TTO 051/V 5
6. Concrete water treatment plant (DAB)	TTO 051/V 6
7. Steel treatment plant (DAB)	TTO 051/V 7


SURFACE WATER
ALUM
LIME OR SODA ASH
COAGULATION / FLOCCULATION
SEDIMENTATION
RAPID FILTRATION
LIME OR SODA ASH
NEUTRALIZATION
KAPORIT
DISINFECTION
CLEAR WATER STORAGE

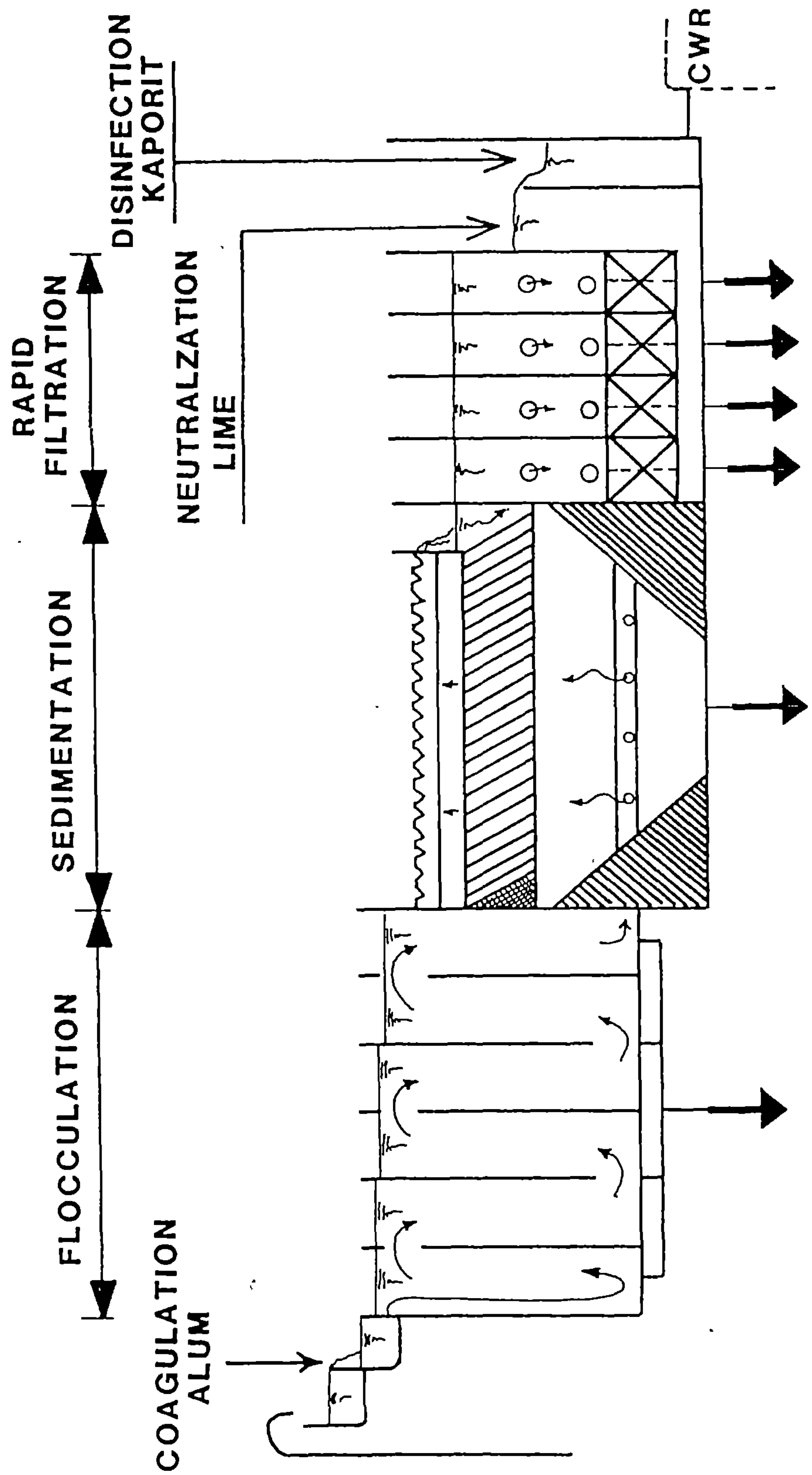

ALUM
AUTOMATIC
KAPORIT
SODA
AUTOMATIC
PACKAGE PLANTS FROM
-STD SUMER TJIPTA DJAYA
-BS BOMA STORK
-WK WIJAYA KUSUMA
AUTOM
CWR
ALUM
MANUAL
KAPORIT/CHLORINE
LIME
MANUAL
DAB STANDARD TREATMENT
PLANT
(CONCRETE/STEEL)
MANUAL
CWR

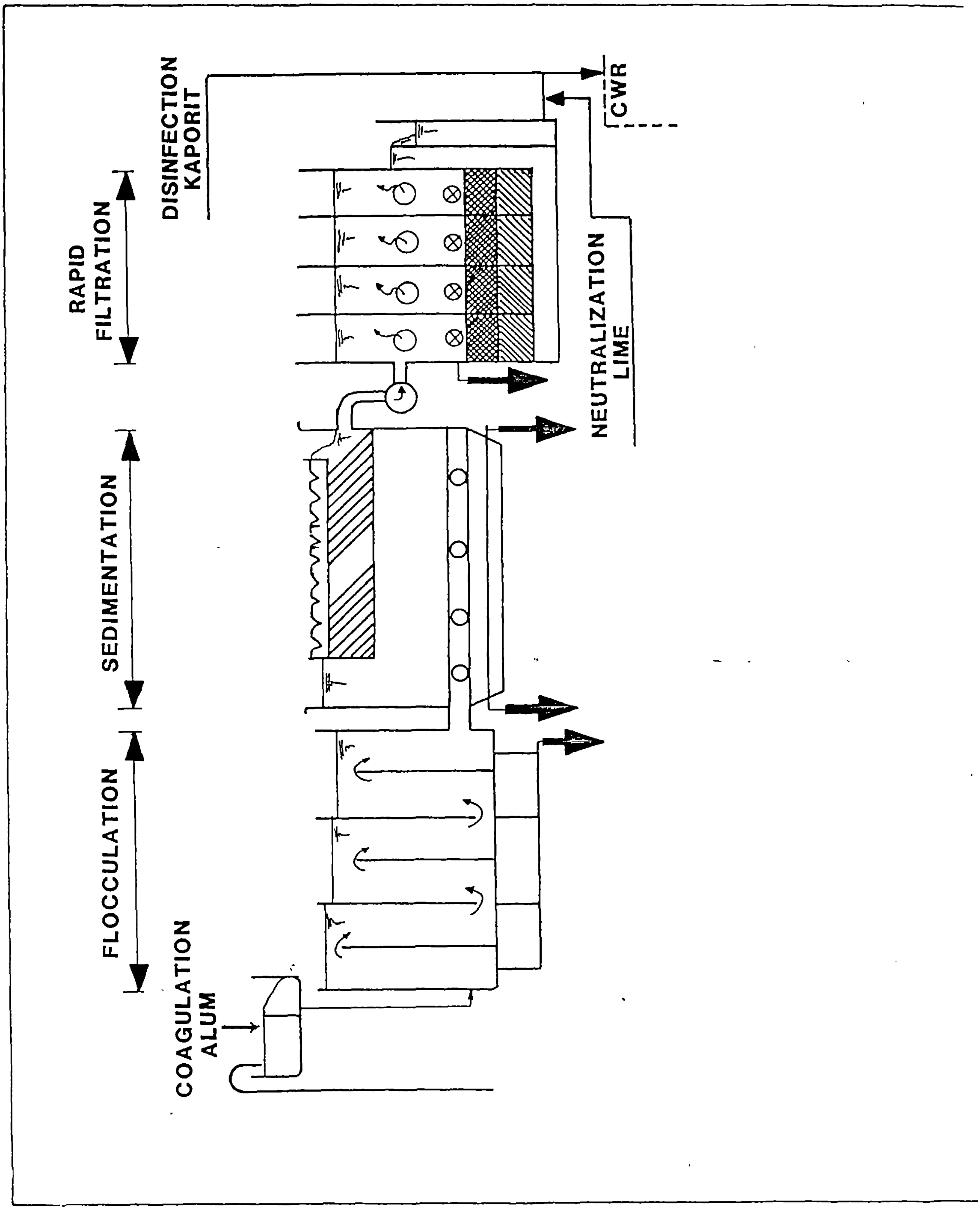

CWR
DISINFECTION
KAPORIT
RAPID
FILTRATION
SEDIMEN
TATION
FLOCCULATION
pH CORECTION
SODA ASH
COAGULATION
ALUM


CWR
DISINFECTION
KAPORIT
NEUTRALIZATION
SODA ASH
RAPID FILTRATION
SEDIMENTATION
FLOCC
COAGULATION
ALUM


RAPID FILTRATION
NEWRALIZATION
SODA ASH
CWR
DISINFECTION
KAPORIT
FLOCCULATION/SEDIMENTATION
COAGULATION
ALUM

Concrete water treatment plant (DAB)




DISINFECTION
KAPORIT
CWR
RAPID
FILTRATION
NEUTRALIZATION
LIME
SEDIMENTATION
FLOCCULATION
COAGULATION
ALUM

Module : JAR TEST	Code : TTO 205
	Edition : 18-03-1985
Section 1 : INFORMATION SHEET	Page : 01 of 01/20

Duration :	45 minutes.
Training objectives :	After the session the trainees will be able to: - recite the purpose, application and functioning of jar test equipment; - recite the procedures for jar test experiments: - perform jar tests and evaluate jar test results.
Trainee selection :	- Head of Technical Department; - Head of Section Production; - Head of Sub-section Water Treatment; - Operator; - Head of Sub-section Laboratory; - Laboratory Assistant.
Training aids :	- Jar test equipment; - Turbidity meter; - pH-meter; - Laboratory glassware; - Audiovisual on Jar tester and Jar test experiments; - Viewfoils : TTO 205/V 1-9; - Handout : TTO 205/H 1.
Special features :	This module shall preferably be used together with the Module "Coagulation/flocculation" and the Audiovisual "Jar tester and Jar test experiments".
Keywords :	Jar test/jar tester.

1. Introduction

- Purpose of jar test: (Show V 1)
  - evaluation of coagulation/flocculation processes.

- Application of jar tests:
  - optimization of coagulation/flocculation processes in existing treatment plants;
  - design of new treatment plants;
  - upgrading/revision of existing plants.

- Output of jar tests: (Show V 2)
  - optimum dosing procedures;
  - optimum doses of chemicals;
  - optimum duration and intensity of mixing;
  - optimum duration of clarification.

2. Description of jar test equipment

- Essential parts: (Show V 3)
  - adjustable motor;
  - stirring rods with impellors (rotors);
  - jars.

- Optional parts: (Show V 4)
  - stators;
  - dosing of funnels for chemicals;
  - siphons for sample withdrawal;
  - bar with test-tubes.

- Suitable jar test equipment for small to medium sized treatment works:
  - Phipps and Bird, type 7790-200;
  - HACH, Type 15.057-02.

- Additional laboratory equipment:
  - Turbidity meter;
  - pH meter;
  - Thermometer;
  - Balance;
  - Laboratory glassware;
  - Miscellaneous laboratory equipment.

3. Jar test procedures

1. Limitations:
   - presented jar test procedures are applicable for:
     . determination of optimum alum dose;
     . determination of optimum pH-range;
   - presented jar test procedures are based on jar tester with 4 jars.

2. General preparations: — Show V 5
   - preparation of 1% alum solution;
   - preparation of 0.36% caustic soda solution;
   - collection of raw water sample.

3. Determination of optimum alum dose: — Show V 6
   - preparation of alum and caustic soda doses to jars;
   - filling of jars with raw water sample;
   - rapid mixing and dosing of chemicals;
   - slow mixing (flocculation);
   - clarification;
   - withdrawal of samples;
   - determination of turbidity, pH, temperature;
   - graphical interpretation of results. — Show V 7

4. Determination of optimum pH:
   - preparation of alum and caustic soda doses;
   - filling of jars with raw water;
   - rapid mixing and dosing of chemicals;
   - slow mixing;
   - clarification;
   - withdrawal of samples;
   - determination of turbidity, pH, temperature;
   - graphical interpretation of results. — Show V 8

4. Evaluation

- Improved jar test results will be obtained by subsequent series of tests using results of previous tests (iterative process). — Show V 9

- Final pH adjustment may be required in order to remove aggressivity caused by alum dosing.

5. **Frequency of jar test**

- Before start-up of treatment plant.
- For properly functioning treatment plants once per day.
- If treatment plant does not function properly several times per day.

6. **Summary**

Distribute H 1

Purpose and application of jar-test — TTO 205/V 1

☞ PURPOSE OF JARTEST :

Coagulation/flocculation processes evaluation

☞ APPLICATIONS OF JARTEST :

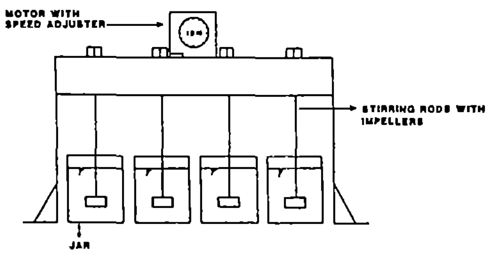
1. Optimizing coagulation/flocculation processes in existing treatment plants
2. Design of new treatment plants
3. Upgrading of existing treatment plants

Possible results of jar-test — TTO 205/V 2

POSSIBLE RESULTS OF JAR TEST :

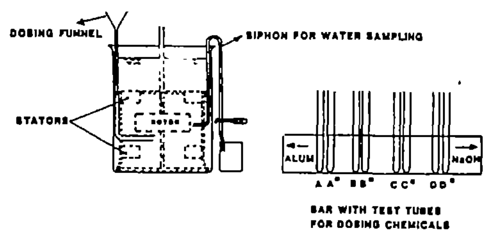
1. OPTIMAL DOSES OF CHEMICALS :
   - alum dose
   - pH range (Soda-ash or caustic soda dose)
2. OPTIMAL CHEMICAL DOSING PROCEDURES
   - Simultaneous or subsequent dosing of various chemicals on or beneath water surface
   - Dosing location in relation to mixing device
   - Solution strength of chemical solutions
3. OPTIMAL INTENSITY AND DURATION OF MIXING
4. OPTIMAL SEDIMENTATION PERIOD

Main parts of jar-tester — TTO 205/V 3



MAIN PARTS OF THE JAR TESTER

Optional jar-tester equipment — TTO 205/V 4



OPTIONAL JAR TEST EQUIPMENT

Preparation of standard chemical solution — TTO 205/V 5

A. REACTIONS OF ALUM AND CAUSTIC SODA IN WATER

$$Al_2(SO_4)_3 + 6H_2O \longrightarrow 2Al(OH)_3 + 3SO_4^{2-} + 6H^+$$
$$6NaOH + 6H^+ \longrightarrow 6Na^+ + 6H_2O$$
$$Al_2(SO_4)_3 + 6NaOH \longrightarrow 2Al(OH)_3 + 6Na^+ + 3SO_4^{2-}$$

OR: 1 MOLE OF ALUM ∽ 6 MOLES OF CAUSTIC SODA

OR 1 g $Al_2(SO_4)_3 \cdot 18H_2O$ ∽ $\frac{6 \times 40}{666} = 0.36$ g NaOH

B. ALUM SOLUTION AND CAUSTIC SODA SOLUTION

1 % ALUM SOLUTION ∽ 10 GRAMMES OF ALUM PER LITRE OF WATER

0.36 % NaOH SOLUTION ∽ 3.6 GRAMMES OF NaOH PER LITRE OF WATER

C. FROM A AND B :

1 ml ALUM SOLUTION (1 %) ∽ 1 ml NaOH SOLUTION (0.36 %)

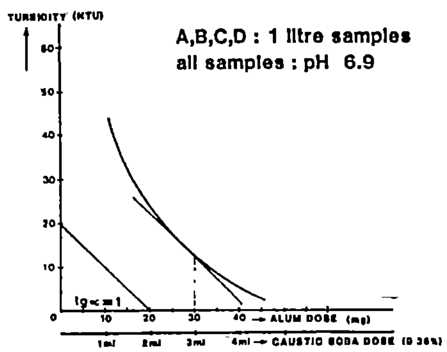
Jar test - alun dosis — TTO 205/V 6

DETERMINING OPTIMAL ALUM DOSING :

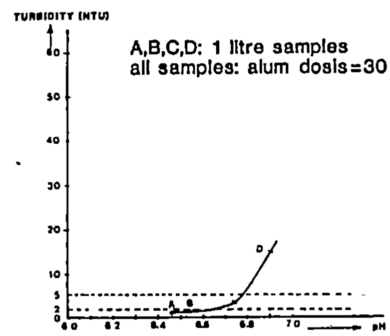
1. prepare chemical solutions
2. pour raw water into jars
3. rapid mixing of chemicals
4. slow mixing
5. sedimentation
6. remove samples
7. determine turbidity, pH, temperature
8. graphical presentation of results

Module : **JAR TEST**	Code : TTO 205
	Edition : 18-03-1985
Section 3 : **T R A I N I N G A I D S**	Page : 02 of 02

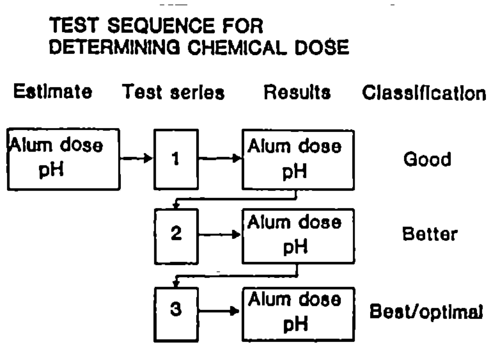
Turbidity and alum dose — TTO 205/V 7



Relation turbidity and pH — TTO 205/V 8



Iterative process — TTO 205/V 9



Jar test — TTO 205/H 1

1. INTRODUCTION

The jar test is a method to evaluate coagulation/flocculation processes. When the test is carefully performed, useful information can be derived to aid the plant operator in optimizing the coagulation, flocculation and clarification processes, and the engineer in designing a new water treatment plant or revising an existing one. The jar test may provide data on the optimum conditions for process parameters such as:
- dosage of coagulant and coagulant aid(s);
- pH;
- method of dosing of chemicals (on or beneath water surface, simultaneous or subsequent dosing of several chemicals, dosing location in relation to mixing device, etc.);
- solution strength of chemical solutions;
- duration and intensity of rapid mixing and slow mixing (flocculation);
- duration of clarification.

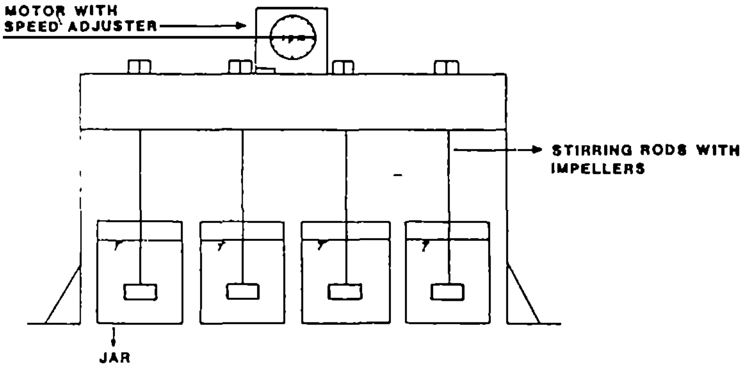
For jar tests the establishment of standardized, fixed procedures is a prerequisite in order to obtain reproducible, meaningful results.

Apart from the the abovementioned process parameters the following variables shall also be carefully monitored and controlled:
- temperature of water in jars;
- turbidity, color and alkalinity of raw and treated water;
- method of sample withdrawal;
- laboratory test equipment and laboratory analysis procedures.

2. APPARATUS

Jar test equipment of various designs is nowadays commercially available. Specific designs allow for accurate monitoring and controlling of various process variables. All jar testers contain the following parts (see also Figure 1):
(i) an adjustable motor which actuates;
(ii) stirring rods with impellors, or rotors; the rotational speed of the rotors is adjustable;
(iii) a beaker glass or jar under each of the rotors.

In addition, the jar tester may contain the following equipment parts:
- stators in each of the jars;
- dosing funnels for chemicals, one for each jar;
- siphons for sample withdrawal, one for each jar;
- a bar with test-tubes for dosing of chemicals to the jars.



MAIN PARTS OF THE JAR TESTER

Fig. 1.

Professional jar testers contain jars, rotors and stators of standard design whereby the intensity of mechanical agitation during rapid mixing and slow mixing (flocculation), expressed in terms of the mean velocity gradient, can be obtained from corresponding tables and graphs. Also less sophisticated jar testers produce relevant results for surveying, monitoring and controlling of coagulation/flocculation processes. Examples of suitable jar testers for small to medium sized treatment plants are the Phipps and Bird, and the HACH jar tester.

The Phipps and Bird, Type 7790-200, jar tester contains four stirring rods and impellors, and allows for four 1 litre jars. The HACH, Type 15.057-02, jar tester applies magnetic stirrers and allows for six jars of 500 ml.

3. APPLICATION

The jar tester can be used for the design of a treatment plant in order to define process parameters such as mixing intensity, rapid and slow mixing periods, sedimentation period, and type and amount of chemicals to be applied as well as location of application. For existing treatment plants the jar tester is mainly used to determine the optimum operational conditions for varying raw water qualities, in particular the appropriate doses of chemicals, while for other process parameters the actual conditions in the treatment plant are simulated.

The various jars of the jar tester allow for comparative investigations into the effects of different conditions for a specific process variable.

In order to monitor the effects of varying of a particular process parameter on the coagulation/flocculation/clarification process, the other process parameters should be kept at the same value for all jars taking part in the comparative study.
For example if a jar test is undertaken to determine the optimum dosage of the coagulant alum for a particular raw water, the following process conditions should be kept identical in all jars:

- the raw water samples;
- the temperature;
- the pH;
- the configuration of the rotors (and stators);
- the configuration of the jars;
- the mixing intensities;
- the mixing periods;
- the sedimentation period.

If the purpose of the jar test is to determine the optimum mixing intensities, different rotors and stators will be applied in the different jars so as to create different mixing intensities. All other process parameters, including the alum dose, then must have the same values in all jars.

For existing treatment plants jar tests are mostly used to determine optimum doses of chemicals for coagulation/flocculation, in particular the optimum dose of the coagulant and conditioning chemicals for pH correction, for different raw water qualities. All other process variables are normally kept at their fixed value. The procedures for the execution of the jar test under such conditions are briefly described in paragraph 4, Procedures. It is thereby assumed that alum is used as coagulant, and caustic soda as conditioning chemical for pH-correction.

4. PROCEDURES

Coagulation and flocculation are the result of the addition of alum to raw water under subsequent rapid and slow mixing conditions. Alum has acidic properties. By adding this chemical to raw water the pH of the raw water will be reduced.
The magnitude of the pH reduction depends on the raw water composition, in particular on its buffering capacity. The pH can have a strong influence on the coagulation/flocculation and the subsequent sedimentation process. The pH can be adjusted by adding a certain amount of the base, such as caustic soda.

In order to investigate the particular influence of both alum and pH on the coagulation/flocculation process by means of the jar tester only one variable at the time should be changed: either the alum concentration or the pH. Therefore actually two comparative investigations have to be executed: one in which the dose of alum to the various jars is varied while the pH is kept constant, and one in which the pH in each of the jars is varied while dosing the same amount of alum.

The test procedures for the determination of the optimum dose of alum, and the optimum value of the pH for coagulation/flocculation of a particular raw water are given below. It is assumed that use is made of a jar tester with four jars labelled A, B, C and D respectively.

I. General preparations

1. Preparation of alum solution and caustic soda solution:
   - preparation of a 1% (by weight) alum solution by dissolving 10 grammes of alum ($Al_2(SO_4)_3.18H_2O$) in 1 litre of distilled water;
   - preparation of a 0.36% (by weight) caustic soda solution by dissolving 3.6 grammes of caustic soda (NaOH) in 1 litre distilled water.

2. Collection of raw water sample:
   - with a bucket take 10 litres of raw water from the river when the plant is not running, or from the inlet to the treatment plant when the plant has been running for several hours;
   - measure and record the pH of the raw water. It is good practice also to determine the EC, alkalinity, calcium content, turbidity and temperature of the raw water. Record the appropriate data on the jar test form. See Figure 2.

II. Determination of optimum alum dose

1. Prepare dosage of 10, 20, 30 and 40 mg of alum to 1 litre of raw water in the jars A, B, C and D by bringing 1, 2, 3 and 4 ml of alum solution in the test-tubes A, B, C and D respectively (use a pipet of 10 ml). Record the appropriate data on the jar test form.

   Note 1: The said quantities of the alum solution are applicable for raw water turbidities up to 500 NTU. For higher turbidities apply double quantities.

DATE : TIME OF SAMPLING : TIME OF TESTING : NUMBER OF SAMPLE : TESTED BY :	RAW WATER SOURCE pH EC (US/Cm) m VALUE (as $CaCO_3$) CALCIUM (as $CaCO_3$)	TURBIDITY (NTU) COLOUR (mg Pt/l) TASTE TEMPERATURE (°C)
ALUM DOSE (gr/l) CAUSTIC SODA DOSE (gr/l)	REMARKS	

No	JAR	ALUM		CAUSTIC SODA		MIXING PERIOD				OBSERVATIONS		TURBIDITY (2)	pH	TEMPERATURE	REMARKS
						RAPID (s)	SLOW (minutes)			FLOCCULATION (1)	SEDIMENTATION (1)				
		mg/l	ml	mg/l	ml	100rpm	60rpm	40rpm	20rpm			(NTU)		(°C)	
1	A														
	B														
	C														
	D														
2	A														
	B														
	C														
	D														
3	A														
	B														
	C														
	D														
4	A														
	B														
	C														
	D														
5	A														
	B														
	C														
	D														
6	A														
	B														
	C														
	D														

1. Legend: + + + = very good; + + = good, + = fair; - = weak; - - = poor; - - - = very poor
2. See footnote 1 if there is no turbidity meter available.

Fig. 2.

2. In order to compensate for pH reduction of raw water after dosing of alum, prepare dosage of 3.6 mg, 7.2 mg, 10.8 mg and 14.4 mg of caustic soda to 1 litre of raw water in the jars A, B, C, and D, by bringing 1, 2, 3, and 4 ml of caustic soda solution in the test-tubes A*, B*, C*, and D*, respectively (use a pipet of 10 ml).

   Note 2: See Note 1, if alum doses are doubled also caustic soda doses are doubled.

   Note 3: For raw waters with pH values above 7 a complete neutralization of the acid produced by alum is not recommendable since practical experience has shown that for alum the coagulation/flocculation process performs best in the pH-range 6-7. At raw water pH-values above 7 the caustic soda dose can be reduced by 50% (or 0.5 ml caustic soda solution for each ml of alum solution).

3. Mix the raw water sample thoroughly and fill each of the jars A, B, C, and D with exactly 1 litre of raw water.

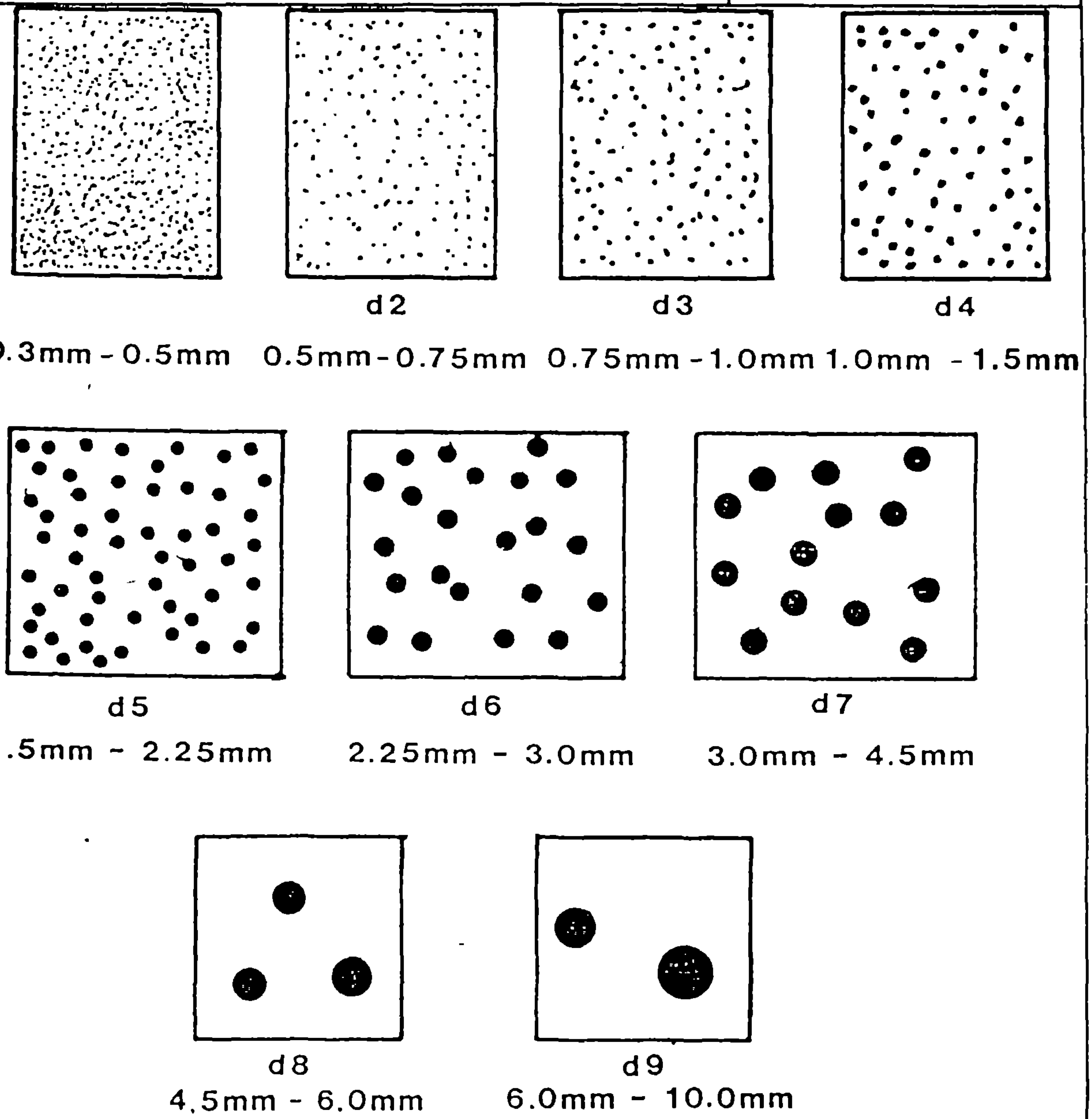
4. Place the jars under the corresponding rotors, insert the rotors in the jars, and start and adjust motor to 100 r.p.m.

5. Add simultaneously the contents of the test-tubes (A+A*, B+B*, C+C*, D+D*) to the corresponding jars; simultaneously start a stopwatch and continue the rapid mixing for 30 seconds. Make sure that the test tubes are completely emptied, or rinse with distilled water and add to corresponding jars within the 30 seconds of rapid mixing period.

   Note 4: In order to simulate actual process conditions in a treatment plant a different period of rapid mixing may be applied.

6. After 30 seconds of rapid mixing, reduce mixing intensity to 40 r.p.m. for flocculation. Keep this mixing intensity for 20 minutes. Observe the appearance of flocs and classify the flocs in each jar by using the Floc Size Chart (see Figure 3). Record the data on the jar test form.

   Note 5: In order to simulate process conditions in a treatment plant different procedures for slow mixing may be applied, e.g. 3 intervals of 6 minutes each with subsequent mixing intensities of 60, 40, and 20 r.p.m.



NOTE : WATER BETWEEN FLOCS WILL BE CLEAR
IF NOT, REPEAT THE TEST
WITH A HIGHER ALUM AND/OR DIFFERENT
SODA ASH DOSE (DIFFERENT pH VALUE)

Fig. 3.

7. After 20 minutes of slow mixing (flocculation):
   (i) stop the mixers;
   (ii) remove them from the jars, and
   (iii) allow the formed flocs to settle in the jars during 20 minutes.

   Note 6: In order to simulate actual process conditions in a treatment plant a different period of clarification can be applied.

8. After 20 minutes of clarification carefully transfer a 200 ml sample of each jar into a clean beaker glass of 250 ml by siphoning (with inlet of siphon approx. 2 cm below water surface) and carry out the following laboratory measurements for each of the four samples:
   - turbidity;
   - pH;
   - temperature.

   Record all data on the jar test form.

9. Prepare a graph of turbidity versus alum dose, i.e. plot the turbidities of the clarified water from the jars A, B, C and D against the alum doses for these jars. See Figure 4.

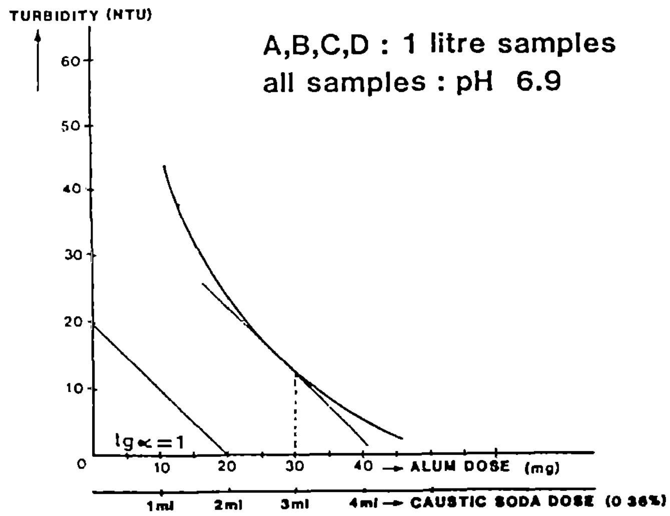


Fig. 4. Graph of clarified water turbidities versus alum doses.

10. Determine the optimum alum dose as follows:

    (i) draw the tangent line to the graph, that has an inclination with a tangent value of 1;
    (ii) from the graph read which alum dose corresponds with the intersection of graph and tangent line. This alum dose is considered the optimum alum dose resulting from the first jar test.

    Note 7: For the selected alum dose an increase of the dose by 1 mg/l will exactly result in an increase of turbidity removal by 1 NTU. For higher alum doses the effect on turbidity removal is gradually decreasing. It is obvious that the procedure mentioned under (i) and (ii) for determining the optimum alum dose is partly based on an economic criterion, and needs to be checked further on its technical applicability in subsequent tests.

    Note 8: If no tangent line as specified above can be drawn to the graph the coagulation/flocculation of the raw water is incomplete and a new test will have to be carried out with higher alum doses and/or lower pH-values.

III. **Determination of optimum pH**

All parts of the jar tester shall be cleaned thoroughly before the test for the determination of the optimum pH is undertaken.

1. Prepare dosage of optimum alum dose (see II; optimum alum dose is x mg per litre raw water) to each of the jars by bringing x ml of alum solution in each of the test-tubes A, B, C, and D.

2. In order to create different pH values in each of the jars, prepare dosage of caustic soda doses that will neutralize 0%, 20%, 50% and 100% of the acid production of the alum dose, by bringing 0 ml, 0.2x ml, 0.5x ml and x ml of caustic soda solution in the test tubes A*, B*, C*, and D*, respectively.

3. See II.3.

4. See II.4.

5. See II.5.

6. See II.6.

7. See II.7.

8. See II.8.

9. Prepare a graph of turbidity versus pH, i.e. plot the turbidities of the clarified water from the jars A, B, C, and D against the pH values of the clarified water in these jars. See Figure 5.

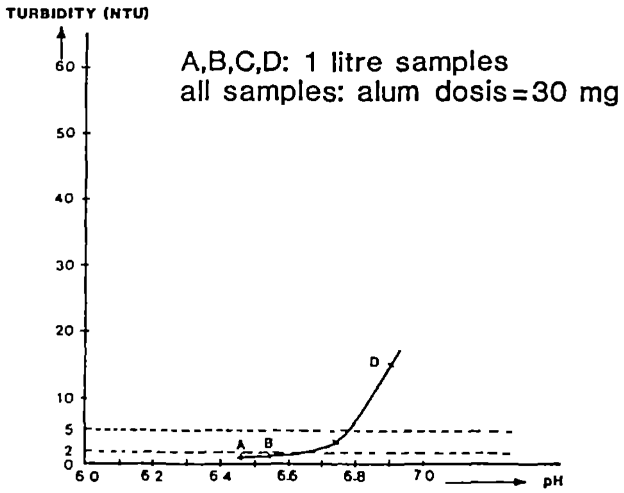


Fig. 5. Graph of turbidities of clarified water versus pH values.

10. Determine the optimum pH value as follows:

    (i) Draw horizontal lines on the graph for Turbidity = 5 NTU and Turbidity = 2 NTU, and read the pH values at the intersections of these lines with the graph.

    (ii) The pH-range for which the turbidity is between 2-5 NTU is considered the optimum pH-range for coagulation/flocculation. Normally this pH range will amount to approx. 0.3 pH units.

5. EVALUATION

1. Optimum chemical dosages

The tests described under II and III normally produce satisfactory results for a first estimate of the optimum coagulant dose and optimum pH-range for coagulation/flocculation. Jar test experiments have, however, an iterative character. Often more series of tests are required. By repeating the tests with doses slightly higher and lower than the "optimum" doses found during the first series of tests more accurate data on the optimum chemical doses and optimum pH-range may be found. See also Figure 6.

For example, if the test for the determination of the optimum alum dose (see II) would now be repeated while applying the optimum pH values (see III), it may be found that the optimum alum dose is 0.8x mg alum per litre of raw water. This would result in 20% savings in alum consumption.

For subsequent test to determine the optimum alum dose while observing the optimum pH-range (as found in III) normally the following dosages are applied (assuming an optimum dose of x mg alum per litre of raw water found in II, series 1):

- series 2 : x-30%, x-20%, x-10%, and x mg alum in jars A, B, C and D, respectively;
  output : new optimum dose of y mg alum;
- series 3 : y-10%, y-5%, y, and y+5% mg alum in jars A, B, C and D respectively;
  output : new optimum dose of z mg/l.

2. pH adjustment

The jar tests may indicate that for coagulation/flocculation/sedimentation no or only partial pH adjustment is desirable in conjunction with the alum addition, in order to obtain a good purification of the water. By adding the alum the acidity of the water has, however, been increased and it may now have obtained an aggressive character towards materials applied in the treatment works, transmission system and distribution system.

This in turn will cause operation and maintenance problems, as well as costs for repairs and replacements. The secondary effects of possible corrosion in the system on the water quality should also be taken into account. Therefore a further pH adjustment shall be carried out after the sedimentation. This can be done before or after the final filtration process, depending on possible additional treatment.

TEST SEQUENCE FOR DETERMINING CHEMICAL DOSE

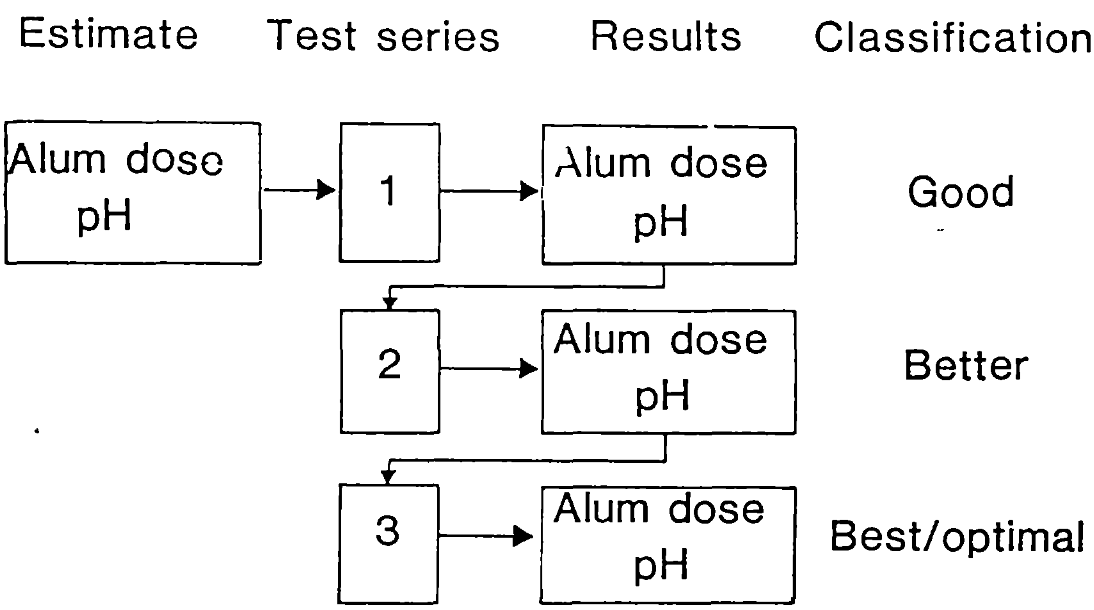


Fig. 6.

3. Floc formation

Both during and after the jar testing a number of observations are made in order to assess the efficiency of the treatment process. Already at an early stage of the flocculation, commonly some 1 minute after the chemical injection, first floc growth can be distinguished. As the test continues, these very fine flocs gradually increase in size while the water between the floc becomes clear.

In a properly executed test the clear water becomes evident after some 3.5 to 5 minutes; its absence is a definite indication that the chemical dosing or the pH was incorrect. The growing flocs can be light and fluffy or well compacted. The light and fluffy flocs tend to have poor settling characteristics and are deemed undesirable because of their fragility. Even a minor disturbance will disrupt this type of floc.

Generally the fluffy type of flocs is observed in combination with pin point flocs left in the water after the majority of the flocs have settled. Pin point flocs are undersized flocs, of a diameter normally below 0.5 mm, which have not been recombined into larger compounds. Unfavourable mixing conditions during flocculation may be the cause of these flocs. More likely, however, it is an incorrect alum dosing or pH of the sample.

6. FREQUENCY OF JAR TESTING

The frequency of the execution of jar tests strongly depends on the variations and fluctuations in the raw water quality (turbidity, type of suspended and colloidal matter). Usually, directly before or immediately after the start-up of the coagulation/flocculation plant, a jar test with a representative raw water sample has to be performed in order to establish the optimum doses of applied chemicals.

During normal and satisfactory operation of the coagulation/flocculation plant the jar test should be performed at least once a day. If purification results are not satisfactory, the frequency of jar testing has to be increased in order to define the right conditions for production of water with an acceptable quality.

7. SUMMARY

The jar tester appears to be an excellent piece of laboratorium equipment for the determination of optimum process conditions for coagulation, flocculation and sedimentation of various raw water qualities.

It is used in survey and design stages for new treatment plants, as well as during the operation of existing treatment plants in order to determine optimum doses of chemicals for fluctuating raw water qualities.

* * *

☞ PURPOSE OF JARTEST :

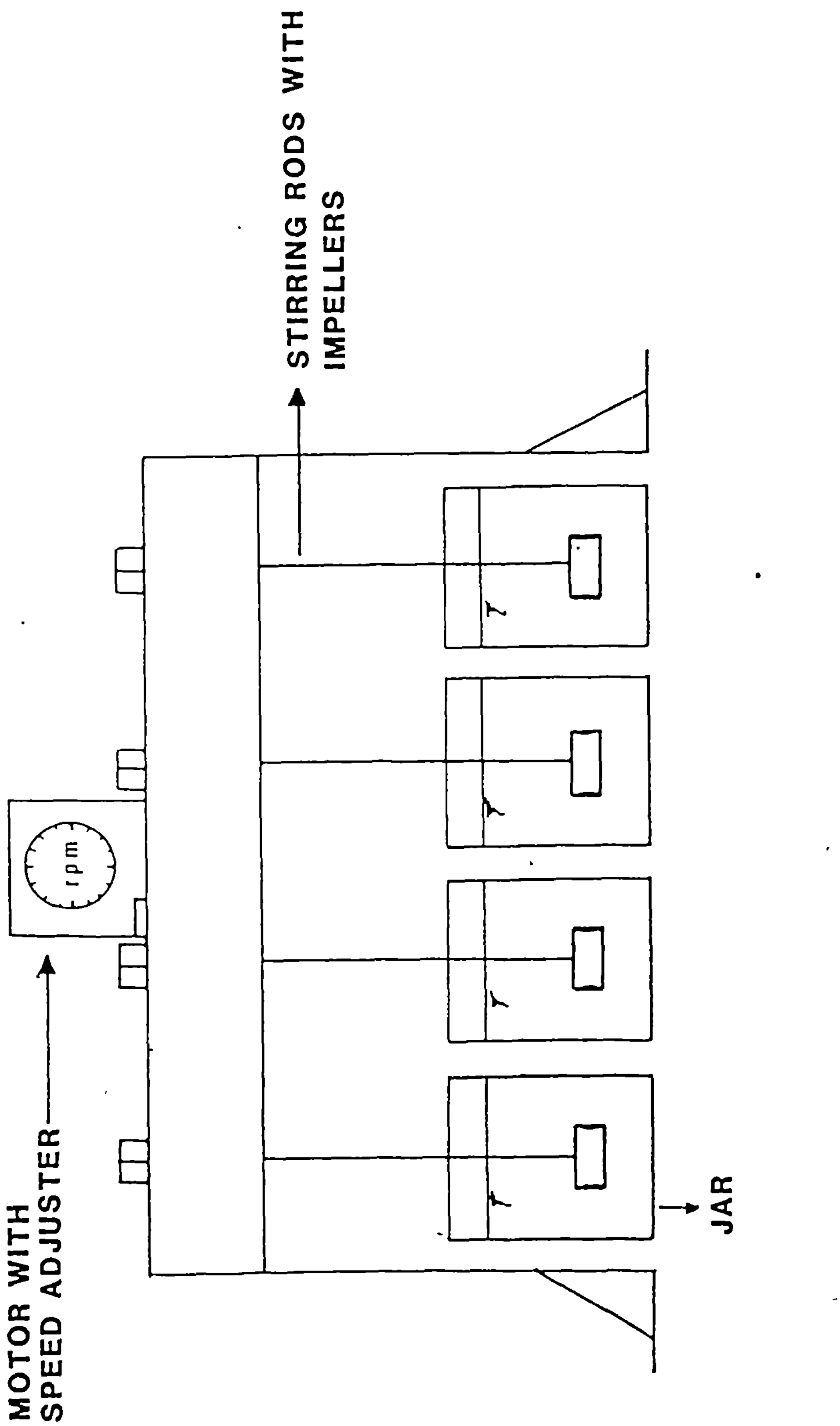
Coagulation/flocculation processes evaluation

☞ APPLICATIONS OF JARTEST :

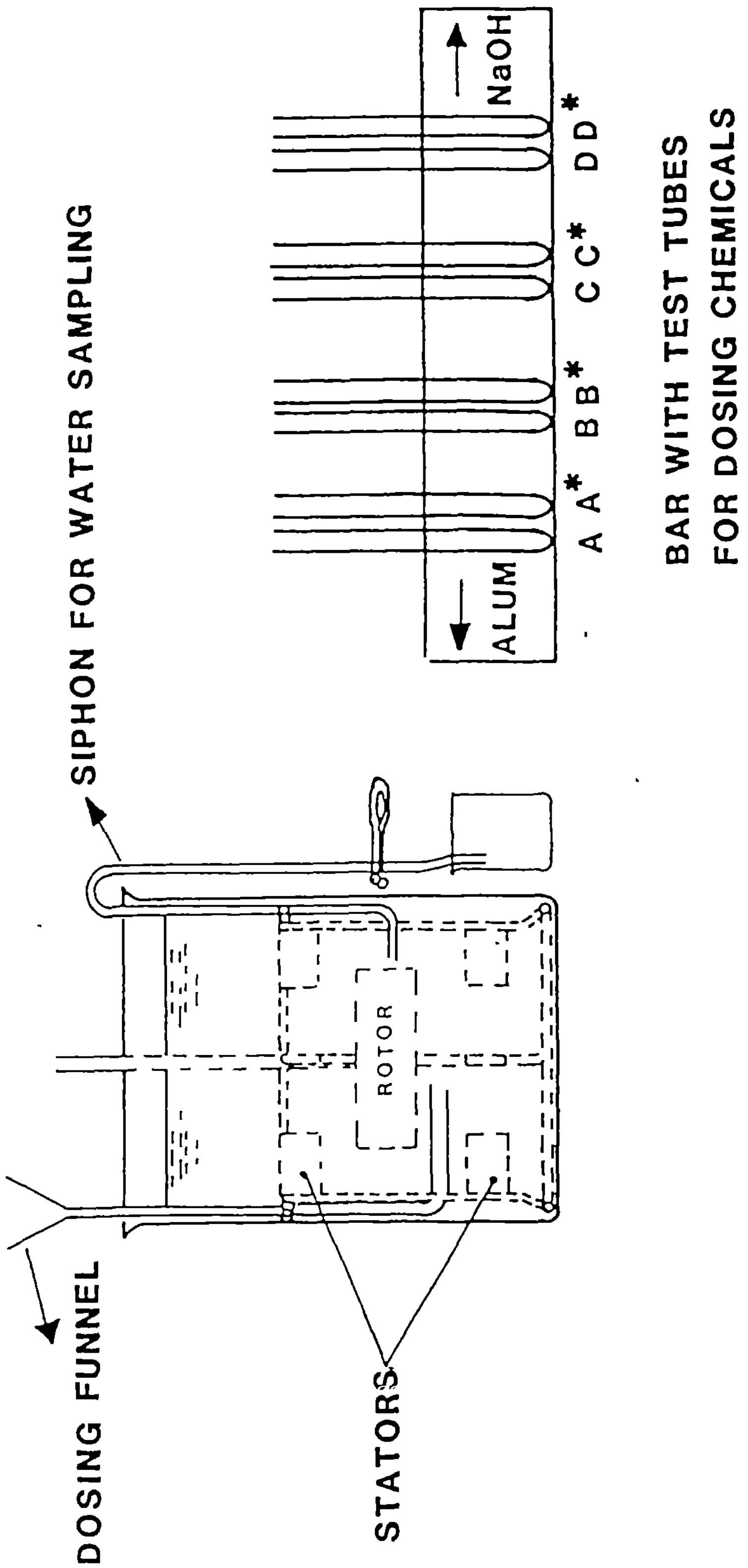
1. Optimizing coagulation/flocculation processes in existing treatment plants
2. Design of new treatment plants
3. Upgrading of existing treatment plants

POSSIBLE RESULTS OF JAR TEST :

1. OPTIMAL DOSES OF CHEMICALS :
   - alum dose
   - pH range (Soda-ash or caustic soda dose)
2. OPTIMAL CHEMICAL DOSING PROCEDURES
   - Simultaneous or subsequent dosing of various chemicals on or beneath water surface
   - Dosing location in relation to mixing device
   - Solution strength of chemical solutions
3. OPTIMAL INTENSITY AND DURATION OF MIXING
4. OPTIMAL SEDIMENTATION PERIOD



MAIN PARTS OF THE JAR TESTER



OPTIONAL JAR TEST EQUIPMENT

A. REACTIONS OF ALUM AND CAUSTIC SODA IN WATER

$$Al_2(SO_4)_3 + 6H_2O \longrightarrow 2Al(OH)_3 + 3SO_4^{2-} + 6H^+$$
$$6\,NaOH + 6H^+ \longrightarrow 6Na^+ + 6H_2O$$
$$Al_2(SO_4)_3 + 6NaOH \longrightarrow 2Al(OH)_3 + 6Na^+ + 3SO_4^{2-}$$

OR: 1 MOLE OF ALUM ∽ 6 MOLES OF CAUSTIC SODA

OR : $1g\ Al(SO_4)_3 \cdot 18H_2O$ ∽ $\frac{6 \times 40}{666} = 0.36$ g NaOH

B. ALUM SOLUTION AND CAUSTIC SODA SOLUTION

1 % ALUM SOLUTION ∽ 10 GRAMMES OF ALUM PER LITRI OF WATER

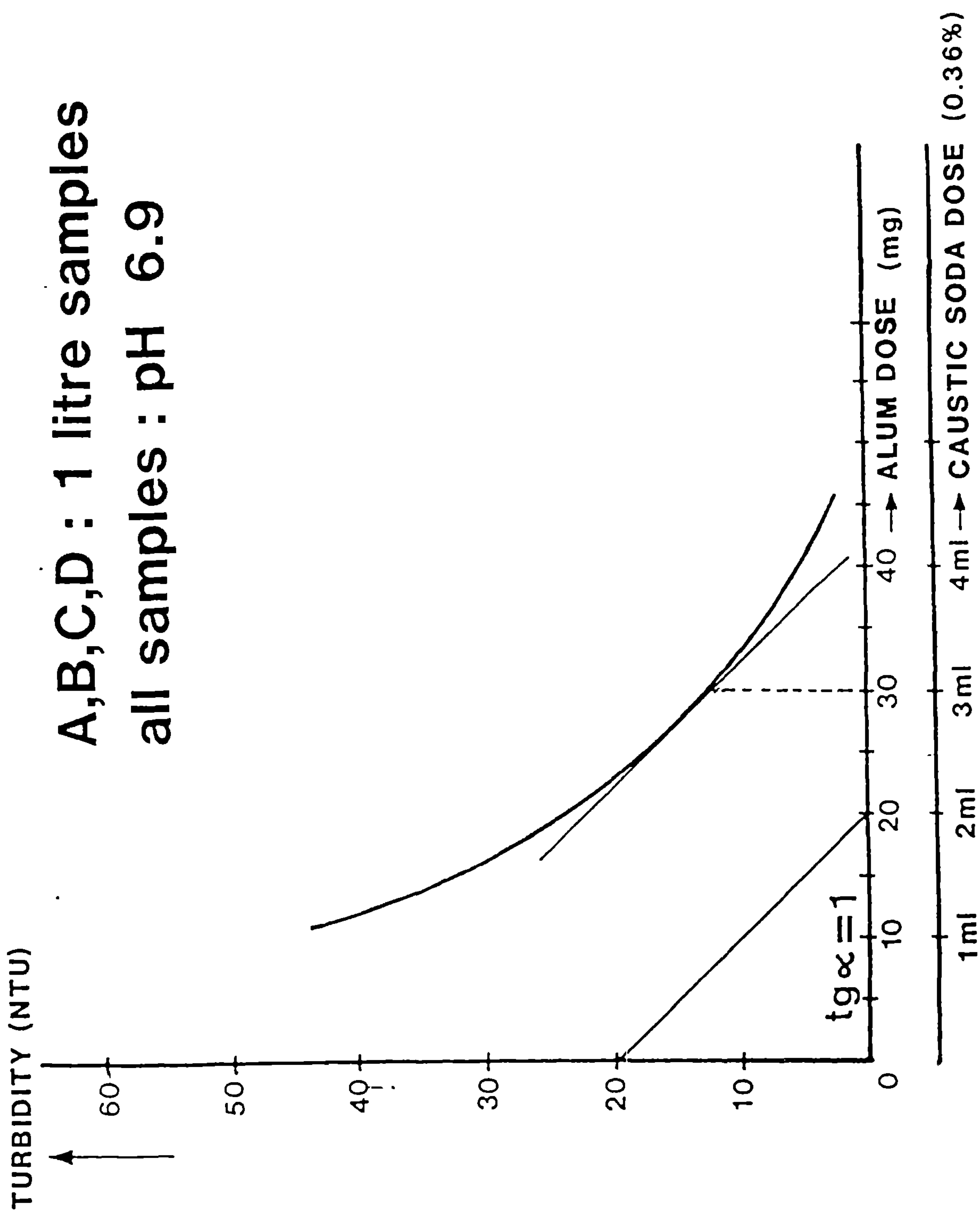
0.36 % NaOH SOLUTION ∽ 3.6 GRAMMES OF NaOH PER LITRE OF WATER

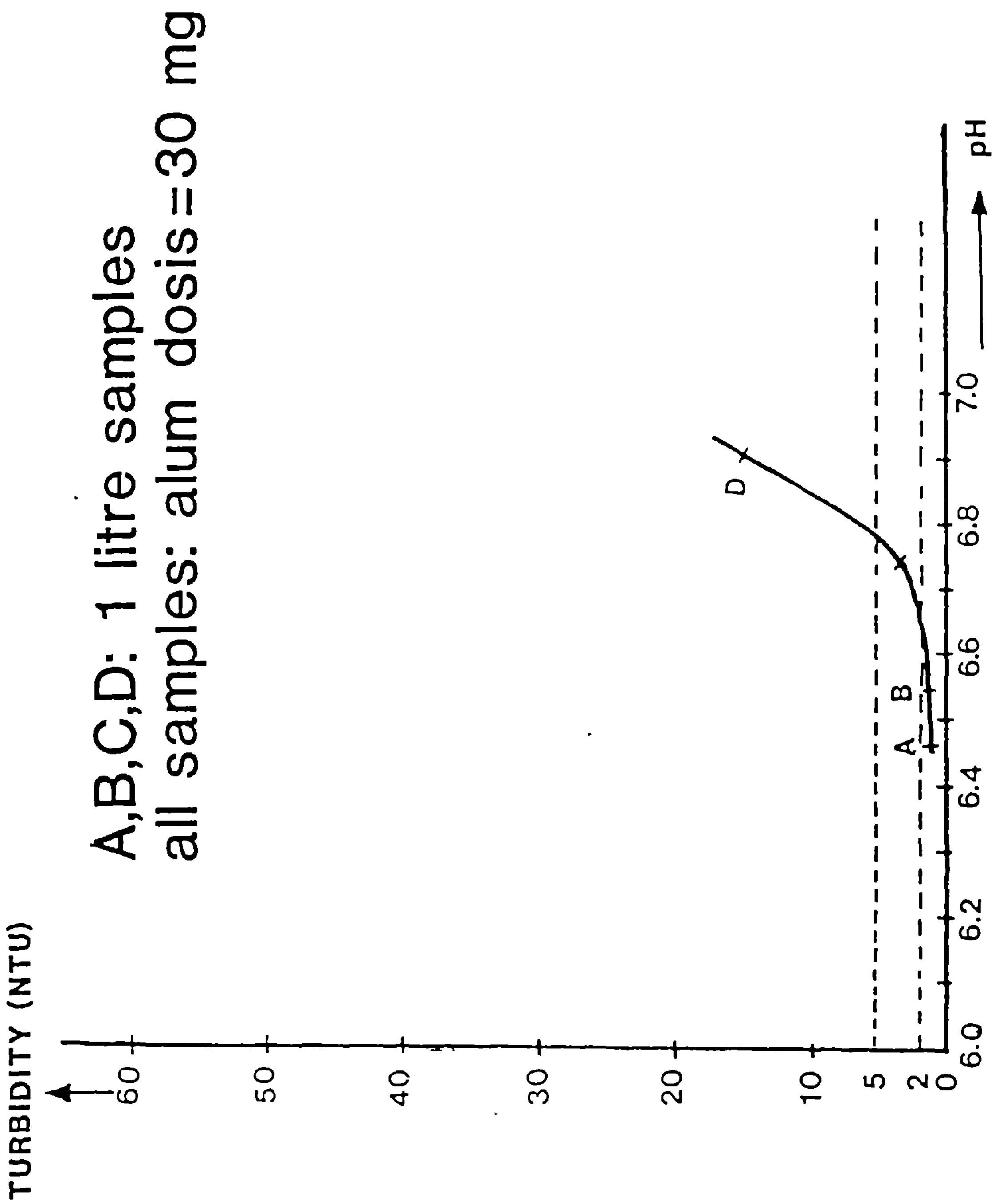
C. FROM A AND B :

1 ml ALUM SOLUTION (1 %) ∽ 1 ml NaOH SOLUTION (0.36

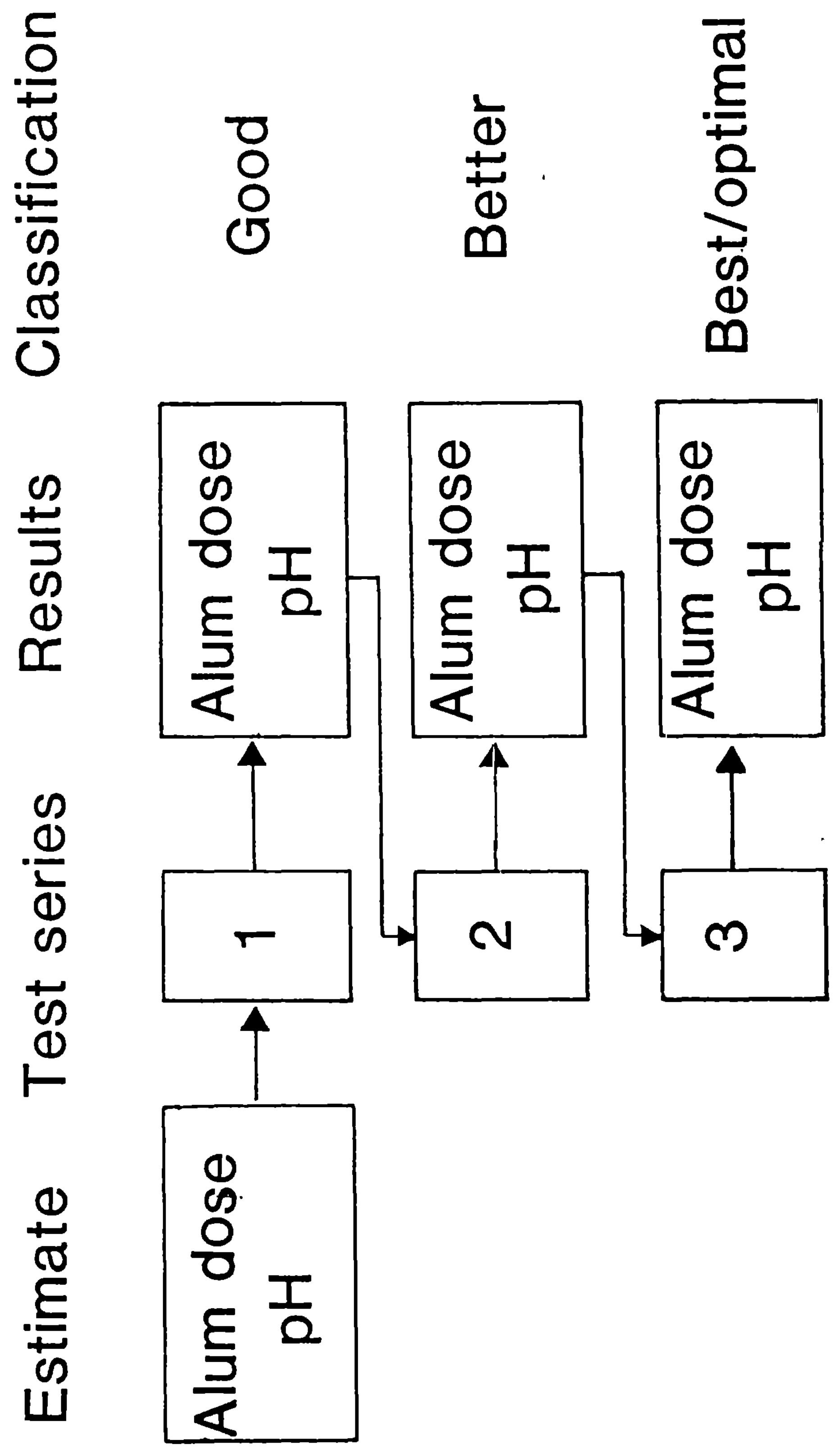
DETERMINING OPTIMAL ALUM DOSING :

1. prepare chemical solutions
2. pour raw water into jars
3. rapid mixing of chemicals
4. slow mixing
5. sedimentation
6. remove samples
7. determine turbidity, pH, temperature
8. graphical presentation of results


A,B,C,D : 1 litre samples
all samples : pH 6.9
TURBIDITY (NTU)
60
50
40
30
20
10
0
10
20
30
40
ALUM DOSE (mg)
1ml
2ml
3ml
4ml
CAUSTIC SODA DOSE (0.36%)
tgα=1


A,B,C,D: 1 litre samples
all samples: alum dosis=30 mg
TURBIDITY (NTU)
60
50
40
30
20
10
5
2
0
6.0
6.2
6.4
6.6
6.8
7.0
pH
A
B
D

TEST SEQUENCE FOR DETERMINING CHEMICAL DOSE



Duration :	45 minutes.
Training objectives :	After this session the trainees will be able to: - recognize the various maintenance activities; - supervise the various maintenance activities.
Trainee selection :	- Head of Technical Department; - Supervisor of Production Section; - Supervisor of Workshop.
Training aids :	- Handout : TTM 050/H 1-2.
Special features :	-
Keywords :	Water treatment/maintenance/treatment plant maintenance.

1. **Maintenance activities**	
- Routine "Preventive" actions: . daily and weekly; . inspection, lubrication and tests; . during production while operation continues.	Explain using whiteboard
- Periodic "preventive" actions: . monthly, 1/2 year, year, 2 years; . inspections (use detailed checklists); . lubrications; . tests; . cleanings; . overhauls; . repainting.	Write on whiteboard
- Immediate repair/replacement of broken parts and/or failures.	
2. **Inspection (checks)**	Explain using whiteboard
- Daily: observation. - Weekly: recording/reporting. - Use checklists for periodical inspection. - Pay attention to: . leakages; . functioning; . obstructions; . moveable parts/items; . rotating parts/items; . deviations from standards; . lubrication needs. - Unusual phenomena have to be reported immediately.	

3. Lubrications	Explain and write on whiteboard
- Drain/refill of oil bathes: . water pumps; . air blowers; . compressors; . gensets; . gearboxes. - Grease weekly: . shafts (mixers a.o.); . valve actuators; . air blowers; . compressors. - Follow the instruction manuals.	
NOTE 1: Use only recommended types of oil and grease.	Read full NOTES 1-4
NOTE 2: Too much grease catches dust and sand (abrasion); too little grease: rotating parts may be blocked and damaged.	
NOTE 3: Too much oil will damage packings in the machine and oil will leak; too little oil will block rotating parts.	
NOTE 4: Unusual oil consumption should be reported immediately to the supervisor.	
NOTE 5: No grease or oil may reach the water (to be) treated.	
4. Tests	Explain using whiteboard Write keywords
- Test have to be done periodically. - Dosing systems to be tested daily. - Standards of conditions as specified in manuals like for max. flows, r.p.m., etc. - For more complex equipment: use specific checklists (e.g. genset). - Electrical equipment to be tested by the electrical engineer.	

- Faults to be corrected as soon as possible. - Unusual phenomena to be reported immediately. - Special test of filter bed composition to be done by expert sanitary engineer/ trouble shooter.	
5. **Cleaning**	Use whiteboard
- Plant and plant site and buildings should be kept clean. - Spoiled chemicals and solutions to be rinsed with plenty of water. - Inside walls of plant and clear water reservoir: use brush and plenty of water. - Spoiled, wasted oil and fuel should be collected with cloth and dumped into special containers.	
NOTE: Never forget that the plant is producing water that will be used for consumption. Therefore, keep the plant clean.	Read full NOTE
6. **Overhauls**	Explain using whiteboard
- Simple equipment (valves, etc.) to be overhauled at plant site. - Pumps and their motors in workshop. - Dosing systems with pumps at the plant site by expert/trouble shooter. - Gensets at plant site by expert/trouble shooter/mechanical engineer. - Control panels and electrical wiring by electrical engineer. - Frequency of overhauls depends on total number of operation hours; to be registered for each item.	

7. **Replacement**	Explain using whiteboard
- To be replaced as soon as possible: . broken fuses, lamp; switches and meters; . faulty items found during inspections and tests.	
8. **Repainting**	Explain using whiteboard Write keywords: . REPAINTING . steel parts/surfaces . other surfaces: wood, concrete, etc. . instructions of supplier
- Steel surfaces: . free from dirt and rusty loose particles with steel brush; . use paint equal to original type (see manual).	
- Other surfaces: . free from dirt and loose particles; . repair first if damaged; . use proper paint.	
- Frequency as indicated on "Maintenance services chart".	
Repairs	Explain Write keywords: . REPAIR . faults . production continues
- Faults are to be repaired immediately.	
- Let operations be taken over by stand-by equipment when possible.	
- Use spare parts to ensure that production can be continued.	
- Repair remainder of damaged parts.	
9. **Summary**	
- Maintenance activities for water treatment plants consist of: . routine maintenance; . periodical preventive maintenance.	

- General instructions apply for: . Inspections. . Lubrication. . Tests. . Cleanings. . Overhauls. . Replacements. . Repainting. . Repairs.	Distribute H 1 and H 2

Maintenance activities TTM 050/H 1 for water treatment plants	Maintenance activities TTM 050/H 2 for water treatment plants

1. MAINTENANCE ACTIVITIES

Maintenance activities must be executed at regular time intervals. Those executed once a week or more often are normally classified as routine maintenance.
The activities mainly comprise: regular checks, tests and lubrications. While these activites are carried out, production can be continued or at least partly.

Periodic preventive maintenance activities have longer time intervals, for instance once a month, twice or once a year, or even longer.
These maintenance activities comprise inspections, test, overhauls, etc.

For more complex equipment like gensets, air blowers etc., a special list with frequencies of maintenance activities has to be prepared.

General instructions for these kinds of maintenance activities are:

Inspection/checks

- daily observations: faults have to be reported immediately to the opreators and to the supervisor;
- weekly: the results of the checks carried out during the previous week should be reported (journal);
- for periodic inspections see the check lists in H2 of this module;
- pay attention to leakages (water, oil), proper functioning of machines, obstructions to mobility of movable and rotating parts, levels of water and oil, position of pressure meters, ampere meters.

Lubrication

The need for lubrication of the moving and rotating parts or items should be observed permanently and the operator should pay attention to possible sudden changes in the need for lubrication.
Weekly levels of oil baths must be checked and compared with predescribed levels. Replenish if at any time the oillevel is below standard.
Normally the frequency to drain/refill oil baths depends on the type of machine and the number of running hours, as specified in their respective manuals.

For example:

- dosing pumps: each 350 hours (equal to 2 weeks continous operation, or one month when operation is 8 hours a day);
- water pumps :
  - immediately when the oil contains water caused by leaking of seals (inspect the seals), and
  - once every three months with continuous operation under normal conditions;
- air blowers, diesel engines of gensets and gearboxes must be lubricated and greased very carefully according to the specification in their respective operation and maintenance manuals.
- All moving parts should receive lubrication, so that they can run easily and smoothly without obstructions and without unusual sound or noises.

Only lubrication material qualified in accordance with specifications has to be applied.
Too much grease catches dust and sand, causing moving parts to become overheated, blocked and damaged.
Too much oil will damage packings (oil seals) in the machines and oil will leak; too little oil causes overheating and blockage and damages to rotating parts.
Unusual oil or grease consumption should be reported immediately to the supervisor.

GREASE OR OIL MAY NEVER REACH OR CONTACT THE WATER (IN THE TREATMENT PLANT)

Tests

All machines and equipment have to be tested periodically. Especially dosing systems should be tested every day as clogging occurs easily. Standards to which the machines and equipment much comply are found in operation and maintenance manuals.
Criteria like maximum flow capacities, maximum reachable pressure, etc. should be regarded. Unusual sounds and noises or excessive vibrations must be investigated and repaired or immediately reported to the supervisor.
For more complex equipment such as generator sets, air blowers etc. existing detailed checklists should be followed.
The testing of electrical equipment should be performed by an electrical engineer or trouble shooter. Any fault should be corrected as soon as possible.
The testing of the composition of filter bed layers requires specific know-how and specific equipment like sieves. Therefore it has to be done by a sanitary engineer or well trained trouble shooter. The level of filter beds can be measured more frequently by the maintenance man.

Cleaning

The plant, the building inside and outside and the site of the plant should always look like they are just cleaned.

The inside walls of the plant should be cleaned once a month with water and brush.
Once a year the clear water reservoirs' floor and walls (inside) should be brushed with lots of water. Afterwards they should be disinfected.
Manholes in the reservoir must be clean and free.

Solid waste and waste oil must be carefully collected an properly disposed of.
Never drain fuel and oil to water carrying bodies such as rivers, water sources, canals, etc. or directly upon or into the ground.

Ground mixed with oil or fuel should be collected and properly disposed of.
Waste chemicals and chemical solutions should be rinsed away with plenty of water.
Substantial amounts of kaporit should never be dumped into a river or canal; they will unnecessarily kill biological life.

ALWAYS REMEMBER THAT THE TREATMENT PLANT AND ITS RESERVOIRS CONTAIN WATER THAT WILL BE USED FOR HUMAN CONSUMPTION.

Overhauls

Periodic overhauls will extend the lifetime of the machines due to the exchange of vital parts of them.
Overhauls have to be done regularly, depending on the number of operating hours of the equipment.
Overhaul, for simple equipment such as gate valves, etc. can be done at the plant site.
For overhauls of pumps and electricmotors (smaller size) the equipment can be sent to an adequate workshop. Overhauls of big pumps, motors, air blowers, compressor and generator sets should be done on site, by a special maintenance team and using the proper tools and instruction sheets.
Once every two years the control panels and the electrical system must receive a full check-up and vital items must be repaired or replaced.

Replacement

Broken-down parts like lamps, fuses, meters, switches, windows, doors, laboratory equipment, tools etc. have to be replaced immediately.

Repainting

In general, all steel parts and steel surfaces have to be free of rust. Therefore damaged paint layers should be repainted as soon as possible.
Periodically, once in two years, all steel surfaces should be repainted.
Before applying a new layer of paint all dust and rust particles have to be removed from the steel surfaces with a steel brush.
The proper paint with the same specifications as the paint used before, has to be selected and applied strictly according to the specifications of the paint manufacturers.
Other surfaces (wood, concrete, plastering, etc.) should be repaired to the original conditions and cleaned from dust before repainting.
Proper types of paint have to be applied for repainting at least once in two years.

REPAINTING SHOULD NEVER BE DONE ON WET SURFACES.

Repairs

In general, faults and damages should be repaired immediately or as soon as possible, trying not to shut down the production and distribution of water.
Therefore, spare parts, either new or overhauled, should be installed as quickly as possible as a temporary measure, if otherwise a plant shut-down seems unavoidable.

Faulty items or parts should be repaired or replaced by new spare parts.

3. SUMMARY

- Routine maintenance.
- Periodic preventive maintenance.
- Repair/replacement of failures.
- General instructions for:
  . inspection;
  . lubrications;
  . tests;
  . cleanings;
  . overhauls;
  . repainting;
  . repair/replacement.

* * *

EXAMPLE

NAME: LOCATION WEEK NO: *)

ITEM	CHECK	LUBR.	TEST	CLEAN	OVER-HAUL	REMARKS
INTAKE SCREEN	O					
INTAKE PUMPS			O			
FLOW METER	O			O		
PLANT BASINS				O		
PADDLES (FLOCC.)		O				
PLATES (SETTLER)				O		
FILTER BED						
FILTER BACKWASH	O					
FILTER SURFACE WASH	O					
VALVES						
VALVES OPERATORS	O	O				
PRESSURE METERS	O					
DOSING SYSTEMS	O		O	O		
BACKWASH PUMPS						
SURFACE WASH PUMPS						
EFFLUENT PUMPS						
AIR BLOWER(S)	O					
AIR COMPRESSOR	O	O				
DISTRIBUTION PUMPS						
HYDROPHORE	O					
GENSETS	O			O		
ELECTRICAL SYSTEMS						
LEVEL SWITCH INDIC.	O					
FLOW SWITCH INDIC.	O					
DRAINAGE SYSTEM	O					
BUILDINGS	O			O		
CONCRETE STRUCTURES				O		
SITE	O			O		

WEEKLY INSTRUCTIONS CHECK/LUBR./TEST/CLEAN/OVERHAUL

*) Every week except Week 5, 25 and 51

EXAMPLE

NAME: LOCATION WEEK NO: 5

ITEM	CHECK	LUBR.	TEST	CLEAN	OVER-HAUL	REMARKS
INTAKE SCREEN				O		
INTAKE PUMPS		O	O			
FLOW METER				O		
PLANT BASINS				O		
PADDLES (FLOCC.)		O				
PLATES (SETTLER)				O		
FILTER BED			O			
FILTER BACKWASH			O			
FILTER SURFACE WASH			O			
VALVES						
VALVES OPERATORS		O	O			
PRESSURE METERS						
DOSING SYSTEMS			O	O		
BACKWASH PUMPS		O	O			
SURFACE WASH PUMPS		O	O			
EFFLUENT PUMPS		O	O			
AIR BLOWER(S)		O				
AIR COMPRESSOR		O				
DISTRIBUTION PUMPS		O	O			
HYDROPHORE	O					
GENSETS	O					
ELECTRICAL SYSTEMS						
LEVEL SWITCH INDIC.				O		
FLOW SWITCH INDIC.				O		
DRAINAGE SYSTEM				O		
BUILDINGS				O		
CONCRETE STRUCTURES						
SITE				O		

WEEKLY INSTRUCTIONS CHECK/LUBR./TEST/CLEAN/OVERHAUL

EXAMPLE

NAME: LOCATION WEEK NO: 25

ITEM	CHECK	LUBR.	TEST	CLEAN	OVER-HAUL	REMARKS
INTAKE SCREEN				O		
INTAKE PUMPS		O	O	O	O	
FLOW METER				O		
PLANT BASINS				O		
PADDLES (FLOCC.)		O		O		REPAINT
PLATES (SETTLER)				O		
FILTER BED			O			
FILTER BACKWASH			O			
FILTER SURFACE WASH			O			
VALVES			O			
VALVES OPERATORS		O	O			
PRESSURE METERS				O	O	
DOSING SYSTEMS	O		O	O	O	
BACKWASH PUMPS		O	O			
SURFACE WASH PUMPS		O	O			
EFFLUENT PUMPS		O	O			
AIR BLOWER(S)		O	O			
AIR COMPRESSOR		O	O			
DISTRIBUTION PUMPS		O	O			
HYDROPHORE	O			O		
GENSETS	O	O	O	O	O	
ELECTRICAL SYSTEMS	O					
LEVEL SWITCH INDIC.			O	O		
FLOW SWITCH INDIC.			O	O		
DRAINAGE SYSTEM				O		
BUILDINGS				O		
CONCRETE STRUCTURES				O		
SITE						

WEEKLY INSTRUCTIONS CHECK/LUBR./TEST/CLEAN/OVERHAUL

EXAMPLE

NAME: LOCATION WEEK NO: 51

ITEM	CHECK	LUBR.	TEST	CLEAN	OVER-HAUL	REMARKS
INTAKE SCREEN				O		
INTAKE PUMPS		O	O	O	O	
FLOW METER				O		
PLANT BASINS				O		REPAINT
PADDLES (FLOCC.)		O		O		
PLATES (SETTLER)				O		
FILTER BED			O			
FILTER BACKWASH			O			
FILTER SURFACE WASH			O			
VALVES			O			
VALVES OPERATORS		O	O			
PRESSURE METERS				O		
DOSING SYSTEMS	O		O	O	O	
BACKWASH PUMPS		O	O			
SURFACE WASH PUMPS		O	O			
EFFLUENT PUMPS		O	O			
AIR BLOWER(S)		O	O		O	
AIR COMPRESSOR		O	O		O	
DISTRIBUTION PUMPS		O	O			
HYDROPHORE	O			O	O	
GENSETS	O	O	O	O	O	
ELECTRICAL SYSTEMS	O					
LEVEL SWITCH INDIC.			O	O		
FLOW SWITCH INDIC.			O	O		
DRAINAGE SYSTEM				O		
BUILDINGS				O		
CONCRETE STRUCTURES				O		REPAINT
SITE				O		

WEEKLY INSTRUCTIONS CHECK/LUBR./TEST/CLEAN/OVERHAUL

EXAMPLE

Overhaul part		Contents of works	Overhaul time						
			a	b	c	d	e	f	g
Cylinder	Suction valve	Dismantle & clean					o		
	Discharge valve	Dismantle & clean					o		
	Interior face of cylinder	Overhaul abrasive condition							o
	Water jacket	Remove incrustation							o
	Piston ring	Overhaul whether or not something abnormal						o	
	Drain tank	Drain discharge	o						
Lubricant	Level gauge of lubricant	Examine lubricant quantity	o						
	Lubricant tank for crank case	Exchange lubricant							o
Others	Gland packing	Overhaul defect, abrasion, etc.						o	
	Wiper ring	Overhaul, defect, abrasion, etc.						o	
	Suction strainer	Clean: 1st layer			o				
		2nd layer				o			
	Pilot valve	Dismantle, clean, confirm the functioning				o			
	V-belt	Adjust the tension		o			o		
	Receiver	Discharge drain	o						
	After cooler	Discharge drain	o						
	Safety valve	Confirm the functioning			o				
	Each bearing & other whole body	Overhaul							o

a = 8 hours; b = 60 hours;
c = 250 hours; d = 1000 hours;
e = 2000 hours; f = 3000 hours;
g = 4000 hours.

EXAMPLE

Part to be inspected	Points of inspection and adjustments	To be carried out:				
		Daily	50 hrs	100 hrs	200 hrs	800 hrs
Fuel valve	Inspection of jet pressure and automizing condition		o			
	Functioning examination of jet valve	during the ope.				
	Adjustment of jet volume					o
Fuel pump	Cleaning of filter mesh of fuel pump		o			
	Test of discharge valve and oil density of plunger					
	Working examination of fuel pump	during the operation				to be re-placed
Fuel filter	Examination, cleaning and replacement of filter	after the operation		o		
Lubricant	Examination and supply of lubricant and dirt, replacement of lubricant	after the operation		o		
	Supply of each part			o		
Lubricant filter	Cleaning & replacement of filter and its mesh		o	to be re-placed		
Suction & exhaust valves	Adjustment & inspection of gap between the valves				o	
Cylinder	Examination of compressive force of each cylinder					o
Piston and bearing	Examination of abrasion and damage after dismantling					o > 2,000
Looseness of bolts and nuts	Examination of each part	after the operation		o		
Air cleaner	Cleaning of the inside and oil change			o		
Cooling water	Supply, replacement and flushing	before the operation		o		
Engine	Adjustment of idling			o		
	Flushing				o	
Gauge		during the operation				
Electric system	Tension			o		
	Oil supply of starting motor				o	
	Examination of starting motor generator & regulator					o
	Oil supply to generator				o	
Other parts	Examination of starting motor pinion, flywheel ring gear					o
	Thermostat					o