HOGENAKKAL WATER SUPPLY AND FLUOROSIS MITIGATION PROJECT

PACKAGE - I

Operation & Maintenance Manual

Volume 7(a)

1. INTRODUCTION

OPERATIONS AND MAINTENANCE MANUAL

1.1. BACKGROUND

Hogenakkal Integrated Drinking Water Project is a fluorosis mitigation drinking water project being undertaken at Hogenakkal, Dharmapuri district, state of Tamil Nadu, India. It is scheduled to be executed by Tamil Nadu Water Supply and Drainage Board (TWAD), with funding from Japan Bank for International Cooperation (JBIC) using Tamil Nadu's share of Cauvery river water. The project aims to supply safe drinking water to drought prone & fluorosis affected Dharmapuri and Krishnagiri districts of Tamil Nadu.

Dharmapuri and Krishnagiri districts of Tamil Nadu are drought prone and had been the cause of high political debates and riots. Although the Kaveri river enters the state at Biligundulu in Dharmapuri district, it does not contribute to irrigation or drinking water purposes there. With 10 of the 29 constituent districts in Tamil Nadu affected by fluorosis, Dharmapuri district has the highest concentration of endemic fluoride in the State.

1.1.1. Pact on Bangalore & Hogenakal Projects (1998)

The Tamil Nadu government has received a no objection certificate from the central government for the Hogenakkal drinking water scheme. A similar agreement with the J. H. Patel led government of Karnataka in 1998 was based on the premise that both states won't obstruct drinking water schemes from Cauvery as long as the water drawn for such a project is sourced from the respective state's share of Cauvery water, whose proceedings have been recorded.

1.1.2. Areas covered

The project is expected to cover 6,755 households in three municipal areas, 17 panchayats and 18 town panchayats, benefiting about three million people. Drinking water will be pumped to a master balancing reservoir at Madam, about 11 km from Hogenakkal. After treatment, water will be pumped for 145 km to cover areas such as Palakkodu, Marandahalli and Hosur in Tamil Nadu. Remaining areas in Krishnagiri and Dharmapuri districts will be covered by taking advantage of altitude gradient.

1.2. HISTORY OF THE PROJECT

The Hogenakkal Water Supply and Flourosis Mitigation Project (HWS&FMP) has been planned to supply drinking water to 2.9 Million inhabitants of Dharmapuri and Krishnagiri districts of Tamilnadu by the Tamilnadu Water and Drainage Board (TWAD).

OPERATIONS AND MAINTENANCE MANUAL

The project envisages drawing of water from the River Cauvery at Hogenakkal upstream of the famous Hogenakkal Water Falls, treating the same to drinking water standards and supplying to the end consumers.

This is a project assisted by Japan International Cooperation Agency (JICA).

The Project has been envisaged as a complete project divided into 5 distinct packages, as follows:

a. **Package I** – This consists of:

Intake Works and Raw Water Pumping Station at Hogenakkal

Water Treatment Plant including Treated Water Reservoir and Pumping Station.

Booster Pumping Station

Master Balancing Reservoir at MADAM

Complete Instrumentation and Automation works of the water distribution systems envisaged in Packages II to V

7.Package II

8.Package III

9.Package IV

10.Package V

1.3. PROJECT BASIS

1.3.1. RAW WATER

The raw water supply for the project is derived from River Cauvery, at a distance of 45 Km west of Dharmapuri.

1.3.2. CAPACITY

1.3.2.1. The treated water output of the water treatment works shall not be less than 155.82 ML per day.

1.3.2.2. The minimum treated water output of the plant shall be 127.6 ML per day.

1.3.2.3. Mean Annual permitted abstraction rate from River Cauvery – 160.7 ML/d.

1.3.2.4. Mean losses excluding service water consumed – Less than 2.5%

1.3.3. RAW WATER QUALITY

As per Appendix B1 of the contract for Package I and subsequent sampling and tests carried out by Cadagua:

- TSS: 25 mg/l
- Dissolved Solids: 150 – 500 mg/l
- Total Hardness: 50 – 250 mg/l
- Alkalinity: 50 – 250 mg/l
- Ph: 7 – 9
- Turbidity: 1 – 25 NTU
- Coliform Count: 50 – 3000

1.3.4. TREATED WATER QUALITY

1.3.4.1. 100% of the sample results shall have:

i) Turbidity: Not exceeding 1.0NTU (before final pH correction)

ii) Taste and Odour: Unobjectionable

iii) Colour: Not exceeding 5^{o} Hazen

iv) Aluminium: Not exceeding 0.2 mg/l as Al

iii) Iron: Not exceeding 0.3 mg/l as Fe

iv) Manganese: Not exceeding 0.1 mg/l as Mn

v) Free Chlorine: Not exceeding 0.5 mg/l as Cl (at the contact tank outlet)

vi) pH: 7.0 – 8.5

vii) Total coliform bacteria: Nil in any 100 ml sample

1.3.4.2. 95% of the samples shall have:

i) Aluminium: Not exceeding 0.03 mg/l as Al

ii) Iron: Not exceeding 0.1 mg/l as Fe

iii) Manganese: Not exceeding 0.05 mg/l as Mn

iv) pH: $pH_S + 0.3$

1.3.5. OTHER DESIGN BASIS

1.3.5.1. *Variation in Throughput* and *Range of Output* shall be as per the requirements of Section B1.3 and B1.4 of the contract.

1.3.5.2. *Hydraulic Capacity of the treatment works*.

In addition to the requirements of Section 2.1.4.2 above the hydraulic capacity of the process units and the relevant inlet connections shall include provisions for the maintenance of the works throughput with the following operation conditions present:

- One Clarifier taken out of service for maintenance
- Two filters out of service, one for washing and one for maintenance
- One compartment of Chlorine contact tank out of service for maintenance'
- One compartment of Treated Water Reservoir out of service for maintenance
- One compartment or one unit, as appropriate, out of service for maintenance of all other units and interconnections that are necessary for the operation of the water treatment works at the required throughput.
- Minimum Water Level at Intake – 247.5 m.

1.4. PROPOSED SOLUTION

1.4.1. PACKAGE I FACILITIES

a. Raw Water Pumping Station (RWPS) with Intake Works

b. Pipeline from RWPS to Water Treatment Plant

c. Water Treatment Plant (WTP) consisting of:

Parshall flume Intake

Flat Bottom Sludge Blanket Clarifier

Gravity Sand Filter

Building for Gravity Sand Filter with:

Laboratory

Wash Water Tank

Filter Wash Air Blowers

Main Control Room

Chlorine Contact Tank with Pump Room

Wash Water Recovery Tank with Pump Room

Treated Water Storage Reservoir

Treated Water Pumping Station

Chlorination System

Chemical (Lime and alum) Storage and Solution Preparation System

Sludge Handling System with:

Sludge Balancing Tank

Sludge Pumping Station

Sludge Thickener

Sludge Drying Beds

d. Pipeline from WTP to Booster Pumping Station

e. Booster Pumping Station (BPS) with:

1. Booster Reservoir
2. Booster Pumping Station

f. Pipeline from Booster Pumping Station to Master Balancing Reservoir

g. Master Balancing Reservoir (MBR) with:

d) Reservoir

e) Outlet Pipes to Package II and V.

1.4.2. PACKAGE II FACILITIES

a. Booster Pumping Stations – 10 at

Madam

Somanahalli (Konangihalli)

Kuppur (Anjehalli)

Nallampalli

Mukkalnaickenputty

Madam BPS – 2 (Nagampatti)

Atiyamankottai

Mittareddihalli

Thiruvarampatti

Echanahalli

b. Union Reservoir Systems – 9 Nos at:

Madam

Athagapaddi

Nallampalli

Dharmapuri Municipality

Kuppur

Mukkalnaickenputty

Nagampatti

Kondireddipatti & Uthangarai

Olaipatti

c. Tapping Points – 13 Nos at:

Madam

Konangihalli

Package 3 TP (Billaianoor)

Indur

Athagapaddi

Nallampalli

Lakkiampatti – II

Dharmapuri Municipality

Kuppur

Near Olaipatti

Nagampatti

Kondireddipatti & Uthangarai

1.4.3. PACKAGE III FACILITIES

a. Booster Pumping Stations – 11 Nos at:

Pappireddipatti

Pappireddipatti

Vellolai

Nallakuttalnahalli

Maniyambadi (Linganaikkanahalli)

Osahalli

Pattukonampatti

Keelmorappur

Parayanpatti

Keerapatti

Kottapatti

b. Union Reservoir Systems – 4 Nos at:

Odasalpatti (Morappur)
Odasalpatti(Harur)

Pappireddipatti

Harur (B.Mallapuram)

c. Tapping Points – 8 Nos at:

Odasalpatti

Odasalpatti

Pappireddipatti

Vellolai

Settikarai

Satrapatti

Harur

B.Mallapuram

1.4.4. PACKAGE IV FACILITIES

a. Booster Pumping Stations – 26 Nos at:

Palacode

Kaduchettypatti

Kundumaranapalli

Royakkottai, Thakkimandi

Sulagiri

Kuriyanapatti

Pathimadugu

Arasakuppam

Arasakuppam

Denkanikottai

Denkanikottai

Denkanikottai

Denkanikottai
Denkanikottai

Doddamanchi

Jakkeri

H.Chettipalli

Bommathathanur

Bevanatherm

Karandapalli

Mathagiri

Mathagiri

Binnamangalam

Agalakotta

Thumanapalli

b. Union Reservoir Systems – 6 Nos at:

Kaduchettypatti

Royakkottai

Jakkeri

Jakkeri

Mathagiri

Thinnur

c. Tapping Point – 5 Nos at:

Avathanapatti

Kandikuppam

Karakuppam

Kaveripattinam

Karimangalam

Vallaithotam

P.Chetihalli
Pikkili

O.G.Halli

1.4.5. PACKAGE V FACILITIES

a. Booster Pumping Stations – 15 Nos at:

Avathanapatti

Avathanapatti

Kandikuppam

Kandikuppam

Karakuppam

Karimangalam

Vallaithotam

Vallaithotam

P.Chetihalli

Palacode

Palacode

Palacode

Pikkili

O.G.Halli

P.Chettihalli – 2 (Saraparathy)

b. Union Reservoir Systems – 9 Nos at:

Avathanapatti

Kandikuppam

Karakuppam
Kaveripattinam

Karimangalam

P.Chetihalli

Pikkili

O.G.Halli

c. Tapping Points – 12 Nos at:

Kandikuppam

Karakuppam

Kaveripattinam

Karimangalam

Palacode

Pikkili

O.G.Halli

Periyamuttur

Avathanapatti

Krishnagiri Municipality

Bargur township

Valaithottam (Kodletty)

1.5. BRIEF DESCRIPTION OF THE PLANT

1.5.1. Intake Works

The water from the River Cauvery is drawn into the inlet base at intake works through Trash Racks which keep out large objects like animals, trees etc. The inlet base leads on to the Inlet Sump in which are installed Vertical Turbine pumps for pumping the raw water to the Water treatment works (WTP) located about 6.5 KM away. The maximum water level in the WTP is expected to be 313.43 M.

The water from the intake works to the WTP is conveyed in a 1500 diameter Mild Steel pipe duly lined inside with 500 micron Food grade Epoxy coating (Interline 925 of Akzo Nobel).

The facilities at the Intake Works include the following:

g) Trash Racks – 3 sets at water intake from the River.

h) Stop Log Gates – 3 sets.

i) HOT Crane, 5 T capacity, for removal and installation of Stop Log Gates and Trash Racks.

j) Penstock Gates (6 Nos) at the inlet of the Pump Wells (3 Nos).

k) Vertical Turbine Pumps – 6 Nos, 2 in each Pump well for transferring water from Intake to WTP installed in the Pumping Station of the Intake works

l) EOT, 8 T capacity, for maintenance of Equipment installed in the Pumping Station and cleaning of Pump Sumps.

m) Submersible Pumps – 2 Nos for draining the Pump Wells

n) Surge Control System for the Discharge Piping of the Pumping Station consisting of:

- Air Compressors – 2 Nos.
- Air Receiver – 2 Nos
- Air Vessels – 3 Nos.

o) Electrical Supply system consisting of:

Two Pole Electricity Receiving System for 33 KV supply – 2 sets for 2 sources with each set provided with:

- Air Break Switch
- Lightning Arrestors
- HT Fuses
- Set of Insulators
- Outdoor Vacuum Circuit Breaker – 33 KV

- 33 KV Distribution Panel

- Main Transformers – 33KV / 6.6 KV – 2 Nos.
- 6.6 KV Distribution Panel
- Auxiliary Transformers – 6.6KV / 0.43 KV – 2 Nos.
- LT Panel (415 V)
- FCMA Starters for VT Pumps – 6 Nos.
- Battery Chargers and Batteries for Electrical System control supply
- Power Factor Correction system
- UPS

p) Instrumentation and Automation System consisting of:

Set of Instruments

a) PLC for Process control and Operation

b) Surge Control System Control Panel

b Pump Well Ventilation System

c Miscellaneous like Lighting, Fire Alarm etc

1.5.2. Water Treatment Plant

The treatment process adopted in this plant consists of:

i) Clarification followed by Filtration to remove suspended matter and produce water of turbidity less than 1 NTU.

j) Flocculation of suspended matter is required for good clarification. For this purpose a flocculating agent, Alum – Aluminium Sulfate is used.

k) Chlorination of the water to disinfect and produce coliform free water.

l) Dosing of Lime solution in the treated water to correct final pH and maintain positive Langlier Index.

The treatment facilities provided in the WTP are as follows:

ii) Parshall Flume at Inlet for measurement of Water Flow and for creating turbulence for mixing of Alum for flocculation and intermittent addition of Chlorine (Pre-chlorination of raw water).

iii) Clarification – A flat bottom sludge blanket type clarifier is provided with 8 compartments for removal of turbidity and suspended particles

iv) Filtration – Constant rate Rapid Gravity Sand Filters (12 Nos) are provided. Filtration is done to remove fine suspended matter and to ensure treated water of consistent turbidity less than 1 NTU.

v) Chlorination – Post Chlorination of the filtered water is done in the Chlorine Contact Tank with mechanical mixing for killing all bacterial activity. The contact tine provided is 30 minutes at the rated throughput. Two chlorine Contact Tanks are provided with each tank designed for handling the full throughput of the plant. The free chlorine content in the overflow from this tank shall be about 0.5 mg/l. The coliform count after chlorination shall be "nil".

i At the outlet of the Chlorine contact Tank, provision is made for dosing of lime solution in order to provide final pH correction and maintain positive Langlier Index.

ii Treated Water Storage Reservoir – The chlorinated treated water which conforms to the treated water requirements is taken to the Treated Water Reservoir which is a 2 compartment tank. The total retention time in the Reservoir is one hour with each compartment of 30 minutes storage.

iii Treated Water Pumping Station with Vertical Turbine Pumps – 6 Nos. The treated water from the Treated water Reservoir flows to the Treated Water Pump Sumps (3 Nos) each provided with 2 Vertical Turbine Pumps for pumping the water to the Booster Pumping Station located about 1.5 Km away from the WTP. The pipeline size is 1500 dia and it is a cement lined steel pipe.

2 Nos. Submersible Pumps are provided for dewatering the pump sumps, if necessary.

iv Chlorination System consisting of:

b) Chlorine Storage Tonners – 24 Nos.
c) Chlorine Solution Preparation System
d) Chlorine Ventilation and absorption system for fugitive Chlorine leakages.

v Chemical solution Preparation and Dosing system for Lime and Alum each consisting of:

b) Chemical Storage Area
c) Chemical Solution Preparation Tanks
d) Chemical Solution Saturation System
e) Pumps for transfer and Dosing.

vi Sludge Handling System for sludge generated consisting of:

b) Sludge Balancing Tanks with Submersible Mixers
c) Sludge Transfer Pumps
d) Sludge Thickener

e) Sludge Drying Beds

vii Electrical Supply system consisting of:

b) Two Pole Electricity Receiving System for 33 KV supply – 2 sets for 2 sources with each set provided with:

- Air Break Switch
- Lightning Arrestors
- HT Fuses
- Set of Insulators
- Outdoor Vacuum Circuit Breaker – 33 KV

c) 33 KV Distribution Panel

d) Main Transformers – 33KV / 6.6 KV – 2 Nos.

e) 6.6 KV Distribution Panel

f) Auxiliary Transformers – 6.6KV / 0.43 KV – 2 Nos.

g) LT Panel (415 V)

h) FCMA Starters for VT Pumps – 6 Nos.

i) Battery Chargers and Batteries for Electrical System control supply

j) Power Factor Correction system

k) UPS

vi) Instrumentation and Automation System consisting of:

c) Set of Instruments

d) PLCs for Automatic Control and Operation of:

- Clarifier Desludging
- For Filter Flow control and Backwash Control of individual filters – 12 Nos.
- Supervisory PLC for control of individual Filter PLCs
- Treated Water Pumping Station
- Chemical Preparation and Dosing System
- Sludge Handling System
- Telemetry Panel in WTP CCR including for interface with Packages II to V.

e) Control Panels for:

- Surge control System
- Chlorination System including Automatic changeover of Chlorine drums and Chlorine building Ventilation System.

vii) Mechanical Maintenance Workshop

viii) Laboratory

ix) Miscellaneous like Lighting, Fire Alarm etc.

1.5.3. Booster Pumping Station (BPS).

The treated water from the Water Treatment Plant is transferred to the Booster Pumping Station which has the following facilities:

a. Booster Reservoir – This is a 2 compartment reservoir with each compartment of approximately 18 minutes retention time at the maximum plant throughput.

b. Booster Vertical Turbine Pumps (6 Nos) for pumping the treated water to the Master Balancing Reservoir (MBR) at MADAM at a distance of 3.53 Km from the BPS. The delivery line from BPS to MBR is 1500 dia Steel Pipe duly coated with cement lining.

   2 Nos submersible pumps are provided to drain the Pump well sumps, if necessary.

c. EOT, 8 T capacity, for maintenance of Equipment installed in the Pumping Station and cleaning of Pump Sumps.

d. Submersible Pumps – 2 Nos for draining the Pump Wells.

e. Surge Control System for the Discharge Piping of the Pumping Station consisting of:

   - Air Compressors – 2 Nos.
   - Air Receiver – 2 Nos
   - Air Vessels – 3 Nos.

f. Electrical Supply system consisting of:

   - Two Pole Electricity Receiving System for 33 KV supply – 2 sets for 2 sources with each set provided with:
     - ✓ Air Break Switch
     - ✓ Lightning Arrestors
     - ✓ HT Fuses
     - ✓ Set of Insulators
     - ✓ Outdoor Vacuum Circuit Breaker – 33 KV

   i) 33 KV Distribution Panel
   ii) Main Transformers – 33KV / 6.6 KV – 2 Nos.
   iii) 6.6 KV Distribution Panel
   iv) Auxiliary Transformers – 6.6KV / 0.43 KV – 2 Nos.
   v) LT Panel (415 V)

   - FCMA Starters for VT Pumps – 6 Nos.
   - Battery Chargers and Batteries for Electrical System control supply

- Power Factor Correction system
- UPS

vi) Instrumentation and Automation System consisting of:

- Set of Instruments
- PLC for Process
- Control Panel for Surge Control

vii) Miscellaneous like Lighting, Fire Alarm etc.

1.5.4. Master Balancing Reservoir.

This is the main distribution reservoir from where the drinking water is supplied to Packages II and V. This is also a 2 compartment reservoir with each compartment of 12000 M^3 capacity. Package II is supplied by a 1500 dia pipe from the MBR while Package V is supplied by a 1000 dia pipe. A spare 600 dia connection for future use is also provided.

Package III is distributed from Package II while Package IV is distributed from Package V.

Pumping Machinery

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Number	**Date**

WORK INSTRUCTION
Pumping Machinery

7. ANNEXURE

7.1. SKETCH OF JYOTI VERTICAL TURBINE PUMP (WATER LUBRICATED)

7.2. DETAILS OF AIR VESSEL: RWPS, TWPS AND BPS.

7.3. AIR COMPRESSOR LOAD DATA DETAILS

7.4. LEVEL CALIBRATION

1. OBJECTIVE

The purpose of this Operational Procedure is to give a general description of pumping machinery.

2. SCOPE

This procedure applies to all water treatment plants on which pumping machinery have been installed as part of the treatment.

3. REFERENCES

- "INSTALLATION, MAINTENANCE AND TROUBLE SHOOTING INSTRUCTIONS". JYOTI, Vertical Turbine Pump
- "MANUAL OPERATION AND MAINTENANCE OF WATER SUPPLY SYSTEMS*". Central public health and environmental engineering organisation. Ministry of Urban Development New Delhi.*

4. DEFINITIONS

Head loss	It is the dissipation of energy due to friction. In a liquid flow head loss is reflected in a pressure drop along the pipe
Voltage	Otherwise known as electrical potential difference or electric tension (denoted ΔV and measured in units of electric potential: volts, or joules per coulomb), is the electric potential difference between two points
Electric current	Is a flow of electric charge through an electrical conductor. Electric currents flow when there is voltage present across a conductor
Fluid pressure	The pressure exerted by a fluid at any point inside it. The difference of pressure between two levels is determined by the product of the difference of height, the density, and the acceleration of free fall
Electric power	Is the rate at which electric energy is transferred by an electric circuit. The SI unit of power is the watt, one joule per second

5. RESPONSIBILITIES

All personnel involved in the exploitation of pumping machinery with no previous experience in this type of equipment should properly read and understand this document.

6. PROCEDURE

6.1. INTRODUCTION

Pumping machinery and pumping station are very important components in a water supply system. Pumping machinery is subjected to wear, tear, erosion and corrosion due to their nature of functioning and therefore is vulnerable for failures. Generally more number of failures or interruptions in water supply is attributed to pumping machinery than any other component. Therefore, correct operation and timely maintenance and upkeep pumping stations and pumping machinery are of vital importance to ensure uninterrupted water supply. Sudden failures can be avoided by timely inspection, follow up actions on observations of inspection and planned periodical maintenance. Downtime can be reduced by maintaining inventory of fast moving spare parts. Efficiency of pumping machinery reduces due to normal wear and tear. Timely action for restoration of efficiency can keep energy bill within reasonable optimum limit. Proper record keeping is also very important.

Obviously due attention needs to be paid to all such aspects for efficient and reliable functioning of pumping machinery. This S.O.P discusses procedures for operation and addresses pertinent issues involved in operation of pumping machinery and associated electrical and mechanical equipment.

6.1.1. COMPONENTS IN PUMPING STATION

The components in pumping station can be grouped as follows.

i) Pumping machinery

- ✓ Pumps and other mechanical equipment, i.e. valves, pipe work, vacuum pumps.
- ✓ Motors, switchgears, cable, transformer and other electrical accessories.

i) Ancillary Equipment

- ✓ Lifting equipment.
- ✓ Water hammer control device.
- ✓ Flowmeter.

iii) Pumping station

- ✓ Sump/intake/well/tubewell/borewell.
- ✓ Pump house.
- ✓ Screen.
- ✓ Penstock/gate

6.1.2. TYPE OF PUMPS

Following types of pumps are used in water supply systems.

v)Centrifugal pumps

vi)Vertical turbine pumps

- ✓ Oil lubricated
- ✓ Self water (pumped water) lubricated
- ✓ Clear water lubricated

vii)Submersible pumps

- ✓ Vertical borewell type pump-motor set
- ✓ Monobloc open well type pump-motor set

viii) Jet pumps

ix)Reciprocating pumps

6.1.3. COVERAGE IN THE S.O.P.

The S.O.P. covers following aspects regarding operation of components of pumping station and pumping machinery.

i) Pumping Machinery

- ✓ Operation including starting and stopping of pumps and associated electrical and mechanical equipment
- ✓ Trouble shooting

v) Ancillary equipment
Operation and testing of

- ✓ water hammer (surge) control device

6.2. OPERATION OF THE PUMPS

6.2.1. IMPORTANT POINTS FOR OPERATION

General important points as follows shall be observed while operating the pumps.

b) Dry running of the pumps should be avoided.

c) Centrifugal pumps have to be primed before starting.

d) Pumps should be operated only within the recommended range on the head-discharge characteristics of the pump.

- ✓ If pump is operated at point away from duty point, the pump efficiency normally reduces.
- ✓ Operation near the shut off should be avoided, as the operation near the shut off causes substantial recirculation within the pump, resulting in overheating of water in the casing and consequently, in overheating of the pump.

f) Voltage during operation of pump-motor set should be within + 10% of rated voltage. Similarly current should be below the rated current as per name plate on the motor.

g) Whether the delivery valve should be opened or closed at the time of starting should be decided by examining shape of the power-discharge characteristic of the pump. Pump of low and medium specific speeds draw lesser power at shut off head and power required increases from shut off to normal operating point. Hence in order to reduce starting load on motor, a pump of low or medium specific speed is started against closed delivery valve.

The pumps of high specific speed draw more power at shut off. Such pumps should be started with the delivery valve open.

h) The delivery valve should be operated gradually to avoid sudden change in flow velocity which can cause water hammer pressures.

It is also necessary to control opening of delivery valve during pipeline - filling period so that the head on the pump is within its operating range to avoid operation on low head and consequent overloading. This is particularly important during charging of the pumping main initially or after shutdown. As head increases the valve shall be gradually opened.

q) When the pumps are to be operated in parallel, the pumps should be started and stopped with a time lag between two pumps to restrict change of flow velocity to minimum and to restrict the dip in voltage in incoming feeder. The time lag should be adequate to allow to stabilize the head on the pump, as indicated by a pressure gauge.

r) When the pumps are to be operated in series, they should be started and stopped sequentially, but with minimum time lag. Any pump, next in sequence should be started immediately after the delivery valve of the previous pump is even partly opened. Due care should be taken to keep the air vent of the pump next in sequence open, before starting that pump.

s) The stuffing box should let a drip of leakage to ensure that no air is passing into the pump and that the packing is getting adequate water for cooling and lubrication. When the stuffing box is grease sealed, adequate refill of the grease should be maintained.

t) The running of the duty pumps and the standby should be scheduled so that no pump remains idle for long period and all pumps are in ready-to run condition. Similarly unequal running should be ensured so that all pumps do not wear equally and become due for overhaul simultaneously.

u) If any undue vibration or noise is noticed, the pump should be stopped immediately and cause for vibration or noise be checked and rectified.

v) Bypass valves of all reflux valve, sluice valve and butterfly valve shall be kept in closed position during normal operation of the pumps.

w) Frequent starting and stopping should be avoided as each start causes overloading of motor, starter, contactor and contacts. Though overloading lasts for a few seconds, it reduces life of the equipment.

6.2.2. UNDESIRABLE OPERATIONS

Following general undesirable operations should be avoided.

i) Operation at Higher Head

The pump should never be operated at head higher than maximum recommended. Such operation results in excessive recirculation in the pump, overheating of the water and the pump. Another problem, which arises if pump is operated at a head higher than the recommended maximum head, is that the radial reaction on the pump shaft increases causing excessive unbalanced forces on the shaft which may cause failure of the pump shaft. As a useful guide, appropriate marking on pressure gauge be made. Such operation is also inefficient as efficiency at higher head is normally low.

ii) Operation at Lower Head

If pump is operated at lower head than recommended minimum head, radial reaction on the pump shaft increases causing excessive unbalanced forces on shaft which may cause failure of the pump shaft. As useful guide, appropriate markings on both pressure gauge and ammeter be made. Such operation is also inefficient as efficiency at lower head is normally low.

iii) Operation on Higher Suction Lift

If pump is operated on higher suction lift than permissible value, pressure at the eye of impeller and suction side falls below vapour pressure. This results in flashing of water into vapour. These vapour bubbles during passage collapse resulting in cavitation in the pump, pitting on suction side of impeller and casing and excessive vibrations. In addition to mechanical damage due to pitting, discharge of the pump also reduces drastically.

iv) Throttled operation

At times if motor is continuously overloaded, the delivery valve is throttled to increase head on the pump and reduce power drawn from motor. Such operation results in inefficient running as energy is wasted in throttling. In such cases, it is preferable to reduce diameter of impeller which will reduce power drawn from motor. v) Operation with Strainer/Foot Valve Clogged

If the strainer or foot valve is clogged, the friction loss in strainer increases to high magnitude which may result in pressure at the eye of the impeller falling below water vapour pressure, causing cavitation and pitting similar to operation on higher suction lift. The strainers and foot valves should be periodically cleaned particularly during monsoon.

vi) Operation of the Pump with Low Submergence

Minimum submergence above the bellmouth or foot valve is necessary so as to prevent air entry into the suction of the pump which gives rise to vortex phenomenon causing excessive vibration, overloading of bearings, reduction in discharge and efficiency. As a useful guide the lowest permissible water level be marked on water level indicator.

vii) Operation with Occurrence of Vortices If vibration continues even after taking all precautions, vortex may be the cause. All parameters necessary for vortex-free operation should be checked.

6.2.3. STARTING THE PUMPS

Checks before starting

Following general points should be checked before starting the pumps.

- ✓ Power is available in all 3 phases.
- ✓ Trip circuit for relays is in healthy state
- ✓ Check voltage in all 3 phases.
- ✓ The voltage in all phases should be almost same and within + 10% of rated voltage, as per permissible voltage variation.
- ✓ Check functioning of lubrication system specifically for oil lubricated and clear water lubricated VT pumps and oil lubricated bearings.
- ✓ Check stuffing box to ensure that it is packed properly.
- ✓ Check and ensure that the pump is free to rotate.
- ✓ Check overcurrent setting if the pump is not operated for a week or longer period.
- ✓ Before starting it shall be ensured that the water level in the sump/intake is above low water level and inflow from the source or preceding pumping station is adequate.

Starting and operation of pumps

Procedures for starting and operation of different types of pumps are as follows.

a) Centrifugal Pump (of low and medium specific speed)

m) To start a centrifugal pump, the suction pipes and the pump should be fully primed irrespective of the fact whether the pump is with positive (flooded) suction or suction lift.

The centrifugal pump with positive suction can be primed by opening valve on suction side and letting out air from the casing by opening air vent.

Centrifugal pump on suction lift necessitates close attention to prime the pump fully. To achieve this, the suction pipe and the pump casing must be filled with water and entire air in suction piping and the pump must be removed.

vi)Close the delivery valve and then loosen slightly.

vii)Switch on the motor, check that direction of rotation is correct. If the pump does not rotate, it should be switched off immediately.

viii) Check vacuum gauge if the pump operates on suction lift. If the pointer on gauge gradually rises and becomes steady the priming is proper.

ix) Pressure gauge should be observed after starting the pump. If the pump is working correctly the delivery pressure gauge should rise steadily to shut off head.

x) When the motor attains steady speed and pressure gauge becomes steady, the delivery valve should be gradually opened in steps to ensure that the head does not drop below recommended limit. (in the absence of recommendations, the limit shall be about 85% of duty head for centrifugal pump).

xi) Check that ammeter reading is less than rated motor current.

xii) Check for undue vibration and noise.

xiii)When in operation for about 10-15 minutes, check the bearing temperature, stuffing box packing, and leakage through mechanical seal and observe vibrations, if any.

xiv) Voltage should be checked every half an hour and should be within limit.

c) Vertical Turbine Pump (of low and medium specific speed)

i) Close delivery valve, and then loosen slightly.

ii) If the pump is self water-lubricated and length of column assembly is long (15 m or above), external water shall be admitted to wet and lubricate the line shaft bearings before starting the pump. This is not our case.

iii) Open the air vent in discharge/delivery pipe.

iv) Switch on the motor and check correctness of direction of rotation. If the pump does not rotate, it should be switched off immediately.

x) Check that oil is flowing into the pump through the sight glass tube. The number of drops/min. should be as per manufacturer's recommendations (normally 2-4 drops/minute).For clear water lubricated pump, check that lubricating clear water is passing into the column assembly.

xi) Check pressure gauge reading to ensure that pump has built up the required shut off head.

xii) When the motor attains steady speed and pressure gauge becomes steady, the delivery valve should be gradually opened in steps to ensure that the head does not drop below recommended limit. (In absence of recommendation, the limit shall about 75% of duty head for VT & submersible pump).

xiii) If steady water stream is let out through air vent, close the air vent.

xiv) Check that ammeter reading is less than rated motor current.

xv) Check for undue vibration and noise.

xvi) When in operation for about 10-15 minutes, check bearing temperature, stuffing box packing and observe vibration if any.

xvii) Voltage should be checked every half an hour and should be within limit.

c) Submersible Pumps

Starting of a submersible pump is similar to vertical turbine pump except that steps ii, v, and xi are not applicable and since motor is not visible, correctness of direction of rotation is judged from pressure gauge reading which should indicate correct shut off head.

d) Jet Pump

The procedure for starting jet pumps is similar to centrifugal pump except that priming by vacuum pump is not possible. Priming needs to be done by filling the pump casing and suction line from external source or by pouring water.

e) Vacuum Pump

The procedure for starting vacuum pump is similar to centrifugal pump except that priming is not necessary and valves on both suction & delivery side of vacuum pump should be fully open.

f) Reciprocating Pump

The steps stipulated for centrifugal pump are equally applicable for reciprocating pump.

However exceptions as follows are applicable.

- ✓ The pump should be started against partially open delivery valve.
- ✓ The pump should never be started or operated against closed delivery valve.

Stopping the pump under normal condition

Steps to be followed for stopping a pump of low and medium specific speed are as follows:

viii) Close the delivery valve gradually (sudden or fast closing should not be resorted to, which can give rise to water hammer pressures).

ix)Switch off the motor.

x) Open the air vent in case of V.T. and submersible pump.

xi) Stop lubricating oil or clear water supply in case of oil lubricated or clear water lubricated VT pump as applicable.

Stopping after power failure/tripping

If power supply to the pumping station fails or trips, actions stated below should be immediately taken to ensure that the pumps do not restart automatically on resumption of power supply. Though no-volt release or undervolt relay is provided in starter and breaker, possibility of its malfunctioning and failure to open the circuit cannot be ruled out. In such eventuality, if the pumps start automatically on resumption of power supply, there will be sudden increase in flow velocity in the pumping main causing sudden rise in pressure due to water hammer which may prove disastrous to the pumping main. Secondly, due to sudden acceleration of flow in the pumping main from no-flow situation, acceleration head will be very high and the pumps shall operate near shut off region during acceleration period which may last for few minutes for long pumping main and cause overheating of the pump. Restarting of all pumps simultaneously shall also cause overloading of electrical system.

Hence, precautions are necessary to prevent auto-restarting on resumption on power. Following procedure should be followed.

i) Close all delivery valves on delivery piping of pumps if necessary, manually as actuators can not be operated due to non-availability of power.

ii) Check and ensure that all breakers and starters are in open condition i.e. off-position.

iii) All switches and breakers shall be operated to open i.e. off-position.

iv) Open air vent in case of V.T. or submersible pump.

v) Information about power failure should be given to all concerned, particularly to upstream pumping station to stop pumping so as to prevent overflow.

6.2.4. TROUBLE AND SHOOTING INSTRUCTIONS

6.2.4.1. PUMP DOES NOT START

1. Voltage and/or supply frequency is low.
2. Motor is defective.
3. Starting equipment is defective.
4. Over load relay is tripped.
5. One or more fuses burnt out (Test voltage on all phases of motor terminal).
6. Motor connections are wrong.
7. Motor provided with non reversible ratchet is connected for reverse rotation i.e. clockwise when viewed from the top.
8. Pump is sand-locked.
9. Shaft is disengaged or broken.
10. Impeller fouls against the top or bottom surface.

6.2.4.2. PUMP DOES NOT DELIVER WATER

1. Strainer, suction pipe or impeller suction is chocked up.
2. Lowest bowl is not submerged.
3. Pump speed is very low (due to low voltage or frequency or due to excessive load on engine or improper ratio of pulley diameters).
4. Discharge valve is closed.
5. Prevailing head on pump is much higher than specified.
6. Shaft is disengaged or broken.
7. One or more impellers are loose on shaft.
8. Pump revolves in reverse direction.

6.2.4.3. PUMP DOES NOT SPECIFIED QUANTITY

1. Pump speed is very low (due to low voltage or due to excessive load on engine or improper ratio of pulley diameters).
2. There is excessive draw-down of water level in the well.
3. Prevailing head on pump is much higher than specified.
4. One or more impellers are loose on shaft.
5. Stainer, suction pipe or impellers suction is partially chocked up.
6. Pump works against high suction lift.

7. Air or gas is entrapped in water.
8. Suction pipe is leaky. (If pumping water level is below the lowest impeller).
9. Column pipe is leaky.
10. Impellers of neck rings are worn out.
11. Pump revolves in reverse direction.

6.2.4.4. PUMPS TAKES EXCESSIVE POWER

1. Speed is high (due to high voltage or frequency or due to improper ratio of pulley diameters).
2. Bearings run dry or with insufficient lubrication. In our case, water lubricated pumps, the pump is made to start whit-out pre-lubrication.
3. Shaft are bent.
4. The well is crooked resulting misalignment or bearings/shaft.
5. Impellers foul against top or bottom surface of bowls.
6. Discharge head is not properly leveled.
7. Shaft coupling rubs against the inner surface of tubes.
8. Shaft is tight in bearing.
9. There are vibrations due to misalignment, worn out parts, etc.
10. Prevailing head is different from the one specified.
11. Gland packing is excessively tight.
12. Sand is entrained in water.
13. Pump is not free.
14. Impellers have clogged with sand, gravel, etc.

6.2.4.5. WATER ENTERS SHAFT TUBES

1. One or more tube joints are not tightened properly.
2. There are dents or cuts on the tube faces.
3. Burr or foreign matter is present on shaft tube threads or faces.
4. One or more line shaft bearing are broken.
5. Tube is leaky or broken.
6. Discharge head gland is not properly tightened.

6.2.4.6. PUMP VIBRATES

1. The tube well is crooked.
2. Shafts are bent.
3. Bearings are worn out.
4. Rotor of motor is out of balance.
5. Impellers are out of balance due to foreign material caught in them, or due to uneven wear.
6. Shaft tubes are not pulled under tension.
7. Air or gas is present in water.
8. Discharge head is not properly leveled.
9. Foundation bolts are not tightened properly.
10. Turbulent flow at the suction.

6.2.4.7. COMPONENTS WEAR OUT QUICKLY

1. Bearings run dry or with insufficient lubrication. In our case, water lubricated pumps, the pumps made to start whit-out pre-lubrication.
2. Pump bearing are misaligned.
3. The tube well is crooked.
4. The shafts are bent.
5. There is sand in water.
6. There are vibrations due to misalignments, improper leveling of discharge head, etc

6.3. SURGE PROTECTION SYSTEM

6.3.1. CONSIDERATION OF SURGE IN THE RAISING MAIN

Water hammer or Surge is a phenomenon occurring in closed conduit or pipe flows, associated with rapid changes in discharge in the pipe. The rapid change in discharge and the associated velocity is accompanied by a change in pressure, which is propagated through the pipe. The Water hammer wave is propagated at acoustic speed, which varies with the material and wall thickness of the pipe. Like any other wave phenomenon, the wave is transmitted and reflected at different boundaries such as reservoir or pump. It is also dampened by friction as it propagates. In a pumping main, changes in discharge may be caused by:

a) Valve closure or opening
b) Starting or Stopping of a pump
c) Power failure
d) Single pump failure when multiple pumps are in parallel operation. The planned Starting or Stopping of a pump is also associated with valve opening or closing. In general, in pumping main carrying water, valve operations need not be very rapid and hence Surge Pressures due to valve operations and planned Starting or Stopping of a pump can be kept under control. Surge pressures due to pump starting cannot exceed shut-off head of the pump (unless a valve at the downstream end is closed).

6.3.2. SURGE PHENOMENON FOLLOWING POWER FAILURE.

During Power failure, the motor speed drops rapidly. The rate of deceleration depends on the inertia of the pump and the motor. As the motor speed reduces, the discharge and head reduces and a down surge pressure wave travels along the transmission main towards the delivery end, at a speed governed by the pressure wave velocity. When the wave reaches the delivery reservoir, it gets reflected as an upsurge wave, which in turn, travels towards the pump end. Within a short interval following power failure, motor speed reaches a level at which no forward pumping is possible. At this stage, flow reversal takes place and the HOPD valve at the pump end closes. It is possible that the valve has allowed some reverse flow to develop before it closes.

The above phenomenon may cause the following problems:

a) When the HOPD valve closes, depending on the magnitude of reverse flow already established, a pressure rise occurs, which may exceed the design / test pressure of pipe.
b) During the initial down surge phase, the magnitude of pressure drop may be such that, at a peak along the alignment, vapor pressure may occur.
c) This now forms a pressure control at the location; it functions as a pseudo-reservoir, segregating the flow upstream and downstream of location. This is termed as water column separation, with inflow velocity at the location being different from the outflow velocity.

Now, the outflow velocity is more than inflow velocity, increasing the cavity size. Later, the inflow velocity becomes more shrinking. The cavity at some instant fully collapses, creating a shock pressure rise and thereafter the inflow and outflow velocities are the same at the location. The shock pressure rise travels on both sides and may cause the pressure to exceed design / test pressure.

For large diameter steel pipes, the occurrence of vapor pressure may also pose a problem. In systems where extensive occurrence of vapor pressure is indicated, analysis considering column separation effect is to be treated as approximately. Hence predictability of the behavior of such a system under surge condition is not good, unless suitable protection system is designed.

6.3.3. FUNCTION OF AIR VESSEL

The Air Vessel can be an effective surge protection system to control both down surge and upsurge. It is a closed pressure vessel, with water in the lower part of vessel and compressed air at working pressure in the upper part. The relative proportion of water and compressed air is a design variable. When power fails, the pump head reduces rapidly, while the pressure in the air vessel reduces much more gradually, accompanied by expansion of air. As a result, the non-return valve located just upstream of the air vessel closes. Now water is supplied in the transmission main from the air vessel, at a gradually diminishing rate, as the air expands. Essentially, the compressed air functions as a stored energy, cushioning the rate of velocity reduction in the transmission main and hence controlling the surge pressures. As the air expands, the forward flow velocity reduces and soon flow reversal takes place. Now water enters the air vessel, compressing the air.

The surge protection depends on the initial volume of air under working conditions. The associated design parameter is defined by the air vessel constant, K given by.

$$K = \frac{2\ Coa}{Qo\ L}$$

Where Co = air volume under working condition, Qo = Design discharge, L = length of the transmission main and a = pressure wave velocity. The design of the air vessel should be such that there is enough compressed air, Co in the air vessel (that is, sufficiently high value of K) to control the surge pressures and enough water in the vessel so that some water is still left in the vessel, when the air expands fully at instant of maximum down surge. With such a design, when the pump is restarted, the water level automatically reaches normal level in the air vessel and no recharging of vessel is required.

While down surge is essentially controlled by a suitable choice of K, it is possible to control up surge to some extent by providing a different orifice in the air vessel connection. The orifice is so shaped that there is greater resistance for inflow into the air vessel, than for outflow from the air vessel. The ratio of head loss in the two directions is 2.5. By reducing the size of the orifice, upsurge comes down significantly. However, there is a limit to this approach, as undue throttling will result in deterioration of down surge and also the velocity through the orifice will increase considerably. To avoid this problem, an independent two way control with a non-return valve bypass connection to the Air Vessel is possible. But, this design critically depends on the HOPD valve function and is better to avoid unless absolutely essential. Generally, the orifice type connection is quite effective and can be designed economically, if required with more than one orifice.

The water level in the air vessel has to be maintained over a specified band. Some quantity of compressed air may be lost due to leakage and dissolution or also due to volume changes associated with temperature variations. It may be necessary to replenish small quantities of compressed air periodically, when water level crosses the upper control level. For this and also for initial charging of the air vessel, an Air Compressor is required as an accessory. A periodic monitoring of the water level in the air vessel and correction through charging (occasionally bleeding) is required. Typically, such monitoring is required once a day and the correction may take just a few minutes.

6.3.4. DESCRIPTION OF AIR VESSEL

Air Vessel (or Air Chamber as it is sometime referred) is a pressure vessel fabricated of steel, containing water in the lower part of the vessel and compressed air at working pressure in the upper part of the vessel. The relative proportion of water and compressed air is a design variable. The air vessel as a surge protection device is invariably located very near the pump house and the vessel is connected to the transmission main by a connecting pipe downstream of the manifold at a convenient location.

A schematic diagram of the Air Vessel is shown. As shown in the diagram, a rounded orifice is normally installed in a connecting pipe, in such a way that the head loss for inflow into the air vessel is much larger than for outflow from the air vessel. This is intended to achieve some control on the up-surge without significant deterioration in the down-surge, without increasing the size of the vessel at the same time.

The function of the air vessel is as follows. When power fails, the pump head reduces rapidly, while the pressure in the air vessel reduces much more gradually, accompanied by expansion of air. As a result, the HOPD valve located just upstream of the air vessel or on the delivery pipes of the pumps closes. Now water is supplied to the transmission main from the air vessel, at a gradually diminishing rate, as the air expands. Essentially, the compressed air functions as a stored energy, cushioning the rate of velocity reduction in the transmission main, and hence controlling the surge pressures. As the air expands, the forward flow velocity reduces and soon flow reversal takes place. Now water enters into the air vessel, compressing the air. This process, wherein the variation in pressure is related to the expansion and compression of air in the air vessel, cushions the surge pressures in the transmission main very significantly.

6.3.5. WATER LEVEL CONTROL BAND IN AIR VESSEL

The water level in the air vessel decides the relative volume of compressed air and water in the air vessel. From practical considerations, it is clear that the water level can not be maintained at a single unique level, but may vary over a small range. This range is to be decided in the design, with the upper most level in the range referred as upper emergency level (UEL) and the lower most level in the range referred as lower emergency level (LEL). Within this band, there may be intermediate control levels.

Depending on the scale of the project and size of the air vessel, there may be, in all, three or five control levels. Further discussion is restricted to the case where there are five control levels that are four small bands between UEL & LEL. The provision of volume for these bands is a matter of judgement by the designer. For horizontal orientation of the air vessel, a volume corresponding to 60 to 70mm band may be allowed between two control levels. For vertical orientation of the air vessel, a volume corresponding to 60 to 100mm band may be allowed between two control levels. In the present design, as the size of the air vessel is decided conservatively, a fairly liberal provision is made for the control level band volume.

6.3.6. SURGE PROTECTION SYSTEM OPERATION

6.3.6.1. GENERAL

The Air Vessel is to be installed near pump house, with the Non-Return Valve just upstream of the Air Vessel. The vessel is installed in a Horizontal orientation at 2 ½ Deg. Inclination from the horizontal.

The water level in the vessel is to be retained within the control level bands indicated. The Magnetic Level Sensor for sensing the water level has to be provided in the separate chamber connected to the air vessel.

6.3.6.2. OPERATION OF AIR VESSEL

Water level changes in the air vessel may occur due to air leakage, air dissolution and temperature changes, besides any load change in the pump house. When the water level reaches Upper Control Level (UCL), air is to be let into the vessel through the pneumatic pipeline. The air charging may be stopped when the water level reaches Normal Level (NL). If water level reaches Lower Control Level (LCL), air is to be bleed-out until the water level comes to normal level. If water reaches either of the two emergency levels (UEL or LEL), the pumps must be stopped unless immediate corrective action is taken for charging / bleeding air. A control for the emergency levels as the water level variation in the air vessel under normal working conditions is a slow and gradual process.

A compressor is necessary for commissioning the air vessel initially and for recharging after any maintenance work, as also for periodic small corrections to take care of air leakage, dissolution etc. These periodic corrections are generally required once in a day and take a few minutes.

6.3.6.3. PUTTING INTO OPERATION

Before putting the system into operation, please ensure that the following points are observed or measures taken:

a) Check the system and connection lines for orderly installation as per Drawings.
b) Ensure necessary oil for Air Compressor.
c) Check the motor for their direction of rotation.
d) Check whether all Electrical Installations are connected properly.
e) Ensure that the isolation valve between the air vessel and air receiver to be kept in open condition.
f) The drain valve is to be in closed condition.
g) The Pump delivery valve is to be in opened condition.
h) The bleed valve should be kept in closed condition.
i) A pressure transmitter is also provided for remote monitoring of air in the air vessel and air receiver.

6.3.6.4. SYSTEM OPERATION

a) START Air Compressors and build up Air pressure in the Air Receiver. The pressure in the Air Receiver should not exceed:
    - RWPS: 12 kg/ cm^2.
    - TWPS: 18 kg/ cm^2.
    - BPS: 15 kg/ cm^2.
b) Drain the moisture in the Air receiver once in 15 days.
c) The charge valve should be kept in closed condition.
d) Check for the water level in the indication panel. Primarily the water level should be maintained at the mean level in the indication panel.
e) If the water level is above the Mean level, the charge valve should be opened for a small period until the pressure in the Air Receiver and Air Vessel is almost equal.
f) The charge valve should now be closed and pressure should be built up in the Air Receiver. Once the pressure is built up in the Air Receiver, the charge

valve should be opened again to charge the Air Vessel. The process is to be continued till the water level reaches the Mean Level in the indication panel.

g) In case, if the water level is below the mean level, the Bleed Valve should be opened and Air should be bleed-out till the water level reaches the mean level in the indication panel.

h) During pump trip, the water level may go above or below the mean level and water level will usually come back to mean level once the pumps are re-started. Hence no charging or bleeding is necessary after the pumps are tripped.

6.3.6.5. SURGE PROTECTION SYSTEM. DO's AND DON'ts

<u>DO's</u>

1. Check the system and connection lines for orderly Installation as per drawings.
2. Ensure necessary oil for air compressors.
3. Check the motor for their direction of rotation.
4. Check whether all electrical installation are connected Properly.
5. Open the ball valve in the compressor line before starting The compressor.
6. Ensure that the isolation valve between the air vessel and air receiver is kept in open condition. During manual operation.
7. The drain valve of air receiver is to be kept in closed condition.
8. The bleed valve should be kept in closed condition.
9. Check and log water level in the air vessel
10. Run air compressors for few minutes every day or atleast once in two days.
11. Replace the air compressor oil at lease once two year.
12. Always maintain mean level by charging or bleeding air chamber.
13. Butterfly valve of delivery manifold and individual air vessel isolation buterfly valve has to be kept in open condition. And should be closed only during long shutdown.
14. Butterfly valve of delivery manifold should be closed only during long shutdown.

<u>DON'Ts</u>

1. Air pressure in the receiver should not exceed 15.0 kg/cm2.
2. Charging and bleeding of air during shut down.

6.4. HEALTH & SAFETY

Following safety precautions should be observed while working in a pump house.

i) No electric live part shall be kept exposed. Particular care should be taken not to keep the motor terminals, starter door, panel door etc. in open condition.

ii) Guard for pump – motor coupling and for extended shaft shall be provided.

iii) Top cover of the VHS (vertical hollow shaft) motor shall not be unnecessarily kept in dismantled condition.

iv) Helmet, gumboots, hand gloves, torch and emergency lamp etc. shall be provided to the workers.

v) Shock proof rubber matting shall be kept in front of panel and starters.

vi) Discharging devices shall also be provided to work safely on HT side of transformer.

vii) Fire fighting equipment suitable for electrical fire shall be provided. The fire extinguisher shall be thoroughly checked and recharged once in a year.

viii) Damaged wooden flooring, damaged grating etc. shall be repaired on priority.

ix) Safety railing shall be provided above all openings, unwalled edges of flooring and all such places vulnerable for falling or slipping of staff.

x) First aid box shall be kept at visible and accessible place. The first aid box shall be checked once in a month and all used items shall be replenished.

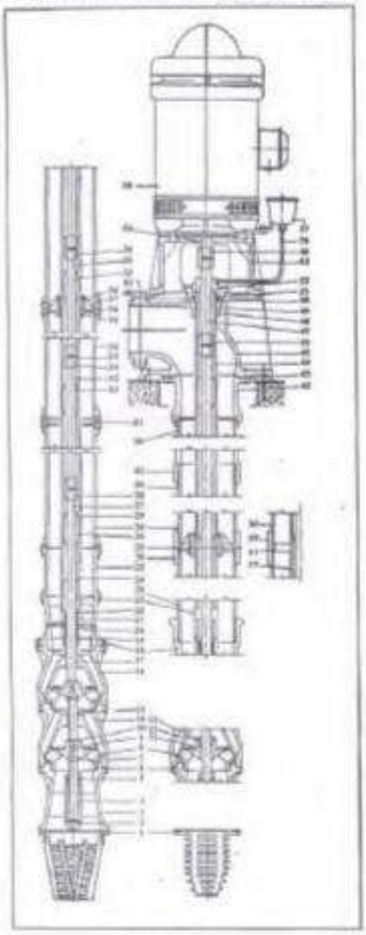
xi) Staff shall be trained in the following aspects to enhance safety awareness and skills to handle safety aspects.

- Fire fighting
- Safety procedures and practices in electrical work
- First aid (general)
- First aid for electric shock.

7. ANNEXURE

7.1. SKETCH OF JYOTI VERTICAL TURBINE PUMP (WATER LUBRICATED)

JYOTI VERTICAL TURBINE PUMP (WATER-LUBRICATED)



Sr. No.	Part Name
58	Vertical Hollow Shaft Motor
57	Automatic Lubricator Assy
56	Oiling Pipe
55	Head Shaft Coupling
54	Head Shaft
53	Motor Stool or Adapting Plate
52	Gland
51	Gland Packing Ring
50	Gland Packing
49	Tube Tension Plate
48	Check Nut
47	Head Shaft Extension
46	Head Shaft Extension Coupling
45	Discharge Head Body
44	Tube Tension Nipple
43	Top Column Flange Gasket
42	Top Column Flange- Flanged or Threaded
41	Delivery Flange Gasket
40	Deliver Flange (Up to D-150 Dis-Head)
39	Column Pipe Coupling
38	Circlip
37	Rubber Guide Ring Washer
36	Rubber Guide Ring
35	Guide Spider
34	Line Shaft Coupling
33	Line Shaft Bearing
32	Line Shaft
31	Column Pipe Spacer
30	Column Pipe Flanged or Threaded
29	Shaft Enclosing Tube
28	Impeller Shaft Coupling
27	Impeller Shaft
26	Impeller Shaft Bearing
25	Column Pipe Adapter
24	Tubing Adaptor
23	Discharge Case Bearing
22	Impeller Shaft Packing Ring
21	Impeller Shaft Packing
20	Lantern Ring
19	Distance Piece
18	Discharge Case Flanged or Threaded
17	Top Bowl Bearing
16	Top Bowl
15	Bowl Bearing
14	Bowl
13	Impeller Collet Nut Washer
12	Impeller Collet Nut
11	Impeller Collet
10	Circlip
9	Impeller Key
8	Impeller
7	Impeller Holding Split Ring
6	Impeller Seal Ring
5	Suction Case Sand Collar
4	Suction Case Bearing
3	Suction Case
2	Suction Case Plug
1	Suction Pipe Strainer

7.2. DETAILS OF AIR VESSEL: RWPS, TWPS AND BPS.

RAW WATER PUMPING STATION (RWPS) : -

Sl. No.	Description	Particulars
1.	Volume of Air Vessel & No. of Air Vessels Two running + One Stand By	38 M^3 x 3 Nos.
2.	I.D of the Vessel	2600 mm
3.	Operating Pressure of Air Vessel Designed	9.50 Kg/cm^2
4.	Operating Pressure as per actual at present with one pumps running	5.50 Kg/cm^2
5.	Design Pressure for the Air Vessel	14.00 Kg./Cm^2
6.	Test Pressure for the Air Vessel	19.00 Kg. / Cm^2
7.	Connecting pipe size for the Air Vessel	500 mm
8.	Compressor free air delivery	1.25 M^3 / Hour
9.	No. of Air Compressor	2 Nos. (1 running + 1 standby)
10.	Air receiver volume / No. One running + One Stand By	4 M^3 x 2 Nos.
11.	Pneumatic plumbing size	40 mm

1. Volume of Air Vessel & No. of Air Vessels 14 M³ x

TREATED WATER PUMPING STATION (TWPS) : -

Sl. No.	Description	Particulars
1.	Volume of Air Vessel & No. of Air Vessels One running + One Stand By	14 M^3 x 2 Nos.
2.	I.D of the Vessel	2000 mm
3.	Operating Pressure of Air Vessel Designed	16.50 Kg/cm^2
4.	Operating Pressure as per actual at present with one pumps running	13.00 Kg/cm^2
5.	Design Pressure for the Air Vessel	25.00 Kg./Cm^2
6.	Test Pressure for the Air Vessel	33.00 Kg. / Cm^2
7.	Connecting pipe size for the Air Vessel	700 mm
8.	Compressor free air delivery	25 M^3 / Hour
9.	No. of Air Compressor	2 Nos. (1 running + 1 standby)
10.	Air receiver volume / No. One running + One Stand By	1.7 M^3 x 2 Nos.
11.	Pneumatic plumbing size	25 mm

2000
16.50 K
13.00 K
25.00 K
33.00 K
700
25 M³
2 N
running
1.7 M³ x
25
11. Pneumatic plumbing size 25 mm

BOOSER WATER PUMPING STATION (BPS) : -

Sl. No.	Description	Particulars
1.	Volume of Air Vessel & No. of Air Vessels Two running + One Stand By	25 M^3 x 3 Nos.
2.	I.D of the Vessel	2400 mm
3.	Operating Pressure of Air Vessel Designed	12.00 Kg/cm^2
4.	Operating Pressure as per actual at present with one pumps running	8.80 Kg/cm^2
5.	Design Pressure for the Air Vessel	18.00 Kg./Cm^2
6.	Test Pressure for the Air Vessel	24.00 Kg. / Cm^2
7.	Connecting pipe size for the Air Vessel	500 mm
8.	Compressor free air delivery	50 M^3 / Hour
9.	No. of Air Compressor	2 Nos. (1 running + 1 standby)
10.	Air receiver volume One running + One Stand By	3.5 M^3 x 2 Nos.
11.	Pneumatic plumbing size	40 mm

7.3. AIR COMPRESSOR LOAD DATA DETAILS

TECHNICAL DATA

AIR COMPRESSOR LOAD DATA DETAILS

TITLE : LOAD DATA FOR AIR COMPRESSORS

CLIENT : TWAD, Dharmapuri

CUSTOMER : M/s. Cadagua Ferrovial Pvt. Ltd., Noida

PROJECT : SURGE PROTECTION SYSTEM FOR RAW WATER PUMPING STATION

1.	Make	*ELGI*
2.	Model	TS 15 120
3.	Free Air Delivery	1.25 M^3 / Hour
4.	Air Compressor Working Pressure	12 kg/cm^2
5.	Type of cooling	*Air Cooled*
6.	Required Pressure for working of Surge Control System for this station	9.5 kg/cm^2
7.	No. of Stages	2
8.	Fusible plugs provided	YES
9.	Motor make / Type	ELGI Squirrel Cage
10.	HP of Motor / Volt / Freq. / phases	15 HP
11.	Type of Drive	V Belt
12.	Type of Unloading	Mechanical
13.	Type of Compressor	Reciprocating
14.	Type of Compressor Mounting	Base Mounted
15.	Air Receiver Volume / No. One running + One Stand By	4 M^3 x 2 Nos.
16.	No. of Air Compressors	2 Nos.

TECHNICAL DATA

AIR COMPRESSOR LOAD DATA DETAILS

TITLE	:	LOAD DATA FOR AIR COMPRESSORS
CLIENT	:	TWAD, Dharmapuri
CUSTOMER	:	M/s. Cadagua Ferrovial Pvt. Ltd., Noida
PROJECT	:	SURGE PROTECTION SYSTEM FOR TREATED WATER PUMPING STATION

1.	Make	*ELGI*
2.	Model	HP 10 300
3.	Free Air Delivery	25 M^3 / Hour
4.	Air Compressor Working Pressure	30 kg/cm^2
5.	Type of cooling	*Air Cooled*
6.	Required Pressure for working of Surge Control System for this station	17 kg/cm^2
7.	No. of Stages	2
8.	Fusible plugs provided	YES
9.	Motor make / Type	ELGI Squirrel Cage
10.	HP of Motor / Volt / Freq. / phases	10 HP
11.	Type of Drive	V Belt
12.	Type of Unloading	Mechanical
13.	Type of Compressor	Reciprocating
14	Type of Compressor Mounting	Base Mounted
15.	Air Receiver Volume / No. One running + One Stand By	1.7 M^3 X 2 Nos.
16.	No. of Air Compressors	2 Nos.

Compressor Pressure Switch Settings :-

Sl. No.	ON	OFF
1.	14.0 Kg/Cm^2	17.0 Kg/Cm^2
2	14.3 Kg/Cm^2	16.7 Kg/Cm^2

TECHNICAL DATA

AIR COMPRESSOR LOAD DATA DETAILS

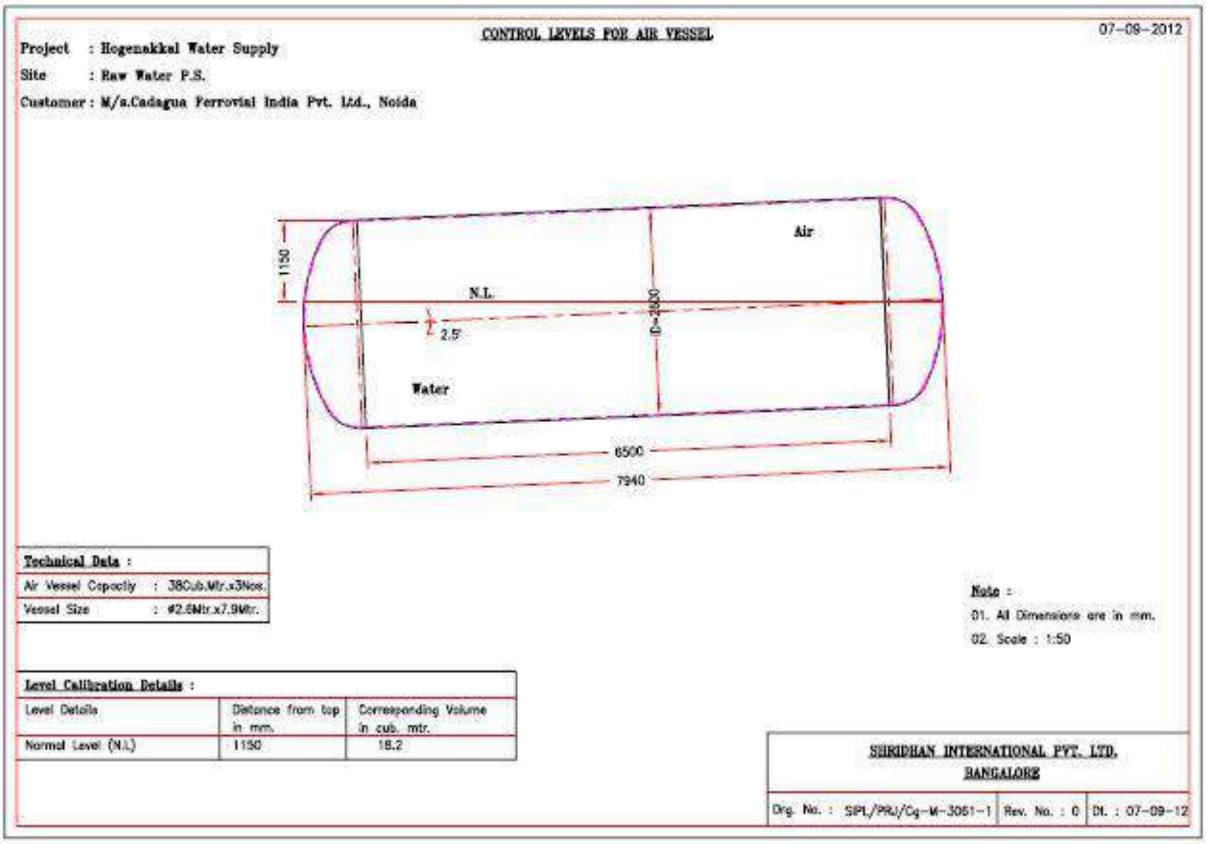
TITLE	:	LOAD DATA FOR AIR COMPRESSORS
CLIENT	:	TWAD, Dharmapuri
CUSTOMER	:	M/s. Cadagua Ferrovial Pvt. Ltd., Noida
PROJECT	:	SURGE PROTECTION SYSTEM FOR BOOSTER PUMPING STATION

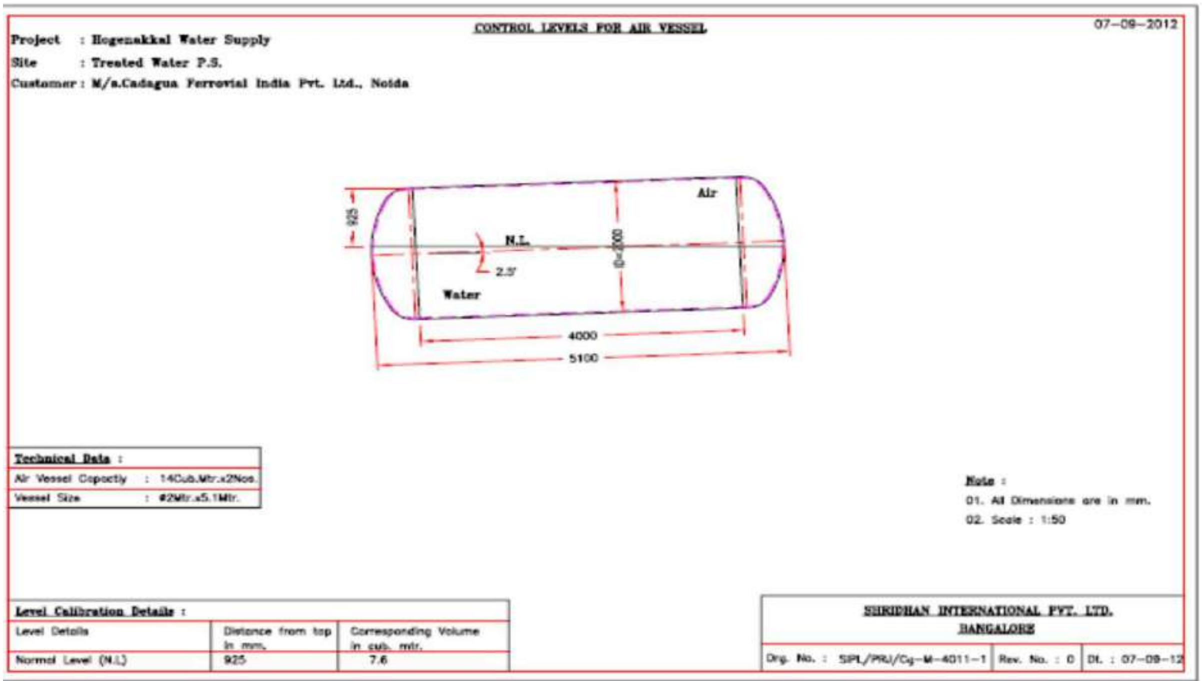
1.	Make	*ELGI*
2.	Model	HP 15 300
3.	Free Air Delivery	50 M^3 / Hour
4.	Air Compressor Working Pressure	30 kg/cm^2
5.	Type of cooling	*Air Cooled*
6.	Required Pressure for working of Surge Control System for this station	14.0 kg/cm^2
7.	No. of Stages	2
8.	Fusible plugs provided	YES
9.	Motor make / Type	ELGI Squirrel Cage
10.	HP of Motor / Volt / Freq. / phases	15 HP
11.	Type of Drive	V Belt
12.	Type of Unloading	Mechanical
13.	Type of Compressor	Reciprocating
14.	Type of Compressor Mounting	Base Mounted
15.	Air Receiver Volume / Nos.	3.5 M^3 x 2 Nos.
16.	No. of Air Compressors	2 Nos.

Compressor Pressure Switch Settings :-

Sl. No.	ON	OFF
1.	10.50 Kg/Cm^2	13.50 Kg/Cm^2
2	10.50 Kg/Cm^2	14.00 Kg/Cm^2

7.4. LEVEL CALIBRATION

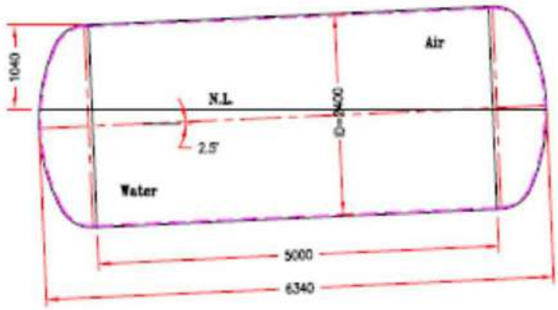




07-09-2012

CONTROL LEVELS FOR AIR VESSEL

Project : Hogenakkal Water Supply
Site : Booster P.S.
Customer : M/s.Cadagua Ferrovial India Pvt. Ltd., Noida



Technical Data :	
Air Vessel Capacity	: 25Cub.Mtr.x3Nos.
Vessel Size	: Ø2.4Mtr.x6.3Mtr.

Note :
01. All Dimensions are in mm.
02. Scale : 1:50

Level Calibration Details :

Level Details	Distance from top in mm.	Corresponding Volume in cub. mtr.
Normal Level (N.L)	1040	13.4

SHRIDHAN INTERNATIONAL PVT. LTD.
BANGALORE

Drg. No. : SIPL/PRJ/Cg-M-5021-1	Rev. No. : 0	Dt. : 07-09-12

LIST OF CONTENTS

1. DESCRIPTION OF THE WORKS

The principal elements of the Project Works are:

- Intake works and raw water pumping station at upstream of river Cauvery, at site location 45 km west of Dharmapuri
- Raw water pipeline of approximate length 6.25 km to connect the raw water pumping station and the Water Treatment Works
- The Water Treatment Works
- The treated water pumping station
- The treated water lift pipeline with a for length of 1.50 km. to the inlet sump of the booster
- The treated water booster pumping station
- The treated water booster pipe lift to MADAM
- The master balancing reservoir at MADAM
- The Supervision, Control and Data Acquisition System (SCADA System) and the communication network for the whole project, including the works at Packages II, III, IV and V
- Operation and maintenance the whole of the Works for 60 months.

2. DESIGN CONDITIONS

2.1. TREATMENT WORKS CAPACITY

According to the meeting on 26/05/2010 at Dharmapuri, the treated water capacity of the system must comply with:

The plant will be able to deliver treated water output of 158.84 Ml per day by running the whole Works for 23 hours. The treated water capacity adopted is:

Maximum (daily)	: 158.84Ml/d
Maximum (hourly)	: 6,906,1 m3/h

The water produced in the washing of the filters (hereafter called used washwater) will be discharged to washwater recovery tank. The supernatant water will be returned to the treatment works inlet. The returned water will be included in the throughput of the works. Sludge from the used washwater recovery tanks and sludge from the clarifiers will be discharged to sludge balancing tank. From sludge balancing tank, the sludge will be pump to thickeners. This sludge will be discharge to drying beds by gravity.

Therefore, the mean output to the treated water reservoir will be the treatment works input less the water discharged as sludge from the clarifiers and from the used washwater recovery tank and less service water used for flushing, irrigation or domestically.

These losses excluding service water used for flushing, irrigation or domestically will not exceed 2.5% of the input.

2.2. RAW WATER QUALITY

The raw water supply for the treatment works will be derived from the River Cauvery at Hogenakkal and will be pumped to the treatment works via a pipeline of approximate length of 6,250 m raw water quality data for the River Cauvery at Hogenakkal is given below:

RAW WATER QUALITY

Parameter	Unit	Value
TDS	mg/l	200-420
pH	-	7.2-8.8
Turbidity	NTU	1-25
P alkalinity	mg CaCo3/l	25

Calcium as Ca	mg/l	35
Magnesium as Mg	mg/l	17
Total Iron	mg/l	0.3

Note: - The data above are provided by TWAD and the design is based in those figures.

2.3. TREATED WATER QUALITY

When operated in accordance with the Contractor's instruction at flows up to the required maximum throughput, the water treatment works treating raw water from the River Cauvery will be capable of producing a reliable and continuous supply of potable water free of waterborne pathogenic organisms.

2.3.1 Raw water Sampling

The water quality from the works sampled after treatment will comply with the following values with 100% of the sample results will have:

WATER QUALITY OF 100% SAMPLE

Parameter	Unit	Value
Turbidity	NTU	≤1
Taste and odour	-	Unobjectionable
Colour	Hazen	≤ 5º
Aluminium	mg/l	≤ 0.2 as Al
Iron	mg/l	≤ 0.3 as Fe
Manganese	mg/l	≤ 0.1 as Mn
Free chlorine	mg/l	≥ 0.5* as Cl2
pH	-	7.0 – 8.5
Total coliform bacteria	mg/l	Nil in any 100 ml sample

* At the contact tank outlet ** before final pH correction

The water quality from the works sampled after treatment will comply with the following values with 100% of the sample results will have:

WATER QUALITY OF 95% SAMPLE

Parameter	Unit	Value
Aluminium	mg/l	≤ 0.03 as Al
Iron	mg/l	≤ 0.1 as Fe
Manganese	mg/l	≤ 0.05 as Mn

The treated water quality will reduce if the raw water quality exceeds the maximum turbidity considered. In the other hand, if the raw water turbidity is less than 25 NTU, the output will be reduced accordingly.

2.4. TREATMENT PROCESSES

The sequence of treatment processes proposed for the treatment works is summarised below.

- Works Inlet Parshall flume Hydraulic mixing with the addition of aluminium sulphate
- Hydraulic mixing with the intermittent addition of chlorine.
- Hydraulic flocculation
- Clarification on sludge blanket flat bottom clarifiers
- Gravity filtration through sand media
- Contact tank with mechanical mixing with addition of chlorine.
- Treated water storage in tank with hydraulic mixing with the addition of lime
- Used washwater recovery system
- Sludge thickeners for thickening of clarifier sludge and sludge from used filter washwater
- Sludge drying beds to remove the excess water

3. RAW WATER PUMPING STATION

3.1. GENERAL

The raw water pumping station will draw water at river Cauvery through the screens and inlet openings and deliver it through the raw water pipeline to the treatment works. The length of the pipeline is about 6.25 km and the treatment works are located in the forest area with raw water discharge level of +313.41 m AMSL.

The duty point at which the best efficiency is selected is at the head when the river Cauvery is at the average water level of about +248.35 m AMSL.

3.2. RAW WATER PUMPS

Pumps will be of the vertical turbine type, with water-lubricated bearings. Pumps will be driven by directly-coupled, vertical-shaft induction motors.

RAW WATER PUMP CAPACITY

Parameter	Unit	Value
Design flow	ML/d	160.7
Design flow	m3/h	6,986.9
Total units	-	6
On duty units	-	4

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4. INLET CHAMBER AND PARSHAL FLUME

4.1. INLET TO WTP

Raw water will be delivered by pipeline from the intake pumping station on the Cauvery River through a steel pipe to the treatment works, terminating at an upturned bell mouth at the inlet works. As summarized at the table below:

Description	Units	25 ppm TSS	50 ppm TSS
Influent raw water flow design	m3/d	160,700	160,700
Back wash water recycling	m3/d	3,461.11	3,466.53

4.2. PARSHALL FLUME

The contract flow is measured through a Parshall Flume with flow meter, and then it must be accurately measured in any condition of flow.

The second roll of Parshall flume is agitation or mixing. Thus, downstream section of the inlet flume will provide required agitation for dosing of aluminium sulphate and chlorine at the point of maximum turbulence.

4.2.1. Coagulation design

A key factor of the coagulation design is the mixing between the coagulant and the inlet water. As hereafter will be explained in the subsequent paragraphs, an adequate velocity gradient is needed to produce a proper mixing. In the project design, as requested by the Tender documents, this G value is obtained by means of the head loss in the Parshall flume. Theoretical and practical detailed information of the mixing process is given below, extracted from Water Supply 3th edition (A.C. Twort, F.M. Law and F.W. Crowley):

"…The principal objective in chemical mixing as applied to water treatment is to obtain uniform dispersion of the chemical in the main flow of water, so as to avoid local over-or under-dosing, which in turn can prevent the chemical reaction process going to completion. For example, inadequate mixing of aluminium sulphate can impair the formation of a good floc in the clarifier and would result in poor plant performance or wastage of chemicals, or both. Despite the importance of ensuring efficient chemical mixing in water treatment, particularly for difficult waters, it seldom receives adequate attention. The addition and mixing of chemicals to the main flow of water is a continuous process and is frequently described as either rapid or flash mixing. The design of mixers is often based upon the concept of velocity gradient and its value is used to express the degree of mixing at any point in the liquid system. The velocity gradient G is defined in terms of power input by the following relationship developed by Camp and Stein for flocculation:

$G = (P/\mu V)^{1/2}$, Where G is the velocity gradient (s-1), P is the useful power input (watts), V is the volume (m3) and μ is the dynamic viscosity (Ns/m2).

Mixing efficiency is directly related to the local flow turbulence created and should give a high degree of chemical-in-water homogeneity within a short time, with low absorption of power. Mixing designs should aim to achieve the optimum combination of maximum turbulence and low power input. The methods used for mixing can be hydraulic or mechanical. (Attention is paid only to the hydraulic method as requested by the Tender documents.)

Hydraulic mixing makes use of the turbulence created due to the loss of head across an obstruction to flow such as from an orifice plate, taper, bend, tee, valve or by a sudden drop in level such as when water flows over a weir or flume. The best results are

Hydraulic mixing makes use of the turbulence created due to the loss of head across an obstruction to flow such as from an orifice plate, taper, bend, tee, valve, or by a sudden drop in level such as when water flows over a weir or flume. The best results are usually obtained by introducing a chemical immediately upstream of the point of turbulence. The usual power input for mixing is based upon a typical mixing time of 2 to 3 seconds, with a G value of about 800 to 1000 s-1. The power is related to the head loss by the equation. P=Qpgh Where P is the useful power input (watts), Q is the flow (m3/s), h is the head loss (m), p is the density of water (kg/m3) and g is the acceleration due to gravity (m/s2). In practice is generally found that adequate mixing is obtainable with a head loss of between 0,25 and 0,40; in any case it should not be less than 0.20m.

Hydraulic mixers are usually simple a particularly suitable where some head loss can be tolerated. They have the advantages of having no moving parts or direct power consumption, and maintenance is therefore negligible. A disadvantage is that the efficiency of mixing drops if works throughput is lowered…."

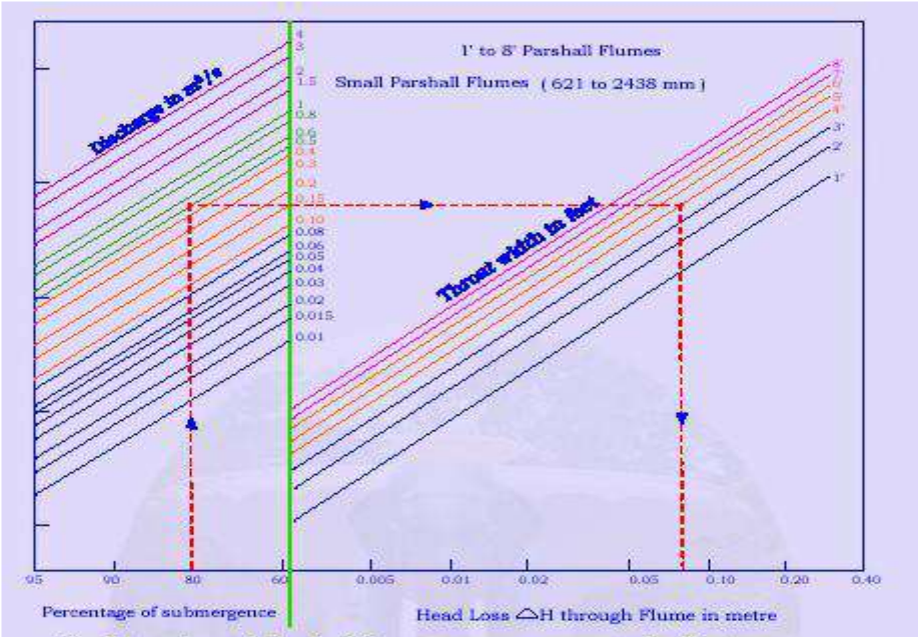
According to the explanation above, in this particular case, head loss in the Parshall Channel is the key factor to ensure an adequate mixing of the coagulant.

Thus, design objectives are:

- Head loss across the flume at the maximum annual throughput shall be not less than 300 mm
- G value shall be around 800 - 1000 s-1
- Mixing time in the flume around 2-3 s

- Head loss across the flume at every condition shall be not less than 200 mm

Head loss calculation has been made through the following chart (Waste Water Treatment Plants, Planning, design and operation, 2nd edition, Syed R Quasim).



Head-loss through Parshall flumes. (621 to 2438 mm) (after Bos)

With the following input data:

- Percentage of submergence : 70% (modular limit)
- Throat width : 1.2 m (3.87 feet)
- Maximum flow : 7,137 m3/h (1.98 m3/s)
- Minimum flow : 3,710 m3/h (1.03 m3/s)

These values are obtained:

- Head loss : 32 cm (approx.)
- Head loss : 22 cm (approx.)

Accordingly:

- Retention time in the Parshall at maximum flow : 1.95 seconds
- Retention time in the Parshall at minimum flow : 3.88 seconds

And finally G values:

- G value at maximum flow : 765 s-1
- G value at minimum flow : 1064s-1

5. CLARIFIERS

Eight (8) vertical flow flat bottom sludge blanket clarifiers have been designed for operation in concrete tanks.

The design considers flat bottom clarifiers with top channels and trident distributors, outlet channels and the flocons with automatic extraction of the sludge.

5.1. DESIGN PARAMETERS:

The design parameter of Clarifiers given as per following:

DESIGN PARAMETER

Parameter	Unit	25 ppm TSS	50 ppm TSS
No. of clarifiers	Units	8	8
Maximum flow	m^3/d	164,161.11	164,166.53
Maximum flow	m^3/h	7,137	7,138
Unitary Flow	m^3/h	892	892
Length	m	31.80	31.80
Width	m	15.00	15.00
Unitary settling surface	m^2	477.00	477.00
Settling velocity	m/h	1.9	1.9
Water depth	m	4.5	4.5

Note: - Hydraulic capacity is sufficient to maintain full flow with one clarifier out of service.

5.2. SLUDGE PURGE

DESIGN PARAMETER

Parameter	Unit	25 ppm TSS	50 ppm TSS
Sludge production	kg/h	165.8	344.6
Outlet Concentration	kg/m^3	5.00	5.00
Water losses in clarification	m^3/d	762.68	1,585.16
Water losses in clarification	m^3/h	33.16	68.92

No. of pumping pits	Units	1	1
No. of pumps per pit	Units	2	2
Type of pump		Submersible	Submersible
Unitary necessary flow	m³/h	59	69
Unitary pump flow	m³/h	70	70

The clarifiers are provided by a maintenance gallery to check valve and discharge sludge valves and pipe, these eccentric plug valves are actuated by solenoid by during 1 minute every 1 hour. It is a normal practice in this kind of clarifiers.

The discharge pipe is also provided by manual knife valve to isolate the discharge line in case of power loss of the plant. In all discharge pipes will be a flushing point to help removing the sludge in case of plugging.

The operator will access with stairs where are closed to clarifiers walls according to general arrangement of clarifiers.

6. GRAVITY SAND FILTERS

Sedimentation, with or without coagulation, will not ordinarily give adequate treatment to water. The production of clear water from the clarifiers requires the use of filters.

The plant design includes twelve (12 Nos.) filters arranged on either side of an enclosed central operating and pipe gallery with the following characteristics:

DESIGN PARAMETERS

Description	units	25 ppm TSS	50 ppm TSS
N º of filtration batteries	units	2	2
N º of batteries / filters	units	6	6
Total N º of filters	units	12	12
N º filters / cells	units	2	2
Filter net width	m	3.60	3.60
Filter net length	m	15.80	15.80
Filtration surface per filter	m²	113.76	113.76
Total filtration surface	m²	1,365.12	1,365.12
Filtering velocity with all filters in service	m/h	5.20	5.18
Filtering velocity with 2 filters not available to filtering	m/h	6.24	6.21

The main characteristics of the filters are the following:

- Turbidity of the water applied to the filters should not exceed 5NTU and preferably not 2.5 NTU.
- Filtration rate is less than 6.5 m/h
- Washing the filter units by reversing flow of filtered water upward through the filter to remove mud and other impurities which have lodged in the sand.

6.1 FILTER MEDIA

6.1. FILTER MEDIA

The choice of a filter medium is dictated by the durability required, the desired degree of purification, and the length of filter run and ease of backwash sought. The ideal medium should have such a size and be of such material that it will provide a satisfactory effluent, retain a maximum quantity of solids, and be readily cleaned with a minimum wastewater.

The size of filter media is specified by the effective size, which is the sieve size in millimetres that permits 10 percent by weight to pass. Uniformity of size is specified by the uniformity coefficient, which is the ratio between the sieve size that will pass 60% by weight and the effective size. Fine materials will provide a better effluent, but will produce high head losses in the upper layers of the bed, thus yielding short filter runs. Coarse media permit deeper penetration of the floc, better utilization of the storage capacity of the filter, longer filter runs, and easier cleaning upon backwash. Sand is the cheapest filter medium and has been widely used.

6.2 CRYPTOSPORIDIUM RISK MITIGATION

The maximum velocity in the filters (6.24 m/h) has been designed in accordance with best engineering practice to mitigate against the risk of Cryptosporidium in the filter water. An automatic valve in each filter outlets is provided to allow filters run to waste for a period following backwashing.

6.3 UNDER DRAIN SYSTEM

The underdrain system collects the filtered water from the sand and also distributes the washwater and air during the backwashing process. To be satisfactory, the underdrains should collect and distribute water as evenly as possible, although this cannot always be done exactly because of the slight difference in head occurring at various points in the system. Hydraulic systems which provide for uniform distribution of water to uniform collection of water from an extensive area require that the head loss through the orifices be large in comparison to that in the main carriage system.

The filter design considers a modern design underdrain false bottom underneath the filter media, which will minimize this problem by using special distribution nozzles, including approx. 68 nozzles per square meter, with a total number of 93,600 nozzles in the Plant. It is also considered 350 mm of gravel layer to avoid any loss of sand trough nozzles.

The filters at the water treatment works will be cleansed daily by means of combined scouring with air and water and subsequent rinsing with final water. Scouring air will be provided through air blowers to be located in the ground floor plan.

Backwash facilities will also be provided through the provision of backwash pumps in the Clearwater tank. The filters backwash water will be routed to the backwash recovery tanks.

6.4 CONTROL SYSTEM FOR FILTER

Cleaning of filters will be triggered by loss of head across the filter and by back-up timer system. Provision will be made to override the automated system and initiate backwash filters manually, including the ability to manually carry out each step of the backwash process via the SCADA System (in Control room).

Standard filter with rate controller is proposed. It is generally intended to work as a constant head loss device. In this filter a variable controller maintains a constant level by opening gradually as the filter bed becomes dirty. The constant water level in the filter is maintaining by isolation weir, 2 each filter. By maintaining both constant head loss and constant water level in the filter, a uniform flow rate should be obtained.

6.5 FILTER BACKWASH

The method of cleaning filters will be by simultaneous application of air and water Followed by a water rinse.

Filter washing will be automatic based on the head loss and the control valve in the outlet pipe of filtered water. Filter valves and penstocks which require to be operated as part of the wash sequence will be fitted with pneumatic actuators of the double acting type.

Wash water flow will be controlled by control valve and flow meter closed to elevated wash water tank. Using the control valve, the operator would control the wash water rated as desired.

OPERATION OF FILTER BACKWASH

Parameters	Units	Value
Air wash flow	$m^3/h/m^2$	60.00
Wash water flow	$m^3/h/m^2$	25.00
Wash time (max.) and phases:		
- Agitation	air	3
- Air/water wash	Air/water	3
- Water wash	Water	5
Wash flow per filter:		
- Agitation	m^3/h.air	6,825.60
- Water	m^3/h.water	2,844.00
Water volume used in each wash	m^3	379.2

ELEVATED WATER PUMPS

Parameters	Units	Value
Total No. of pumps	units	2
No. of active pumps	units	1
Type of pumps		Centrifugal
Unitary necessary flow	m³/h	438.39
Selected unitary flow	m³/h	500

AIR SCOURING BLOWERS

Parameters	Units	Value
Total No. of blowers	units	2.00
No. of active blowers	units	1.00
Type of blowers		Roots
Unitary necessary flow	m³/h	6,800.00
Unitary selected flow	m³/h	7,129.00
TDH	mcl	3.00

6.6 WASH WATER RECOVERY TANK

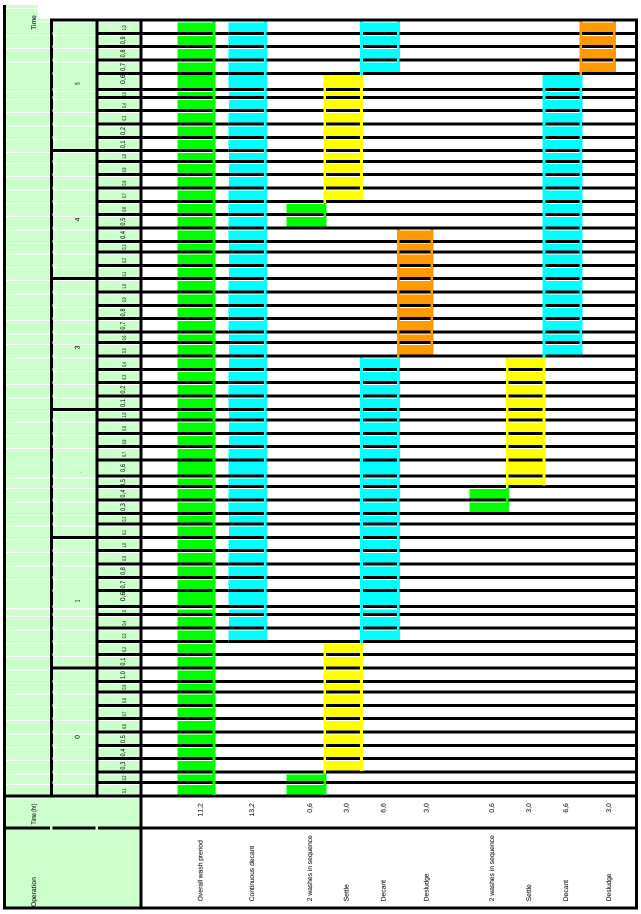
A 2000 cum volume used washwater holding tank has been provided. The tank is rectangular (37m x 12.5m) in plan with the floor laid to a fall and terminating in a pump sump. The capacity of each compartment of the tank will be adequate to store as a minimum, the washwater from two consecutive filter washes.

The used washwater shall flow into an inlet channel and then through penstocks into the compartment in use.

The inlet channel to the tank will be provided with an overflow discharging to the site drainage system.

Each compartment shall have a floating draw-off arm which will be design to remove settled water from the upper part of the tank. The floating arm will be connected to the draw-off connection by an articulated pipe. A restraint system will be provided to prevent excess movement of the floating draw-off arm and articulated pipe during filling and when the compartment is fully emptied.

The operation method is shown below.



Raw water flow	160,7		
Wash per filter	380	m3	
Decant per wash	290	m3	
Decant period	13,2	h	
Decant flow	263		
Proportion return flow	3,9%	Specification maximum value 5%	
Sludge per wash	90	m3	for 50ppm TSS refer to mass balance calcs
Sludge pump period	6,0	h	
Sludge flow	180		

6.7 USED WASHWATER RETURN

After a period of settling the supernatant will be returned to the works inlet from the used washwater recovery tank at a rate not exceeding 5% of the raw water inflow to the treatment plant. The water remaining will be pumped to the sludge balancing tank.

The washwater recovery pump house will be arranged as a dry basement having a common wall with the washwater recovery tank.

Centrifugal pumps (one on duty, one stand by) will be provided for supernatant. Centrifugal pumps (one on duty, one stand by) will be provided for sludge.

Operation of the pumps will be controlled by level probes in each compartment of the used washwater recovery tank. Pumps will be arranged for automatic changeover from duty to standby on the failure of the duty pump.

7. CONTACT TANK

The contact tank is designed to provide a minimum effective contact time t of 30 minutes, between the time of entry into the tank and the time of discharge of disinfected water from the tank into the treated water reservoir, at the rated throughput. The effective contact time has been defined as the detention time at which 90% of the water passing through the contact tank is retained within the tank. The "C.t' value (= free chlorine residual concentration C mg/l at the end of the effective contact time txt minutes) will not be less than 15 mg.min/l.

The tank will be covered and will be constructed with a central division wall, so that either compartment may be drained down for maintenance, the other compartment remaining operational. The hydraulic design of the contact tank will allow the full throughput to pass through one compartment.

Baffle walls will be provided in each compartment of the contact tank to minimise short-circuiting and to ensure maximum effective contact time.

Chlorine solution and water saturated in lime will be mixed into the filtered water at the inlet to the contact tank by mechanical mixer. The inlet jet will be baffled if the inlet pipe discharges directly into the contact section of the tank.

Free fall weirs will be provided on the outlet of the contact tank, at the inlet to the treated water reservoir where this is adjacent to the contact tank to ensure the effective contact time is maintained under all draw-down conditions in the treated water reservoir and to provide for mixing of lime at the exit of the contact tank if this is required.

The contact tank will be provided with all process pipework, inlet isolating valves, ventilators and washouts required, access arrangements, ladders and all necessary fixtures and fittings.

DESIGN PARAMETER

Parameter	Unit	Value
Design flow	m^3/d	163.398,3
Design flow	m^3/h	7.104
Total Volume	m^3	4,060
N º of contact sub-tanks	units	2
Sub-tanks volume.	m^3	2,030

Retention time	h	0.5
Efficiency in piston plug flow conditions	%	90.00
Effective retention time	h	0.57
Dimensions		
Deep	m	4.00
Free chlorine residual concentration C	mg/l	0.50
Cxt value	mg.min/l	15.43

8. TREATED WATER TANK

The reservoir will be provided with a division wall to provide two equal capacity compartments, so that a compartment may be drained down for maintenance, while the other compartment remaining operational. Each compartment of the reservoir will be designed to ensure through circulation of water in the reservoir.

Each compartment will be provided with inlet and outlet isolating penstocks and water level transmitters.

A monitoring and sample house will be located in a suitable position on the roof of the reservoir. This shall house reservoir level monitoring equipment, sampling pumps and associated equipment.

The reservoir is provided with all pipework, valves, penstocks, ventilators and washout pipework together with access covers, ladders, level measuring equipment and all necessary fittings and fixings. Ventilators will be designed to promote cross flow of air through the reservoir.

DESIGN PARAMETER

Parameter	Unit	Value
Design flow	m^3/d	163.398,3
Design flow	m^3/h	7.104
Total Volume	m^3	7150
N º of sub-tanks	units	2
Sub-tanks volume.	m^3	3575
Retention time	h	1.01

9. TREATED WATER PUMPING STATION

9.1. GENERAL

The Treated Water pumping station will draw water from the two chambers of the treated water reservoir.

Water will be pumped to the inlet sump of the Booster Pumping Station located about 1.2 km away at the level of +441.30.

Individual pump discharge shall be of size DN500 and be connected to a DN1200 discharge manifold in pump hall. Main flow meter (and the by pass) shall be located in separate chambers outside the pump hall.

9.2. TREATED WATER PUMPS

Pumps will be of the vertical turbine type, with water-lubricated bearings. Pumps will be driven by directly-coupled, vertical-shaft induction motors.

TREATED WATER PUMP

Parameter	Unit	Value
Design flow	ML/d	158.8
	m3/h	6,906.1
Total units	-	6
On duty units	-	4
On standby	-	2

10. CHEMICALS

10.1 GENERAL

The dimensions of chemical building with ventilation system are 20 meters length x 16 meters width and it is in two floors. The chemical house shall have sufficient unloading space, wide corridors for movement of staff & chemicals, etc. In the ground level are the following parts:

- Two no. lime preparation tank with capacity 31 cum
- Two no aluminium saturator tank with capacity of 38 cum
- Lime storage area (6.5 m x 6.5 m)
- Aluminium storage area (10.5 x 6.5 m)

The ground level will be raised floor to facilitate unloading of Lorries and it is also be equipped by a safety shower. In the other hand in the first floor are the following equipments:

- Two no aluminium preparation tank with capacity 19 cum
- MCC room
- Toilets and Lockers
- Constant head dosing tank with capacity 1000 liters

10.1. LIME DOSING

Hydrated lime is widely used to adjust the pH of water to prepare it for further treatment. Lime is also used to combat "red water" by neutralizing the acid water, thereby reducing corrosion of pipes and mains from acid waters. The corrosive waters contain excessive amounts of carbon dioxide. Lime precipitates the CO2 to form calcium carbonate, which provides a protective coating on the inside of water mains.

The plant for lime storage, handling, slurry and solution preparation, metering, and transfer will be provided.

Lime will be of the hydrated type consisting 92% w/w Ca(OH)2 and will be delivered to the works in 50 kg bags. Lime will be stored in the chemical building, manually emptied into tanks for preparing 5% w/v (50 g/l) slurry and then transferred by pumps to lime saturators for metering to the points of application.

Chemical reactions with Hydrated Lime Addition

$$CO_2 + Ca(OH)_2 \longrightarrow CaCO_3 + H_2O$$

Commercial product average dose	: 7 mg/l
Commercial product maximum dose	: 10 mg/l
Total lime consumption average dose	: 1.143,79 Kg/d
Lime Solution Tank Capacity	: 31m3
Storage for day	: 28
Area Required for storage	: 33.03 m2
MOC of Tank	: RCC

10.1.1 Slurry Preparation Tank

Two vertical concrete tanks have been designed. The concentration of lime slurry prepared in the tanks will be 5% w/v (50 g/l) and the working capacity of a tank will be 31,000 litres. The estimated holding period of a single tank at maximum demand, (combined maximum dose x maximum flow) is about eight hours.

Each tank will be provided with a cover complete with a dust filter sock and a hinged access hatch. A bag loader sized for taking bags up to 50 kg capacity will be provided on each tank. Tanks will be equipped with slow speed paddle type or similar mixers for mixing lime and keeping lime in suspension.

The tanks will be provided with a water supply. Water inlet and slurry outlet will be provided with isolating valves. A valve drain shall also be provided on each tank. Each slurry tank is provided with level electrodes for level monitoring.

10.1.2 Slurry Transfer Pumps

Lime slurry transfer pumps will be of the open impeller centrifugal type. Two pumps (one duty, one standby) each of capacity 20 m^3/h will be provided. Each pump is arranged to draw lime from any selected slurry tank and pump separately to a selected saturator. Each delivery pipe is provided with a magnetic flow meter with local and remote indication.

Pumps are provided with pressure gauges. Flushing connections are provided on pumps, pump suction manifold, pump delivery saturator manifolds and the manifolds at each saturator.

10.1.3 Saturator

Saturators will be designed to prepare a saturated solution of lime. The concentration of a saturated solution is about 1.53 g/l at 30ºC. In practice, the concentration of lime that can be expected from a saturator is estimated to be about 85% of the theoretical value.

The saturators that are based in Cadagua's know-how will help to avoid any blockages in the saturator. Each saturator has two ball valves to discharge the seltted sludge in the saturator. It is an usual practice to open this valves every 8 hours to avoid any excessive sludge.

10.1.4 Lime Injection

Lime solution from the saturators serving each dosing point is combined as applicable and metered to the point of application by pumps. There will be two flow meters at dosing point. One of them will be considered as stand by. The point of application is in the contact tank outlet chamber.

10.3 ALUMINIUM SULPHATE

Coagulation is a physical and chemical reaction occurring between the alkalinity of the water and the coagulant added to the water, which results in the formation of insoluble flocs.

For aluminium sulphate, the pH of the water determines which hydrolysis chemical compounds predominate. Lower pH values tend to favour positively charged compounds which are desirable for reacting with negatively charged colloids and particulates, forming insoluble flocs and removing impurities from the water. Higher pH values favour negatively charged colloids and particulates.

The best pH for coagulation usually is in the range of pH 5 to 7. The proper pH range must be maintained for the coagulants to form flocs. Residual alkalinity in the water serves to buffer a pH change in the system and aids in the complete precipitation of the coagulant chemicals. The amount of alkalinity in the raw water is generally not a problem unless the alkalinity is very low. Alkalinity may be increased by adding lime.

Generally, the operator has no control over the pH and alkalinity of the raw water. Hence, evaluation of these water quality indicators help to select the type of chemical coagulants to be used at a particular water treatment plant or to change the type of coagulant normally used if significant changes in pH and alkalinity occur in the raw water.

Overdosing as well as under dosing of coagulants may lead to reduced solids removal efficiency. This condition can be corrected by carefully performing jar tests and verifying process performance after making any changes in the operation of the coagulation process

10.3.1 Aluminium Sulphate with the Chemical Reaction

Common coagulant chemicals used is Aluminium Sulphate. The Aluminium Sulphate will lower the alkalinity and pH of the solution. The reactions of each follow:

$$Al2(SO4)2 + 3Ca\ (HCO3)2 \longrightarrow 2Al\ (OH)3 + 3CaSO4 + 6CO2$$

Aluminium sulphate is delivered in approximately 17 to 20 kg blocks containing 15.2% w/w Al_2O_3. Aluminium sulphate will be stored in the chemical building, transferred to saturator tanks and drawn by pumps as a saturated solution which will then be diluted to a 10% w/v (100 g/l) solution in stock tanks, transferred to constant head tank for metering under gravity to the point of application.

The effective range of pH of raw water lies in 8.5. The dosing of alum depends on the raw water turbidity.

Pure product minimum dose	: 7.6 mg/l
Pure product maximum dose	: 12.7 mg/l
Maximum daily consumption	: 4.104 Kg/d
Adopted tank Capacity	: 40,000 m3
Constant Head Tank	: 1m3
Storage for day	: 28
Storage Area	: 55.85 m2

10.3.2 Saturator

A total of two saturators constructed in concrete. The effective volume of a tank (excluding the gravel layer and free board) is not less than 40,000 litres. The tanks will be lined with fibre reinforced plastic.

10.3.3 Saturated Solution Recirculation and Transfer

Two pumps (one duty, one standby) are provided for recirculation and transfer of a saturated solution and the pumps are of the centrifugal horizontal type. The pumps will be arranged to draw a saturated solution of aluminium sulphate from any selected saturator downstream of the strainer and return to the same saturator.

Each pump is sized to turn over the solution in a saturator (making an allowance for the solid present) in less than 2.5 hours. The pumps also transfer the solution from one saturator to another. The capacity of each pump is 16 m^3/h. The same pumps will be used to transfer aluminium sulphate from the saturators to the stock tanks.

10.3.4 Stock Tanks

The saturated solution containing approximately 70% w/v (700 g/l) of solid as 15.2% w/w Al_2O_3 will be diluted in the stock tanks to a concentration of 10% w/v (100 g/l).

The dilution process comprises transfer of a known volume of saturated solution to the stock tank followed by the addition of water to the maximum level in the tank and mixing of the contents.

Two GRP lined concrete tanks each of working capacity 19,000 litres are provided. Each tank will be equipped with a mixer. The tanks will be arranged to operate on a rotational batch basis. The estimated holding period for a single tank at the maximum demand is about eight hours.

10.3.5 Diluted Solution Feed to Constant Head Tank

Two feed pumps (one duty, one standby) of the centrifugal type arranged to draw the chemical from any one of the selected stock tanks and feed a constant head tank are provided.

10.3.6 Constant Head Tank

One constant head tank of fibre reinforced plastic construction and of capacity 1,000 litres are provided. The tank will be arranged to operate as a constant head tank by providing a supply of aluminium sulphate solution in excess of the maximum outflow from the tank for the coagulation process and discharging the excess as overflow to the stock tanks.

10.3.7 Aluminium Sulphate Dosing

Aluminium sulphate solution from the constant head tank will be conveyed to the point of application by gravity. The point of application will be provided with a minimum of one duty variable area flow meter. The capacity of the flow meters shall not be less than 3,000 l/.

10.2 CHLORINE DOSING SYSTEM

10.4.1 General

The dimensions of chlorination building is 27 meters x 10 meters width. It is divided in some different rooms as below:

- Drum storage area
- Chlorinator room
- MCC room
- Ejector room
- Pump room

The drum storage room is provided with monorail hoist to change drums. Eight of these drums are provided by automatic changeover devices to avoid to get out of chlorine gas.

10.4.2 Ventilation

The extraction system will consist of eight extraction points (four per side) with low level extraction and high level discharge. The vertical extraction ducts on each side of the storage area will be discharged to a single duct running along the wall at high level terminating in a fan at the drum unloading bay of the building.

10.4.3 Pre Chlorination

Pre chlorination is the application of chlorine to water prior to any unit treatment process. The point of application as well as dosage will be determined by the objectives viz.; control of biological growths in raw water conduits, promotion, of improved coagulation, prevention of mud ball anti lime formation in filters, reduction of taste, and odour and minimizing the post chlorination dosage when dealing with heavily polluted water. This dosing will be used only in case of biological growths, never as everyday dosing

10.4.4 Post Chlorination

Post chlorination is the application of chlorine to water before it enters the treated water reservoir distribution system to control of biological growths.

Chlorine is drawn as a gas from drums and metered under vacuum, mixed with water in ejectors and transferred to the points of application. Plant for storage, metering and dosing of chlorine is provided and contained in a fully segregated self-contained building.

10.4.5 Chlorine Water Reaction

The reaction of pre chlorination and post chlorination given as per following:

$$Cl2 \quad + \quad H2O \qquad\qquad HOCl \quad + \quad H+ \quad + \quad Cl-$$

$$HOCl \qquad\qquad H+ \quad + \quad O\ Cl-$$

The free chlorine can react with compounds such as ammonia, proteins, amino acids and phenol that may be present in water to form chloramines and chloro—derivatives which constitute the combined chlorine. This combined available chlorine possesses solid disinfection properties though to a much lower degree than the free available chlorine. Theoretically some free available chlorine can exit along with combined available chlorine since these reactions do not go to 100% completion. The reactions with ammonia are:

$$Cl_2 + H_2O \longrightarrow HOCl + HCl$$

$$NH_3 + HOCl \longrightarrow NH_2Cl + H_2O$$

$$NH_2Cl + HOCl \longrightarrow NHCl_2 + H_2O$$

11. SLUDGE TREATMENT

11.1. GENERAL

Sludge from the clarifiers and from the used washwater recovery tank will be thickened before disposal to the drying beds. Sludge works shall include the following treatment stages and plant:

- Sludge balance tanks
- Thickener feed pumps
- Sludge thickeners
- Supernatant and thickened sludge discharge system
- Sludge drying beds

11.2 SLUDGE BALANCING TANK

The function of the sludge balance tanks is to balance the intermittent sludge discharges from the clarifiers and from the used washwater recovery tank, to provide a well mixed uniform sludge to the thickeners and act as a sump for the thickener feed pumps. The tanks are sized to balance the intermittent flow while it is withdrawn at a steady rate and concentration to the thickeners. One tank with two equal compartments of combined capacity adequate to balance sludge discharges will be provided.

One no submersible mixer (no standby) is provided in each tank and has been designed to maintain solids in suspension and keep the sludge fully mixed. The mixers will comprise a drive unit and propeller integrated into a compact installation with guide rails and lifting chains. The tank will be provided by a walkway to facilitate the maintenance of the mixers and easy lifting.

Each balance tank will be provided with level measuring equipment for pump control, to ensure a minimum submergence required for the mixer is maintained, to prevent dry running of the pumps.

DESIGN PARAMETER

Parameter	Unit	Value
Design flow	m3/h	252
Storage time	h	2

Total volume	m3	554
Width	m	8
Length	m	20
Sludge depth	m	3.4

11.3 SLUDGE THICKENER

Two thickeners of the continuous flow type suitable to thicken the sludge feed to a concentration greater than 15 g/l without the aid of any polyelectrolyte.

The thickeners are sized for a nominal design surface loading rate of 0.75m3/h/m2 at the maximum feed rate with both thickeners in service.

The sludge thickeners are provided by stairs to easy access to the top of the thickeners and walkway to facilitate the maintenance of the thickener mechanism.

DESIGN PARAMETER

Parameter	Unit	Value
Design flow	m3/d	1852
Daily dried solids	Kg/d	5448
Design mass load	kg/h/m2	3.5
Design hydraulic load	m3/h/m2	.75
Thickener diameter:	m	11
MOC of Thickener	RCC	

11.4 SLUDGE DRYING BEDS

Eight numbers reusable type of sludge dry bed is provided with in rectangular shape and material of construction in RCC. The dimension of sludge dry bed is 40 m length x 20 m width.

It has been provided to accept sludge from the thickeners concentration up (15 g/l) and of dewater to a concentration greater than 15% w/w dry solids.

Dewatering will be by settling and supernatant decanting followed by evaporation drying and under floor drainage. The decanting system includes manual weir penstocks which shall be accessible at all times and which also serve as overflows.

The drying beds are provided by RC concrete rails to avoid removing the sand with the tipper trucks.

Concrete access ramps into the drying beds will be provided. Ramps will be 3m wide and set at a gradient of 5.82%. Slope transitions will be provided at the top of the ramps. Road access will be provided around the area of the drying beds for transportation of the sludge by tipper trucks to remote landfill sites.

During high turbidity season the retention time of the drying beds will be less than expected. It should take into account that this situation will happen during few days per year.

DESIGN PARAMETER

Parameter	Unit	Value
Design flow	m3/d	1852
Daily dried solids	Kg/d	5448
Design mass load	kg/h/m2	3.5
Design hydraulic load	m3/h/m2	.75
Thickener diameter:	M	11
MOC of Thickener	RCC	

12. EMERGENCY CONDITIONS

12.1 OVERFLOWS

There are some overflows installed in the WTP area:

- Inlet chamber
- Sand filters
- Contact tank

The function of those overflows was exposed in the Hazop, but a small summary is explained here:

12.1.1 Inlet chamber overflow

This overflow will be used when the clarifier inlet penstocks are closed in case of bad operation and the raw water pumps are working. In this case, one alarm will appear at raw water pumping station.

12.1.2 Sand filters overflow

This overflow will be used when the back wash of the filters do not work. In case of excessive clogging of the sand, the water level will increase and the water will overflow trough weir.

12.1.3 Contact tank

This overflow will be used when the treated water pumping station is stopped and the WTP is continuously treating raw water. This situation has to be avoid because the loss of the treated water.

12.2 LOSS OF POWER

If the plant loss all the power, all the actuators in the plant will stop. That means that treated water pumping station will stop. If the raw water pumping station will continue pumping we will be in 12.1.1 point situation. The raw water will overflow in the inlet chamber until an operator stops the intake pumping.

12.3 CHEMICALS LEAKS

In the chemical building aluminium pumps are rounded by a bund to avoid any leaks out of the tank range. It is also provided a chemical waste holding tank to collect all the leaks and overflow in the chemical building.

12.4 WATER SAMPLING

The plant will be provided by some sampling location and pumps. Those pumps will be operating all the time, the flow will be directed to the laboratory where it will be installed the following instruments:

- Turbidity (outlet of clarifier, outlet of filters and outlet of contact tank)
- Chlorine residual measure (outlet of the contact tank)
- pH (outlet of the treated water reservoir)

14. FACILITY

Systematic safety management practices will be carried out to provide safe working conditions. Personal protective equipments will be supplied to the workers at work place.

14.1 PLANT LAYOUT

Layout for water pre-treatment plant shall be designed in such a way that all facilities are interconnected by at least 1 meter wide walkway at appropriate elevations with hand railing one meter high on both sides.

The layout of all equipment and accessories shall be developed in a way to facilitate easy accessibility and maintenance of all equipment.

Various Systems/ equipments/ structures/ buildings shall be designed in such a way that they are approachable from main roads by means of access roads/pathways.

Proper access for maintenance of equipment shall be provided as per system requirements. All tank and sumps shall be provided with access rungs and dewatering pits.

Adequate provision of space for maintenance of equipments shall be kept in all the areas/facilities/ buildings.

14.2 BUILDING LAYOUT

The building layout design shall provide as per following:

- Adequate ventilation;
- Adequate lighting;
- Adequate drainage;
- f. Accessibility of equipment for operation, servicing, and removal;
- g. Flexibility of operation;
- h. Operator safety;

- Convenience of operation;
- Chemical storage and feed equipment in a separate room to reduce hazards and dust problems and
- Employee facilities

14.3 LABORATORY FACILITIES

Laboratory equipment and facilities shall be compatible, intended use of the treatment plant and the complexity of the treatment process involved. Testing equipment and supplies provided shall be adequate for the purpose intended and recognized procedures must be used. Laboratory test kits which simplify procedures for making one or more tests may be acceptable.

An operator or chemist qualified to perform the necessary laboratory tests is essential. Analyses conducted to determine compliance with drinking water regulations must be performed in an appropriately certified laboratory in accordance with latest "Standard Methods for the Examination of Water" or approved alternative methods.

Methods for verifying adequate quality assurances and for routine calibration of equipment shall be provided.

14.4 PIPING COLOR CODE

To facilitate identification of piping and tubing in pre treatment plant and pumping stations are considered as per tender documents.

15. SAFETY

All plants and equipment shall be complete with approved safety devices wherever a potential hazard for personnel exists, and with provision for safe access to personnel to and around equipment for operational and maintenance functions.

Systematic safety management practices will be carried out to provide safe working conditions. Personal protective equipments will be supplied to the workers at work place.

PARSHALL FLUME DESCRIPTION

INDEX

EDITION Nr	**1.1**	
Date:	**2012-11-19**	
PREPARED	Position	PROCESS ENGINEER
	NAME	JULIÁN SANCHEZ-MORENO MARTIN RAFAEL M. LLORET SALINAS
REVIEWED	Position	HEAD OF COMISSIONING DEPARTMENT
	NAME	ESTEBAN APELLANIZ DIAZ DE MENDIVIL
APPROVED	Position	HEAD OF COMISSIONING DEPARTMENT
	NAME	ESTEBAN APELLANIZ DIAZ DE MENDIVIL

PREVIOUS EDITIONS	
Number	**Date**
1.0	2012-04-26

1. OBJECTIVE

The purpose of this Operational Procedure is to give a general description of the parshall flume as well as its role at water treatment plants.

2. SCOPE

This procedure applies to all water treatment plants on which a parshall flume has been provided.

3. REFERENCES

- "Parshall flume" Edmundo Pedroza González.
- "TWORT'S WATER SUPPLY". Michael Johnson; Don D. Ratnayaka & Malcolm J. Brandt.

4. DEFINITIONS

Head loss:	It is the dissipation of energy due to friction. In a liquid flow head loss is reflected in a pressure drop along the pipe or in a water level drop along a channel.
Turbulence flow:	Type of fluid flow in which the fluid undergoes irregular fluctuations, or mixing, in contrast to laminar flow in which the fluid moves in smooth paths or layers.

5. RESPONSIBILITIES

All personnel involved in the exploitation of any water treatment plant with no previous experience in parshall flume operation should properly read and understand this document.

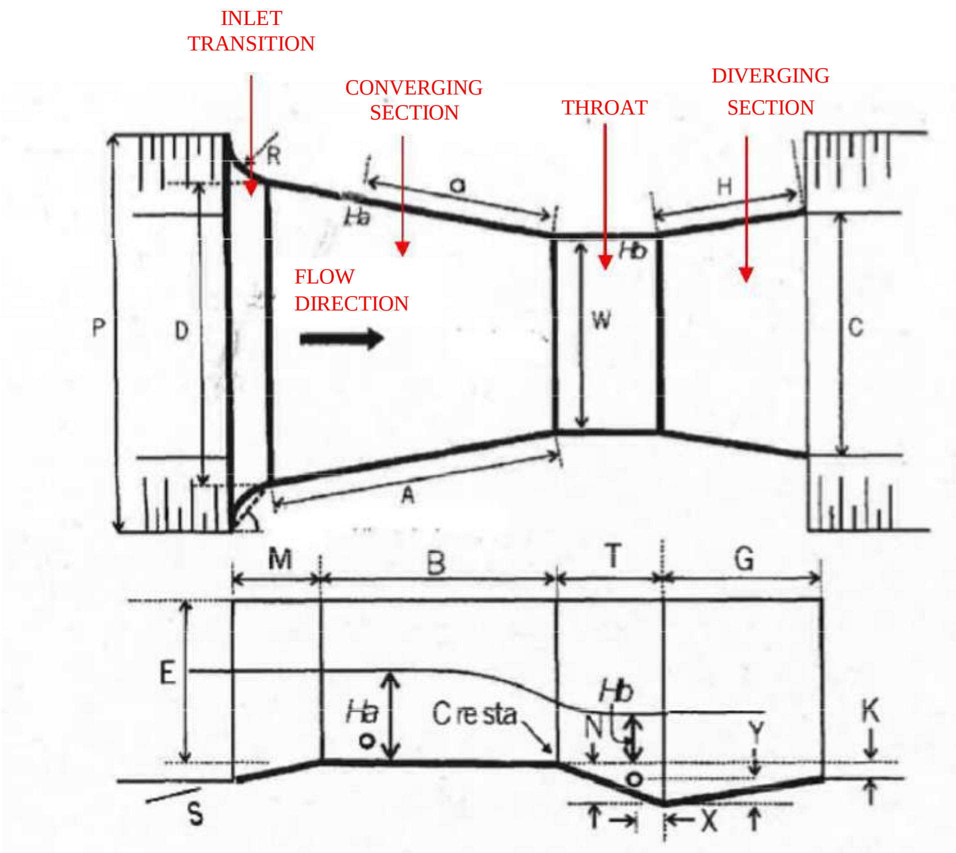
6. PROCEDURE

6.1. PARSHALL FLUME DESCRIPTION

Parshall flume is an hydraulic structure which due to special design allows measurement of the flow rate passing through it. Basically, parshall flume is comprised of four main parts:

a) Inlet transition
b) Converging section
c) Throat
d) Diverging section

A top and side view of a parshall flume is shown in the figure below:



At the inlet transition floor's slope slightly increases while flume section gets narrower. At the converging section the floor is even and flume section continues decreasing. At the throat floor's slope decreases, and at the end of it floor's slope increases again at the diverging section.

6.2. PARSHALL FLUME PURPOSE

6.2.1. Flow measurement

Parshall flume is used for flow measurement by simply monitoring water level at the converging section and applying its characteristic formula which relates water level and flow rate. This formula is expressed below:

$$Q = 4 \times W \times Ha^{1.522 \times W^{0.026}}$$

Where:

- Q: is the water flow in m^3/s
- W: is the throat width in m
- Ha: is the water level at the converging section in m

Flow level is measured by means of one ultrasonic level transmitter located at the beginning of the converging section. In order to have accurate flow measurement the level transmitter must be properly calibrated as indicated in the Instruction Manual.

A picture of one ultrasonic level transmitter installed in a parshall flume is shown below:

*Note: Accurate construction of Parshall Flume **is a must** for proper flow measurement.*

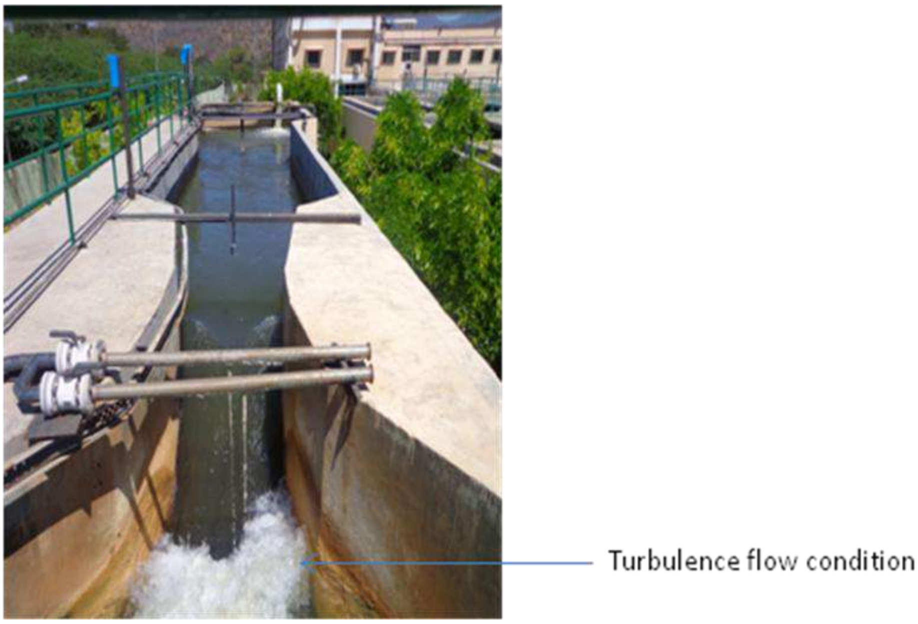
6.2.2. Hydraulic chemical mixing

Most chemical reactions in water treatment applications are completed within 5 seconds and therefore the principal objective in chemical mixing is to obtain a rapid and uniform dispersion of the chemical in the main flow of water to ensure that chemical reactions are completed in the shortest possible time.

Hydraulic mixing makes use of the turbulence created due to the head loss across an obstruction to flow such as an orifice plate, pipe expansion or valve or by the sudden drop in water level when water flows over a weir or hydraulic jump. The latter is usually formed at a flume in a channel with a local width constriction and change in floor level.

Hydraulic mixers are usually simple and particularly suitable where some head loss can be tolerated. They have no moving parts or direct power consumption so maintenance is negligible.

Parshall flume perfectly matches the requirements for proper hydraulic mixing due to the head loss which occurs at the throat. In the picture below, turbulence flow conditions can be perfectly observed at a parshall flume.



6.2.3. Parshall flume accuracy: Log-Data sheet.

Based on filling in the data sheet shown in **ANNEX**, is possible detect any problems in the operation of the Parshall flume. For this is necessary to previously determine the flow of the sludge pumps.

7. ANNEX

CONTROL RAW WATER FLOW

MONTH:

YEAR:

DATE	(a) RAW WATER FLOW (m^3/d)	(b) CLARIFIED WATER FLOW (m^3/d)	(c) SLUDGE PUMPS TIME (h/d)	(d) SLUDGE FLOW (m^3/d)	Desviation ((a-(b+c))/a)*100
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
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29					
30					
31					

ALUMINUM SULPHATE DOSING SYSTEM DESCRIPTION

INDEX

EDITION Nr	**1.0**
Date:	**2012-11-06**
PREPARED	Position: PROCESS ENGINEER NAME: JULIÁN SANCHEZ-MORENO MARTIN RAFAEL MARÍA LLORET SALINAS
REVIEWED	Position: HEAD OF COMISSIONING DEPARTMENT NAME: ESTEBAN APELLANIZ DIAZ DE MENDIVIL
APPROVED	Position: HEAD OF COMISSIONING DEPARTMENT NAME: ESTEBAN APELLANIZ DIAZ DE MENDIVIL

PREVIOUS EDITIONS	
Number	**Date**
1.0	2012-06-14

1. OBJECTIVE

The purpose of this Operational Procedure is to give a general description of the aluminum sulphate dosing system, as well as its basic operation principle and the role of this chemical within the treatment plant.

2. SCOPE

This procedure applies to all water treatment plants on which aluminum sulphate solution must be prepared from solid grade product for further dosing to the water stream.

3. REFERENCES

- "TWORT'S WATER SUPPLY". Michael Johnson; Don D. Ratnayaka & Malcolm J. Brandt.

4. DEFINITIONS

Coagulant-Coagulation	Coagulant is a chemical product which neutralizes electrically charged colloidal and suspended particles. After neutralization, these particles may approach and attach to each other creating bigger particles by coagulation
Colloidal particles	A system in which finely divided particles, which are approximately 10 to 10,000 angstroms in size, are dispersed within a continuous medium in a manner that prevents them from being filtered easily or settled rapidly.
Total suspended solids	Total suspended solids is defined as the residue retained in a fiber glass filter with a pore diameter of 1,2 µm, dried at 105ºC after filtering a given volume of sample.

5. RESPONSIBILITIES

All personnel involved in the exploitation of aluminum sulphate solution preparation and dosing system with no previous experience in this type of equipment should properly read and understand this document.

6. PROCEDURE

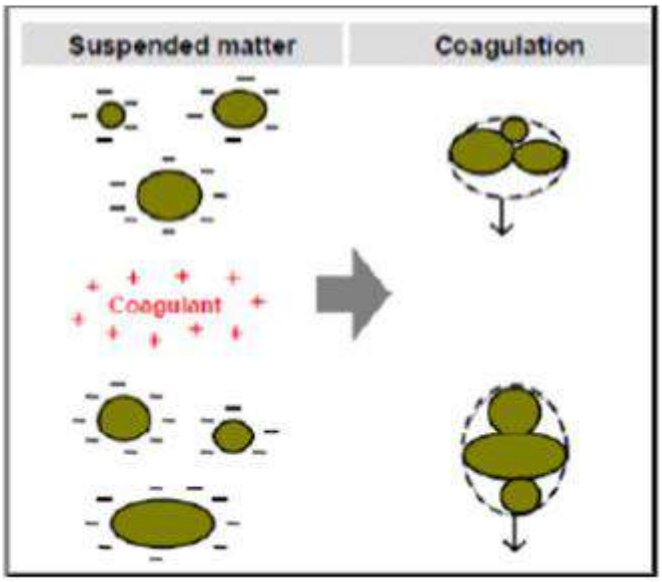
6.1. INTRODUCTION

6.1.1. Aluminium sulphate dosing purpose: coagulation

At drinking water treatment plants pollutants such as turbidity, suspended solids, colour, colloidal and organic matter must be removed from the water in order to obtain a high quality effluent for human consumption. Even though most of those pollutants has specific weight greater than water, due to its extremely small size its settling velocity is quiet low.

Aluminum sulphate ($Al_2(SO_4)_3$) significantly improves settling velocity of those pollutants by coagulation. Particles responsible of turbidity, color, organic matter and colloids are negatively charged. This fact keeps particles dispersed in the water by the action of repulsive forces which occurs between same electrically charged particles. Coagulation is the mechanism in which negatively charged particles are neutralized by various species of positively charged aluminium hydroxides. As particles have no net charge after neutralization, they may approach and attach to each other, creating bigger aggregates which lead to increase its settling velocity, thus, its removal efficiency.

A representative illustration of coagulation mechanism is shown below:



Hydrolysis reaction of aluminum sulphate is as follow:

a) $Al_2(SO_4)_3 + 6H_2O \rightarrow 2Al(OH)_3 + 6H^+ + 3SO_4^{3-}$

This reaction decreases pH of the solution. If water contains bicarbonates, pH may be held constant as they act as pH buffer following next reaction:

b) $Al_2(SO_4)_3 + 3Ca(HCO_3)_2 \rightarrow 2Al(OH)_3 + 3CaSO_4 + 6CO_2$

pH of the water determines which hydrolysis compounds predominate. Lower pH values tend to favour positively charged compounds which are desirable for reacting with negatively charged particles, forming insoluble flocs and removing pollutants from the water. Optimum pH for coagulation employing aluminum sulphate is in the range of 5.5-7.5.

Colloids neutralization is a quick reaction, where the most important variable is the mixing efficiency between the coagulant and the water. For that reason, at Hogenakkal Drinking Water Treatment Plant, aluminum sulphate is dosed at the parshall flume, where high turbulence flow conditions will favour good mixing.

Proper coagulant dosage must be established by carefully performing jar test since coagulant overdose and under dose will decrease treatment efficiency. This test should be done whenever raw water characteristics change, adjusting a new coagulant dosage.

6.1.2. Aluminium sulphate dosing system description

Aluminum sulphate solution is prepared on site from solid product grade delivered in blocks of 17-20 kg containing 15.2% (w/w) of Al_2O_3.

Main equipment of the aluminum sulphate dosing system is listed below:

- Two saturator tanks of 38 m^3 of volume, concrete made. Both units are equipped with one low-low switch level.
- Two recirculation/transfer pumps (1+1R) centrifugal type.

- Two preparation tanks of 19 m^3 of volume, concrete made. Both units are equipped with one level indicator transmitter, one low-low switch level and one mixer.
- Two head pumps (1+1R) centrifugal type.
- One head tank of 1 m^3 of volume, fibre reinforced plastic made. This unit is equipped with one level indicator transmitter.

Overflows and drainages of these tanks will be sent to the chemical waste holding tank, which is common for all the chemicals used at the DWTP. This tank is located outside, close to the chemical building.

The idea is to prepare a saturated solution of aluminum sulphate in the first tank (saturator tank), then transfer it to a second tank (preparation tank) where original solution is diluted. From preparation tank, diluted solution will be pumped into a head constant tank at a flow rate greater than the required flow for dosing in such way that the a portion of the volume pumped will overflow from the constant head tank back to the preparation tank. Dosing flow will be set manually by opening the discharge manual valve of the constant head tank. Flow rate is measured by one rotameter.

The saturator tanks and recirculation/transfer pumps are located at the ground floor of the chemical building in order to facilitate discharging operations of the aluminum sulphate blocks into the tanks. Preparation tanks and constant head tank are located at the first floor of the chemical building together with the head pumps. In the chemical building there is also a delimitated area for storage of aluminum sulphate blocks.

Aluminum sulphate solution must be prepared as follows (see point 7. **Annex 3**):

1. The saturated solution shall be prepared by partly filling the saturators with water followed by manually charging the saturators with the required quantity of aluminum sulphate. The tank shall then be filled to the maximum level by manually opening the water supply valve until the float valve stops the supply. The saturated solution prepared in the saturator tanks must contain approximately 700 g/l of solid product.

2. The operator shall manually set the valves to recirculate to the same saturator for pre-determined period for mixing. When the valves are set the operator shall start one of the saturator solution recirculation / transfer pumps from a Local Control Station pushbutton start/stop device which shall be positioned adjacent to the operating platform.
3. The operator shall then set the valves to transfer saturated solution to the stock tanks.
4. The operator shall stop the recirculation/transfer pump when required level is reached in the stock tank. Water shall then be added to the stock tank until the maximum level is reached. The operator shall then start the mixer. The stock tank shall be displayed on the LCS (local control station) to enable the transfer pumps to be started and stopped at the required level and to start/stop the mixer. The diluted solution obtained in the preparation tanks must contain approximately 100 g/l of solid product.
5. When the aluminum sulphate solution has been prepared the operator shall start the constant head tank feed pump from LCS. The excess flow into the constant head tank shall be arranged to be returned to the duty stock tank. The pumps will be stopped automatically when low level in the stock tank is detected.
6. The dosing rate shall be set manually through variable area flow meter located at the outlet of the constant head tank.

6.2. OPERATIONAL PROCEDURE

6.2.1. Operation tasks

The jobs performed by employees in the normal operation of the coagulation process include the following (see point 7. **Annex 2**):

TASK	EMPLOYEE
Monitor process performance.	Analyst
Evaluate water quality conditions (raw and treated water).	Analyst
Check and adjust process controls and equipment	Analyst

TASK	EMPLOYEE
Visually inspect facilities.	Operator
Examine the water samples at several points enroute the flow line of the water.	Analyst
Look at the clarity of the water between the flocs and study the shape and size of the floc. The floc should be small and well dispersed throughout the flow.	Operator/Analyst
Tiny alum floc may be an indication that the chemical dose is too low. A 'popcorn flake' is a desirable floc. If the water has a milky appearance or a bluish tint, the alum dose is probably too high.	Operator/Analyst
Examine the settlement of the floc in the flocons. If a lot of floc is observed flowing over, then the floc is too light for the detention time. By increasing the chemical dose a heavier, larger floc may be produced. The appearance of the fine floc particles washing over the effluent weir could be an indication of too much alum and the dose should be reduced. For precise evaluation you should make only one change at a time and evaluate the results.	Operator

Records of the following items should be maintained (see point 7. **Annex 2**):

- Source water quality (pH, turbidity, temperature, alkalinity, chlorine demand and colour).
- Process water quality (pH, turbidity, and alkalinity).
- Process production inventories (chemicals used, chemical feed rates, amount of water processed, and amount of chemicals in storage).
- Process equipment performance (types of equipment in operation, maintenance procedures performed, equipment calibration and adjustments).
- A plot of key process variables should be maintained. A plot of source water turbidity vs. coagulant dosage should be maintained. If other process variables such as alkalinity or pH vary significantly, these should also be plotted.

6.2.2. Common operational problems

The most common operational problem is a sudden change in raw water quality, usually a result of changing turbidity. The causes are many. Some of the most common causes are:

- Heavy rainstorms.
- High wind.
- Algae blooms or insect hatches.

A significant change in raw water quality means that adjustments may be needed including:

- Adjusting coagulant dosages.

In cases where such a change in raw water quality occurs, jar tests may only provide some of the answers. Final adjustments should be based on careful plant observations and measurements.

Accurate records are essential in preparing for, and responding to, raw water quality changes. Often, events occur at similar times and with similar intensity. Records should include what worked and how well, and what didn't work so mistakes are not repeated.

Annex 1 is a summary of coagulation process problems; how to identify the causes of these problems and also how to go to correct the problems.

6.2.3. Residual aluminium in finished waters

With most waters the best pH for coagulation is treatment plant specific though it is generally between 5 and 7. The natural alkalinity in the water may not be enough to support typical alum dosages without affecting pH. Heavy rainstorms and associated high turbidity may cause a further demand on alkalinity as alum doses increase. Alkalinity needs to be assessed throughout the year and varying conditions, and appropriate adjustments made to keep pH in the optimum range.

Residual aluminium in finished waters has become a great concern. Residual aluminium comes from two sources: floc carryover and soluble aluminium. High soluble concentrations result when the pH is less than 6.0. In order to minimize the amount of soluble aluminium the pH should be maintained in the range of 6.0 to 6.8. Floc carryover can be reduced through the use of sedimentation and filtration.

Therefore, it is important to undertake routine unit process analysis to ensure that chemicals such as aluminium are not carried over in the finished water.

Water treatment plant employees should strive to treat water to the lowest aluminium extent possible in drinking water. 100% of the sample results shall have aluminium not exceeding 0.2 mg/l as Al. 95% of the sample results shall have aluminium not exceeding 0.03 mg/l as Al.

6.3. HEALTH & SAFETY

6.3.1. Safety considerations

In the coagulation process, the operator will be exposed to a number of hazards such as:

- Electrical equipment,
- Rotating mechanical equipment,
- Water treatment chemicals,
- Laboratory reagents (chemicals),
- Slippery surfaces caused by certain chemicals
- Flooding.

Strict and constant attention must be given to safety procedures. The operator must be familiar with general first aid practices such as mouth-to-mouth resuscitation, treatment of common physical injuries, and first aid for chemical exposure.

6.3.2. Hazards in chemical handling-salts

The various salts (chemicals) used in water treatment are given in the following table:

SALTS USED IN WATER TREATMENT

NAME, FORMULA	COMMON NAME	AVAILABLE FORMS	DENSITY, LBS/CU FT	FLAMMA-BILITY	COLOR	ODOR	CONTAINERS
Aluminum Sulphate, $Al_2(SO_4)_3 14H_2O$	Alum, Filter Alum	Liquids, Powder, Lump	1.69 38-67	None	Ivory	N/A	Bags, Tank Truck, Bulk
Ferric Chloride, $FeCl_3$	Ferrichlor, Chloride of Iron	Syrup, Liquid, Lump	60-90	None	Dark Brown, Yellow	N/A	Carboys, Tank Cars
Ferric Sulphate, $Fe_2(SO_4)_3$	Ferrifloc, Ferrisul	Powder, Granule	70-72	None	Red-Brown	N/A	Bags, Drums
Ferrous Sulphate, $FeSO_4 7H_2O$	Coppras, Green Vitriol	Crystal, Granule, Lump	63-66	None	Green	N/A	Bags, Drums, Bulk
Sodium Aluminate, $NaAlO_2$	Soda Alum	Dry Crystal, Liquid	(27°)	None	White, Green-Yellow	N/A	Bags, Bulk
Copper Sulphate, $CuSO_4$	Blue Vitriol, Blue Stone	Crystal, Lump, Powder	60-90	None	Blue	None	Bags, Drums
Sodium Chlorite, NaOCI	Technical Sodium Chlorite	Powder, Flake, Liquid	70 dry	Oxidizer	Light Orange	None	Tank Truck, 100 Ib-Drums

In the case of the aluminum sulphate, the followings instructions should be considered:

1. These materials should be stored in a clean dry place, for moisture has a tendency to cake the material.
2. Handlers should wear protective clothing and protective cream on exposed skinsurfaces because these chemicals can cause irritation to the skin and mucous membranes and serious injury to the eyes. Use the same precautions for liquid solutions, with added protection for the eyes.
3. Do not use compressed air to clean dry feed machines and equipment. Keep covers on feeding equipment.
4. Remember that mixtures of dry alum and quicklime can explode.
5. First aid for skin irritations and mild burns should be the same as for any acid burn. Scrub with plenty of warm water and soap, followed by a good shower as soon

as possible. For any irritation of the mouth and nasal passages, irrigate freely with warm water. If the material is in the eyes, flush with large quantities of warm water, and consult a physician.

6.4. ROUTINE TASKS

See **Annex 2.**

6.5. LOG-DATA SHEET

See **Annex 2.**

7. ANEXES

7.1. ANNEX 1: COAGULATION PROCESS TROUBLESHOOTING

TROUBLE SHOOTING	OPERATOR ACTIONS	POSSIBLE PROCESS CHANGES
Source water quality changes		
Turbidity Temperature	1. Perform necessary analyses to determine extent of change. 2. Evaluate overall process performance. 3. Perform jar tests. 4. Make appropriate process changes. 5. Increase frequency of process monitoring.	1. Adjust coagulant dosage. 2. Change Coagulant.
Coagulation Process Effluent Quality Changes		
Turbidity Alkalinity pH	1. Evaluate source water quality. 2. Perform jar tests. 3. Verify process performance: (a) Coagulant feed rate (b) Mixing (Dosage point) 4. Make appropriate process changes.	1. Adjust coagulant dosage. 2. Change Coagulant 3. Asses the possibility of running more clarifiers

7.2. ANNEX 2: ROUTINE TASKS AND LOG-DATA SHEETS

CONCEPT	LOCATION	FREQUENCY	POSSIBLE ACTIONS
Monitor process performance			
Turbidity / Colour	Raw Water/ Clarified Water	At least once per 8-hour shift.	1. Increase sampling frequency when process water quality is variable. 2. Perform Jar Tests. 3. Make necessary process changes: ○ Adjust coagulant dosage. ○ Change Coagulant.
Make Visual Observations of the floc			
Look at the clarity of the water between the flocs and study the shape and size of the floc Examine the settlement of the floc in the flocons	Clarified water and flocon	At least once per 8-hour shift.	1. Increase sampling frequency when process water quality is variable. 2. Perform Jar Tests. 3. Make necessary process changes: ○ Adjust coagulant dosage. ○ Change Coagulant. ○ Assess the possibility of running more clarifiers
Inspect Facilities			
Check physical facilities	Parshall Flume	At least once per 8-hour shift.	1. Clean if is necessary the metering point

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DATE	CLARIFIERS								RAW WATER						TREATED WATER			FLOW	ALUMINIUM SULPHATE		
	1	2	3	4	5	6	7	8	pH	Turbidty	Alk.	T (C)	Cl	Colour	pH	Turbidty	Alkalinity	m^3	Kg fd	Kg st.	Rate ppm
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2																					
3																					
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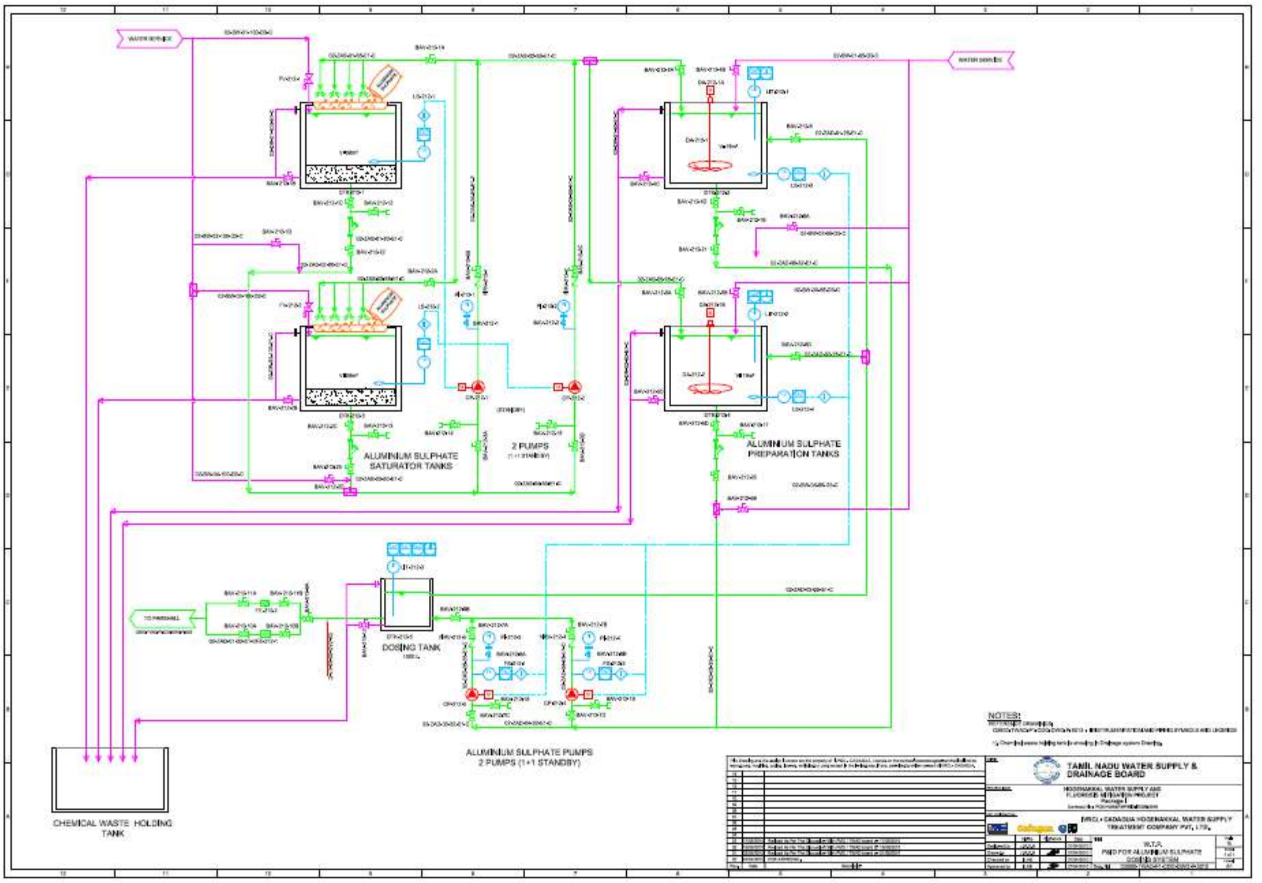
7.3. ANNEX 3


ALUMINIUM SULPHATE SATURATOR TANKS
2 PUMPS
ALUMINIUM SULPHATE PREPARATION TANKS
DOSING TANK
ALUMINIUM SULPHATE PUMPS
2 PUMPS (1+1 STANDBY)
CHEMICAL WASTE HOLDING TANK
NOTES:
TAMIL NADU WATER SUPPLY & DRAINAGE BOARD

SECONDARY CLARIFICATION PROCESS DESCRIPTION

INDEX

EDITION Nr	**1.1**	
Date:	**2012-11-14**	
PREPARED	Position	PROCESS ENGINEER
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PREVIOUS EDITIONS	
Number	**Date**
1.0	2012-04-30

1. OBJECTIVE

The purpose of this Operational Procedure is to give a general description of the flat bottom clarifier, as well as its basic operation principle.

2. SCOPE

This procedure applies to all water treatment plants on which flat bottom clarifier have been installed as part of the treatment.

3.REFERENCES

- "TWORT'S WATER SUPPLY". Michael Johnson; Don D. Ratnayaka & Malcolm J. Brandt.
- "MANUAL ON OPERATION AND MAINTENANCE OF WATER SUPPLY SYSTEMS". Central Public Health and Environmental Engineering Organisation. Ministry of Urban Development New Delhi.

4.DEFINITIONS

Total suspended solids	Total suspended solids is defined as the residue retained in a fiber glass filter with a pore diameter of 1,2 µm, dried at 105ºC after filtering a given volume of sample.
Colloidal particles	A system in which finely divided particles, which are approximately 10 to 10,000 angstroms in size, are dispersed within a continuous medium in a manner that prevents them from being filtered easily or settled rapidly.
Coagulant-Coagulation	Coagulant is a chemical product which neutralizes electrically charged colloidal and suspended particles. After neutralization, these particles may approach and attach to each other creating bigger particles by coagulation
Sludge blanket	Layer of settled suspended solids and colloidal matter. In the clarification process the sludge blanket is located underneath the clarified water level

5. RESPONSIBILITIES

All personnel involved in the exploitation of the flat bottom clarifier with no previous experience in this type of process should properly read and understand this document.

6. PROCEDURE

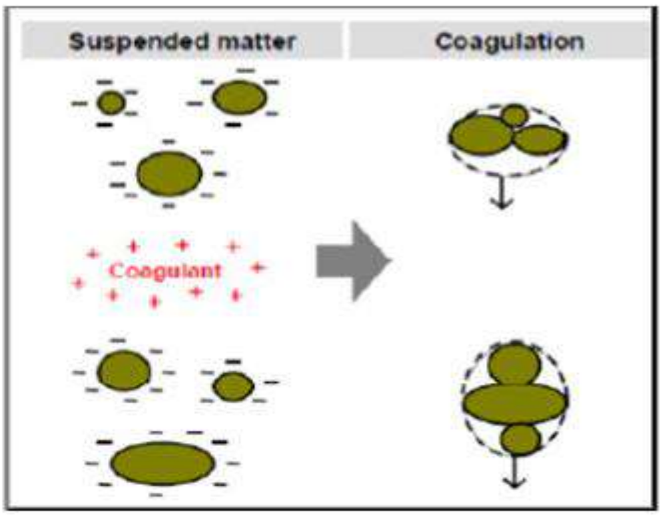
6.1. INTRODUCTION

Clarification is a solid-liquid separation process in which suspended solids, colloidal and organic matter and other pollutants with specific weight greater than water can be removed as they settle by the action of the gravity.

This operation takes place in tanks called clarifiers. The success of clarification is based, among other factors, in the optimum size and shape tank design, in which hydraulic retention time allows solids settling.

In order to increase settling velocity, thus, decreasing tank size, clarification may be enhanced by coagulant dosage (e.g. aluminum sulphate) into the raw water stream. By coagulant dosage, electrically charged colloidal particles are neutralized. Neutralized particles may approach and attach to each other by coagulation, creating bigger particles with greater settling velocity.

In the figure below, coagulant mechanism illustration can be seen:



There are several types of clarifiers, depending on how raw water is fed to the clarifier, the extraction method of the settled solids, shape of the clarifier, etc. However, this document will be focused solely on flat bottom clarifier.

6.2. FLAT BOTTOM CLARIFIER: DESCRIPTION AND BASIC PRINCIPLE OF OPERATION

A typical flat bottom clarifier is shown in the picture below.

The flat bottom clarifier consists of a concrete rectangular tank with a level, flat bottom. Tank size is 15 m width, 31.8 m length and 4.5 m depth. Feed water is distributed toward the inlet water troughs through the raw water inlet channel located at one side of the clarifier. A penstock allows isolating the raw water inlet channel and putting the clarifier out of service.

Each clarifier has seven raw water inlet troughs. These troughs are located in the cross section of the clarifier at regular intervals. From raw water inlet troughs, water with coagulant flows downward to the tank bottom, through several PVC vertical pipes. At the end of the PVC pipe, the outlet is divided in three discharge points (distributors). PVC pipe plus the distributors are called "tridents". There are nine tridents located along the raw water inlet troughs at regular intervals. That means that each clarifier is provided with sixty three tridents.

Suspended solids settle at the tank bottom creating a sludge blanket as clarified water flows upward and enters the clarified water outlet troughs through several holes along the trough. Clarified water troughs are located at both sides of the raw water inlet trough, so there are fourteen clarified water outlet troughs in each clarifier. Clarified water outlet troughs discharge into a general clarified water channel located at the opposite side that the raw water inlet channel.

In the picture below the raw water inlet trough and the clarified water troughs can be seen:

As water flows upward from the tank bottom to the surface of the clarifier, the sludge blanket is suspended. On the other hand, as coagulated water flows through the sludge blanket, an intimal contact between the coagulated solids and already existing sludge blanket take place, contributing to increasing floc size and consistency.

Sludge withdrawal system consists of simple cone-shaped flexible sludge concentrators installed throughput the tank, with their rims at the upper surface of the blanket. There are twelve cones (flocon) in each clarifier. Sludge blanket settles and concentrates itself inside the flocons due to its conical shape. It can be understood that a minimal sludge blanket thickness is required for a proper performance of the flat bottom clarifier.

As it can be seen in the picture above, each flocon is connected to a channel through a hose. This channel is located underneath the inlet raw water channel. Sludge purge is done at regular intervals by opening an automatic valve located at the outlet of the hose. This hose is provided with a cleaning fitting in order to avoid sludge clogging inside the hose.

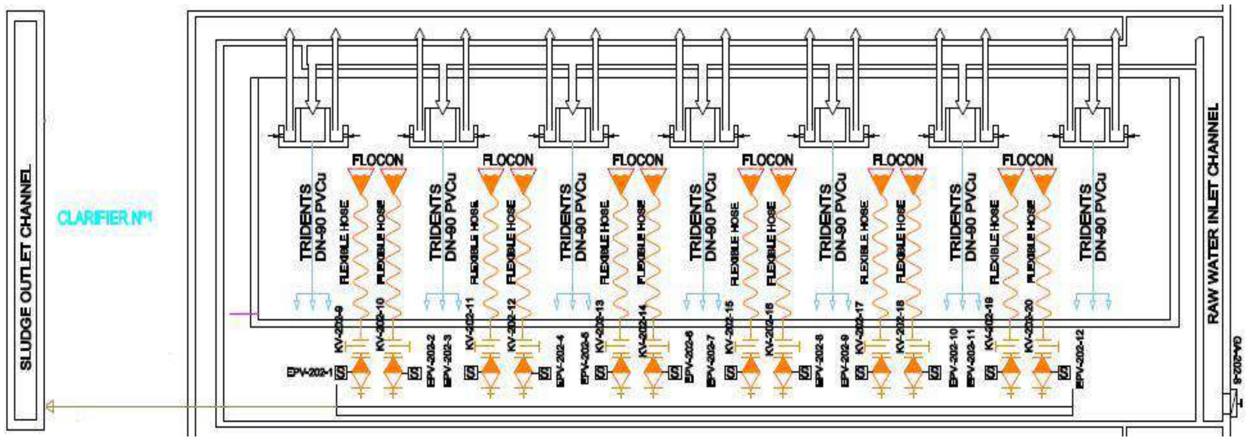


Fig. Clarifier P & ID

6.3. OPERATING CONTROL

6.3.1. Introduction and main ratios

The purpose of sedimentation process is to remove suspended particles so as to reduce load on Filters. If adequate detention time and basin surface area are provided in the clarifiers, solids removal efficiencies greater than 95% can be achieved.

Sludge blanket clarifiers are suitable for many types of waters, including turbid ones, provided the particulate matter is of low density. A safe upper limit for turbidity is about 500 NTU but,depending on the nature of the particulate matter, much higher (up to 1000 NTU) peaks can be accommodated. Heavy particulate matter tends to settle on the bottom of the clarifier. They should be drained down and cleaned after the rainy season, or about once or twice a year. The surface loading rates of flat bottomed sludge blanket clarifiers typically vary from 2 to 5 $m^3/h.m^2$.They usually have sludge blanket of 2.15–2.25 m and clarified water depth of 1.75 m. In sludge blanket tanks, the blanket concentration is typically 20–25% v/v (after 10 minutes settlement in a 250 ml cylinder) and 0.1–0.2% w/v.

However, high sedimentation basin removal efficiencies may not always be the most cost effective way to remove suspended solids. In low turbidity source waters (less than about 10 NTU) effective coagulation and filtration may produce satisfactory filtered water without the need for sedimentation. In this case, coagulation process is operated to produce a highly filterable pinpoint, which does not readily settle due to its small size; instead the pinpoint is removed by the filters. There is, however, a practical limitation in applying this concept to higher turbidity conditions. If the filters become overloaded with suspended solids, they will quickly clog and need frequent back washing. This can limit plant production and cause degradation in filtered water quality.

Thus, the sedimentation process should be operated from the standpoint of overall plant efficiency. If the source water turbidity is only 3 mg/l, and the jar tests indicate that 0.5 mg/l of coagulant is the most effective dosage, then you cannot expect the sedimentation process to remove a significant fraction of the suspended solids. On the other hand, source water turbidities in excess of 50 mg/l will probably require a high coagulant dosage for efficient solids removal. In this case, the majority of the suspended particles and alum floc should be removed in the clarifiers.

6.3.2. Operating procedures

From a water quality standpoint, filter effluent turbidity is a good indication of overall process performance. However one must monitor the performance of each of the individual water treatment processes, including sedimentation, in order to anticipate quality or performance changes. Normal operating conditions are considered to be conditions within the operating ranges of your plant, while abnormal conditions are unusual or difficult to handle conditions. In normal operation of the sedimentation process one must monitor.

- Turbidity of the water entering and leaving the clarifier and temperature of the entering water. Turbidity of the entering water indicates the floc or solids loading on the sedimentation process. Turbidity of the water leaving the basin reveals the effectiveness or efficiency of the sedimentation process. Low levels of turbidity are desirable to minimize the floc loading on the filter.
- Temperature of the water entering the sedimentation basin is important. As the water becomes colder, the particles will settle more slowly. To compensate for this change, you should perform jar tests and adjust the coagulant dosage

to produce a heavier and thus a settling floc. Another possibility is to enforce longer detention times when water demand decreases.

- Visual checks of the sedimentation process should include observation of floc settling characteristics, distribution of floc at the basin inlet and clarity of settled water spilling over the outlet channel. An uneven distribution of floc, or poorly settling floc may indicate that a raw water quality change has occurred or that the operational problems may develop.

A summary of routine sedimentation process actions is given in the **Annex 1**.

6.3.3. Start Up and Shut Down procedures

The procedures are given below:

(a) Start up Procedure

1. Check operational status and mode of operation of equipment and physical facilities.
   - ✓ Check that clarifier valves are closed.
   - ✓ Check that clarifier isolation gates are closed.
   - ✓ Check to ensure that all trash, debris and tools have been removed from clarifier.

1. Test sludge removal equipment.
   - ✓ Check that mechanical equipment is properly lubricated and ready for operation.
   - ✓ Observe operation of sludge removal equipment.

2. Fill clarifier with water.
   - ✓ Observe proper depth of water in basin.
   - ✓ Remove floating debris from basin water surface.

3. Start sample pumps.

4. Perform water quality analyses.

5. Operate sludge removal equipment. Be sure that all valves are in the proper position.

(b) Shut Down Procedures

1. Stop flow to clarifier. Install clarifier isolation gates.
2. Turn off sample pump.
3. Turn off sludge removal equipment.
   - ✓ Shut off mechanical equipment and disconnect where appropriate.

- ✓ Check that valves are in proper position.

3. Lock out electrical switches and equipment.
4. Dewater clarifier if necessary. Open clarifier drain valves.

6.3.4. Operating problems

The operation of sludge blanket tanks is somewhat sensitive to sudden changes in flow and raw water quality and requires greater operator skill. They are not suitable for stop/start operation. Restart following a lengthy shut down may take more than 24 hours. However this could be reduced if sludge from a similar clarifier is available for seeding the blanket. Stoppages of 3–6 hours, can however be accommodated.

The performance of sludge blanket clarifiers (and horizontal flow settling tanks) is known to be influenced by temperature (Hudson, 1981). The temperature effect is normally diurnal and is caused by the creation of thermal gradients within the clarifier due to the walls of the tank being heated. The result is disturbance of the blanket and carry-over of floc towards the evening. Sometimes similar effects have been attributed to the release of gases due to bacterial activity in sludge. Measures taken to minimize carry-over of floc include: use of polyelectrolyte as a coagulant aid. Intermittent chlorination would help to overcome bacterial activity in sludge. So long as their sensitivity is appreciated and they are operated intelligently sludge blanket clarifiers will produce a good quality effluent (turbidity of about 1 NTU) and are very tolerant to changing conditions of raw water quality which would be detrimental to the operation of many other types of clarifiers.

Annex 2. gives a summary of sedimentation process problems and remedial measures.

6.3.5. Record keeping

Maintain daily operations log of process performance and water quality characteristics and keep the following records:

- ✓ Influent and effluent turbidity and influent temperature.
- ✓ Process production inventory (amount of water processed and volume of sludge produced).
- ✓ Process equipment performance (type of equipment in operation, maintenance procedures performed and equipment calibration).

6.4. SAFETY CONSIDERATIONS

(a) Electrical Equipment

- ✓ Avoid electric shock.
- ✓ Avoid grounding yourself in water or on pipes.
- ✓ Ground all electric tools.
- ✓ Use a lock out and tag system for electric equipment or electrically driven mechanical equipment.

(b) Mechanical Equipment

- ✓ Keep protective guards on rotating equipment
- ✓ Do not wear loose clothing around rotating equipment.
- ✓ Keep hands out of valves, pumps and other equipment.
- ✓ Clean up all lubricant and sludge spills.

(c) Open Surface water – filled structures

- ✓ Use safety devices such as hand rails and ladders
- ✓ Close all openings.
- ✓ Know the location of all life preservers.

(d) Valve and Pump Vaults, Sumps

- ✓ Be sure all underground or confined structures are free of hazardous atmosphere (toxic or explosive gases, lack of oxygen).
- ✓ Work only in well ventilated structures.
- ✓ Take proper stops against flooding.

6.5. ROUTINE TASKS

See **Annex 1**.

6.6. LOG-DATA SHEET

See **Annex 2**.

7.ANNEXES

7.1. ANNEX 1

SUMMARY OF ROUTINE SEDIMENTATION PROCESS ACTIONS

CONCEPTS	LOCAT.	FREQUENCY	POSSIBLE ACTIONS
Monitor Process Performance and Evaluate Water Quality Conditions			
Turbidity Temperature	Influent/ Effluent Influent	At least once every 8-hour shift Occasionally	1. Increase sampling frequency when process water quality is variable. 2. Perform jar tests. 3. Make necessary process change: a) Change coagulant dosage. b) Change frequency of sludge removal. c) Change coagulant
Make Visual Observations			
Floc settling characteristics Floc distribution Turbidity (clarity) of settled water	First half of clarifier Inlet Outlet	At least once per 8-hour shift At least once per 8-hour shift At least once per 8-hour shift	1. Perform jar tests. 2. Make necessary process changes: a) Change coagulant dosage. b) Change frequency of sludge removal. c) Change coagulant
Check Sludge Removal Equipment			
Noise, Vibration, Leakage, Overheating	Various	Once per 8-hour shift	1. Correct minor problems. 2. Notify others of major problems.
Operate Sludge Removal Equipment			
Perform normal operations sequence Observe conditions of sludge being removed	Sed. Clarifier	Depends on process conditions (may vary from once per day to several days or more)	1. Change frequency of operation: a) If sludge is too watery, decrease frequency of operation and/or pumping rate. b) If sludge is too dense, bulks, or clogs discharge lines, increase frequency of operation and/or pumping rate. c) If sludge is septic, increase frequency of operation and/or pumping rate.

Inspect Facilities			
Check clarifiers Observe clarified water over outlet channels Observe clarifier water surface Check for algae buildup on basin walls and launders	Various Various Various Various	Once every 8 hour shift Once per 8-hour shift Once per 8-hour shift Occasionally	1. Report abnormal conditions. 2. Make flow changes. 3. Remove debris from basin water surface.

SEDIMENTATION PROCESS TROUBLESHOOTING

Source water quality changes		
Turbidity Temperature Alkalinity Ph Color	1. Perform necessary analysis to determine extent of change. 2. Evaluate overall process performance. 3. Perform jar tests. 4. Make appropriate process changes (next column). 5. Increase frequency of process monitoring.	1. Adjust coagulant dosage. 2. Change frequency of sludge removal (increase or decrease). 3. Increase alkalinity by adding lime, caustic soda or soda ash. 4. Change coagulant.
Coagulation Process Effluent Quality Changes		
Turbidity Alkalinity Ph	1. Evaluate overall process performance. 2. Perform jar tests. 3.Verify performance of coagulation process. 4. Make appropriate process changes (next column).	1. Adjust coagulant dosage. 2. Adjust improperly working chemical feeder. 3. Change coagulant.
Clarifier Changes		
Floc Settling Rising or Floating Sludge	1. Observe floc settling characteristics: a. Dispersion b. Size c. Settling rate 2. Evaluate overall process performance. 3. Perform jar tests. a. Assess floc size and settling rate. b. Assess quality of settled water (clarity and color). 4. Make appropriate process changes (next column).	1. Adjust coagulant dosage. 2. Change frequency of sludge removal (increase or decrease). 3. Remove sludge from clarifier. 4. Change coagulant.

Sedimentation Process Effluent Quality Changes		
Turbidity Color	1. Evaluate overall process performance. 2. Perform jar test. 3. Verify process performance: Coagulation-flocculation process 4. Make appropriate process changes (next column).	1. Change coagulant. 2. Adjust coagulant dosage. 3. Change frequency of sludge removal (increase or decrease).
Upflow Clarifier Process Effluent Quality Changes		
Turbidity Turbidity caused by sludge blanket coming to top due to rainfall on watershed	1. Sec 4. above. 2. Open main drain valve of clarifier.	1. See 3. above (sedimentation process). 2. Drop entire water level of clarifier to bring the sludge blanket down.

7.2. ANNEX 2

DATA SHEET CLARIFIERS

MONTH:

YEAR:

DAY	RAW WATER		CLARIFIED WATER TURBIDITY (NTU)																Flow	Surface Rate	Sludge PurgeTime	Sludge Flow
			1		2		3		4		5		6		7		8					
	T. (NTU)	T (°C)	T.(NTU)	PERF.(%)	T.(NTU)	PERF.(%)	T.(NTU)	PERF.(%)	T.(NTU)	PERF.(%)	T.(NTU)	PERF.(%)	T.(NTU)	PERF.(%)	T.(NTU)	PERF.(%)	T.(NTU)	PERF.(%)	(m^3/d)	$(m^3/m^2/h)$	(h/d)	(m^3/d)
1																						
2																						
3																						
4																						
5																						
6																						
7																						
8																						
9																						
10																						
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31																						

GRAVITY SAND FILTER UNIT

INDEX

EDITION Nr	**1.2**	
Date:	**2012-11-07**	
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PREVIOUS EDITIONS	
Number	**Date**
1.1	2012-05-30

1. OBJECTIVE

The purpose of this Operational Procedure is to give a general description of gravity sand filtration, as well as its basic operation principle.

2. SCOPE

This procedure applies to all water treatment plants on which gravity sand filters have been installed as part of the treatment.

3. REFERENCES

- *"TWORT'S WATER SUPPLY".* Michael Johnson; Don D. Ratnayaka & Malcolm J. Brandt.
- *"Wastewater treatment and exploitation of W.W.T.P".* CEDEX, Ministry of Development of Spain.

4. DEFINITIONS

Effective size	Size of sieving opening through which 10% (by weight) of a sand sample will pass
False bottom	Platform on which filtering nozzles are coupled. It is also the plate which separates feed water and filtered water
Filtering media	It is the material through which raw water flows during filtering process. Filtering media retain pollutants such as: suspended solids, color, and organic matter.
Filtration velocity	Is defined as volumetric feed water flow entering to the filter (m^3/h) divided by the filter surface (m^2).
Head loss	It is the dissipation of energy due to friction. In a liquid flow head loss is reflected in a pressure drop along the pipe
Total suspended solids	Total suspended solids is defined as the residue retained in a fiber glass filter with a pore diameter of 1,2 μm, dried at 105ºC after filtering a given volume of sample.

5. RESPONSIBILITIES

All personnel involved in the exploitation of gravity sand filters with no previous experience in this type of process should properly read and understand this document.

6. PROCEDURE

6.1. INTRODUCTION

Sand filtration is a water treatment on which water flows through a sand bed while pollutant such as suspended solids, color, organic matter and, in a lesser extent, some pathogenic microorganisms are retained by the sand. Sand filtration provides a high quality effluent for human consumption.

Sand filtration units are quite simple and robust. In normal production stage, feed water flows from one side of the filtering bed to the opposite side where filtered water is collected leaving the filter through the outlet pipe. Since pollutants retention causes clogging of the sand bed, filtration units require sand washing to remove retained particles.

Depending how water flows through filter bed there are two types of sand filters: gravity or pressure filters. According to the washing operation, sand filters can be divided in two different groups: non-continuously working filters and continuously working filters. Filters on the first group must be taken out of operation for backwashing whenever certain head loss is reached due to clogging of the filtering media. Head loss may be measure by water level (gravity filters) or by a differential pressure transmitter (pressure filter). In the second group of filters, filtration stage and sand washing occurs at the same time, thus, this type of filters do not need to be taken out of operation for sand backwashing. Filters can be also divided in function of the type of filtering media: single media (typically silica), dual media (e.g. anthracite and silica or gravel and silica) multimedia filters (e.g. anthracite, silica and garnet or coarse gravel, fine gravel and silica).

6.2. DESCRIPTION AND GENERAL PRINCIPLE OF OPERATION

Gravity sand filter consists of a rectangular concrete tank inside which houses the filter media. At Hogenakkal Drinking Water Treatment Plant (DWTP) filtering media is composed of three different layers: coarse gravel, fine gravel and sand (from bottom to top). Sand is the medium which retains the pollutants while fine and coarse gravel allow a quick drain of the filtered water without sand loosing from the filter. Sand layer is 900 mm thick, while each gravel layer is 100 mm thick. Effective size of sand is 0.6-1.18 mm.

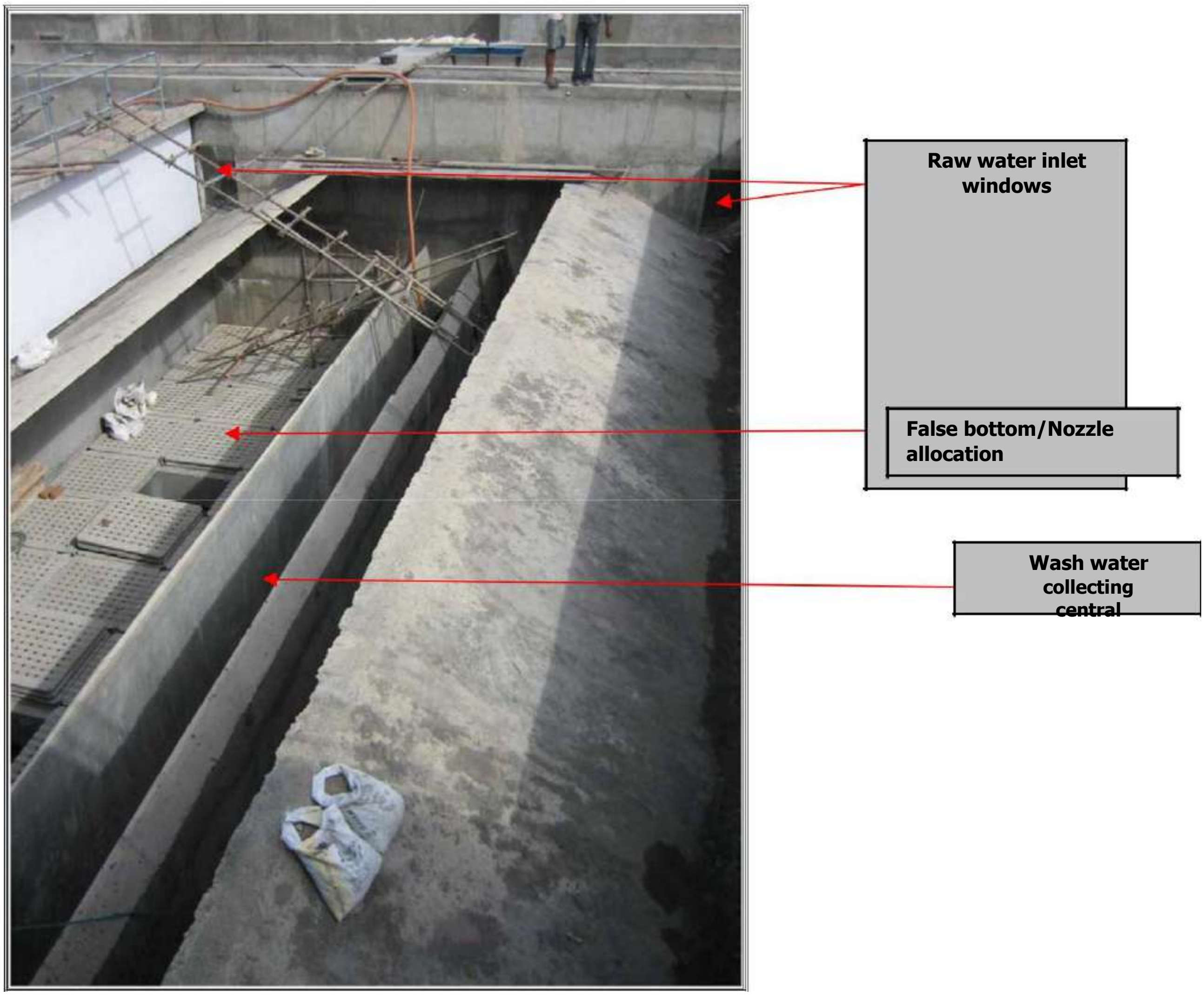
Filtering media is located upon the false bottom of the filter. False bottom is concrete made and divides filtering zone from filtered water zone. All over the false bottom, filtering nozzles are evenly distributed along its surface. Theses nozzles collect filtered water toward the filtered water zone. Nozzles also provide even water and air flow across the filter surface for backwashing stage.

Downstream the filtered water zone a butterfly control valve regulates the water level within the filter, keeping it at a constant value. This level is measured by an ultrasonic level transmitter.

Along the length of the filter, there is a central trough which collects wash water from the backwashing stage. As complementary parts/equipment of the gravity sand filter it must be mentioned the elevated wash water tank and the air blower which are employed for backwashing stage.

Filter size must be in accordance to the water flow to be treated. The number of filtering units of the system must be enough to enable complete water flow treatment while one of them is being backwashed and the rest of them are kept in operation.

In the picture below different parts of the gravity sand filter under construction can be seen.

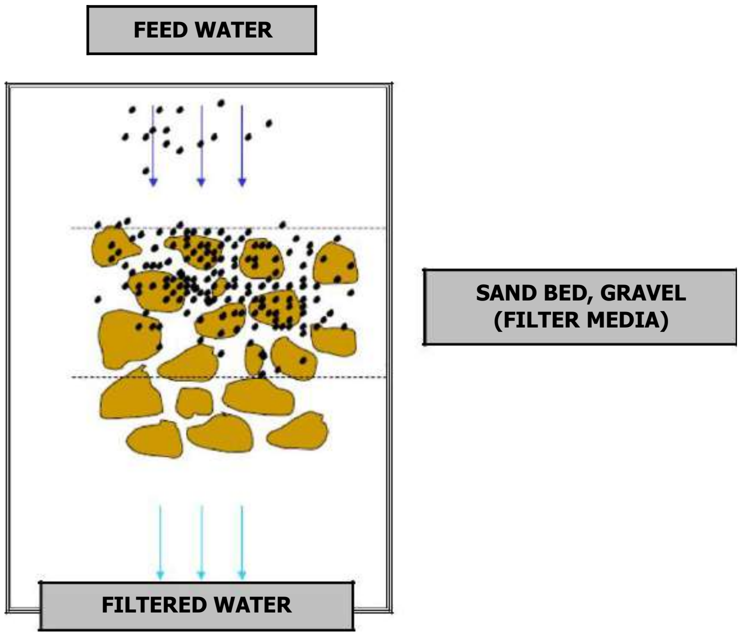

Raw water inlet windows
False bottom/Nozzle allocation
Wash water collecting central

A picture of one nozzle is shown below:

6.2.1. FILTRATION STAGE

During filtration stage, raw water enters into the filter through the inlet windows located at both sides of one end of the filter (see the picture above). Water is evenly distributed over the filter surface by the inlet orifices and flows downward to the tank bottom while pollutants such as solid particles, color, organic matter and some microorganisms are retained by the filtering media. There are several mechanism through which pollutants are removed in sand filtration process: sedimentation, interception, hydrodynamic diffusion, etc.

Figure below illustrates sand filtration process:



Gravity sand filter operates under constant water level which ensures constant filtration velocity. The water level is measured by one ultrasonic level transmitter. The signal of this level transmitter is manage by one butterfly control valve in order to keep constant water level. As more pollutants are retained by the sand, the flow control valve will opening in order to counteract head loss due to filter clogging.

In order to avoid biological growth in the sand filters, chlorine is dosed at the parshall flume, located at the entry to the DWTP.

Once the maximum allowed head loss is reached (filter clogging), backwashing of the sand filter takes place. This point will be reached as soon as the control valve is 100% opened.

6.2.2. BACKWASING STAGE

Backwashing requires taking the filter out of operation. This is done by closing the inlet feed water penstock and the outlet filtered water control valve.

Backwashing is done with air and filtered water in countercurrent flow, thus, as it was already pointed, auxiliary equipment such blowers and elevated wash water tank are integrated in the sand filters system. Backwash water flow rate must be great enough to remove solid particles attached to the sand without dragging sand of the filter bed, producing loos of the filtering media.

Air is provided in order to expand the filtering media which will facilitate pollutants removal by backwash water. Furthermore, air reduces filtered water consumption for backwashing.

Backwashing sequence can be described as follows (refer to the FDS of sand filter for specific information about exactly valve and penstock operation for backwashing and duration of each single backwashing stage):

1. First of all the filter must be taken out of operation by closing inlet penstock and outlet control valve.

2. *Fluidization* of the filter bed: this step improves backwashing stage. This is done by countercurrent air flow provided by an air blower.

3. While blower is still in operation, backwashing with filtered water starts. Filtered water for backwashing is fed to the filter by gravity from an elevated tank. Wash water flow is measured by an electromagnetic flowmeter and it is controlled by a control valve.

4. Blower stops and backwashing is kept just with feed water.

5. Wash water control valve closes.

6. Once the filtered has been washed, it is ready for filtration stage.

Wash water is collected by the wash water central trough and flows toward the wash water recovery tank. From this tank, settled sludge is pumped toward the sludge balancing tank while supernatant is pumped toward the works inlet.

At the beginning of the filtration stage, filtered water will be sent to drainage by opening an automatic valve located at the filter outlet. After this initial period, filtration will be set to regular filtered water production.

6.2.3. WASH WATER RECOVERY TANK

The washwater recovery tank is a 2,000 m^3 concrete tank. This tank has been divided in two independent compartments in order to allow maintenance operations in one compartment while the other one is in operation. Each compartment is 14.5 meters wide and 16 meters length. The floor of both chambers laids to a fall and terminates in a pump sump. The slope of the floor is 10%. The volume of each single chamber is enough to store the washwater from two consecutive filter washes. Nevertheless, both chambers may be communicated by opening a central penstock located in the common wall. On the other hand, both compartments have their own inlet penstock.

In normal operation, washwater recovery tank works following four steps sequence: filling up, settling, supernatant pumping and sludge pumping.

1. Filling up:

Washwater enters to one of the compartments through its inlet penstock. Once the whole washwater volume has been received into the chamber, the inlet penstock will close, isolating the tank. Note that each compartment may receive the whole washwater volume from two consecutive backwashes.

2. Settling:

A settling period of 3 hours ensures solid-liquid separation which will result in a clear water upper layer (supernatant) and settled sludge bottom layer.

3. Supernatant pumping:

Once the settling period has been completed, an automatic valve will open allowing the clear water to flow into the supernatant pit, from which supernatant will be pumped by one centrifugal pump. There are two centrifugal pumps for supernatant (1+1R). Clear water flows from the chamber to the supernatant pit through a floating draw-off arm which has been designed in order to remove clear water from the upper part of the tank. The floating arm will be connected to the draw-off connection by an articulated pipe. This system ensures only clear water from the tank surface is pumped toward the works inlet. This step lasts about 6.6 hours.

4. Sludge pumping:

Once the supernatant has been pumped from the tank to the works inlet, sludge pumping toward the sludge balancing tank takes place. There are two centrifugal pumps for sludge pumping, one pump for each compartment. Sludge is pumped directly from each compartment toward the sludge balancing tank. Due to the high slope of the tank floor, all the sludge will flow to the pump sump ensuring no sludge remains on the tank floor. The duration of sludge pumping will be around 3 hours.

Note: Time and duration of filtering processes to be configured while commissioning period.

6.3. OPERATIONAL PROCEDURES AND TROUBLE SHOOTING INSTRUCTIONS

6.3.1. OPERATIONAL PROCEDURES

6.3.1.1. The indicators of normal operating conditions

The filter influent and effluent turbidities should be closely watched with a turbidimeter. Influent and effluent filter turbidity levels are monitored and recorded on a continuous basis by on-line turbiditimeter.

6.3.1.2. Process Actions

Follow the steps as indicated below:

1) Monitor process performance.
2) Evaluate turbidity and make appropriate process changes.
3) Check and adjust process equipment (change chemical feed rates).
4) Backwash filters.
5) Evaluate filter media condition (media loss, mud balls, cracking).
6) Visually inspect facilities.

6.3.1.3. Important process activities and Precautions.

1) Monitoring process performance is an ongoing activity. You should look for and attempt to anticipate any treatment process changes or other problems that might affect filtered water quality, such as a chemical feed system failure.
2) Measurement of head loss built up in the filter media will give you a good indication of how well the solids removal process is performing.
3) The rate of head loss build up is an important indication of process performance. Sudden increase in head loss might be an indication of surface sealing of the filter media (lack of depth penetration). Early detection of this condition may permit you to make appropriate process changes such as adjustment of chemical filter aid feed rate or adjustment of filtration rate.
4) Monitoring of filter turbidity on a continuous basis with an on-line turbiditimeter is highly recommended. This will provide you with continuous feedback on the performance of the filtration process. In most instances it is desirable to cut off (terminate) filter at a predetermined effluent turbidity level. Preset the filter cutoff control at a point where you experience and tests show that breakthrough will soon occur.

5) In the normal operation of the filter process, it is best to calculate when the filter cycle will be completed on the basis of the following guidelines:

   - Head loss (Automatic).
   - Effluent turbidity level.
   - Elapsed run time.

A predetermined value is established for each guideline as a cut off point for filter operation. When any of these levels is reached, the filter is removed from service and backwashed.

6) At least once a year one must examine the filter media and evaluate its overall condition. Measure the filter media thickness for an indication of media loss during the backwashing process. Measure mud ball accumulation in the filter media to evaluate the effectiveness of the overall backwashing operation.
7) Routinely observe the backwash process to qualitatively assess process performance. Watch for media boils (uneven flow distribution) during backwashing, media carry over into the wash water trough, and clarity of the waste wash-water near the end of the backwash cycle.
8) Upon completion of the backwash cycle, observe the condition of the media surface and check for filter sidewall or media surface cracks. You should routinely inspect physical facilities and equipment as part of good housekeeping and maintenance practice. Correct or report the abnormal equipment conditions to the appropriate maintenance personnel.
9) Never bump up a filter to avoid backwashing. Bumping is the act of opening the backwash valve during the course of a filter run to dislodge the trapped solids and increase the length of filter run. This is not a good practice.
10) Shortened filter runs can occur because of air bound filters. Air binding will occur more frequently when large head losses are allowed to develop in the filter. Precaution should be taken to minimize air binding to avoid damage to the filter media.

A summary of routine filtration process action is given in a log sheet (**Annex 1**).

6.3.1.4. Trouble shooting instructions

Annex 2 gives Filtration process trouble shooting problems.

6.4. HEALTH AND SAFETY

6.4.1.1. Electrical Equipment

1) Avoid electric shock (use preventive gloves).
2) Avoid grounding yourself in water or on pipes.
3) Ground all electric tools.
4) Lock out and tag electrical switches and panels when servicing equipment.

6.4.1.2. Mechanical Equipment

1) Use protective guards on rotating equipment.
2) Don't wear loose clothing around rotating equipment.
3) Keep hands out of energized valves, pumps and other pieces of equipment.
4) Clean up all lubricant and chemical spills (slippery surfaces cause bad falls).

6.4.1.3. Surface Filters

1) Use safety devices such as handrails and ladders.
2) Know the location of all life preservers and other safety devices.

6.4.1.4. Valve and Pump Vaults, Sumps, Filter galleries

1) Be sure that all underground or confined structures are free of hazardous atmospheres (toxic or explosive gases, lack of oxygen) by checking with gas detectors.
2) Only work in well ventilated structures (use air circulation fans).

6.5. ROUTINE TASKS

See **Annex 1.**

6.6. LOG-DATA SHEET

See **Annex 1.**

7. ANNEXURE

7.1. ANNEX 1

CONCEPT	LOCATION	FREQUENCY	POSSIBLE ACTIONS
Monitor process performance and evaluate water quality conditions			
Turbidity Colour Head loss	Influent/ Effluent Influent/ Effluent	At least once per 8-hour shift. At least once per 8-hour shift. At least two times per 8-hour shift.	1. Increase sampling frequency when process water quality is variable. 2. Perform Jar Tests. 3. Make necessary process changes: ○ Adjust coagulant dosage. ○ Change filtration rate. ○ Back wash filter. ○ Change chlorine dosage. ○ Change Coagulant.
Operate Filters and Backwash			
Put filter into service. Change filtration rate. Remove filter from service. Backwash filter. Change backwash rate.	Filter module	Depends on process conditions	
Check Filter Media Condition			
Media depth evaluation. Media cleanliness. Cracks or shrinkage.	Filter module	At least monthly.	1. Replace lost filter media. 2. Change backwash procedure. 3. Change chemical coagulants.
Make Visual Observations of Backwash Operation			
Check for media boils and media expansion. Check for media carryover into washwater trough. Observe clarity of wastewater.	Filter module	At least once per day or whenever backwashing occurs.	1. Change backwash rate. 2. Change backwash cycle time. 3. Adjust surface wash rate or cycle time. 4. Inspect filter media and support gravel for disturbance.
Check Filtration Process and Backwash Equipment Condition			
Noise, Vibration, Leakage, Overheating	Various	Once per 8-hour shift.	Correct minor problems.
Inspect Facilities			
Check physical facilities and algae on sidewalls and troughs.	Various	Once a day.	1. Remove debris from filter media surfaces 2. Adjust chlorine dosage to control algae.

No.	Time		Hours operated			Head loss		Wash		Physical condition of filters
	Start	Stop	Today	Previous	Total	Start	Stop	Min.	m3	
1.										
2.										
3.										
4.										
5.										
6.										
7.										
8.										
9.										
10.										
11.										
12.										
No. of filters washed						Average filter rate				
Average run-hours						Max. hourly rate				
Total wash water						Total water filtered				
Percent of water filtered						No. filters operating				
Av. Time of wash-min						Filters out per wash-min.				
						Shift				
						Operator				

7.2. ANNEX 2

TROUBLE SHOOTING	OPERATOR ACTIONS	POSSIBLE PROCESS CHANGES
Source water quality changes		
Turbidity Temperature Alkalinity pH Colour Chlorine Demand	1. Perform necessary analysis to determine extent of change. 2. Assess overall process performance 3. Perform Jar tests. 4. Make appropriate process changes. 5. Increase frequency of process monitoring. 6. Verify response to process changes (be sure to allow sufficient time for change to take effect) 7. Add lime if alkalinity is low.	1. Adjust coagulant dosage. 2. Change frequency of sludge removal (increase or decrease). 3. Adjust backwash cycle (rate, duration). 4. Change filtration rate (add or delete filters). 5. Start filter aid feed. 6. Change coagulant.
Sedimentation Process Effluent Quality Changes		
Turbidity or floc carryover	1. Assess overall process performance. 2. Perform Jar tests. 3. Make appropriate process changes.	Same as source water quality changes.
Filtration Process Changes/Problems		
Headloss increase Short filter runs media surface sealing Mudballs Filter media cracks, shrinkage Filter not clean Media boils Media loss Excessive head loss	1. Assess overall process performance. 2. Perform Jar tests. 3. Make appropriate process changes.	1. Adjust coagulant dosage. 2. Change frequency of sludge removal. 3. Adjust backwash cycle (rate, duration). 4. Manually remove mudballs. 5. Decrease filtration rate (add more filters) 6. Decrease or terminate filter aid. 7. Replenish lost media. 8. Clear under drain openings of media, corrosion or chemical deposits; check head loss. 9. Change coagulant.
Filter Effluent Quality Changes		
Turbidity breakthrough Colour pH Chlorine	1. Assess overall process performance. 2. Perform Jar tests. 3. Verify process performance: a) Coagulation. b) Sedimentation process c) Filtration process. 4. Make appropriate process changes.	1. Adjust coagulant dosage. 2. Change frequency of sludge removal. 3. Start filter aid feed. 4. Decrease filtration rate (add more filters). 5. Change chlorine dosage. 6. Change coagulant.

CHLORINATION-DISINFECTION PROCESS DESCRIPTION

INDEX

EDITION Nr		**1.1**
Date:		**2012-11-24**
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PREVIOUS EDITIONS	
Number	**Date**
1.0	2012-05-04

1. OBJECTIVE

The purpose of this Operational Procedure is to give a general description of disinfection by means of chlorine gas, as well as basic operation principle of chlorine metering system.

2. SCOPE

This procedure applies to all water treatment plants on which disinfection system by chlorine gas has been installed as part of the treatment.

3. REFERENCES

- "TWORT'S WATER SUPPLY". Michael Johnson; Don D. Ratnayaka & Malcolm J. Brandt.
- "WASTEWATER TREATMENT AND EXPLOITATION OF W.W.T.P". CEDEX, Ministry of Development of Spain.

4. DEFINITIONS

Bacteria	Any of a class of microscopic single-celled organisms reproducing by fission or spores. Characterized by round, rod-like spiral or filamentous bodies often aggregated into colonies or mobile by means of flagella. Widely dispersed in soil, water, organic matter and bodies of animals or plants. Autotrophic, parasitic and sometimes pathogenic.
Bactericidal	Agent capable of killing bacteria.
Disinfection	The process of killing organisms in a water supply or distribution system by means of chemical, physical, mechanical or radiation methods.
Disinfectant	Product used to carry out disinfection treatments.
Germicide	See disinfectant
Pathogenic microorganism	Organism including bacterias, viruses, protozoans and fungi that may cause diseases.
Plug Flow	Flow pattern in which chemicals reactions can be described as series of

Reactor	infinitely thin coherent "plugs", each with a uniform composition, traveling in the axial direction of the reactor, with each plug having a different composition from the ones before and after it.
Virus	A microorganism that is smaller than a bacterium that cannot grow or reproduce apart from a living cell. A virus invades living cells and uses their chemical machinery to keep itself alive and to replicate itself.

5. RESPONSIBILITIES

All personnel involved in the exploitation of a chlorination system with no previous experience in this type of process should properly read and understand this document.

6. PROCEDURE

6.1. INTRODUCTION

Water is the perfect medium in which microorganism may live and develop. Some types of microorganisms, called pathogenic microorganisms, are responsible of diseases transmission. If pathogenic microorganisms are present in the drinking water network supply, it may lead to epidemic situation. Disinfection is the treatment addressed to destruction of those microorganism. For that reason, disinfection is the most important stage at drinking water treatment plants.

The table below summarizes the most important type of pathogenic microorganisms that are to be destructed by water disinfection:

Microorganism type	Example
Bacterias	Escherichia coli
	Salmonella typhosa
	Vibrio cholerae
	Salmonella sp.
	Shigella sp.
Viruses	Poliomyelitis

Microorganism type	Example
	Hepatitis A
	Echovirus
	Coxsackie virus
	Adeno virus
Protozoa	Endamoeba histolytica
	Micobacterium tuberculosis
	Schistosoma sp.
	Cryptosporidium parvum

6.2. DISINFECTION METHODS

Water disinfection can be done by means of different methods. The table below summarizes disinfection methods as well as its main disinfectant agents.

Disinfection method	Disinfectant agent	Disinfection mechanism
Chemical	Chlorine gas (Cl_2)	Enzymatic process inhibition
	Sodium hypochlorite (NaOCl)	Enzymatic process inhibition
	Chlorine dioxide (ClO_2)	Enzymatic process inhibition
	Bromine (Br_2)	Enzymatic process inhibition
	Chlorine bromide (BrCl)	Enzymatic process inhibition
	Iodine (I_2)	Enzymatic process inhibition
	Ozone (O_3)	Cellular wall destruction
Physic	UV rays	Inhibition of reproductive functions
Mechanical	Sieving	Microorganism retention
	Settling	Microorganism retention

Disinfection method	Disinfectant agent	Disinfection mechanism
	Sand filtration	Microorganism retention
	Membrane processes: UF, RO, etc.	Microorganism retention
Radiation	Gamma rays	Inhibition of reproductive functions

6.3. FACTORS INVOLVED IN DISINFECTION PROCESSES

Main factors affecting water disinfection are pointed and described below:

- *Contact time:*

Contact time or duration of exposure to the disinfectant agent is the most important variable. For a given disinfectant agent concentration, mortality of pathogens increases as contact time increases.

- *Type and concentration/intensity of disinfectant agent:*

Efficacy of disinfection processes depend on the type of employed agent. For the same agent, disinfection efficiency is related to its concentration, thus, the higher the concentration the higher disinfection efficiency.

- *Temperature:*

As in many other processes, disinfection efficiency increases as temperatures increases.

- *Microorganisms concentration:*

As a general rule, increasing of microorganism concentration will required higher contact time to achieve the same disinfection efficiency.

- *Type of microorganisms:*

Effectiveness of disinfectant agents is strongly affected by the type of microorganism. For example, bacterial cells are easily destructed. On the other hand, spores have a coat and cortex that act as a barrier to disinfectants. Mycobacteria can also prevent disinfectant entry as they have a waxy cell wall. More resistant microorganisms require stronger concentrations of disinfectant and longer period of exposure.

- *Quality of the medium (water):*

Presence of organic matter may reduce disinfection efficiency by consuming a portion of the disinfectant agent. Suspended solids and other colloidal matter may provide shelter to microorganism, reducing as well the efficiency of disinfection treatment.

- *pH:*

Increased pH levels can lead to two outcomes. The disinfectant molecule or the cell surface may be altered by increased pH levels. In some disinfectants, such as quaternary ammonium compounds, increased pH improves the disinfectant's ability to kill microorganisms. In other disinfectants, including hypochlorites and iodine, the effect of the disinfectant is reduced by increase in pH.

6.4. DISINFECTION TROUGH CHLORINE GAS

Chlorine gas is widely employed in drinking water disinfection as it is a powerful disinfectant agent, easily available and cheap. Main disadvantages of chlorine are: slight solubility in water, oxidizes organic matter (loss of germicide activity), it is toxic and irritant for humans and it is highly corrosive.

Next table reflects chlorine-water solubility at different temperatures and 1 atmosphere of pressure:

T^a (ºC)	10	20	30	40	50	60	70	80	90	100
Solubility (g/l)	9.93	7.33	5.64	4.60	3.87	3.33	2.78	2.10	1.20	0

Hydrolysis of chlorine gas occurs following next reaction:

$$Cl_2 + H_2O \leftrightarrow ClOH + H^+ + Cl^-$$

This reaction is almost instantaneous. Bactericidal strength of chlorine is based on the highly oxidizing capability of hypochlorous acid, ClOH, which oxidizes respiratory enzymes, thus, inhibiting Krebs cycle of the microorganism.

Depending on the pH of the medium, a certain amount of hypochlorous acid is ionized as follows:

$$ClOH \leftrightarrow H^{+} + ClO^{-}$$

Bactericidal strength of hypochlorite ion (ClO^{-}) is lower than hypochlorous acid. The dissociation is favored by high pH and temperature, as shown in the table below:

	Percent HOCl at water temperatures (percent OCl^{-} = 100 – percent HOCl)						
pH	0 °C	5 °C	10 °C	15 °C	20 °C	25 °C	30 °C
6.0	98.5	98.3	98.0	97.7	97.4	97.2	96.9
6.25	97.4	97.0	96.5	96.0	95.5	95.1	94.6
6.5	95.5	94.7	94.0	93.2	92.4	91.6	91.0
6.75	92.3	91.0	89.7	88.4	87.1	86.0	84.8
7.0	87.0	85.1	83.1	81.2	79.3	77.5	75.9
7.25	79.1	76.2	73.4	70.8	68.2	66.0	63.9
7.5	68.0	64.3	60.9	57.7	54.8	52.2	49.9
7.75	54.6	50.5	46.8	43.5	40.6	38.2	36.0
8.0	40.2	36.3	33.0	30.1	27.7	25.6	23.9
8.25	27.4	24.3	21.7	19.5	17.6	16.2	15.0
8.5	17.5	15.3	13.5	12.0	10.8	9.8	9.1
8.75	10.7	9.2	8.0	7.1	6.3	5.8	5.3
9.0	6.3	5.4	4.7	4.1	3.7	3.3	3.0

Under acid conditions, hypochlorous acid ionization degree is very low, but for pH above 8.0 at any temperature, concentration of hypochlorite ion is higher than concentration of hypochlorous acid. As it was mentioned above, high pH's values decrease bactericidal strength of chlorine as ionization of hypochlorous acid to hypochlorite ion increases.

Total free chlorine is the sum of both species and it is expressed as follows:

$$T = [ClOH] + [ClO^{-}]$$

Both hypochlorous acid and hypochlorite ion are extremely reactive with many other compounds present in the water such as ammonium, organic matter and reducing inorganic matter (SH_2, SO_3^{2-}, NO_2^{-}, Fe^{2+}, Mn^{2+}). Those reactions result in many different compounds, whose bactericidal strength is lower than hypochlorous acid and hypochlorite ion.

Combined chlorine is defined as chlorine which has reacted with organic matter and ammonium. Sum of both free chlorine and combined chlorine is known as total chlorine.

6.4.1. CHLORINE METERING POINTS

At Hogenakkal Drinking Water Treatment Plant chlorine is dosed in two different points. Each metering point has its own target.

Following water stream, first metering point is located at the parshall flume. This step is known as pre-chlorination and it is addressed to ensure no biological growth takes place along the subsequent stages of the treatment including: pipes, flat bottom clarifier, sand filters. It must be pointed that sand filters are prone to biological growth so it can be understood the importance of the pre-chlorination step. Nevertheless, pre-chlorination is not perform on daily basis but as a shock treatment.

Second chlorine metering point is located at the outlet of the sand filters, just before the contact tank, where properly water disinfection takes place. Due to its special design, contact chamber ensures, under appropriated chlorine dose, completely disinfection of treated water. A P&ID of the contact tank is shown in the point 8. **ANNEX 2**.

Basically, contact tank is a channel where water flows under plug flow reactor pattern. Chlorine dosing rate at contact chamber should be great enough to guarantee a minimum residual free chlorine concentration which ensures disinfection remains effective downstream the treatment plant: BPS, Madam tank reservoir and water network supply.

Contact tank is comprised of two units of 2,030 m^3 each one (4,060 m^3 total volume). This design allows maintenance operation in one of them while the other one is in operation. The minimum effective contact time is 30 minutes. Each single tank has its own inlet penstock. After the penstock and before the contact tank itself, one impeller mixer ensures proper mixing between filtered water and chlorine. There are two mixers, one for each contact tank.

6.4.2. ALGAE CONTROL

6.4.2.1. Introduction

Algae are unicellular or multicellular chlorophyll bearing plants without any true root, stem or leaves. They may be microscopic unicellular colonial or dense mat forming filamentous forms commonly inhabiting surface waters. Their growth is influenced by a number of factors, such as mineral nutrients, availability of sunlight, temperature and type of reservoir. During certain climatic conditions there is an algal bloom which creates acute problems for treatment and production of potable water.

The algae encountered in water purification plants are Diatoms, Green Algae, Blue Green Algae and Algal Flagellates. Algae may be seen floating (plankton) in the form of blooms.

6.4.2.2. Problems caused by algae

1) Many species of algae produce objectionable taste and odour due to characteristic oil secretions. These also impart colour ranging from yellow-green to green, blue-green, red or brown.
2) Profuse growth of algae interferes with chemical treatment of raw water by changing water pH and its hardness.
3) Some algae act as inhibitors in process of coagulation carried out for water purification.

4) Some algae clog filters and reduce filter run.
5) Some algae produce toxins and their growth in drinking water reservoirs is harmful for humans and livestock.
6) Some algae provide shelter to a large number of bacteria, some of which may be pathogenic.
7) Some algae corrode metal tanks, forming pits in their walls.
8) Algae may also cause complete disintegration of concrete in contact with them.
9) Prolific growth of algae increases organic content of water, which is an important factor for the development of other organisms.

6.4.2.3. Chlorine treatment

Algicide dose used should be harmless to humans, have no effect on water quality, should be inexpensive and easy to apply. The most commonly used algaecides are copper sulphate and chlorine.

Chlorine treatment is relatively cheap, readily available and provides prolonged disinfecting action. Though chlorine is generally used for disinfecting potable water it can also be used as an algaecide. Prechlorination has specific toxic effect and causes death and disintegration of some of the algae. It also assists in removal of algae by coagulation and sedimentation. It prevents growth of algae on basin walls and destroys slime organisms on filter sand thus prolonging filter run and facilitating filter washing.

Dosage: Effective chlorine dose should be such that sufficient chlorine is there to react with organic matter, ammonia, iron, manganese and other reducing substances in water and at the same time leave sufficient chlorine to act as algaecide. Dose required for this purpose may be over ***5 mg/l***. With chlorine treatment essential oils present in algae are liberated which may lead to development of odour and color and taste. Occasionally these oils as well as organic matter of dead algae may combine with chlorine to form intensified odour and taste. In such cases break point - chlorination is required. Post chlorination dose can be adjusted to obtain minimum ***0.2 mg/l*** residual chlorine in potable water at consumer end.

6.4.2.4. Method of application

Chlorine is preferably applied as a strong solution of chlorine from chlorinator. For algal growth control chlorine is administered at the entry of raw water before coagulant feeder.

6.4.3. CHLORINE STORAGE AND METERING SYSTEM BASIC DESCRIPTION

Chlorine gas is supplied in 915 kg tonners at 6 bar pressure. These tonners are storage in the chlorine tonner room. Several tonners are connected to the tonner manifold. Connection from tonners to this manifold is done through the coiled copper tube. Whenever a tonner which is in service gets empty, an automatic valve system switch to a new full chlorine tonner.

After the automatic valve system, chlorine manifold ramify into three pipes, each one to its own chlorinator. There are three chlorinators located in the chlorinators room, two of 25 KPH capacity and the other one of 16 KPH capacity. Before chlorinators, a gas filter is provided to remove impurities, mainly ferric chloride.

Main equipment of chlorinator is: automatic vacuum regulator, flow control valve, rotameter, differential pressure regulator and injector. The automatic vacuum regulator is a device which closes under pressure and opens under vacuum. It is a safety item which does not allow chlorine flow to the injector without vacuum. The function of the differential pressure regulator is to regulate the pressure drop created due to the differential across the orifice of the flow control valve, which will lead to a precise chlorine dosage. The flow control valve allows setting a constant flow of chlorine, which is measured by the rotameter. Injector creates the required vacuum for chlorine flow from the tonners toward the injector, where it is mixed with make-up water. From the injector, chlorine-water solution flows to the dosing points. There are three booster pumps, one for each injector, which pump make-up water through the injector. This water flow through the injectors is actually what creates the required vacuum for chlorine flow from the tonners to the injector.

Since chlorine gas is extremely toxic and corrosive, there are two chlorine gas leak detector, one in the chlorine tonner room and the other one in the chlorinators room. Whenever a chlorine leak gas is detected by those devices, the Automatic Chlorine leak Absorption System (ACAS) will start-up. ACAS is comprised of two blowers (1+1), two recirculation pumps (1+1), an absorption tank and an absorption tower. Chlorine gas leak is removed by the suction of the blowers. The outlet pipe of the blowers ends at the bottom of the absorption tower. Chlorine gas flows upward while is absorbed by the absorbent solution. Absorbent solution is a caustic soda solution (NaOH), which is recirculated from the bottom to the top of the towers.

6.4.4. START UP OF GAS CHLORINE SYSTEM

1) First start the booster pumps and make certain that the hydraulic conditions are satisfactory. For that purpose see the delivery water pressure & injector vacuum gauge reading. If the conditions are satisfactory, the vacuum gauge should show reading above 590 mm of Hg.
2) Check that all the chlorine valves on the supply line to chlorinators are closed.
3) When the injector system is functioning properly, open the valve of chlorine tonner partially to allow the gas. Chlorine container should be connected to the system and kept ready before starting the plant.
4) Verify that all of the tubing, manifold and auxiliary valve connections are correct and that all union joints are properly gasketed. Check the leakage with ammonia stick and if there is any leakage, close the cylinder valve immediately and attend to the leaking joint to make it leak proof.
5) Check all the joints between tonner valve to end.
6) Open the chlorine valve slightly to injector and check all the tubing and components of chlorinators for leakage. Attend if necessary by closing inlet valve. If there is no leak, then the chlorinator is ready for further testing.
7) Open fully the chlorinator gas inlet valve and check the chlorinator for range, automatic control and so on.
8) If at any stage leakage of chlorine is found, close the tonner valve. Allow the gas in the system to be consumed through injector and then attend for leaking joints.
9) If the leakage is due to missing gaskets etc., close the tonner valve. Leave the site immediately for safe area. With the help of breathing apparatus carry out the gas evacuation procedure through the chlorinators.

10) After all leaks have been corrected the next step will be to see that the chlorinator will reach its maximum capacity as specified. This is the most important operative criteria of the chlorinator installation.
11) If the chlorinator is not giving specified dose check for injector vacuum and chlorine pressure in the system and attend to the defects. The fault is normally in the hydraulics of the injector system. The next likely place is within chlorinator itself. A malfunction in either place is reflected by a low vacuum reading on the injector vacuum gauge.

    i) The first step in this case is to check the vacuum leak within the chlorinators. If the leak is major, it can be discovered by shutting off the injector water suddenly and using ammonia on all the joints. This sudden removal of vacuum will create slight pressure and chlorine will be expelled into atmosphere. Very small leak will not show up in this procedure.

    ii) Then check for 'O' ring seal in metering tube, vacuum relief valve, for defective spring or seat etc. and attend to it.
12) Vacuum will be affected due to long vacuum line between injector and chlorinator. If this is filled with air, the large amount of air reduces injector vacuum. Moreover if this line is leaking it will also reduce the vacuum.

    Like a long vacuum line, a long chlorine solution line will also affect the injector vacuum. The air in this line, therefore needs to be removed.
13) Defective injector may also affect vacuum.

6.4.5. PROCEDURE FOR STOPPING THE PLANT

Stopping the chlorination system is also important in order to avoid chlorine leakages as well as for the system safety. The procedure is as follows:

1) Shut off the chlorine supply system.
2) When the chlorine pressure gauge reaches zero remove the tonner connection & allow the air to evacuate all the residual chlorine gas in the system while the injector is still in operating condition.
3) After the chlorine has been purged to the satisfaction of the operator, the injector system may be shut down.
4) Connect the openings with plastic plugs.
5) For liquid system the chlorine in the evaporator shall be completely consumed.
6) Then close the heater supply to the evaporator.

6.5. TROUBLE SHOOTING INSTRUCTIONS

See **ANNEX 1**.

7. SAFETY CONSIDERATIONS

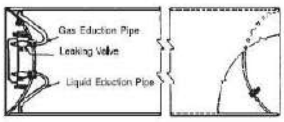
7.1. GENERAL

Chlorine is potentially dangerous. It is, therefore, important that person engaged in a chlorine plant or in any activity involving handling of chlorine should understand the hazards of chlorine and should know preventive measures needed. These are given below:

7.2. TONNERS

Bigger containers are commonly known as 'Tonners" Indian tonners are generally fabricated conforming to the British standards (B.S:1500).

These are kept horizontally so as to bring the two valves in vertical plane. Each has a capacity of approx. 900 kg. It has built-in safety by way of providing concave dished ends. Both the valves are covered by a protective hood connected to the container by means of lugs. The inside ends of the valves are connected to the eduction pipes. (Fig. I).



GENERAL SPECIFICATION

Water Capacity (approx.) Kg.	-	780
Chlorine Capacity (approx.) Kg.	-	930
Design Pressure, Kg/Cm^2	-	19.9
Inside Diameter (approx.) mm	-	760
Shell Thickness, mm	-	10
Dished Ends Thickness, mm	-	9.6 (Min.)
Overall Length (approx.) mm	-	2085
Tare Weight (approx.) Kg.	-	520

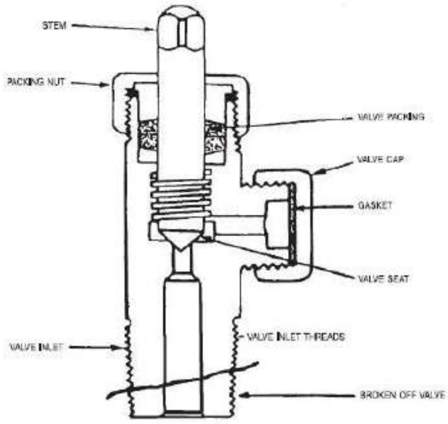
I. Valves connection

Tonners manufactured in India after 1981 do not have fusible plug as per the Gas Cylinder Rules 1981. However, in imported design where these are provided, they melt between the temperatures of 70ºC and 74ºC thereby reducing the pressure inside the container in case of fire or high temperature.

The withdrawal rates of Cl_2 at 20ºC are 7 kg/hr and 180 kg/hr for gas and liquid respectively. It depends upon ambient temperature.

7.3. CONTAINER VALVS

Tonners must be fitted with standard valves conforming to IS: 3224 (Fig. II).



II. *Standard chlorine container valve*

7.4. STORAGE AND HANDLING OF CHLORINE TONNERS

Chlorine is stored in special grade steel containers. As per IS:4379-1967, the colour of Chlorine container should be 'golden yellow'.

7.4.1. STORAGE AREA

Obtain storage licence from controller of explosives under Gas Cylinder Rules 1981 if the quantity of Cl_2 containers to be stored is more than 5 Nos.

a) Storage area should be cool, dry, well ventilated, and clean of trash and protected from external heat sources.
b) Ventilation must be sufficient to prevent accumulation of vapour pockets. The exhaust should be located either near the floor or duct be provided extending to the floor. All fan switches should be outside the storage area.
c) Do not store container directly under the sun.
d) Weather cock should be installed near the storage to determine wind direction.
e) The storage building should be of non-combustible construction with at least two exits opening outside.
f) Neutralization system should be provided.
g) Continuous monitoring of chlorine leak detection equipment with alarm should be installed in the storage area.
h) The area should be free and remote from elevators, gangways or ventilating system to avoid dangerous concentration of Chlorine during leak.
i) Two portable foam type fire extinguishers should be provided in the premises.
j) Corrosive substances shall not be stored nearby which react violently with each other.
k) Unauthorized person should not be allowed to enter into the storage area.
l) The floor level of storage shed should be preferably 30 cms (at least one foot) higher from the ground level to avoid water logging.
m) Ensure that all containers are properly fitted with safety caps or hooks.

7.4.2. TONNERS

1) Tonners should be stored on their sides on rails, a few inches above the floor. They should not be stacked one upon the other. They should be stored such that the valves are in vertical plane.
2) Keep enough space between containers so as to have accessibility in case of emergency.
3) Store the containers in a covered shed only. Keep them away from any source of heat as excessive heat may increase the pressure in container which will result into burst.
4) Do not store explosives, acids, turpentine, ether, anhydrous ammonia, finely divided metals or other flammable material in the vicinity of Chlorine.
5) Do not store containers in wet and muddy areas.
6) Store filled and empty containers separately.
7) Protective covers for valves are secured even when the containers are empty, except during use in the system.
8) Never use containers as a roller to move other equipment.
9) Never tamper with fusible plugs of tonners.
10) Check leakages every day by means of ammonia torch. However, it should not be touched to brass components like valves of container for safety.
11) Never carry out any welding work on the chlorine system as combustion of steel takes place at 2510C in presence of chlorine.
12) The boxes containing emergency kit, safety applications and self contained breathing apparatus should be kept in working order in an easily approachable area.

7.4.3. USE OF DRUM CONTAINERS IN PROCESS SYSTEM

1) Use containers in the order of their receipt, as valve packing can get hardened during prolonged storage and cause gas leaks.
2) Do not use oil or lubricant on any valve of the containers.
3) Badly fitting connections should not be forced and correct tool should always be used for opening and closing valves. They should never be hammered.
4) The area should be well ventilated with frequent air changes.

5) Transport the cylinders to the process area by using crane, hoist or railings etc.
6) The tonners should be kept in a horizontal position in such a way that the valves are in a vertical plane. The upper valve gives out gas and the lower one gives out liquid chlorine.
7) Connect the containers to the system by using approved accessories.
8) Use copper flexible tube, with lead washer containing 2 to 4% antimony or bonded asbestos or teflon washer. Use yoke clamp for connecting chlorine container.
9) Never use rubber tubes, PVC tubes etc. for making connections.
10) Use the right spanner for operating the valve. Always keep the spanner on the valve spindle. Never use ill fitting spanner.
11) After making the flexible connection, check for the leakage by means of ammonia torch but it should not come in contact with a valve.
12) Keep minimum distance between the container valve and header valve so that during change-over of the container, minimum amount of gas leaks.
13) The material of construction of the adopter should be same as that of valve outlet threads.
14) The valve should not be used as a regulator for controlling the chlorine. During regulation due to high velocity of Chlorine, the valve gets damaged which in turn can cause difficulty in closing.
15) The tools and other equipment used for operating the container should be clean and free of grease, dust or grit.
16) Wear breathing apparatus while making the change-over of the container from the process header.
17) Do not heat the container to withdraw more gas at faster rate.
18) Use pressure gauge and flow measuring device to control the flow and to know the quantity of gas left in the container.
19) Use an inverted U type barometric leg or vacuum breaking arrangement for connecting the container to the process piping.
20) Withdrawal of the gas should be stopped when the gas pressure inside the container is between 0.1 to 0.5 kg/cm2 approximately.

21) If withdrawal of the gas from the container connected to the process system has to be suspended for long intervals, it should be disconnected from the system, and the valve cap and hood replaced.
22) Gas containers should be handled by trained persons only.

7.4.4. DISCONNECTING CONTAINERS FROM PROCESS SYSTEM

1) Use breathing apparatus before disconnecting the container.
2) First close the container valve fully. After removal of chlorine the process valve should be closed.
3) Remove the flexible connection, plug the flexible connection in order to avoid entry of humid air. Replace the valve cap or hood on the container.
4) Put the tag on the empty container & bring it to storage area marked for empties.
5) Check for the leakage.

7.4.5. LOADING AND UNLOADING OF CONTAINERS

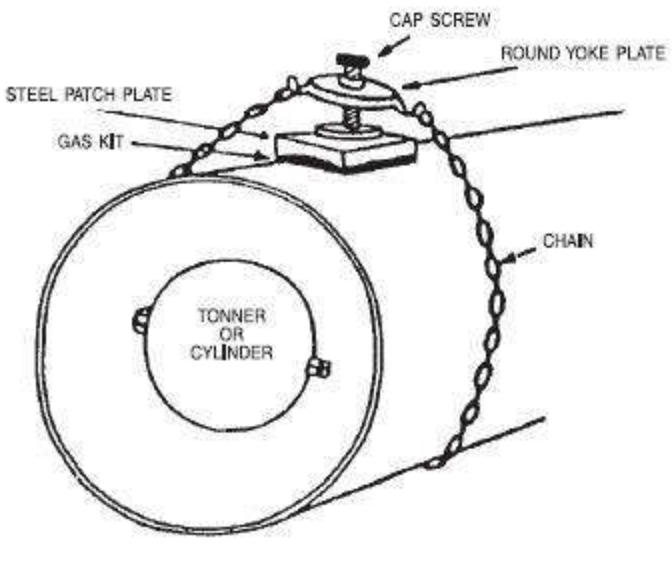
1) The handling of containers should be done under the supervision of trained and competent person.
2) It should be done carefully with a crane, hoist or slanted ramp. Do not use magnet or sharp object for lifting the containers.
3) The containers should not be allowed to strike against each other or against any hard object.
4) Vehicles should be braked and isolated against any movement.
5) After loading, the containers should be secured properly with the help of wooden wedges, rope or sling wire so that they do not roll away.
6) The containers should never be dropped directly to the ground or on the tyre from the vehicle.
7) There should be no sharp projection in the vehicle.
8) Containers must have valve caps and plugs fitted properly.
9) Check containers for leakage before loading/unloading.

7.4.6. EMERGENCY KIT

It consists of various tools and appliances like gaskets, yokes, studs, tie rods hoods, clamps, spanners, mild steel channels, screws, pins, wooden pegs etc. of standard sizes. All the gadgets are designed for using in controlling or stopping the leakages from valves, fusible plug and side walls of containers used for handling chlorine.

1) Leakage may occur through the valve. There are basically four types of valve leaks.
   i) Valve packing
   ii) Valve seat
   iii) Defective inlet thread
   iv) Broken valve thread

   For controlling the leak please refer Fig. III.



III. *Use of chain and round yoke plate for tonner cylinder wall leak*

2) Leakage may occur through container wall. For controlling such leakages, clamps are used for cylinders and chain and yoke arrangement is used for tonner. Sometimes wooden peg is used by driving into the leaking hole as a temporary arrangement.
   For controlling leak please refer Fig. III.

3) Leakage may occur through fusible plug.
   i) If the leakage is through the threads of fusible plug, yoke, hood and cap nut arrangement is used to control the leak.
   ii) If fusible metal itself in the plug is leaking, yoke and stud arrangement is used to control the leak.

7.5. HEALTH HAZARDS

Wet chlorine being corrosive, it forms corrosive acid with body moisture. Inhalation can cause respiratory injury ranging from irritation to death depending upon its concentration and duration of inhalation.

7.5.1. ACUTE EXPOSURE

The first symptom of exposure to chlorine is irritation to the mucous membranes of eyes, nose and throat. This increases to smarting and burning pain. Irritation spreads to chest. A reflex cough develops which may be intense and often associated with pain behind the breast-bone. The cough may lead to vomiting. Cellular damage may occur with excretion of fluid in the alveoli. This may prove fatal if adequate treatment is not given immediately. Vomit frequently contains blood due to lesions of the mucous membrane caused by the gas. Other common symptoms include headache, retrosternal burning, nausea, painful breathing, sweating, eyes, nose, throat irritation, coughing, vomiting, increase in respiration and pulse rate. Massive inhalation of chlorine produces pulmonary oedema, fall of blood pressure and in a few minutes, cardiac arrest.

7.5.2. CHRONIC EXPOSURES

Persons rapidly lose their ability to detect the odour of chlorine in small concentrations. On account of this, the concentrations beyond threshold limit value may exceed without notice. Prolonged exposure to concentrations of 5 ppm results in disease of bronchitis and predisposition to tuberculosis and concentration of 0.8- 1.0 ppm can cause moderate but permanent reduction in pulmonary function.

Person exposed for long period of time to low concentrations of chlorine may suffer from acne, tooth enamel damage may also occur.

7.6. FIRST AID - TRAINED PERSONNEL AND EQUIPMENT

In the plant trained first aider having the knowledge in the use of aid equipment and rendering artificial respiration should be available. First aid box with necessary contents should be available. Properly designed showers and eye fountains should be provided in convenient locations and they should be properly maintained. If oxygen is available the same should be administered by authorized person. Such training is imparted by civil defence.

7.6.1. GENERAL

Remove the affected person immediately to an uncontaminated area. Remove contaminated clothing and wash contaminated parts of the body with soap and plenty of water. Lay down the affected person in cardiac position and keep him warm. Call a physician for medical assistance at the earliest.

Caution: Never attempt to neutralize chlorine with other chemicals.

7.6.2. SKIN CONTACT

Remove the contaminated clothes, wash the affected skin with large quantity of water.

Caution: No ointment should be applied unless prescribed by the physician.

7.6.3. EYE CONTACT

If eyes get affected with liquid chlorine or high concentration of chlorine gas, they must be flushed immediately with running water for at least 15 minutes keeping the eyelids open by hand.

Caution: No ointment should be used unless prescribed by an eye specialist.

7.6.4. INHALATION

If the victim is conscious, take him to a quiet place and lay him down on his back, with head and back elevated (cardiac position). Loosen his clothes and keep him warm using blankets. Give him tea, coffee, milk, peppermint etc. for making good effect on breathing system. If the victim is unconscious, but breathing, lay him down in the position mentioned above and give oxygen at low pressure until the arrival of doctor. If breathing has stopped, quickly stretch him out on the ground or a blanket if available, loosen his collar and belt and start artificial respiration without delay. Neilson arm lift back pressure method is useful. Automatic artificial respiration is preferable if available. Continue the respiration until the arrival of the doctor. Amboo bag can also be used for this purpose.

7.7. FIRE & EXPLOSION HAZARDS

Chlorine may react to cause fires or explosions upon contact with turpentine, ether, ammonia gas, hydrocarbons, hydrogen, powdered metals, sawdust and phosphorus.

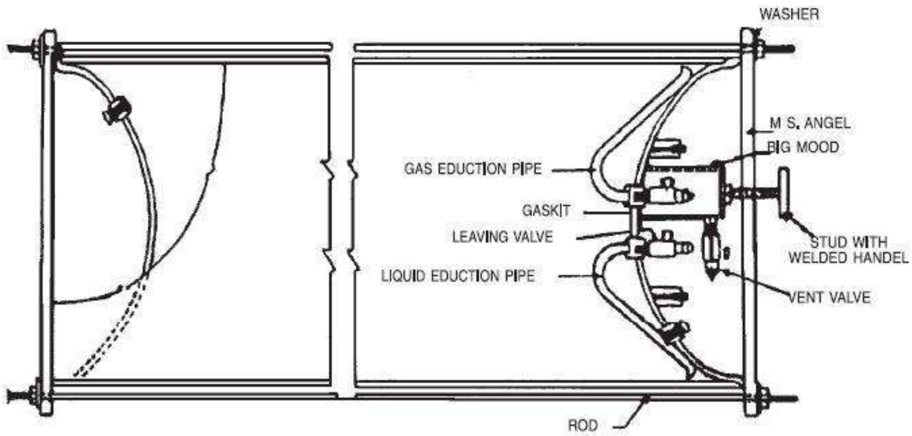
Due to fire in the vicinity, the temperature of the containers rises excessively which results in explosion. In order to avoid explosion of the containers, remove all the movable containers from the fire zone immediately by wearing full protective clothing with respiratory protection. In the case of immovable containers, use water for cooling provided there is no leak.

7.8. EMERGENCY MEASURES

In case of leakage or spillage:

1) Take a shallow breath and keep eyes opened to a minimum.
2) Evacuate the area.
3) Investigate the leak with proper gas mask and other appropriate Personal protection.
4) The investigator must be watched by a rescuer to rescue him in emergency.
5) If liquid leak occurs, turn the containers so as to leak only gas.
6) In case of major leakage, all persons including neighbours should be warned.
7) As the escaping gas is carried in the direction of the wind all persons should be moved in a direction opposite to that of the wind. Nose should be covered with wet handkerchief.

8) Under no circumstances should water or other liquid be directed towards leaking containers, because water makes the leak worse due to corrosive effect.
9) The spillage should be controlled for evaporation by spraying chilled water having temperature below 9.4 ºC. With this water crystalline hydrates are formed which will temporarily avoid evaporation. Then try to neutralize the spillage by caustic soda or soda ash or hydrated lime solution carefully.
10) If fluroprotein foam is available, use for preventing the evaporation of liquid chlorine.
11) Use emergency kit for controlling the leak (Fig IV.).
12) On controlling the leakage, use the container in the system or neutralize the contents in alkali solution such as caustic soda or hydrated lime.
13) Caution: Keep the supply of caustic soda or soda ash or hydrated lime available. Donot push the leaking container in the alkali tank. Connect the container to the tank by barometric leg.



IV. *Application of emergency kit*

14) If container commences leak during transport, it should be carried on to its destination or manufacturer or to remote place where it will be less harmful. Keeping the vehicle moving will prevent accumulation of high concentrations.
15) Only specially trained and equipped workers should deal with emergency arising due to major leakage.
16) If major leak takes place, alert the public nearby by sounding the siren.
17) Any minor leakage must be attended immediately or it will become worse.
18) If the leakage is in the process system, stop the valve on the container at once.

7.9. PERSONAL PROTECTIVE EQUIPMENT

7.9.1. BREATHING APPARATUS

Various types of respirators and their suitability are as follows:

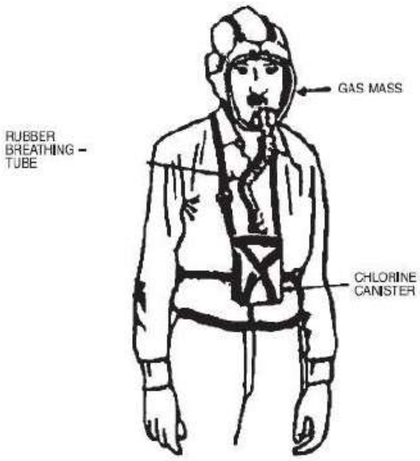
i) Self-contained breathing apparatus

This apparatus is equipped with a cylinder containing compressed oxygen or air which can be strapped on to the body of the user or with a canister which produces oxygen chemically when the reaction is triggered. This type of equipment is suitable for high concentration of chlorine in an oxygen deficient atmosphere (Fig V.).

V. *Self-Contained breathing apparatus*

ii) Industrial Canister Type Mask : Duration: 30 min. for 1% Cl_2

It is suitable for moderate concentration of chlorine provided sufficient oxygen is present. The mask should be used for a relatively short exposure period only. If the actual chlorine concentration exceeds 1% by volume or oxygen is less than 16% by volume, it is not useful. The wearer in such cases must leave the place on detection of chlorine or experiencing dizziness or breathing difficulty.(Fig VI.)



VI. *Use of chlorine canister gas mask*

7.9.2. PROTECTIVE CLOTHING

Rubber, or PVC clothing is useful in massive exposure which otherwise creates mild skin burns due to formation of acid on the body.

7.9.3. MAINTENANCE OF PROTECTIVE EQUIPMENT

1) Clean with alkali after every use.
2) Keep in polythene bag at easily accessible place.
3) Check them periodically about their suitability. Many times the seal ring of face mask gets hardened.

7.10. EMPLOYEES SELECTION

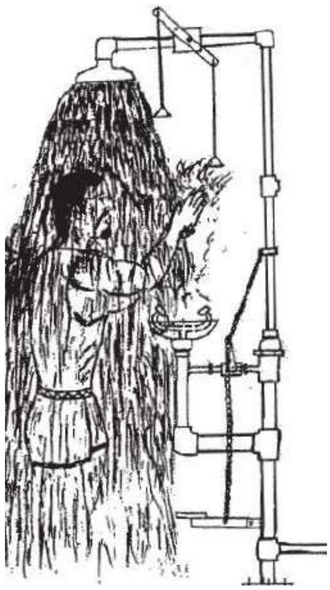
Preplacement medical examination should be carried out of the persons to confirm that they are free from Asthma, Bronchitis and other chronic lung conditions.

Follow up medical examination should be carried out once in a year.

7.11. EMPLOYEES TRAINING

It is essential to impart training to the employees who have to face emergency.
This training should include following:

a) Instructions in the action to be taken in an emergency.
b) Use of emergency kit.
c) Handling of containers.
d) First aid.
e) Use of protective equipment.
f) Knowledge of Chlorine hazards.
g) Fire fighting.
h) Use of safety showers and eye fountains. (Fig. VII).
i) Crash shut down procedure for valves and switches.
j) Communication system.
k) Study of plant layout with diagram.
l) Mock drills.



VII. *Emergency shower and eye wash fountain*

7.12. NEUTRALISATION OF CHLORINE

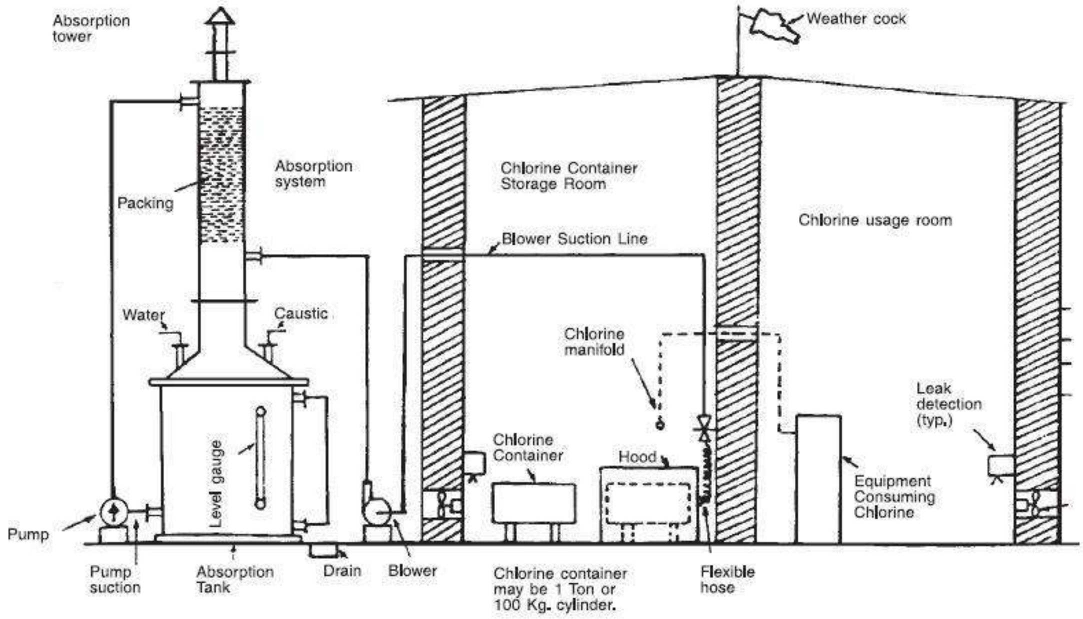
A suitable provision should be available for emergency disposal of chlorine from the leaking container. Chlorine may be absorbed in solution of caustic soda, soda ash and hydrated lime. Caustic soda is recommended as it absorbs chlorine more readily. If hydrated lime is used, the slurry must be continuously agitated and recirculated for chlorine absorption. The neutralization can be carried out by:

- Neutralisation tank holding caustic soda or hydrated lime or sodium carbonate in solution form.
- Scrubber.

7.12.1. SCRUBBER

This system consists of a blower, an alkali (NaOH) tank, an absorption tower packed with rasching rings, alkali circulation pump, piping valves, light weight FRP and PVC duct. In the event of leak which is uncontrollable with emergency kit this system would allow the person to breath easily rather than panic. In this system, the leak is confined in the storage area, sucking the Chlorine by blower and delivering it to absorption tower (Fig. VIII).

Chlorine leak absorption capacity of the system is kept 200 kg./ h for 900 kg. tonner.



VIII. *Typical chlorine leak absorption system*

7.13. EMERGENCY RESPONSE PLANNING

When a large quantity of chlorine or similar toxic or flammable gases are stored it is essential to have an emergency response planning as leakage of such gases may lead to a major accident such as emission, fire or explosion resulting from uncontrolled developments in the course of an industrial activity, leading to serious danger to man, immediate or

delayed, inside or outside the establishment and/or to the environment, and involving one or more dangerous substances. It has, therefore, become obligatory on the part of occupier to take all measures necessary to prevent accidents and to limit their consequences for man and the environment. The hazard control can be achieved by drawing an effective 'onsite emergency plan' for individual organization and if necessary 'offsite emergency plan' by the local authority for that area.

As chlorine is a hazardous chemical, handling and storage of it demand adequate precautions to avoid possible hazards. Leakage of chlorine may develop into a major emergency. Therefore the emergency procedure to cover this eventuality is essential. It is drawn in the form of onsite emergency plan.

The elements of onsite emergency plan are as follows:

7.13.1. IDENTIFICATION OF HAZARD CHART

In this case the site risk is evaluated by the expert and the extent of the probable damage is calculated on the basis of stored chlorine quantity, nearby population, win direction, type of equipment failure etc. For this purpose hazard analysis is conducted in which case all the hazardous properties of chlorine are considered. If evacuation is required, the range of it is calculated.

7.13.2. APPOINTING KEY PERSONS

In order to control the incident like chlorine leakage, it is essential to appoint various persons with their well defined responsibilities. Taking into account the various activities likely to be involved, the following key persons are appointed (i) Site Controller, (ii) Incident controller, (iii) Shift Executive Incharge, (iv) Communication Officer, (v) Safety Officer, (vi) Fire and Security Officer, (vii) Utilities and Services Incharge, (viii) Traffic Controller, (ix) First Aider

7.13.3. ASSEMBLY POINTS

These points are set up where persons from the plant would assemble in case of chlorine leakage. At these points the in-charge for counting the heads will be available.

7.13.4. EMERGENCY CONTROL CENTER

The control centre is the focal point in case of an emergency from where the operations to handle the emergency from are directed and coordinated. It contains site plan, telephone lines, public address system, safety equipment, first aid boxes, loud speaker, torches, list of essential telephone numbers, viz. fire brigade, police, hospital, civil defence, collector, factory inspector, organizational authorities, chlorine suppliers, mutual aid group, social workers, list of key persons and their addresses, copy of chemical fact sheet, location plan of fire hydrant, details of dispersion model of chlorine gas, population distribution pattern, location of alarm system.

7.13.5. PROCEDURE TO MEET EMERGENCY

The actions to be taken by the staff and authority are given below;

Emergency Alarm: An audible emergency alarm system is installed through out the plant. On hearing the alarm the incident controller will activate the public address system to communicate with the staff about the emergency and give specific instructions for evacuations etc. Any one can report the occurrence of chlorine leakage to section in-charge or incident controller through telephone or intercom or in person.

Communication: Communication officer shall establish the communication suitable to that incident.

Services: For quickness and efficient operation of emergency plan the plant is divided into convenient number of zones and clearly marked on the plan. These are emergency services viz. fire fighting, first aid, rescue, alternative source of power supply, communication with local bodies etc. The incident controller will hand over the charge to the site controller of all these coordinating activities, when the site controller appears on the site. The site controller will coordinate all the activities of the key persons. On hearing the emergency alarm system all the key persons will take their charge. Incase of their absence other alternatives are nominated.

The person nominated for personnel and administration purposes will be responsible for informing all statutory authorities, keeping account of all persons in the plant including contract labour, casual workers and visitors. He will be responsible for giving information to press or any outside agencies. He is also responsible for organizing canteen facilities and keeping informed the families of affected persons.

The person nominated as security officer should guide police, fire fighting and control the vehicle entries.

The site controller or any other nominated person will announce resumption of normalcy after everything is brought under control.

The on site emergency plan needs to be evaluated by mock drill. Any weaknesses noticed during such drills should be noted and the plan is modified to eliminate the weaknesses.

STATUTORY REGULATIONS

Applicable Acts and Rules are:

1. The Gas Cylinder Rules 1981.
2. The Factories Act 1948.
3. The Manufacture, Storage and Import of Hazardous – Chemicals Rules, 1989.
4. Public Liability Insurance Act & Rules, 1991.
5. The National Environment Tribunal Act 1995.
6. Chemical Accident Rules 1996.
7. National Environment Appellate Authority Act & Rules 1997.

8. ANNEXES

8.1. ANNEX 1

MATERIALS OF CHLORINE EQUIPMENT & ANCILLARIES

Equipment	Material
Piping Rigid	Seamless carbon steel ASTM A 106 grade 'B' schedule 80 or equivalent BIS- 1030-1974
For gas below atmospheric pressure	Rigid uPVC (for under shed), polyethylene tube, HDPE (outside shed).
Piping (Flexible)	Annealed copper with cadmium plating.
Globe valves	Body : Forged carbon steel Trim : monel or hastelloy 'C' Stuffing box : PTFE or graphite packing.
Ball valves	Body & end piece: Forged carbon steel, ASTM A 105 or equivalent IS Seat : PTFE Ball : Monel
Springs	Tantalum alloy, hastelloy
Gasket	Lead containing 2 to 4% antimony or bonded asbestos.
Chlorinator	Vacuum Regulator body : Carbon Steel Regulator diaphragm : FLUON, FEP, Cabinet: FRP 'O' ring & gaskets : Fluorocarbon lead oxide (litharge cured) viton
Pressure gauge	Diaphragm: silver, tantalum, hastelloy, monel alloy Liquid: fluorocarbon, (silicon oil) fluorolube 'MO'10
Differential Regulator	Body: u PVC, ABS, ebonite, PVDF
Pressure relief valve	Body: uPVC, ABS, ebonite, PVDF Stem: Ag, hastelloy, monel
Injector	Block: ebonite or PVC, ABS
Evaporator	Vessel: boiler quality steel
Rupture disc	Silver: monel, tantalum, hastelloy 'C'
Rotameter	Glass: borosilicate Float: PTFE, tantalum, hastelloy, glass
Filter media	Glass wool
Diffuser & solution line	Rigid uPVC, saran or rubber lined steel, HDPE, natural rubber hose.
Pressure reducing Valve	Body: Ductile cast iron Diaphragm: FPM (Viton), ECTFE/FEP Plugs: silver or tantalum, hastelloy Seats: PTFE
Check valve springs	Tantalloy/hastelloy
Non permanent joints	Mixture of linseed oil and white lead or mixture of linseed oil and graphite or teflon tape
Permanent joints	Glycerine & litharge
Screws	Monel & stainless steel

LIST OF SAFETY SYSTEMS AT CHLORINATION PLANT

1. Breathing apparatus.
2. Emergency kit.
3. Leak detectors.
4. Scrubber system.
5. Siren system.
6. Display of boards in local language for public cautioning, first aid and list of different authorities with phone numbers.
7. Communication system.
8. Tagging system for equipments.
9. First aid including tablets and cough mixtures.
10. Exhaust fans.
11. Testing of pressure vessels, chlorine lines etc. every year as per factory act.
12. Training & mock drill.
13. Safety showers.
14. Eye fountain.
15. Personal protective equipments.
16. Protecting hoods for ton-containers.
17. Fire extinguishers.
18. Wind cock.

TROUBLE SHOOTING CHART FOR VACUUM TYPE CHLORINATOR

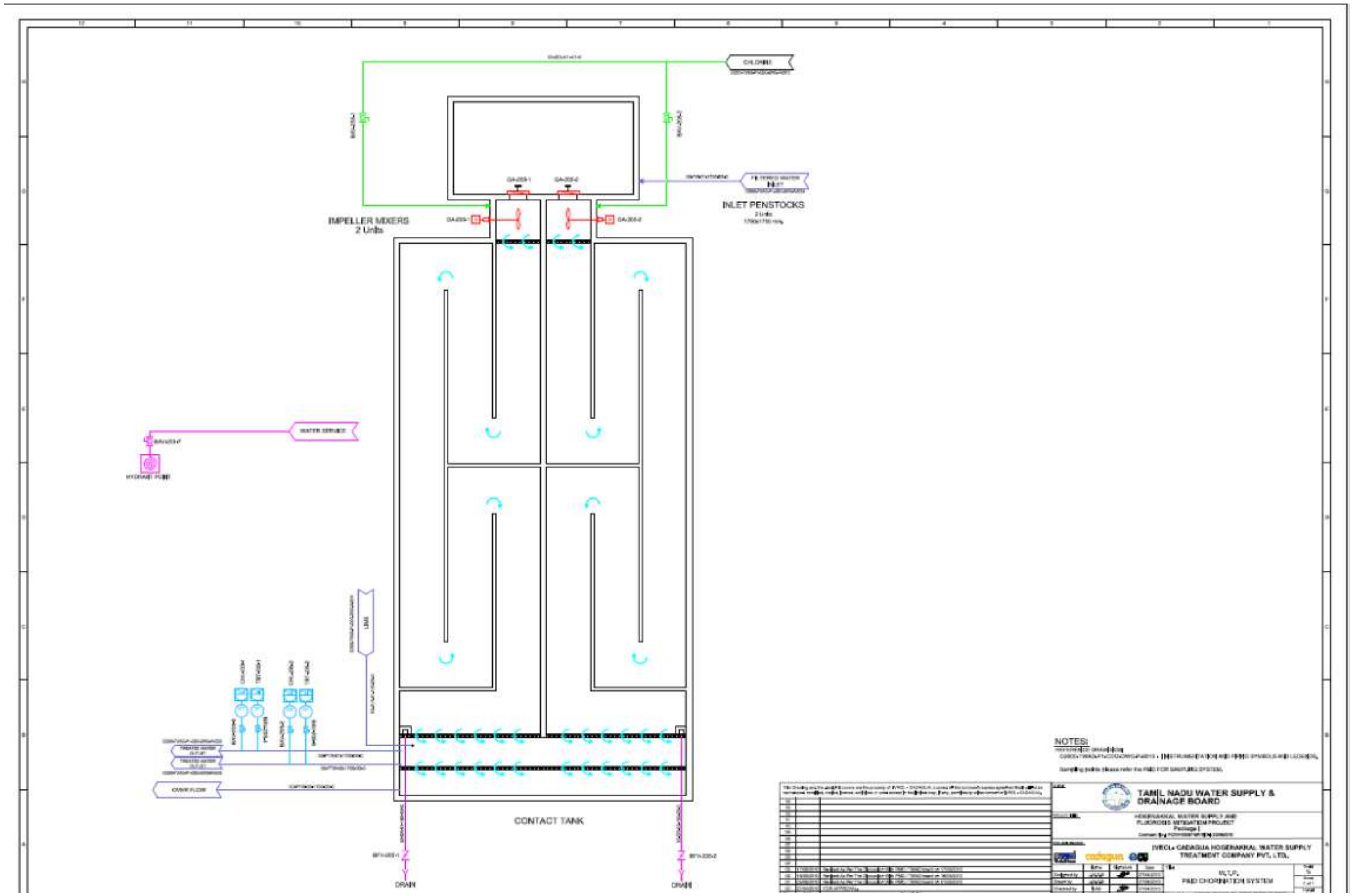
TROUBLE	CAUSE	REMEDY
1. Required gas flow not achieved at start-up.	a. Insufficient ejector vacuum caused by insufficient water supply by pressure or excessive back pressure. b. Leakage at vacuum line connection at outlet from flowmeter, rate control valve, differential from flowmeter, differential pressure regulator, and/or inlet to ejector. c. Vacuum line(s) if flexible, crimped.	a. Refer to Trouble at S.no.6. b. Inspect each connection and remake if necessary. c. Replace vacuum tubing and arrange line(s) to eliminate crimping.
2. Required gas flow rate is not achieved on start-up following an extended period of shutdown.	a. Insufficient ejector vacuum. b. Leakage at vacuum line connection at outlet of flowmeter, rate control valve, differential pressure regulator, or inlet to ejector. c. Vacuum line(s), if flexible, crimped. d. Leakage around flowmeter gaskets.	a. Refer to Trouble at S.no.6. b. Inspect each connection and remake if necessary. c. Replace vacuum tubing and arrange line(s) to eliminate crimping. d. Inspect and align flowmeter or replace gaskets.
3. Flowmeter float observed bouncing and/or maximum gas flow cannot be achieved during normal operation.	a. Gas inlet filter of vacuum regulator dirty. b. Rate valve dirty. c. Flowmeter dirty. d. Ejector water supply pressure fluctuating too wide (float bounce) or insufficient ejector vacuum.	a. Replace gas inlet filter assembly. b. Clean rate valve. c. Clean flowmeter. d. Correct water supply pressure as necessary.
4. Flowmeter fails to indicate gas flow during normal operation but there is no out-of-gas indication.	a. Rate valve plugged. b. Gas flowmeter plugged. c. Vacuum lines, if flexible, crimped.	a. Clean rate valve. b. Clean gas flowmeter. c. Replace vacuum tubing and re-arrange lines to eliminate crimping.
5. No gas indication during normal operation.	a. Gas supply valve(s) closed. b. Gas supply exhausted. c. Clogging of filter in vacuum regulator.	a. Open gas supply valves. b. Replenish gas supply. c. Replace filter.
6. Insufficient ejector vacuum.	a. Y-strainer in water supply line is dirty reducing available supply pressure. b. Back pressure is greater than value listed for one of the following reasons; i) solution valve, if present, not fully open ii) solution line, if present, partially blocked. iii) back pressure at point of application has increased above its original value. c. Ejector nozzle and/or throat dirty.	a. Clean Y-strainer. b. Open solution valve, clean solution line. c. Clean nozzle and/or throat.
7. Loss of gas feed.	a. Dirty or plugged ejector nozzle. b. Insufficient water pressure to operate ejector. c. No gas supply.	a. Check for vacuum in ejector. Clean nozzle. b. Provide proper water pressure. c. Replenish gas supply.
8. Flooded feeder.	Dirt lodged on the ejector check valve seat.	Clean or replace seat or o-ring.

(*)In this case the measure of Chlorine flow is with rotameter

STANDARDS RELATED TO CHLORINATORS

1. BS: 1500	-	For tonners.
2. IS: 7681	-	Specification for welded low carbon steel gas cylinders for chlorine gas.
3. IS: 3224	-	Specification for valve fittings for compressed gas cylinders.
4. IS: 4263	-	Code of practice for chlorine.
5. IS: 10553	-	Parts I & II: Requirements for chlorination equipment.
6. IS: 5844	-	Recommendations for hydrostatic stretch testing of compressed gas cylinders.
7. IS: 4379	-	Identification of contents of industrial gas cylinders.
8. IS: 646	-	Specification for liquid chlorine.
9. IS: 8198 Part 6	-	Code of practice for steel cylinders for liquified chlorine gas.
10. IS: 5845	-	Code of practice for visual inspection of low pressure welded steel gas cylinders in use.
11. IS: 8868	-	Periodical inspection interval of gas cylinders in use.
12. IS: 9200	-	Methods of disposal of unserviceable compressed gas cylinders.
13. IS: 5903	-	Recommendation for safety devices for gas cylinders.
14. IS: 3710	-	Filling ratios for low pressure liquifiable gases contained in cylinders.

8.2. ANNEX 2


IMPELLER MIXERS
2 Units
INLET PENSTOCKS
CONTACT TANK
DRAIN
DRAIN
NOTES:
TAMIL NADU WATER SUPPLY &
DRAINAGE BOARD

SLUDGE GRAVITY THICKENING PROCESS DESCRIPTION

INDEX

EDITION Nr	**1.1**	
Date:	**2012-11-19**	
PREPARED	Position	PROCESS ENGINEER
	NAME	JULIÁN SANCHEZ-MORENO MARTIN RAFAEL M. LLORET SALINAS
REVIEWED	Position	HEAD OF COMISSIONING DEPARTMENT
	NAME	ESTEBAN APELLANIZ DIAZ DE MENDIVIL
APPROVED	Position	HEAD OF COMISSIONING DEPARTMENT
	NAME	ESTEBAN APELLANIZ DIAZ DE MENDIVIL

PREVIOUS EDITIONS	
Number	**Date**
1.0	2012-05-25

1. OBJECTIVE

The purpose of this Operational Procedure is to give a general description of sludge gravity thickening, as well as basic operation principle of sludge gravity thickener.

2. SCOPE

This procedure applies to all water treatment plants on which sludge gravity thickener have been installed as part of the treatment.

3. REFERENCES

¾ "TWORT'S WATER SUPPLY". Michael Johnson; Don D. Ratnayaka & Malcolm J. Brandt.
¾ "MANUAL ON OPERATION AND MAINTENANCE OF WATER SUPPLY SYSTEMS". Central Public Health and Environmental Engineering Organisation. Ministry of Urban Development New Delhi.

4. DEFINITIONS

Total suspended solids	Total suspended solids is defined as the residue retained in a fiber glass filter with a pore diameter of 1,2 μm, dried at 105ºC after filtering a given volume of sample.
Sludge blanket	Layer of settled suspended solids and colloidal matter. In the clarification process the sludge blanket is located underneath the clarified water level

5. RESPONSIBILITIES

All personnel involved in the exploitation of sludge gravity thickener with no previous experience in this type of process should properly read and understand this document.

6. PROCEDURE

6.1. INTRODUCTION

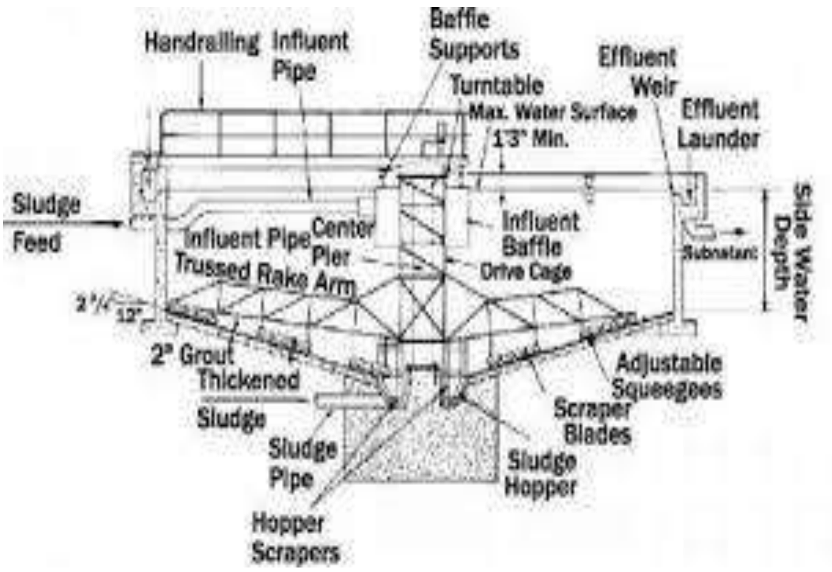
Sludge thickening is the operation focused on sludge volume reduction by increasing solids concentration when free draining liquid is partially eliminated.

The importance of sludge thickening lies on improvement subsequent treatment process both technically and economically. Increasing solids concentration leads to reduce the volume of residuals, improves operation, and reduces cost for subsequent storage, processing, transfer, end use or disposal.

There are several methods for sludge thickening, including dissolved air flotation, centrifugal thickening, gravity belt thickening and gravity thickening. Gravity thickening uses the natural tendency of higher-density to settle out of a liquid to concentrate the solids.

6.2. SLUDGE GRAVITY THICKENER: SYSTEM AND PROCESS DESCRIPTION

A schematic figure of a sludge gravity thickener is shown below:



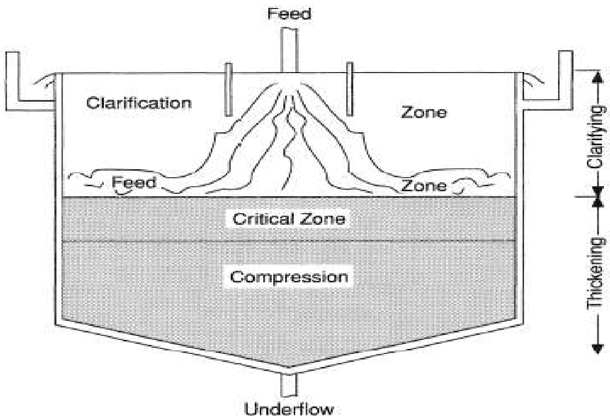
Sludge gravity thickener consists of circular tank, conic bottom, which is fitted with collectors or scrappers at the bottom. Sludge enters to the tank through the inlet pipe and is discharged into the influent baffle which releases the solids at low velocity near the surface of the tank. The solids settle to the bottom of the tank by gravity, and the scraper slowly move the settled, thickened solids to a discharge pipe located at the central point of the tank bottom. Besides the scraper blades, which push and collects the thickened sludge, the scraper is provided of thin vertical bars which significantly improve sludge thickening by homogenizing the sludge and releasing gas or air trapped inside the sludge blanket.

In the picture below central cone, scraper blades and vertical bars can be seen:

Clear water or supernatant leaves the tank through the overflow weir located at the periphery of the tank. In addition, many systems incorporate a skimmer to collect and remove floating solids out of the tank. The system is also equipped with a bridge for routine inspection. Scraper is central driven by an electrical motor.

Clarified water is discharged into the drainage system of the plant while thickened sludge is discharged by gravity to the drying beds.

The solids concentration and thickening that occurs in the tank is achieved through three different settling processes, which include gravity settling, hindered settling and compacting settling. Gravity settling occurs when solid particles travel downward due to their weight. Settlement continues as solids begin to concentrate near the bottom of the tank, but the settlement rate decreases as solids concentration increase. This is known as "hindered settling". Compacting settling occurs when bottom solids are further concentrated due to the pressure of solids on top them. The figure below shows the different layers-zone of a gravity thickener:



6.3. PROCESS CONTROL

Feeding to gravity thickener should be done continuously or if that is not possible, feeding intervals should be as continuous as possible. A good feeding pattern will lead to obtain a stable sludge blanket without sludge gasification which may produce floating sludge, thus, a poorer thickening process.

The operator can optimize thickening by monitoring the quality of the supernant and the solids concentration of the thickened sludge, while also tracking feed rate, pumping time and rates, and solids blanket depth, and inspecting the tank surface for potential problems, including gas bubbles and odors. Gas bubbles cling to solids particles increases solids' buoyancy reducing their settling. Odors may be the result of septic conditions, which may also lead to formation of gas bubbles. The operator should also check for turbulence in the tank. Turbulence can cause the solids either to miss the weir, or to become unsettled. Under proper conditions, solids recovery ratio in the thickened sludge shall be around 95%.

As a guideline, following tracking of the unit shall be done:

- Sample the feed solids and the thickened sludge solids once per day
- Sample the supernant and analyze for total solids
- Record feed flow to the gravity thickener and volume of removed solids per day
- Measure the temperature in the thickener once per shift
- Record the depth of solids blanket

6.4. DRYING BEDS

Reusable type sludge drying beds has been provided to accept sludge from gravity thickeners of concentration up to 15 g/l (1.5%) and dewater it to a concentration greater than 150 g/l (15%). There are 8 drying beds, each one is 40x20 meters (length x wide). The bottom of drying beds is constructed with a slope falling into the central longitudinal axis. Along this axis a drainage pipe has been installed in order to collect drained liquid from the sludge. In order to obtain a good drainage, bottom is comprised of a layer of coarse gravel, fine gravel and sand (from bottom to top).

Sludge from gravity thickeners flows by gravity and it is distributed to the drying beds by the distribution channel. Each drying bed has its own isolation penstock through which sludge is fed into it.

Dewatering mechanism is quite simple. It is based on drainage and evaporation of free draining liquid of the thickened sludge. Drained liquid is sent to the drainage network of the plant.

Required drying period is around 8 days. After that period sludge has been dewatered up to a concentration which allows easy transportation by tipper truck. Each drying bed has its own ramp for truck access and dewatered sludge removal. Once a drying bed has been fully emptied after dewatering period, it is ready to receive new fresh thickened sludge.

6.5. SAFETY CONSIDERATIONS

- Electrical Equipment ☜ Avoid electric shock.
  - ✓ Avoid grounding yourself in water or on pipes.
  - ✓ Ground all electric tools.
  - ✓ Use a lock out and tag system for electric equipment or electrically driven mechanical equipment.
  - ✓

(b) Mechanical Equipment

- ✓ Keep protective guards on rotating equipment
- ✓ Do not wear loose clothing around rotating equipment.
- ✓ Keep hands out of valves, pumps and other equipment.
- ✓ Clean up all lubricant and sludge spills.

(b) Open Surface water – filled structures

- ✓ Use safety devices such as hand rails and ladders
- ✓ Close all openings.
- ✓ Know the location of all life preservers.

(c) Valve and Pump Vaults, Sumps

- ✓ Be sure all underground or confined structures are free of hazardous atmosphere (toxic or explosive gases, lack of oxygen).
- ✓ Work only in well ventilated structures.
- ✓ Take proper steps against flooding.

6.6. LOG-DATA SHEET

In the **Annex** are shown two sheets to track the correct operation and performance of the sludge gravity thickeners and drying beds.

7. ANNEX

SLUDGE THICKENING

MONTH:

YEAR:

DAY	FEED SOLIDS			1st THICKENER				1st THICKENER			
				SLUDGE		SUPERNANT	PERFORMANCE	SLUDGE		SUPERNANT	PERFORMANCE
	SS (mg/l)	TS (%)	S30 (ml/l)	SS (mg/l)	TS (%)	SS (mg/l)	(%)	SS (mg/l)	TS (%)	SS (mg/l)	(%)
1											
2											
3											
4											
5											
6											
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DRYING BEDS

DRYING BED 1						DRYING BED 2						DRYING BED 3						DRYING BED 4						DRYING BED 5						DRYING BED 6						DRYING BED 7						DRYING BED 8					
INLET DATE		OUTLET DATE		PERFORM.		INLET DATE		OUTLET DATE		PERFORM.		INLET DATE		OUTLET DATE		PERFORM.		INLET DATE		OUTLET DATE		PERFORM.		INLET DATE		OUTLET DATE		PERFORM.		INLET DATE		OUTLET DATE		PERFORM.		INLET DATE		OUTLET DATE		PERFORM.		INLET DATE		OUTLET DATE		PERFORM.	
DATE	TS(%)	DATE	TS (%	DAYS	%	DATE	TS(%)	DATE	TS (%	DAYS	%	DATE	TS(%)	DATE	TS (%	DAYS	%	DATE	TS(%)	DATE	TS (%	DAYS	%	DATE	TS(%)	DATE	TS (%	DAYS	%	DATE	TS(%)	DATE	TS (%	DAYS	%	DATE	TS(%)	DATE	TS (%	DAYS	%	DATE	TS(%)	DATE	TS (%	DAYS	%

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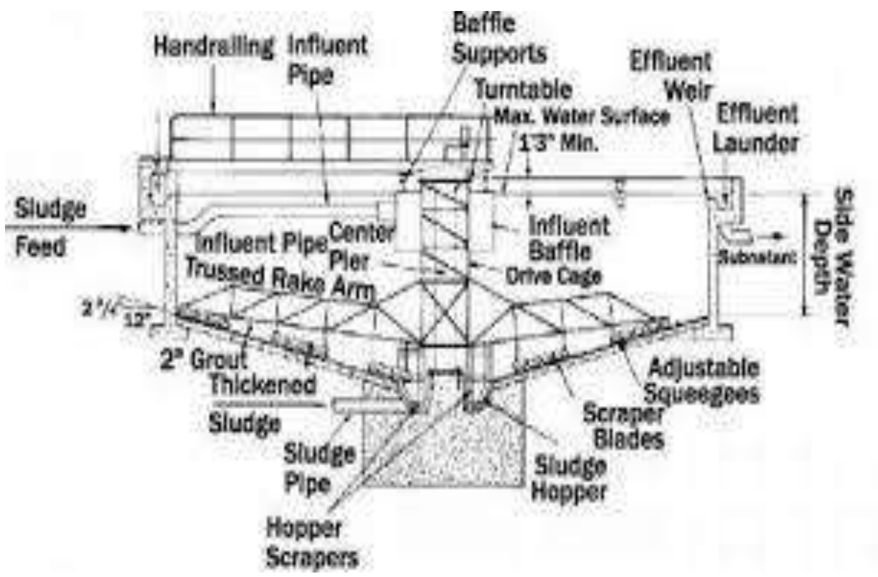

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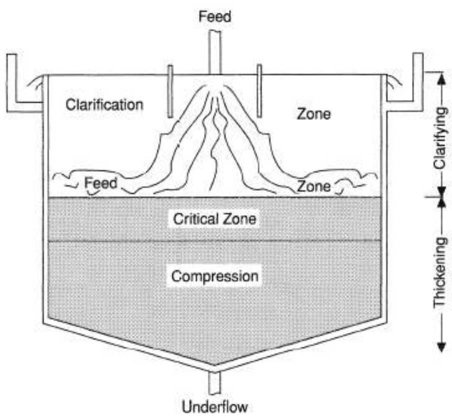

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- ✓ Know the location of all life preservers.

(b) Valve and Pump Vaults, Sumps

- ✓ Be sure all underground or confined structures are free of hazardous atmosphere (toxic or explosive gases, lack of oxygen).
- ✓ Work only in well ventilated structures.
- ✓ Take proper steps against flooding.

6.6. LOG-DATA SHEET

In the **Annex** are shown two sheets to track the correct operation and performance of the sludge gravity thickeners and drying beds.

7. ANNEX

SLUDGE THICKENING

MONTH:

YEAR:

DAY	FEED SOLIDS			1st THICKENER				1st THICKENER			
				SLUDGE		SUPERNANT	PERFORMANCE	SLUDGE		SUPERNANT	PERFORMANCE
	SS (mg/l)	TS (%)	S30 (ml/l)	SS (mg/l)	TS (%)	SS (mg/l)	(%)	SS (mg/l)	TS (%)	SS (mg/l)	(%)
1											
2											
3											
4											
5											
6											
7											
8											
9											
10											
11											
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22											
23											
24											
25											
26											
27											
28											
29											
30											
31											

DRYING BEDS

DRYING BED 1						DRYING BED 2						DRYING BED 3						DRYING BED 4						DRYING BED 5						DRYING BED 6						DRYING BED 7						DRYING BED 8					
INLET DATE		OUTLET DATE		PERFORM.		INLET DATE		OUTLET DATE		PERFORM.		INLET DATE		OUTLET DATE		PERFORM.		INLET DATE		OUTLET DATE		PERFORM.		INLET DATE		OUTLET DATE		PERFORM.		INLET DATE		OUTLET DATE		PERFORM.		INLET DATE		OUTLET DATE		PERFORM.		INLET DATE		OUTLET DATE		PERFORM.	
DATE	TS(%)	DATE	TS (%	DAYS	%	DATE	TS(%)	DATE	TS (%	DAYS	%	DATE	TS(%)	DATE	TS (%	DAYS	%	DATE	TS(%)	DATE	TS (%	DAYS	%	DATE	TS(%)	DATE	TS (%	DAYS	%	DATE	TS(%)	DATE	TS (%	DAYS	%	DATE	TS(%)	DATE	TS (%	DAYS	%	DATE	TS(%)	DATE	TS (%	DAYS	%

HOGENAKKAL WTP COMMISSIONING DESCRIPTION

INDEX

EDITION Nr	**1.0**	
Date:	**2012-05-29**	
PREPARED	Position	PROCESS ENGINEER
	NAME	JULIÁN SANCHEZ-MORENO MARTIN
REVIEWED	Position	HEAD OF COMISSIONING DEPARTMENT
	NAME	ESTEBAN APELLANIZ DIAZ DE MENDIVIL
APPROVED	Position	HEAD OF COMISSIONING DEPARTMENT
	NAME	ESTEBAN APELLANIZ DIAZ DE MENDIVIL

PREVIOUS EDITIONS	
Number	**Date**

1. OBJETIVE

The purpose of this Work Instruction is to describe the Hogenakkal WTP Commissioning procedure, considering every single process which takes part in the treatment: raw water pumping to treatment plant, raw water flow measurement through Parshall flume, aluminium sulphate dosing system, pre-chlorination, flat bottom clarification, sand filtration, post-chlorination, lime dosing, treated water pumping, booster pumping station, sludge balancing tanks, sludge thickeners and sludge drying beds.

2. SCOPE

This work instruction applies to the Hogenakkal WTP, located at Dharmapuri, Tamil Nadu State (India).

3. RESPONSIBILITIES

This procedure shall be observed by all the personnel related to the Hogenakkal WTP commissioning.

4. REFRENCES

5. PROCEDURE

5.1. INTRODUCTION

This document is based solely on the first stage of the process start-up and is subsequently assumed that the erection of all mechanical, electrical and instrumentation equipment has been already checked and approved. Also, all the electrical and I/O communication tests have been successfully done. Every pump, drive and mechanical equipment has been lubricated in accordance to supplier recommendation, every single field instrument has been calibrated following supplier operation manual, all pipes and tanks have successfully passed the pressure test or hydrotest and are clean and free of debris, all disinfection procedures of tanks and pipes have been carried out, fines particles from sand filter have been already removed and filter are ready for influent feeding, etc. In summary, this document will only describe the process start-up as well as the necessary tests to do in order to confirm proper performance of the whole plant.

Finally, it is important to mention that the document is not written as sequence of steps to do in the same order but it needs to be completely read to understand that some equipment which is related to one part of the WTP or even a whole process cannot be start until a downstream equipment or process is in operation.

5.2. RAW WATER PUMPING STATION

Before starting the raw water pumps in auto mode operation it is necessary to fill up the whole pipe and start the anti-hammer system. To do this one vertical pump will be start-up manually. If the pump to start-up is VP-102-1, the procedure is as follows:

1. GA-102-1A and 1B fully open.
2. GAV-102-1 partially open.
3. BFV-102-1 slightly open.
4. Surge Vessels feed valve BVF-106-1 and BFV-106-2 100% open. At least two of them available.
5. BFV-107-1 100% open.
6. BFV-107-2 50% open.
7. Air release valve fully open.

The pump will be now started and with BFV-102-1 putting the same in its operational curve (design characteristics 7.5 bar approx) observing the discharge pressure on PI-102-01. As soon as water exists through the air release valve, the valve will be close.

We will be controlling the surge vessels water level with BFV-107-2 until it remains stable. The compressor shall be now put in service. Surge equipment is now available. After that, GAV-102-1 and BFV-107-2 will be fully opened while the pump is in operation.

It will take from 6 to 8 hours to fill up the pipe from the RWPS to the WTP. During this time it will be observed that measurement of LIT-102-1 is stable and neither abnormal noise nor vibrations are detected on the pump. It will be also check that flow measurement by FIT-107-1 is approximately 1,746 m^3/h which correspond with the optimum operational point of the pump design curve (7.5 bar). After 3 hours of operation, the pump will be stop and proper performance of the surge system will be check.

The pipe will continue to be filled up using a different pump, e.g. VP-102-6. As it was done with the first pump, this pump will be start-up manually from the LCP or CCR. To do this next steps will be followed up:

1. GA-102-3A and 3B fully open.
2. GAV-102-6 partially open.
3. BFV-102-6 slightly open.

The pump will be now start-up and with BFV-102-6 putting the same in its operational curve (7.5 bar approx.) observing the discharge pressure on PI-102-6. After that, GAV-102-6 will be fully open. As it was done with the first pump, it will be observed that measurement of LIT-

102-3 is stable and neither abnormal noises nor vibrations are detected on the pump. Again, it will be check that flow registered by FIT-107-1 is approximately 1,746 m^3/h.

All the inlet penstocks to the flat bottom clarifiers will be closed in order to check proper performance of the over flow located at the parshall flume. While testing the operation of the overflow, it may be also verify appropriate operation of the parshall flume in terms of flow measurement. Since electromagnetic flow meters are more accurate than flow measurement through parshall flume and flow over the entire pipe must be the same, both measurements of FIT-107-1 (electromagnetic) and FIT-201-1 (parshall flume) may be compared. Once this test has been done, VP-102-6 will be stop. Now the raw water pipe from RWPS to WTP is completely full of water.

5.3. ALUMINIUM SULPHATE DOSING SYSTEM

A batch of coagulant should have been prepared prior to pumping raw water into the flat bottom clarifiers in order to create the necessary sludge blanket for the appropriate process performance.

First of all one of the saturator tanks, e.g. DTK-212-1, must be filled up to 70% of its capacity with water. Since the total volume of the tank is 38 m^3, the product is supplied in 20 kg bags and the concentration in this tank must be 700 g/l of solid product, 1,330 bags of aluminium sulphate must be discharge into the saturator tank. Afterwards, operator must filled the tank up to its full capacity by opening again the service water valve until the float valve FV-212-1 will stop water supply. Once the tank is full, one of the recirculation pumps must be start, e.g. CP-212-1. This is done by opening BAV-212-1C, BAV-212-22, BAV212-3A, BAV-212-3B and BAV-212-1A, and then CP-212-1 may be start-up from the LCS pushbutton. Recirculation period must be long enough to allow good solid product-water mixing degree.

Second step is to transfer a portion of the saturated solution to one of the preparation tanks, e.g. DTK-212-2. This is done by opening inlet manual valve to this tank, BAV-212-4A and closing BAV-212-1A. The target is to obtain a solution containing 100 g/l of solid product into the preparation tank. This is achieved by filling one-seventh part of the preparation tank with the saturated solution and then stopping CP-212-1. Preparation tank must be filled up with service water to its full capacity, 19 m^3, and then starting the mixer DA-212-1A from the LCS. While transferring saturated solution first and then filling up the tank with service water, adequate operation of LIT-212-1 must be observed, that means that the level registered by LIT-212-1 smoothly rises as water level increases without sudden jumps on the transmitter measurement.

The solution contained into the preparation tank may be now transferred to the constant head tank, DTK-212-15, by starting one of the constant head tank feed pumps, e.g. CP-212-13. To do that operator must open BAV-212-4D, BAV-212-21, BAV-212-6, BAV-212-7C, BAV-212-7A and BAV-212-9B and then start up the pump from the LCS. While filling up the constant head tank it will be check the appropriate level measurement by LIT-212-3 located at the constant head tank as it was done with LIT-212-1. Once product reaches the overflow level, level registered by LIT-212-3 must remain constant and the product must return to the preparation tank DTK-212-2. Last test will be to check that prepared product reaches the parshall flume at the required flow. This can be done by opening BAV-212-9A, BAV-212-11B and BAV-212-11A. Then with BAV-212-11B regulate the flow through the variable area flow meter FE-212-2. With a graduated cylinder the actual flow may be checked by simply taking a certain volume and measuring the time to obtain that volume. Flow measured by this method must be the same that the flow registered by FE-212-2. This operation can be repeated at three different flows. Once this test has been verified BAV-212-11A can be closed.

5.4. CHLORINE DOSING SYSTEM

Due to the fact that chlorine gas is hazardous to the health first target will be to proper performance of the chlorine plant ventilation: one chlorine gas detector located at the chlorinators room, two chlorine gas detector located at the tonners room, two blowers (1+1) for chlorine gas extraction and two caustic soda recirculation pumps (1+1).

CHECK INJECTOR

Open the Valve on water line. Then water supply is fed to the Injector. Unless the Injector is creating vacuum, the Chlorinator will not work.

STEPS TO BE FOLLOWED

1. Disconnect the vacuum line. Then water supply is fed to the Injector. Unless the injector is creating the vacuum, the Chlorinator will not work.

2. Open the Injector water supply Valve. The Injector should be operating and creating a vacuum. At least 50 to 60 psi water pressure should be supplied to the Injector to create vacuum at zero backpressure. See PERFECT CHLORO SYSTEM recommended water Pressure and Flow rate details.

3. Put the palm of your hand on opening of the suction side of the Injector and feel the vacuum. The vacuum normally created is strong and there should be no doubt that the vacuum exists.

4. If vacuum does not exist, make certain the supply pressure is sufficient and the nozzle or supply line is not clogged.

5. Also make certain that there is no excessive backpressure/ No Airlock and no Choking in Chlorine Solution line [downstream of Injector].

6. Reconnect the vacuum line to check the Chlorinator. Leave the Injector operating. Check chlorinator.

Have liquid ammonia and piece of cloth tied on a glass rod or stick available to check for chlorine leaks.

STEPS TO BE FOLLOWED

1. With the Injector operating and chlorine supply Valve closed, the float in the rotameter tube will drop to bottom and remain there. If the float does not drop or bounces up and down, there is air leak either at gasket where the chlorine supply is connected to the chlorine pressure manifold or a loose connection somewhere in the system. Check and correct.

2. Shut-off water line valve.

3. Open chlorine supply valve ¼ turns and close immediately.

4. Wet the cloth in liquid ammonia and hold underneath all the gas connections, manifold valves, flanges connection and inlet pipe to Automatic Vacuum Regulators.

5. Open chlorine valve, leave open and recheck for chlorine leaks.

6. Allow water to injector and adjust rate valve to desired chlorine flow rate. Flow rate (Kgs/hr) is read on the meter scale at the top of the spool type float.

7. Open chlorine valve, leave open and recheck for chlorine leaks.

NOTE

1. The Flow Control Valve should not be used to shut-off the chlorine supplies. This Valve is for adjusting flow rate while the system is in operation.
2. To shutoff chlorine, close the chlorine supply valve.

5.5. FLAT BOTTOM CLARIFICATION

Chlorine dosing system will not be available for operation until filtered water has reached the filtered water channel, where the booster pumps are located. These pumps pump the water through the ejectors creating the necessary vacuum for chlorine dosing to perform pre-chlorination treatment.

Once coagulant dosing system is ready for operation and raw water pumping pipe has been filled up, flat bottom clarification may be start-up. At the beginning only two clarifiers will be fed with raw water. In order to check good flow by gravity of the sludge over the discharge sludge channel, it will be start one clarifier of each side. That means clarifier 1 and 5, or 2 and 6; for example, in such way that both sludge discharge channels will be check. To do this just one raw water pump must be in operation in automatic mode.

To start any raw water pump the water level in the sump must be higher than 20%, the outlet butterfly valve BFV-102-X must be closed and neither failures nor alarms related to the pumps shall be active. Set points to be introduced are:

- SP time to open the butterfly outlet valve after pump start-up: for this SP it will be selected a delay time of 4 seconds.
- SP maximum flow to WTP: to operate with just one pump the maximum flow to WTP SP shall be 1746 m^3/h in order to avoid any of the rest pumps to start. However, this can be avoid by selecting just one pump in remote auto operation.
- SP level at anti-hammer device: this level SP will have been established when filling the pipe operating the pumps in manual pumps.

Once SP's has been selected any of the raw water pumps may be started. First of all inlet penstocks of clarifiers 1 and 5 must be open, GA-202-8 and GA-202-4. Then vertical pump may be start-up. As soon vertical pump starts coagulant dosage shall start. The optimum dosage of aluminium sulphate must be established by performing a jar-test at the on-site laboratory. Nevertheless it will be pointed out an example of how to establish and hypothetical optimum dosage of coagulant:

1. Hypothetical optimum dosage of coagulant: 10 mg/l of pure product<> 10 g/m^3

2. Inlet flow: 1746 m^3/h

3. Coagulant concentration: 100 g/l containing 15.2% (w/w) of Al_2O_3, that means 15.2 g/l of Al_2O_3

4. Required flow of coagulant: 1746 x 10 / 15.2 = 1,149 l/h

5. The variable area flow meter FE-212-1 or FE-212-2 must be set up at a flow of 1,149 l/h

Also, in order to prevent biological growth on the sand filters, shock chlorination treatment shall be carried out. Since the booster pump used for chlorine dosage is located at the filtered water channel, it will not be possible to perform the first pre-chlorination treatment until the sand filtration has been started.

Sludge purge from the clarifiers will not start until the sludge blanket is visible above the flocons. This period may take between few hours to two weeks, depending on the amount of solids of the raw water. If the sludge blanket is produced few hours after the start-up of the process purge valves may be set to open one minute every hour. On the other hand, if due to low solids content in the raw water the sludge blanket needs longer time to produce itself, purge times must be set up accordingly. However, purge periods must not be established based on strict rules and the best way to keep the thickness of the sludge blanket constant and at an adequate level is the visual monitoring of the process.

Sludge from clarifiers flows toward the sludge pumping chamber where two pumps (one on duty and one in stand-by) are installed. SP-201-1 will be set as the duty pump while SP-201-2 will be set as the stand-by one. It must be observed that the pumps starts as soon as high level switch LS-202-2 gets activated and stops as soon as low level LS-202-2 gets activated. Sludge is pumped to the sludge balancing tank. See point 5.11. for sludge balancing tank start-up.

Clarified water flows from the clarified water channel to the sand filters. Clarified water quality is on-line monitored by means of a turbidity meter (TBT-202-1). Appropriate operation of the clarification will be reflected when turbidity is less than 5 NTU, preferably less than 2.5 NTU. Clarified water flow to the sand filters is registered by the flow meter FIT-

202-1. When no sludge is being purged the measurement of this flow meter must be very similar to the flow registered by the parshall flume flow meter, FIT-201-1.

5.6. SAND FILTRATION

Since just one raw water pump is in operation at this very first stage of the WTP commissioning; only three filters will start up in fully auto mode. Nevertheless, as it was done at the inlet parshall flume overflow, prior feeding the filters with clarified water, sand filters overflow will be tested to check its adequate operation.

Once the operation of the sand filters overflow has been successfully tested, clarified water feeding to the filters may start. Filters to start up at the begging will be filter nº 1, 2, and 12. Selector at the ALCD must be in REM position in such way that the filters may be put in service from the CCR/MLCP. Also, all the associated valves to each filter as well as the common services equipment must be in auto mode position: inlet penstocks (GA-203-1, GA-203-2 and GA-203-12), wash water outlet valve (BFV-203-1, BFV-203-2 and BFV-203-12), wash water inlet valve (BFV-203-26, BFV-203-27 and BFV-203-37), air inlet valve (BFV-203-38, BFV-203-39 and BFV-203-49) and filtered water outlet regulation valve (BFV-203-50, BFV-203-51 and BFV-203-61). Regarding the common service equipment, one of the air scouring blowers must be selected as the duty one while the other one as the stand-by one, for example BAV-203-4 may be selected as the duty blower and BAV-203-5 the stand by blower. To carry out the back wash sequence one or both wash water tanks must be filled up with treated water. This is done through any of the pumps CP-206-1 or CP-206-2, so one of the them must be selected as the duty one, e.g. CP-206-1, while the other one must be selected as the stand-by one (CP-206-2). Make sure outlet valves BFV-206-3 and BFV-206-4 are completely open. As only three filters will be in operation at this stage of the commissioning, just one compartment of the wash water tank will be used. The compartment in use shall be specified in the HMI, which means that the high level alarm which will stop CP-206-1 will come from the compartment in use. Wash water supply control valve (BFV-203-65) shall be in remote auto position.

Several set points shall be selected prior to start the filters:

- Water level within the filter: 2.1 m
- Drain down level: 0.10 m
- Delay to open wash water inlet valve: 6 minutes
- Wash water flow: 2,844 m^3/h

- Washing stage period (air+water): 8 minutes
- Rinse and surface flush: 5 minutes

From the CCR/MCLP filters nº 1, 2 and 12 shall be switch to "IN SERVICE" which will lead to the inlet penstocks to open. Once the water reaches 2.1 m within the filters, level control valve BFV-203-X shall start to regulate this level at the set point value. It must be observed that as time goes by and subsequently clogging degree of the filter media increases, level control valve gradually open to counteract the head loss over the filter due to clogging.

Whenever any of the control valves has fully opened, so there is no any further level control possibility, automatic back wash sequence shall start. It is expected that backwash of filters will be required every 24 hours of operation. Backwash sequence is described below:

<u>STAGE 1: DRAIN DOWN</u>

1.1.) Inlet penstock closes

1.2.) Outlet regulation valve stops regulation and maintain position

<u>STAGE 2: RAPID DRAIN DOWN</u>

2.1.) Inlet penstock closes

2.2.) Outlet regulation valve stops regulation and closes

2.3.) Wash water outlet valve opens

<u>STAGE 3: AIR AND WATER BACK WASH</u>

3.1.) Outlet regulation valve closes totally

3.2.) Air blower start

3.3.) Filter air inlet valve opens

3.4.) Wash water outlet valve opens

There is a delay time from when air scouring starts and application of wash water so in the beginning only air is applied for 3 minutes to the filter. After that time, wash water will be applied together with air for 3 more minutes and finally 5 more minutes with water.

3.5.) Filter wash water inlet valve opens

3.6.) Air blower stops

3.7.) Air inlet valve closes

STAGE 4: RINSE AND SURFACE FLUSHING

4.1.) Inlet penstock opens

4.2.) Filter wash water inlet valve closes

4.3.) Inlet penstock closes

STAGE 5: RESET

5.1) Reset time counters

STAGE 6: FILTER RE-START

6.1) Inlet penstock opens

6.2.) Outlet regulation valves starts to control the level

During backwash sequence adequate operation of every device must be checked. There is one common pressure transmitter (PT-203-13) for both air scouring blowers which shall indicate 0.3 bar when any of the two blowers are in operation. On the other hand, wash water control valve (BFV-203-65) shall regulate the flow in such way that the flow registered by the flow transmitter for wash water (FIT-203-2) must indicate 2,844 m^3/h.

Filtered water is collected into the filtered water channel from where flows toward the contact tank. Filtered water level within the filtered water channel is monitored by level transmitter LIT-203-13. It must be observed adequate operation of this level transmitter. There is also a turbidity meter for the filtrated water (TbT-203-1). Proper operation of the sand filters will be reflected when turbidity measurement by TbT-203-1 is ≤ 1.0 NTU.

From filtered water channel, both booster pumps for pre and post-chlorination will pump the water through the injectors. As soon as the water level is high enough, pump for pre-chlorination (CP-203-1) shall start in order to perform the first pre-chlorination shock.

5.7. WASH WATER RECOVERY TANK

Wash water from filters backwash is collected into the wash water recovery tank, which is divided in two independent compartments. The volume of each compartment has been designed to store the wash water volume from two consecutive backwashes. Based on this fact, startup of the wash water recovery tank will be done as soon as two back wash have been done.

First of all, inlet penstock to the wash water recovery tank must be open, e.g. GA-208-1. While the tank is getting filled up it must be observed proper operation of the level transmitter associated to that tank (LIT-208-1). Once the tank has been filled up, the adequate sequence to proceed is as follows:

1. Close inlet penstock GA-208-1.

2. Allow a settling period of 3 hours. After settling period clear water must be seen on the top of the tank while settled sludge, invisible, must be on the bottom.

3. Open BFV-208-1 and BFV-208-3 and start the pump CP-208-3.

4. It will be observed that the floating draw off arm works properly. As the water level drops the floating draw off arm shall drop following the water level. It will take almost three hours for the complete withdrawal of the supernatant. Once the sludge starts to be visible CP-208-3 shall be stop.

5. To pump the sludge to the sludge balancing tank the pump CP-208-1 must be start. To do that, valves BFV-208-4 and KV-208-1 must be open. Once the valves are open the pump may be start. It will be checked that the sludge is completely drained toward the sludge pump due to the slope of the tank bottom. It will take around 1.5 hours for the complete desludge of the tank. The pump CP-208-1 will stop as soon as low level switch LS-208-1 is activated.

5.8. CONTACT TANK

Filtered water flows toward the contact tank where disinfection takes place. Only one compartment of the contact time will be used at this first stage of the WTP start-up. This will be done by opening the inlet penstock of one of the two compartments, e.g. GA-205-01, so the water gets into the mixing chamber where an impeller mixer ensures good mixing between water and chlorine. As soon as water level within the mixing chamber is above the propeller, mixer can be started as well as post chlorination treatment.

Post chlorination requires starting any of the two pumps, CP-203-2 or CP-203-3. One of them will be the duty pump while the other one will be the stand-by one. Chlorine dosing rate is manually set-up through the flow control valve located at the chlorinator in such way that the free chlorine residual concentration registered by CHL-205-1 or CHL-205-2 must be 0.5 mg/l.

Treated water quality is on-line registered by the turbidity meter TbT-205-1 and TbT-205-2. Turbidity registered by any of these two analyzers must be ≤ 1.0 NTU.

Prior starting to dose saturated lime solution into the treated water stream it will be check appropriate operation of the treated water overflow. Once this has been check for about 10 minutes, lime dosing may start.

5.9. LIME DOSING SYSTEM

As soon as treated water leaves the contact tank through the overflow weir a saturated solution of lime shall be dosed into the treated water stream in order to correct the pH, which has drop due to chlorine dosage. The dosage rate of saturated lime will be established by pH measurement by the analyzer PHT-207-1 in such way that the pH of the treated water measured by this analyzer must be in the range between 7.0 and 8.5.

For the reason explained above the lime saturated solution must have been prepared before the treated water reaches the outlet chamber of the contact tank.

The procedure to prepare the lime solution is explained here below:

1. Operator selects the slurry preparation tank on duty through the LCP.

2. The slurry preparation tank on duty must be partially filled up with service water.

3. The mixer of the selected tank must be start up from the LCP or MCC, e.g. DA-213-1A.

4. Since the product concentration in the slurry preparation tank shall be 50 g/l, the useful capacity of the tank is 31 m^3, the lime is supplied in bags of 50 kg (92 %(w/w)), the total amount of bags to unload into the tank may be calculated as follows:

$$(31 \times 50)/(50/0.92) \cong 34 \text{ bags}$$

5. The tank must be filled up to its total capacity with service water. The level of the slurry within the tank will be check by the level transmitter LIT-213-1A

6. Operator must select the slurry transfer pump on duty (e.g. CP-213-1A) to pump the slurry toward the saturator. To do that, first the valves BAV-213-2A (bottom valve

of the preparation tank), BAV-213-5A (inlet valve to the pump), BAV-213-6A (outlet valve of the pump), BAV-213-17 (inlet valve to one saturator) will be open.

7. The pump CP-213-1A will be now started up from the LCP. While pumping the slurry into the saturator it will be observed that the flow switch FS-213-1A gets activated. The flow meter FIT-213-1 shall measure the nominal flow of the pump (20 m3/h)

8. While the slurry is being transferred to the saturator it will be also added the service water in such way that the saturated solution is being produced since the begging. Once the saturated solution reaches the overflow weir and subsequently overflows toward the saturated water tank, conductivity of the solution will be measured by CL-213-2. Once the conductivity drops under a certain value it will be necessary to use the other saturator to produce the saturated solution.

9. Pump CP-213-2A will be set as the duty pump for saturated lime dosage while CP-213-2B will be set as the stand-by pump. Valves BFV-213-1A and BFV-213-2A will be open. Dosing rate of saturated lime into the treated water stream will be set up by

means of a variable area flow meter, FE-213-1 or FE-213-2. If FE-213-1 is selected, valves BAV-213-12 and BAV-213-13 will be open. Flow rate will be established by regulating the valve BAV-213-13.

10. As it has been mentioned above, dosing rate must be established by the pH registered by PHT-207-1 in such way the treated water has a pH in the range between 7.0 and 8.5.

As it was done with the coagulant, lime flow will be tested at the dosing point. To do this, three different positions of the variable area flow meter will be checked by comparing the readout given by this flow meter and the flow measured using a graduated cylinder at the dosing point. Once this has been checked, lime dosing system is ready for operation.

5.10. TREATED WATER RESERVOIR AND PUMPING STATION

Treated water reservoir is divided in two independent compartments. It will be first filled up the compartment which is isolated by the penstock GA-206-1. So as treated water overflows from the contact tank toward de TWPS, GA-206-1 and GA-203-3 will be open. Then there are six treated water pumps, one of them will be start up manually to fill up the treated water pipe from TWPS to BPS. It will be use the pump VP-207-1 to do this operation. Subsequently the procedure is as follows:

1. GA-207-1 fully open
2. GAV-207-1 partially open
3. BFV-207-1 slightly open
4. Surge vessel feed valve BFV-215-1 fully open.
5. BFV-207-7 fully open
6. BFV-207-8 50% open
7. Air release valve fully open

The pump will be now started and with BFV-207-1 putting the same in its operational curve observing the discharge pressure on PI-207-1. As soon as water exists through the air release valve, the valve will be close.

We will be controlling the surge vessels water level with BFV-207-2 until it remains stable. Compressors will be now put in service. Surge equipment is now available. After that, GAV-207-1 and BFV-207-7 will be fully opened while the pump is in operation.

It will take around 1.5 hours to fill up the pipe from the TWPS to the BPS. During this time it will be observed that level in the treated water reservoir measured by LIT-206-1 is stable and does not drops or increases rapidly. It will be also observed that level within the pump well 1 measured by LIT-207-1 does not drop below 20%, which may be unsafe for the correct pump operation. The flow registered by FIT-207-1 shall be approximately equal to 1,726 m^3/h which is the nominal flow of the pump. It is important to check that neither abnormal noise nor vibrations are detected on the pump.

While doing these operations, elevated water tanks, which are located at the TWPS, shall be put in service in order to have availability of water for filter backwashing. To do that BFV-203-62A will be open. This is the isolation valve of one of the two compartments of the elevated water tank. The pump CP-206-1 will start which will be the duty one while the pump CP-206-2 will be the stand-by one. The pump on duty will start automatically until the high level switch LS-203-3 gets activated. As successive backwashes are done, water level within the elevated water tanks will decrease. CP-206-1 will start again whenever low level switch LS-203-3 gets activated.

As soon as water reaches the BPS, proper operation of the surge vessel will be tested. To do that the pump VP-207-1 will be stop and the water hammer must be cushioned by the surge equipment. Once the surge equipment has been tested a different pump will be started in automatic mode for the BPS start up.

The pump VP-207-6 will be start up in automatic mode operation. Before doing that GA-207-3 and GAV-207-5 will be fully open. It will be check that BFV-207-5 is closed and in remote auto.

Some set points shall be established before starting the pump:

- SP time to open the butterfly outlet valve after pump start-up: for this SP it will be selected a delay time of 4 seconds.

- SP level at anti-hammer device: this level SP will have been established when filling the pipe operating the pumps in manual pumps.

Water level within the pump well 3 must be higher than 20% to allow the pump to start-up. Once all these preliminary steps have been done the pump must be switch into remote auto operation which will lead to the start-up of the pump.

5.11. BOOSTER PUMPING STATION

It will be filled up the compartment which is isolated by the valve BFV-301-9. So as soon as treated water is pumped from TWPS, BFV-301-9 will be open. GA-301-1, GA-301-2 will be also open in order to start up the pump VP-301-1 as soon as the water is at adequate level within the pump well. While the level within the compartment and pump well is increasing it will be checked proper operation of both level transmitters, LIT-301-4 and LIT-301-1.

Valves for start up of VP-301-1 will be set up:

- GAV-301-1 partially open

1. BFV-301-1 slightly open
2. Surge vessel feed valve BFV-303-A and BFV-303-B completely open
3. BFV-304-1 completely open
4. BFV-304-2 slightly open
5. Air release valve completely open

The pump will be now manually start-up and with BFV-301-1 putting the same in its operational curve (14 bar approx.) observing the discharge pressure on PI-301-1. As soon as water exists through the air release valve, the valve will be close.

We will be controlling the surge vessels water level with BFV-304-2 until it remains stable. Compressors will be now put in service. Surge equipment is now available. After that, GAV-301-1 and BFV-304-1 will be fully opened while the pump is in operation.

It will take around 4 hours to fill up the pipe from BPS to MBR. During this time it will be observed that water level measured by LIT-301-4 is stable and does not drops or increases rapidly. It will be also observed that level within the pump well 1 measured by LIT-301-1 does not drop below 20%, which may be unsafe for the correct pump operation. The flow registered by FIT-304-1 shall be approximately equal to 1,726 m^3/h which is the nominal flow of the pump. It is important to check that neither abnormal noise nor vibrations are detected on the pump.

As soon as water reaches the MBR, proper operation of the surge vessel will be tested. To do that the pump VP-301-1 will be stop and the water hammer must be cushioned by the surge equipment. Once the surge equipment has been tested a different pump will be started in automatic mode for the BPS start up.

The pump VP-301-6 will be start up in automatic mode operation. Before doing that GA-301-5 and GAV-301-6 will be fully open. It will be check that BFV-301-6 is closed and in remote auto.

Some set points shall be established before starting the pump:

- SP time to open the butterfly outlet valve after pump start-up: for this SP it will be selected a delay time of 4 seconds.
- SP level at anti-hammer device: this level SP will have been established when filling the pipe operating the pumps in manual pumps.

Water level within the pump well 3 must be higher than 20% to allow the pump to start-up. Once all these preliminary steps have been done the pump must be switch into remote auto operation which will lead to the start-up of the pump.

5.12. SLUDGE BALANCING TANK AND SLUDGE THICKENERS

As it has been mentioned before, sludge from clarifiers and sludge from WWRT is pumped to the sludge balancing tank. There are two sludge balancing tanks and one of them will be set as the duty one. The tank on duty will generate the high level alarm which will stop desludging of clarifiers.

It will be selected the tank on duty which is isolated by the valve KV-210-1. So prior starting the clarification and sand filtration, the sludge treatment elements must be ready for receiving sludge. In that way, KV-210-1 must be open. The associated thickener feed pumps to this tank are CP-210-1 and CP-210-3. CP-210-1 will be selected as the duty one while CP-210-3 will be selected as the stand-by one.

The level transmitter associated to this tank, LIT—210-1 will be set up in order that it will generate different signals at different levels which will start/stop the equipment related to the tank:

- Low-low level, 1.5 m approx. It will be check that when low-low level is reached the mixer SA-201-1 stops.
- Low level, 2.0 m approx. At this level it must be verified that the mixer SA-201-1 starts up and thickener feed pump CP-210-1 stops, so this levels acts as a safety interlock to the thickener feed pump.
- High level, 3.6 m approx. At this level it will be generated an alarm which will interrupt desludging from clarifiers. This situation will be only possible when both sludge balancing tanks are in service. This level will trigger an alarm which will lead to the thickener feed pump to start until this alarm gets deactivated. The pump will keep running for period of time after the alarm has disappeared. This delay period will be a set point of the system.

Thickener feed pumps will run temporized, so there will be a configurable period on which the pump is in operation (in seconds) and a different period on which the pump is off (in minutes). The idea is to feed sludge to the thickener as continuously as possible, so in the begging it will be established a running period of 120 seconds and 10 minutes as off period.

There are two thickeners but at the first stage of the WTP start-up only one of the will be put in service. The selected thickener is the one which is associated to the scrapper driven by the motor D-211-2. In remote auto operation the driven motor will run continuously. It must be also established a purge time period for the thickener. In the beginning it will be established an opening period of 1 minute every 30 minutes for the valve ECV-210-2. The thickened sludge will flow by gravity to the available sludge drying bed.

JAR-TEST PROCEDURE

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1. JAR-TEST PROCEDURE

Jar-Test is a procedure focused on finding out the optimal pH, coagulant dosage and the optimal flocculant type and dosage. This research is carried out using a jar-testing apparatus. This device is comprised of a set of several small mixers (depending on the apparatus type and brand) on which laboratory coagulation/flocculation tests may be performed. Rotation speed can be manually selected.

There is not a fixed protocol to carrying out a jar-test regarding to rotation speed and reaction time, but those parameters must be selected according to the project design parameters.

At the present jar-test, first step will be testing different coagulant dosages at different pH's, and then different flocculant types and dosages will be tested under the optimal pH and coagulant dosage established on the first set of experiments.

Before starting jar-test, raw water must be analyzed. Parameters to analyze are: pH, Tª, conductivity, turbidity, T.S.S., alkalinity and T.O.C.

1.1. pH and coagulant testing

Considered acid for pH correction is sulfuric acid while Ferric chloride as coagulant will be used in all the trials. In this first set of experiments different coagulant concentrations will be tested at different pH values. Considered pH values are: 8.0; 7.8; 7.6; 7.4; 7.2; 7.0. For each one of these pH values nine coagulant concentrations have been considered of interest to test with: 2, 3, 4, 5, 6, 7, 8, 9 and 10 ppm.

Based on this, next table can be built up showing the whole set of test.

		Coagulant Concentrations (ppm)								
		2	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
pH Values	**8.0**	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Test 7	Test 8	Test 9
	7.8	Test 10	Test 11	Test 12	Test 13	Test 14	Test 15	Test 16	Test 17	Test 18
	7.6	Test 19	Test 20	Test 21	Test 22	Test 23	Test 24	Test 25	Test 26	Test 27
	7.4	Test 28	Test 29	Test 30	Test 31	Test 32	Test 33	Test 34	Test 35	Test 36
	7.2	Test 37	Test 38	Test 39	Test 40	Test 41	Test 42	Test 43	Test 44	Test 45
	7.0	Test 46	Test 47	Test 48	Test 49	Test 50	Test 51	Test 52	Test 53	Test 54

Jar-test conditions for coagulation are listed below:

Sample Volume (ml)	400
Mixing speed (rpm)	Maximum
Mixing time (s)	10
Settle time (min)	5

The number of the test to be done at the same time depends on the type of jar-test apparatus.

Experimental sequence is as shown:

1. - Introduce 400 ml of sample in each beaker. Raw water pH has been previously corrected in accordance with the current tests.
2. - Locate each beaker at the jar-test apparatus.
3. - Start mixing at maximum speed.

4.- Add coagulant dosage to each sample as indicated at the table above.
5. - Allow 10 seconds for mixing.
6. - Stop mixing.
7. - Allow 5 minutes for settling.
8. - From each test a qualitative flocs and supernatant description will be done. In this description, aspects such floc size, floc density, floc compactness and supernatant color will be reflected. A couple of pictures from each test will be also very helpful. One picture should be done at the end of coagulation stage (step 5) and the other one at the end of settling stage (step 7).
10. - From each beaker a 50 ml sample shall be taken. Sampling will be done using a syringe from a level of about 1cm below the liquid level. Syringe must be rinse between two different samples. T.S.S. and turbidity will be measure from each sample.

According to analytical results, the optimal pH and coagulant dosage will be obtained.

1.2. Flocculant testing

Four (4) types of flocculants will be tested (minimum). Once the best flocculant has been chosen, trials will be focused on finding out the optimal dosage of the best flocculant.

For the first set of experiments, the same dosage will be used for each type of flocculant. Considered dosages are shown in the table below:

Test number	**1**	**2**	**3**	**4**
Flocculant type	A	B	C	D
Flocculant dosage (mg/l)	1.0	1.0	1.0	1.0

Note: pH and coagulant dosage are determined at the point ***6.11.1***

Jar-test conditions for flocculation are listed below:

Sample Volume (ml)	400
Mixing speed (rpm)	150
Mixing time (min)	5
Settle time (min)	5

Experimental sequence is as shown:

1. - Introduce 400 ml of sample in each beaker. pH has been previously corrected at the optimal value established before.
2. - Locate each beaker at the jar-test apparatus.
3. - Start mixing at maximum speed.
4. - Add optimal coagulant dosage to each sample.
5. - Allow 10 seconds for mixing.
6. - Decrease mixing speed to 150 r.p.m.
7. - Add the flocculant dosage to each beaker.
8. - Allow 5 minutes reaction.
9. - Stop mixing and allow 5 minutes settling.
10. - From each test a qualitative flocs and supernatant description will be done. In this description, aspects such floc size, floc density, floc compactness and supernatant color will be reflected. A couple of pictures from each test will be also very helpful. One picture should be done at the end of flocculation stage (step 8) and the other one at the end of settling stage (step 9).
11. - From each beaker a 50 ml sample will be taken. Sampling will be done using a syringe from a level of about 1cm below the liquid level. Syringe must be rinse between two different samples. T.S.S. and turbidity will be measure from each sample.

According to the analytical results, the best type of flocculant will be obtained.

Once the best type of flocculant has been chosen, the target will be finding out the optimal dosage. Four different dosages will be tested:

Test number	**1**	**2**	**3**	**4**
Flocculant dosage (mg/l)	0.5	1.0	1.5	2.0

Testing conditions and experimental sequence are the same as mentioned above for flocculation test. Analytical results will determine the optimal flocculant dosage.

SAND SIEVE ANALYSIS OF SAND FILTER

1. SAND SIEVE ANALYSIS INTRODUCTION

The sand filter requires a certain range of sand grain sizes to effectively treat drinking water.

In "Sand Media Prep", crushed rock sand grains, when packed together, fit like puzzle pieces.

Their varied sizes and jagged edges produce tiny pores small enough to filter out pathogens found in water.

Please remember that the "sand" in a sand filter:

1. originates as crushed rock,

2. is angular in structure, and

3. has grains of various sizes.

Any sand filter media that does not meet these parameters will not work effectively in a sand filter.

There is an optimum distribution of sand grain sizes that make a sand filter the most effective.

Some sand grains are small and others are larger, and there is a range of sizes that are desirable for making a filter that works best.

It is possible and advisable to conduct a sand sieve analysis of the sand media that is to be used in a sand filter.

This sand sieve analysis, although a bit technical and meticulous, will provide information needed to determine grain size distribution of the sand to be used in a filter and its potential for providing optimum filter effectiveness.

Before studying the information below, it is advisable to print out the sand sieve analysis blank form and the sand sieve analysis example form PDF files below.

This will give you valuable visual information that will be helpful in understanding the sand sieve analysis process.

2. PURPOSES OF A SAND SIEVE ANALYSIS

The information from a sand sieve analysis has various uses.

It can be used to:

1. Determine if the prepared sand (sand that has been initially sieved and washed) that is to be installed in a sand filter is within the Effective Size (ES) and

SAND SIEVE ANALYSIS OF SAND FILTER

Uniformity Coefficient (UC) ranges recommended for the filtration sand in the sand filter.

Prepared Sand – This is sand that has been initially sifted to eliminate the largest rock pieces (grains that will not pass through a #24 sieve) and washed to remove the smallest sand particles that will pass through the #150 sieve.

Effective Size (ES) – This is defined as the size of screen opening that will pass 10% of the sand sample (see more explanation below)

Uniformity Coefficient (UC) – This is defined as a ratio and is calculated as the size opening that will just pass 60% of the sand (d60 value) divided by the size opening that will just pass 10% of the sand sample (d10 value).

ES is basically a value describing the average size of sand grains in a sand sample.

UC is basically a value describing the range of grain sizes present in a sample

2. Determine what useable sand will be produced from a sand source (e.g. a rock quarry or road cut) and how much sand will be rejected as too fine or too coarse.

Not all rock or sand from a crushed rock source will be used in the sand filter. Some grains that are too large or two small will be rejected.

The sand sieve analysis can be used to determine how much sand will be rejected from a particular rock source.

The sand that is larger than the top sieve (e.g. 0.7 mm opening size) is too coarse for filtration sand and needs to be removed (though this size may be used as aggregate in making concrete for the filter body).

Notes: If there is a large amount of coarse sand in the rock source, then the load that you will be transporting to the production site becomes unnecessarily heavy. There is no need to carry oversized sand if you cannot use it in the filters. The sand can be sieved at the quarry site to remove this coarse material before transporting it to your production site.

On the other hand, sand smaller than the finest sieve (e.g. 0.1 mm opening size), which is collected in the catch pan at the bottom, is too fine for filtration sand. In that case, washing the sand in water will be required to remove this very fine sand (also known as rock flour).

If a sand sample that has been initially sieved and washed has too much of this very fine sand in it, then the sand to be used in the filter may need to be washed again to get rid of this rock dust.

3. Estimate if a sand source would be a good supply to produce filtration sand (once the sand had been prepared by sieving and washing).

This is done by determining the Effective Size (ES) and Uniformity Coefficient (UC) for the portion of the sand sample that would be useable.

This means performing the sand sieve analysis method described below, but only using the portion of sand that went through the largest sieve but did not go through the smallest sieve.

Most of the very fine sand that goes through the #150 sieve will be removed by washing, and so should not be included in the sample for this analysis.

3. MATERIALS REQUIRED FOR A SAND SIEVE ANALYSIS

***Sand Sample:** at least 100 ml of very dry sand for analysis that is representative of sand to be used in a filter

***Graduated cylinder:** 100 ml size, with 1 ml markings, plastic is recommended

Note: experience has shown that it is preferable to use a graduated cylinder that has ml marks that begin at the bottom of the graduated cylinder.

Some graduated cylinders have marks that start at 10ml, so you cannot measure quantities of less than 10ml with such graduated cylinders.

***Set of screens:** A set of sand sieves that stack one upon the other with a catch pan on the bottom and a lid on the top (see photo).

Screens are stacked together in order with largest openings (#24) at the top and smallest openings (#150) at the bottom, with a lid on top and a catch pan at the bottom.

- **#24 sieve** (opening size = 0.71 mm)

- **#40 sieve** (opening size = 0.38 mm)

- **#60 sieve** (opening size = 0.25 mm)

- **#80 sieve** (opening size = 0.18 mm)

- **#150 sieve** (opening size = 0.10 mm)

- **Catch pan** (to catch all sand that passes #150 sieve)

- **Sieve set lid** (placed on top of the #24 sieve to contain the sand while shaking)

NALYSIS OF SAND FILTER

***Semi-log graph paper** (provided in the PDF files on this web page)

***Pencil** (If the graph paper is laminated, then you can use an erasable pen so that the markings can be erased and the graph can be reused many times.)

***Ruler**

***Calculator**

4. GENERAL METHOD OF PERFORMING A SAND SIEVE ANALYSIS

Sand sieve analysis is performed by shaking a sample of sand through a series of five screens with a catch pan at the bottom.

Each sieve size is smaller than the one before so that, after 5 minutes of shaking the sieve set, the sand will either be retained on top of the sieves or passed through the sieves.

The sieve sizes used in these instructions were specifically selected for analyzing sand for the sand filter and the sand to be analyzed should be initially prepared.

This means that the sand should have already been sieved through a #24 screen to remove the coarse sand before taking the sample. The sand should also be well washed to remove the smallest particles that would pass through the #150 screen.

After measuring the amount of sand retained on each of the sieves, we calculate the percent of sand that passed through each sieve.

A point is marked on a semi-log graph for the Percent Passed through the Sieve for each sieve size.

SAND SIEVE ANALYSIS OF SAND FILTER

A line is then drawn on the graph connecting the five points. Using this line we can find the size of screen that would allow 10% of the sand to pass through.

This value is denoted as d10 and is called the Effective Size (ES) of the sand.

Further up this same line we can find the size of screen that 60% of the sand would pass through. This value is denoted as d60.

By dividing the d60 value by the d10 value we can determine the Uniformity Coefficient (UC = d60/d10) for that sand sample.

These two values, the Effective Size (ES) and Uniformity Coefficient (UC), are then compared to recommended ranges for filtration sand.

The instructions below describe this procedure in detail.

Notes: Using volume measurements rather than weight minimizes the equipment required while still providing adequate results for purposes of analyzing sand for sand filters.

It is very important that the sand sample is totally dry before it is placed in the sieve set.

Wet or damp sand often plugs the screens making it difficult to sieve and the results will be incorrect.

Try to select the sand sample for sieve analysis so that it is representative of the sand you will be using.

5. DETAILED INSTRUCTIONS FOR PERFORMING SAND SIEVE ANALYSIS,

1. Stack the sand sieves with the coarsest (#24) on top followed by the #40, #60, #80, #150, and finally, the catch pan on the bottom.

2. Fill the graduated cylinder to the 100 ml mark with a sample of the **dry prepared sand**. Use a piece of paper, rolled or folded, as a "funnel" to make it easier to fill the graduated cylinder.

3. Pour the entire 100 ml sample from the graduated cylinder onto the top sieve (#24) and place the lid on top of the sieve.

4. Shake the entire sieve set, including the bottom catch pan and top lid, for at least 5 minutes. Shake both sideways and up and down to ensure the sand falls through the various screens.

5. After 5 minutes, remove the top lid and pour the sand from the #24 sieve into the graduated cylinder. Use a piece of paper as a funnel to help pour the sand into the cylinder.

Read the amount of sand in the graduated cylinder. **Do not pour out the sand from the cylinder afterwards.**

SAND SIEVE ANALYSIS OF SAND FILTER

There should be very little sand caught in the #24 screen if the larger particles have been removed during preparation at the rock source.

In the table on the semi-log graph paper provided, record the value in the column labeled **"Cumulative ml Sand Retained"** for the #24 sieve.

Note: There should be very little or no sand on the #24 sieve since your sample should have already been sieved through the #24 sieve size to remove the coarse sand.

6. Remove the next #40 sieve and pour the sand from it into the cylinder**(on top of the sand from the #24 sieve), then read the total amount of sand in the cylinder.**

Record the value in the column labeled "Cumulative ml Sand Retained" for the #40 sieve.

7. Repeat Step 6 for the #60 sieve, then the #80 sieve, the #150 mesh, and finally the catch pan. Once all of these sieves (and catch pan) have been poured into the graduated cylinder, **it should read approximately 100 ml.**

Some sand may have been lost in the shaking and the total may not add up to exactly 100 ml. Try to avoid any sand loss by emptying the sieves thoroughly and lightly tapping the cylinder after each sieve to help settling.

8. Calculate the **"Percent Retained"** on the sieve and the **"Percent Passing Through the Sieve"** for each sieve and record your results.

Example Sand Sieve Analysis

Sieve Size	Cumulative Sand Retained On the Sieve – Read From Graduated Cylinder (A)	Percent Retained On the Seive (C=A/B*100)	Percent Passing Through the Sieve (100-C)
#24	0 ml	0 %	100 %
#40	17.1 ml	18.0 %	82.0 %
#60	72.9 ml	76.7 %	23.3 %
#80	87.8 ml	92.4 %	7.6 %
#150	94.6 ml	99.6 %	0.4 %
Catch pan	95 ml (B)	100 %	0 %

9. Plot the "Percent Passing Through the Sieve" value for each sieve size on the graph paper and then draw a line joining the 5 points as shown on the Example Worksheet.

(Line starts at #24 sieve size and ends at #150 sieve size)

10. **Determine the Effective Size (ES).**

This is defined as the screen size opening that will just pass 10% of the sand **(d10 value)**. Read this value from the graph where the line crosses the "Passing Through the Sieve" line at 10%.

Recommended ES range = 0.15 mm to 0.20 mm (an ES within this range is likely to achieve 0.4 liters per minute flow rate in the sand filter).

11. **Determine the Uniformity Coefficient (UC).**

SAND SIEVE ANALYSIS OF SAND FILTER

This is defined as a ratio and calculated as the screen size opening that will just pass 60% of the sand **(d60 value)** divided by the screen size opening that will just pass 10% of the sand sample (the d10 value).

Recommended UC range = 1.5 to 2.5 (a UC within this range is likely to achieve 0.4 liters per minute flow rate in the sand filter).

12. **Determine the Percent Passing Through the #150 Sieve.**

This is the measure of the very fine sand (also called rock flour) that can plug the filtration sand and cause turbid water to come out of the sand filter.

The sand is washed sufficiently so that not more than 4% of the sand will pass through the #150 sieve.

(If you find that your sand sample contains more than 4% in the catch pan, you may have to wash and dry your sand sample again to remove rock dust that can cause clogging of a sand filter).

6. INSTRUCTIONS TO DETERMINE PERCENT REJECTED

To determine what percentage of a sand source will be too large to use as filtration sand:

1. Place only the #24 sieve on to the catch pan. Take a representative sample of your dry sand.

2. Fill the graduated cylinder with 100 ml of the dry sand sample.

3. Pour the entire 100 ml sample from the graduated cylinder onto #24 sieve and place the lid on top of the sieve.

4. Shake the #24 sieve, including the bottom catch pan and top lid, for about 20 seconds. Shake both sideways and up and down to ensure the sand falls through the screen.

Remove the top lid and pour the sand from the #24 sand sieve into the graduated cylinder. Use a piece of paper as a funnel to help pour the sand into the cylinder. Read the amount of sand in the graduated cylinder.

This value is the Percent Rejected as Too Coarse.

Remember, your initial preparation of the rock source material should get rid of most, if not all, of any material that would be caught in the #24 screen. You may want to sift your rock source a second time if the amount of sand that is too coarse would make the load to be transported unnecessarily heavy.

To determine what percentage of a sand source will be too fine to use as filtration sand:

1. Place only the #150 sieve on to the catch pan. Take a representative sample of your dry sand.

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2. Fill the graduated cylinder with 100 ml of the dry sand sample.

3. Pour the entire 100 ml sample from the graduated cylinder onto #150 sieve and place the lid on top of the sieve.

4. Shake the #150 sieve, including the bottom catch pan and top lid, for about 20 seconds. Shake both sideways and up and down to ensure the sand falls through the screen.

Remove the top lid and pour the sand from the #150 sand sieve into the graduated cylinder. Use a piece of paper as a funnel to help pour the sand into the cylinder. Read the amount of sand in the graduated cylinder.

This is approximately the Percent Rejected as Too Fine for use in the sand filter.

This extra fine material will need to be removed by washing sand again if the percent captured in the catch pan is more than 4%.

SAND SIEVE ANALYSIS

Sample Description:

Sieve Size	A Cumulative ml Sand Retained	C Percent Retained C = A/B * 100	Percent Passing Through Sieve 100% - C
#24	0	0.0%	100.0%
#40	21	21.2%	78.8%
#60	69	69.7%	30.3%
#80	91	92.0%	8.0%
#150	97	98.0%	2.0%
Catch Pan	99 = B	100.0%	0.0%

EXAMPLE

Sample Results:

		Recommended:
Effective Size: d_{10} =	0.19	0.15 to 0.20 mm
Uniformity Coefficient: d_{60} / d_{10} =	1.7	1.5 to 2.5
Very Fine Sand Percent: % Passing #150 =	2%	Less than 4%