NAGPUR MUNICIPAL CORPORATION

AUGMENTATION TO NAGPUR CITY WATER SUPPLY SCHEME – PENCH - IV

DRAFT PROJECT REPORT – PART 2

CONVEYANCE OF WATER FROM MAHADULA TO WTP AT GODHANI,TREATMENT AND FURTHER CONVEYANCE UPTO MBR AT GOVERNOR HOUSE

VOLUME - 1

Submitted to :
The Executive Engineer
Pench Project Cell
Nagpur Municipal Corporation
Ground Floor North Wing
Mahanagarapalika Marg
Nagpur 440 001

Prepared by

STC SHAH TECHNICAL CONSULTANTS PVT. LTD.

WITH

DINESH RATHI & ASSOCIATES

DRAFT PROJECT REPORT - PENCH IV
PART – 2

CONVEYANCE OF WATER FROM MAHADULA TO WTP AT GODHANI ,TREATMENT AND FURTHER CONVEYANCE UPTO MBR AT GOVERNOR HOUSE

VOLUME - I

CONTENTS

1.0 BACKGROUND

The work for preparation of detailed project report of augmentation to Nagpur water supply scheme (pench-4) is entrusted to M/s Shah Technical Consultants (STC), Mumbai by Nagpur Municipal Corporation (NMC).

The submission of the detailed project report is divided in four parts as,-

1) Part –1 – Lifting Water at Pench Reservoir and conveying it upto Mahadula.
2) Part-2- Conveyance Of Water From Mahadula To WTP At Godhani, Treatment And Further Conveyance Upto MBR At Governor House
3) Part-3- Transmission Of Water Upto Different ESR's From MBR At Governor House ,including Elevated Service Reservoirs.
4) Part-4-Distrubution System.

Out of these four parts, Part-1 is already submitted to NMC.

The present report covers part-2 i.e Conveyance Of Water From Mahadula To WTP At Godhani, Treatment And Further Conveyance Upto MBR At Governor House

1.1 System Components

The components covered under this part are,-

- Bifurcation Arrangement At Mahadula.
- Raw Water Gravity Main From Mahadula To WTP At Godhani
- Water Treatment Plant At Godhani
- Pure Water Rising Main From WTP At Godhani To MBR At Governor House.

2.0 BIFURCATION ARRANGEMENT

Bifurcation arrangement at Mahadula will be provide to bifurcate the incoming flow of 315 MLD from Pench into two branches: 200 MLD to existing Raw water main from Mahadula to Gorewada tank and 115 MLD through proposed transmission main from Mahadula to proposed WTP at Godhani.

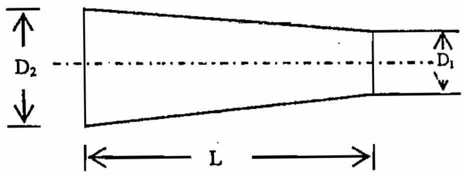
A valve complex is provided at Mahadula with butterfly valves of appropriate size to regulate the discharge through these two branches.

Due consideration is given to valve and sizing of fittings ,reducers, lateral etc. while preparing general arrangement plan.

IS: 13095: 1991 have been referred for butterfly valve provisions and ANSI/AWWA G-208-01 has been referred to fix the dimensions for fabricated pipe fittings. The length of reducer (L) is calculated by;

$$L = 4\,(D_2 - D_1)$$

Where D1 and D2 are outside diameter of steel cone at ends of reducers as shown;



To calculate the dimensions of fitting for lateral, following formulas have been used;

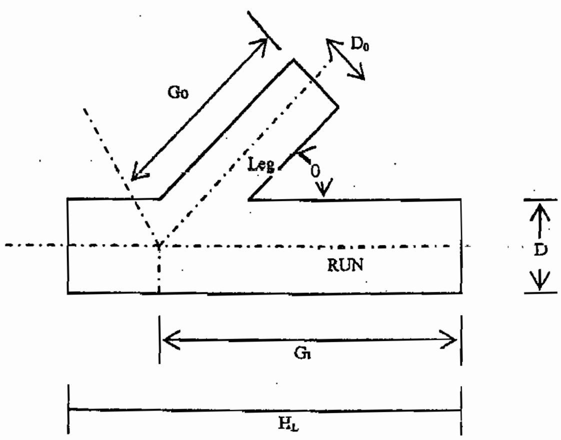
1. $$Gr = \frac{D}{2\tan\theta} + \frac{D_0}{2Sin\theta} + 2\,\text{fr}$$

2. $$H_L = \text{Gr} + \text{fr}$$

3. $$G_0 = \frac{D}{2\sin\theta} + \frac{D_0}{2\tan\theta} + 2\,f_0$$

Where;

Gr	=	Centerline length of run in lateral from point of intersection of lateral to end run.
H_L	=	Overall length of run in lateral
Go	=	Centerline length of leg in lateral from point of intersection of lateral to end of leg.
D	=	Outside diameter of steel cylinder
Do	=	Outside diameter of steel cylinder of lateral.
θ	=	Angle of fitting.
fr	=	Formula factor corresponding to diameter of lateral (=14)



2.1 Typical Design of Horizontal Thrust Block for Lateral Pipe

Inside Diameter of the Pipe (D)		=	140.2 cm
Outline Coating		=	2.0 cm
Steel Plate Thickness		=	1.0 cm
Internal Coating		=	1.2 cm
Outer diameter of the pipe (Bc)		=	148.6 cm
Field Test Pressure (P)		=	12.00 kg/cm^2
Horizantal Bearing Capacity of Soil		=	15.29 T/m^2
Cross Section Area of Pipe	A	=	15437.85 cm^2
Trench Depth	H	=	263.6 cm
Resultant Thrust	T	=	PA
		=	185.3 Tone

Thrust Block Dimentions

Contact area of thrust block		=	$\frac{Applied Thrust}{Horz. Bearing Capacity of soil}$
		=	12.12 m^2
Height of block	B	=	Trench depth - 20
		=	243.6 cm
	Say	=	2.44 m
Length of block	L	=	$\frac{Contact Area of Thrust Block}{Height of Block}$
		=	496.72 cm
	Say	=	4.97 m
Width of block	d	=	0.5 m

2.2 Details of Thrust Block for Horizontal bends

Angle of Bend	Thrust Block Dimentions		
	Length(m)	Width (m)	Height(m)
15	2.0	2.1	0.5
22.5	2.6	2.1	0.5
30	3.4	2.1	0.5
45	5.0	2.1	0.5
60	5.2	2.4	0.5
90	7.3	2.4	0.5

3.1 RAW WATER TRANSMISSION MAIN FROM MAHADULA TO GODHANI

3.1.1 Hydraulic Design For

Outer diameter = 1422 mm

Cement mortar lining = 12 mm

Plate thickness = 10 mm ✓

C.C. out coating = 20 mm

For flow of 115 MLD

$$Q = \frac{115 \times 1000}{24 \times 3600}$$

$$= 1.3310 \text{ m}^3/\text{s}$$

$$\text{Velocity} = \frac{Q}{A}$$

$$= \frac{1.3310}{\frac{\Pi}{4} \times 1.378^2}$$

$$= \mathbf{0.8924 \text{ m/s}}$$

Frictional Losses

$$Q = 7.436 \times 10^{-9} \times C \times D^{2.63} \times hf^{.54}$$

$$115 = 7.436 \times 10^{-9} \times 130 \times 1378^{2.63} \times hf^{.54}$$

hf = 0.4625 say 0.463 m / 1000m

Length of main = 2825 m 2.825 KM

Loss of head in friction = 2.825 x 0.463

= **1.308 m**

3.1.2 Design Notes - Structural Design of M.S. Pipe Line(R/W Transmission Main From Mahadula To Godhani

For the design of shell thickness following critical conditions are considered.

1. Stress in shell due to internal pressure (60% of the specified minimum yield stress)

2. Deflection of shell under prism load

3. Buckling from elastic instability resulting from loads and deformation.

   The following references are considered for the design of Steel Shell

   1. IS 3589 : 2001 Steel Pipes for Water and Sewage 168.3 to 2540 mm outside diameter - specification
      Bureau of Indian Standards
      Bureau of Indian Standards

   2. Pipe Material Selection Manual
      1st Edition – 1988
      WRc plc.

   3. AWWA Manual M 11
      Steel Pipe of Guide for Design & Installation – Fourth Edition 2004

   4. IS 783 : 1985
      Code of practice for laying of concrete pipes 1st revision

   5. Standard Specification & Code of Practice for Road Bridges
      Section II Loads & Stresses – 4th revision 2000
      Indian Roads Congress

4. For checking vertical deflection of the pipe line Iowa Spangler Equation has been considered.

$$\frac{\Delta}{D} = \frac{k\left(D_L \; Pb + Ps\right)}{8\,\dfrac{EI}{D^3} + 0.061\,E^1} \times D_R$$

Where,

Δ = Linear deflection of pipe vertical diameter

D	=	Pipe diameter
D_L	=	Deflection lag factor
D_R	=	Re-rounding factor
Pb	=	Vertical pressure due to backfill
Ps	=	Vertical pressure to surcharge loads
EI/D^3	=	Pipe stiffness
E^1	=	Modulus of passive resistance of pipe zone fill material
k	=	Bedding constant

Allowable deflection for various lining and coating systems are :

Mortar lined and coated	=	2 percent of pipe diameter
Mortar lined and flexible coated	=	3 percent of pipe diameter
Flexible lined and coated	=	5 percent of pipe diameter

5. AWWA M11 gives a formula for horizontal deflection of pipe in inches

$$\Delta x = Dl\left(\frac{kWr^{3}}{EI + 0.061\ E'r^{3}}\right)$$

Where,

Δx	=	Horizontal deflection of pipe (inches)
Dl	=	Deflection lag factor (1-1.5)
k	=	Bedding constant (0.1)
W	=	load / unit length of pipe length (lb/inches of pipe)
r	=	radius (inches)

EI = Pipe wall stiffness (inches – lb)

E = Modulus of elasticity

I = Transverse moment of inertia, per unit length of wall

E' = Modulus of soil reaction (lb/inches^2)

6. IRC class AA loading has been considered for load. A single maximum wheel load of 6.25 T has been considered as a point load.

7. Minimum plate or sheet thickness for handling for pipe sizes greater than 54 inches internal diameter is given by

$$t = \frac{D+20}{400} \text{ inches}$$

8. Buckling :

Pipe embedded in soil may collapse or buckle from elastic instability resulting from loads and deformations. The summation of external loads should be less than or equal to allowable buckling pressure.

The allowable buckling pressure is determined by

$$qa = \left(\frac{1}{FS}\right) x \left(32 \text{ x Rw x B' x E' x } \frac{EI}{D^3}\right)^{1/2}$$

qa = allowable buckling pressure

FS = design factor 2.5 for h/D ≥ 2
3.0 for h/D < 2
where h = ht of ground surface above top of pipe (inches)
D = diameter of pipe (inches)

Rw = Water buoyancy factor

$$= 1 - 0.33\left(\frac{hw}{h}\right), \quad 0 \le hw < h$$

Where hw = height of water surface above top of pipe (inches)

In the worst case hw = h

B' = empirical coefficient of elastic support (dimension less)

$$= \left(\frac{1}{1 + 4e^{-0.065\,H}}\right)$$

Where H = height of fill above pipe in ft.

$$Yw \times hw + Rw\frac{Wc}{D} + \frac{W_L}{D} < qa$$

Check for Deflection

Iowa Spangler Equation

$$\frac{\Delta}{D} = \frac{k\left(D_L\ Pb + Ps\right)}{8\dfrac{EI}{D^3} + 0.061\,E^1} \times D_R$$

Where

Δ = Linear deflection of pipe vertical diameter

D = Pipe diameter

D_L = Deflection lag factor

D_R = Re-rounding factor

Pb = Vertical pressure due to backfill

Ps = Vertical pressure to surcharge loads

EI/D^3 = Pipe stiffness

E^1 = Modulus of passive resistance of pipe zone fill material

k = Bedding constant 0.1 for sand

Load on pipe due to backfill

= w x H x Bc

= 18 x 1 x 1.462

= 26.316 kN/m.

$$Pb = \frac{26.316}{1.462}$$

$= \quad 18\ kN/m^2 \quad or \quad 18\ kPa$

Ps

Wheel load IRC class AA $= \quad 6.25$ T

IS 783-85 Cl. 11.2

Cover > 900 mm, Impact factor 1

$$Wc = CP\frac{P\alpha}{1}$$

Where l $= 1.15H + 2D + S$

$= 1.15 \times 1 + 2 \times 1.462 + 0$

$= 1.15 + 2.924$

$= 4.074$

$$\frac{1}{2H} = 2.037, \quad = \frac{D}{2H} = \frac{1.462}{2H} = 0.731$$

From fig. 3, IS 783 – 1985 for $\frac{l}{2H} = 2.037, \quad \frac{D}{2H} = 0.731$

Cp $= 0.675$

$$wc = \frac{0.675 \times 6.25 \times 1}{4.074}$$

$= 1.0355$ T

$= 10.158$ kN/m.

$$Ps = \frac{10.158}{1.462}$$

$= 6.948\ kN/m^2$

or 6.948 kPa

Pipe stiffness $= EI/D^3$

$$= \frac{2 \times 10^5 \times \frac{1}{12} \times 10^3}{1412^3} \times (1000)^2$$

$= 5920.312\ N/m^2$

or

5.920 kPa

$$\frac{\Delta}{D} = \frac{k\left(D_L\ Pb + Ps\right)}{8\dfrac{EI}{D^3} + 0.061\,E^1} \times D_R$$

k	=	0.1
D_L	=	1
E^1	=	3000 kPa
D_R	=	1

$$= \frac{0.1\,(1+18+6.948)}{8\times5.920+0.061\times3000}$$

$$= \frac{0.1\times25.948}{47.36+0.061\times3000}$$

$$= 0.011264 \quad \text{or} \quad 1.1264\ \%$$

This is within permissible limit of 2 % for cement mortar lined and coated pipes

Horizontal Deflection (AS per M-11)

$$\Delta x = Dl\left(\frac{kWr^3}{EI + 0.061\,E'r^3}\right)$$

Where,

Δx	=	Horizontal deflection of pipe (inches)
Dl	=	Deflection lag factor (1)
k	=	Bedding constant (0.1)
W	=	load / unit length (lb/inches of pipe)
r	=	radius (inches)
EI	=	Pipe wall stiffness (inches – lb)
E	=	Modulus of elasticity (30000000 p.s.i. for steel)
I	=	Transverse moment of inertia, per unit length of pipe wall
E'	=	Modulus of soil reaction (lb/inches^2)

$$W = \text{load due to back fill + load due to live load}$$

$$= 26.316 + 10.158 \text{ kN/m.}$$

$$= 36.474 \text{ kN/m}$$

$$= 2498.70 \text{ lb/ft.}$$

$$= 208.225 \text{ lb/in.}$$

$$I = \frac{t^3}{12} \qquad r = \frac{55.5905}{2}$$

$$= \left(\frac{10}{25.4}\right)^3 / 12 \qquad = 27.79 \text{ inches}$$

$$= 5.0853 \times 10^{-3}$$

$$EI = 30000000 \times 8.0853 \times 10^{-3}$$

$$= 152559$$

$$\Delta x = Dl\left(\frac{kWr^3}{EI + 0.061 E'r^3}\right)$$

$$\Delta x = 1\left(\frac{0.1 \times 208.225 \times 27.79^3}{152559 + 0.061 \times 400 \times 27.79^3}\right)$$

$$= \frac{1 \times 0.1 \times 208.225 \times 21461.775}{152559 + 523667.3133}$$

$$= \frac{446883.5176}{676226.3133}$$

$$= 0.66 \text{ inches}$$

$$\frac{\Delta x}{D} = \frac{0.66}{55.5905} \times 100$$

$$= 1.187 \text{ percent}$$

This is within 2% allowed for cement mortar lined and coated pipes.

Minimum Wall Thickness

Minimum plate or sheet thickness for handling for pipe sizes greater than 54 in. ID is given by

$$t = \frac{D+20}{400} \quad Inches$$

$1402 = 1402 \div 25.4$

$= 55.196"$

$$t = \frac{55.12+20}{400}$$

$= 0.1879$ inches or 4.77 mm.

Check Against Buckling

Allowable buckling pressure p.s.i

$$qa = \left(\frac{1}{Fs}\right)\left(32\,Rw\,B'\,E'\,\frac{EI}{D^3}\right)^{1/2}$$

FS = Design factor $\geq 2\frac{h}{D}$ 2.5

< 2 3.0 $\frac{h}{D}$

h = ht. of ground surface above top of pipe in

D = diameter of pipe inches

Rw = water hougency factor

$$1 - .33\frac{hw}{h}, \quad 0, < hw \leq h$$

Where hw = ht of water surface above top of pipe in

B' empirical coefficient of elastic support

$$= \frac{1}{1+4e^{-(.065H)}}$$

Where H = ht of fill above pipe ft.

D = 1422 + 40

= 1462 mm

$= \quad 57.56 \text{ Inches}$

$h \quad = \quad 1000 \text{ mm} \quad = \quad 39.37 \text{ inch.}$

$\frac{h}{D} \quad = \quad 0.684 \quad < \quad 2$

$Fs \quad = \quad 3.0$

$Rw \quad = \quad 1 - 0.33 \ \frac{hw}{h}$

Assuming that ground water table reaches the ground level

$Rw \quad = \quad 1 \frac{1}{1} 0.33$

$= \quad 0.67$

$$B^1 = \frac{1}{1 + 4e^{(-0.065H)}}$$

$$= \frac{1}{1 + 4e^{-.065 \text{ x } 3.28}}$$

$$= \frac{1}{1 + 4e^{-.2132}}$$

$$= \frac{1}{1 + 4 \ x \ .807994522}$$

$$= 0.236926119$$

$$I = \frac{t^3}{12}$$

$$= \left(\frac{10}{25.4}\right)^3 \div 12$$

$$= 5.085312 \text{ x } 10^{-3}$$

$$\frac{EI}{D^3} = \frac{30 \times 10^6 \times 5.085312 \times 10^{-3}}{57.56^3}$$

$$= 0.799975$$

$$\text{Say} = 0.80$$

Allowable buckling pressure

$$qa = \left(\frac{1}{Fs}\right) \left(32 \text{ Rw B}' \text{E}' \frac{\text{EI}}{\text{D}^3}\right)^{1/2}$$

$$= \frac{1}{3} \left(32 \times 0.67 \times .236926119 \times 400 \times 0.8\right)^{1/2}$$

$$= \frac{1}{3} \times 40.3175237$$

$$= 13.439 \text{ p.s.i.}$$

Load on pipe due to backfill = 26.316 kN/m

= 1802.818 lb/ft.

Load due to line load = 10.158 kN/m

= 695.8471 lb/ft.

$$\wp w \times hw + Rw \frac{Wc}{D} + \frac{W_L}{D} < qa$$

$$\wp w \times hw + Rw \frac{Wc}{D} + \frac{W_L}{D} = 0.0361 \times 3.28 \times 12 + \frac{0.67 \times 1802.818}{12 \times 57.56} + \frac{695.8471}{12 \times 57.56}$$

$$= 1.42 + 1.748 + 1.0074$$

$$= 4.1754 \text{ p.s.i.} < 13.439 \text{ p.s.i.}$$

3.3 Calculations of Restrained Length for Horizontal bends for Raw Water Gravity Main

Inner diameter (D)	=	1378 mm
Thickness of Outlining	=	20 mm
Thickness of steel shell	=	10 mm
Inner lining	=	12 mm

If the soil prism above the pipe is restrained from movement:

$$L = \frac{PA \sin^2 \frac{\Delta}{2}}{f\,(2w_e + w_p + w_w)}$$

Where

L	=	Restrained length in cm		
P	=	Internal pressure in kg/sq. cm		
A	=	Cross section area of pipe in sq. cm		
Δ	=	Bend deflection in degrees		
We	=	Weight of prism of soil over the pipe in kg/cm		
Wp	=	Weight of pipe in kg/cm		
Ww	=	Weight of contained water in kg/cm		
f	=	Friction between pipe and soil	=	0.4

Weight of steel shell (W1	=	3.52 kg/cm
Weight of Outer lining (V	=	2.419 kg/cm
Weight of inner coating (	=	1.505 kg/cm
Total weight of pipe (Wp	=	W1 + W2 + W3
	=	7.444 kg/cm
Outer diameter (Bc)	=	1462 mm

Weight of prims of soil over the pipe(We)	=	$\gamma_s \times H \times B_c$
where,	=	Density of soil = 18 kN/m^3
H	=	Minimum depth of cover = 1 m
We	=	26.826 kg/cm
Weight of contained water (Ww)	=	14.920 kg/cm
$2w_e+w_p+w_w$	=	76.016 kg/cm
Area of pipe (A)	=	14913.8 sq.cm
Maximum pressure (P)	=	12.400 kg/sq.cm

Δ in degrees	90	60	45	30	22.5	15
sin(Δ/2)	0.707	0.500	0.383	0.259	0.195	0.131
$\sin^2(\Delta/2)$	0.500	0.250	0.147	0.067	0.038	0.017
L in m	30.41	15.20	8.94	4.07	2.31	1.03
L say	31	16	9	5	3	2

3.4 Calculations of Restrained Length for Vertical Downward Bends for Raw Water Gravity Main

Inner diameter (D)	=	1378 mm
Thickness of Outlining	=	20 mm
Thickness of steel shell	=	10 mm
Thickness of inner lining	=	12 mm

If the soil prism above the pipe is restrained from movement:

$$L = \frac{S_f PATan\frac{\theta}{2}}{F_f}$$

Where,

Ff	=	Frictional force = (πBc/2)*C+(2We+Wp+Ww)Tanδ		
L	=	Restrained length in cm		
P	=	Internal pressure in kg/sq. cm		
A	=	Cross section area of pipe in sq. cm		
q	=	Bend deflection in degrees		
We	=	Weight of prism of soil over the pipe in kg/cm		
Wp	=	Weight of pipe in kg/cm		
Ww	=	Weight of contained water in kg/cm		
ϕ	=	Angle of friction	=	30 Degrees
Fϕ	=	Ratio of pipe friction angle to soil friction angle	=	0.75
Tanδ	=	Friction between pipe and soil =Tan(Fϕ*ϕ)	=	0.4
C	=	Cohision	=	0.00 kg/cm^2
S_f	=	Factor of safity	=	1.5

Weight of steel shell (W_1)	=	3.52 kg/cm
Weight ofOuter Lining (W_2)	=	2.419 kg/cm
Weight of Inner lining (W_3)	=	1.505 kg/cm
Total weight of pipe (W_p)	=	$W_1 + W_2 + W_3$
	=	7.446 kg/cm
Outer diameter (Bc)	=	1462 mm

Weight of prims of soil over the pipe(We)	=	γ_s X H X Bc		
where,	=	Density of soil	=	0.001835 kg/cm^3
H	=	inimum depth of cove	=	1.0 m
We	=	26.8 kg/cm		
Weight of contained water (Ww)	=	14.9 kg/cm		
$2w_e+w_p+w_w$	=	76.0 kg/cm		
Area of pipe (A)	=	14913.8 sq.cm		
Maximum pressure (P)	=	12.4 kg/sq.cm		
Frictional force (Ff)	=	31.5 kg/cm		

θ in degrees	90	60	45	30	22.5	15	10
Tan(θ/2)	1.000	0.577	0.414	0.268	0.199	0.132	0.087
L in m	88.14	50.89	36.51	23.62	17.53	11.60	7.71
L say	89	51	37	24	18	12	8

3.5 **Calculations of Restrained Length for Vertical Upward Bends for Raw Water Gravity Main**

Inner diameter (D)	=	1378 mm
Thickness of Outlining	=	20 mm
Thickness of steel shell	=	10 mm
Inner lining	=	12 mm

If the soil prism above the pipe is restrained from movement:

$$L = \frac{S_f PA Tan\frac{\theta}{2}}{F_f + (1/2)R_s}$$

Where,

Ff	=	Frictional force = (πBc/2)*C+(2We+Wp+Ww)Tanδ		
L	=	Restrained length in cm		
P	=	Internal pressure in kg/sq. cm		
A	=	Cross section area of pipe in sq. cm		
θ	=	Bend deflection in degrees		
We	=	Weight of prism of soil over the pipe in kg/cm		
Wp	=	Weight of pipe in kg/cm		
Ww	=	Weight of contained water in kg/cm		
ϕ	=	Angle of friction	=	30 Degrees
Fϕ	=	Ratio of pipe friction angle to soil friction angle	=	0.75
Tanδ	=	Friction between pipe and soil = Tan(Fϕ*ϕ)	=	0.4
C	=	Cohision	=	0.00 kg/cm^2
γs	=	Unit weight of soil	=	0.001835 kg/cm^3
S_f	=	Factor of safity	=	1.5
Rs	=	Unit Bearing Resistance	=	Kn*Pp*Bc
Pp	=	Passive soil pressure = γ*He*Nϕ +2*Cs*sqrt(Nϕ)		
Kn	=	Reduction Constant	=	0.6
Nϕ	=	$Tan^2(45+\phi/2)$	=	3.00
Hc	=	Height between center line of the pipe to GL	=	173.1 cm

Weight of steel shell (W_1)	=	3.52 kg/cm
Weight of Outer lining (W_2)	=	2.419 kg/cm
Weight of Innert coating, W_3	=	1.505 kg/cm
Total weight of pipe (Wp)	=	W1 + W2 + W3
	=	7.446 kg/cm
Outer diameter (Bc)	=	1462 mm

Weight of prims of soil over the pipe(We)	=	$\gamma s \times H \times Bc$	=	1.0 m
Where,				
H	=	Minimum depth of cover		
We	=	26.828 kg/cm		
Weight of contained water,W_w	=	14.920 kg/cm		
$2w_e+w_p+w_w$	=	76.021 kg/cm		
Area of pipe (A)	=	14913.60 sq.cm		
Maximum pressure (P)	=	12.40 kg/sq.cm		
Frictinal force (Ff)	=	31.5 kg/cm		
Passive presure (Pp)	=	0.95 kg/cm^2		
Unit bearing resistence (Rs)	=	83.6 kg/cm		

θ in degrees	90	60	45	30	22.5	15
Tan(θ/2)	1.00	0.577	0.414	0.268	0.199	0.132
L in m	37.86	21.86	15.68	10.14	7.53	4.98
L say	38	22	16	11	8	5

3.6 Typical Design of Horizontal Thrust Block for Raw Water Gravity Main

Inside Diameter of the Pipe (D)		=	137.8 cm
Outline Coating		=	2.0 cm
Steel Plate Thickness		=	1.0 cm
Internal Coating		=	1.2 cm
Outer diameter of the pipe (Bc)		=	146.2 cm
Field Test Pressure (P)		=	12.40 kg/cm^2
Angle of Bend (θ)		=	60 Degree
Horizantal Bearing Capacity of Soil		=	15.29 T/m^2
Cross Section Area of Pipe	A	=	14913.83 cm^2
Trench Depth	H	=	261.2 cm
Resultant Thrust	T	=	$\frac{2 \times P \times A \times \sin\frac{\theta}{2}}{1000}$
		=	185.0 Tone

Thrust Block Dimentions

Contact area of thrust block		=	$\frac{AppliedThrust}{Horz.BearingCapacityofsoil}$
		=	12.10 m^2
Height of block	B	=	Trench depth - 20
		=	241.2 cm
	Say	=	2.41 m
Length of block	L	=	$\frac{ContactAreaofThrustBlock}{HeightofBlock}$
		=	502.07 cm
	Say	=	5.02 m
Width of block	d	=	0.5 m

3.7 Typical Design of Thrust Block for Vertical Downward Bends for Raw Water Gravity Main

Inside Diameter of the Pipe (D)	=	137.8 cm
Outline Coating	=	2.0 cm
Steel Plate Thickness	=	1.0 cm
Internal Coating	=	1.2 cm
Outer diameter of the pipe (Bc)	=	146.2 cm
Field Test Pressure	=	Internal Pressure x 1.:
Internal Pressure	=	Maximum FSL in BPT - Lowest Invert Level of the Pipe Line
	=	365.0 - 282.35
	=	82.65 m
	=	8.27 kg/cm^2
Field test pesure (P)	=	12.41 kg/cm^2
Unit weight of the concrete (W_m)	=	24 kN/m^3
	=	0.002446 kg/cm^3
Factor of safety (Sf)	=	1
Angle of Bend (θ)	=	60 degree
Horizontal bearing capacity of the soil (qh)	=	3000 lb/ft^2
	=	143.692 kN/m^2
Cross section area of pipe (A)	=	14913.8 cm^2
Upward thrust (T_v)	=	P x A x Sinθ
Volume of the block required (Vg)	=	$\frac{S_f \times P \times A \times \sin\theta}{W_m}$
	=	65.51618 m^3

Horizontal thrust (T_h)		=	P x A x (1- cosθ)	
		=	92540.1 kg	
Required vertical surface area		=	$\frac{T_h \times S_f}{q_h}$	
		=	6.32 m^2	

Size of Thrust Block

Width of the Block,	B	=	3.50 m	2.086
Height of the Block,	H	=	Trench Depth-20	
			2.44 m	
Vertical Surface Area of the Block		=	8.54 > 6.3 m^2	
			Hence safe	
Length of the Block,	l	=	$\frac{VolemeofConcreteBlock}{verticalSurfaceArea}$	
		=	7.672 m	
	Say	=	7.700 m	

3.8 Typical Design of Thrust Blocks for Vertical Downward Bends for Raw Water Gravity Main

Inside Diameter of the Pipe (D)	=	137.8	cm
Outline Coating	=	2.0	cm
Steel Plate Thickness	=	1.0	cm
Internal Coating	=	1.2	cm
Outer diameter of the pipe (Bc)	=	146.2	cm
Field Test Pressure (P)	=	12.40	kg/cm^2
Unit weight of the concrete (W_m)	=	24	kN/m^3
	=	2.45	t/m^3
Angle of Bend (θ)	=	60	degree
Angle of Repose (ϕ)	=	30	degree
Outer diameter of the pipe (Bc)	=	197	cm
Cross section area of pipe (A)	=	14913.8	cm^2
Horizontal Thrust (Th)	=	P x A x (1-cos θ)	
	=	92.47	MT
Vertical Thrust (Tv)	=	P x A x Sin θ	
	=	160.16	MT
Height of Ground level above the centre of the Pipe (hc)	=	Cover + Bc/2	
	=	1.731	m
Minimum Height of Thrust Block (H)	=	Trench depth-20	
	=	2.4	m

Size of Thrust Block:

L	=	6.00	m
b	=	2.50	m
H	=	2.32	m

Passive resistance Coefficient (kp)	=	$\frac{1 + \sin \phi}{1 - \sin \phi}$			
	=	3			
Unit weight of soil (γ)	=	1.8	t/m3		
Friction Coefficient (μ)	=	0.3			
Passive Resistance by soil (Fp)	=	kp x hc x γ x H x L			
	=	129.89	MT		
Frictional Resistance between soil and concrete (Ff)	=	Weight of concrete x Friction coefficient			
	=	25.497	MT		
Total Horozontal Resistance (Fh)	=	Fp + Ff			
	=	155.39	MT	>	92.47 MT

Hence Safe

Bearing Capacity of the soil (qv)	=	15	t/m^3		
Total Vertical Resistance offered by the soil (Qv)	=	qv x Bottom area of thrust block			
	=	225	MT	>	160.16 MT

Hence Safe

Therefore provide Thrust Block of size 6.0m X 2.57 m X 2.6 m

3.9 Dimentions for Pipe Fittings (cm)

S	52	78	118	78	118	105	118
L	7	10	15	10	15	13	15
T	33	49	74	100	154	215	372
E	33	49	74	49	74	66	74
Z_2	41	41	41	41	41	41	41
L_1	47	50	55	101	136	203	354

3.10 Design of Pipe for Nalla Crossing

When the pipe passes through the canal or Nalla, the pipe is under floatation, because buoyant force is more than pipe weight, is as shown in figure - i. To prevent floatation, concrete encasement is required for getting negative buoyant force. The forces acting on pipe after concrete encasement in shown in figure - ii. The thickeness of concrete required depends on negative buoyance required on pipe.

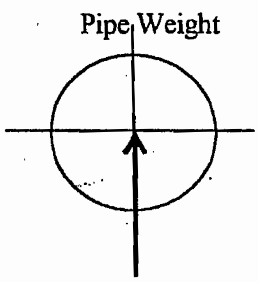


Fig.(i) Pipe is in floatation

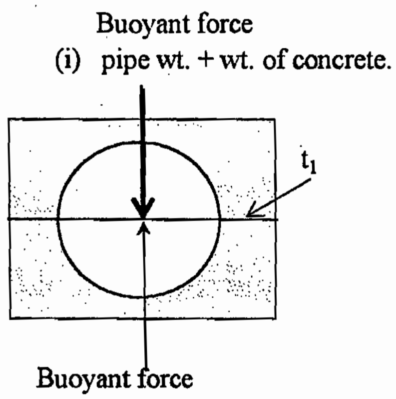


Fig.(ii) Pipe is in steady condition

Outer Diameter of the pipe	=	1486 mm
	=	58.5 inches
Wall Thickeness	=	10 mm
	=	0.4 inches
Buoyancy of the pipe (without encasement)	=	D/3 (D - 32t) + 11 t^2
B	=	897 lb/ft^2

Buoyancy of pipe is possitive. Therefore the pipe is in floating condition.

Therefore concrete coating will be required to give negative buoyancy.

Assume the negative buoyancy on pipe = 897 lb/ft^2

Therefore, concrete thickness required (t_1) can be calculated by,-

$$B = \frac{D}{3}(D-32\, t_1) + t_1 D\left(\frac{63-wc}{48}\right)$$

t_1	=	Thickness of Concrete coating in inches
Wc	=	Unit Weight of concrete = 146 lb/ft^3

$\therefore\ t_1$ = 17.7 inches

= 0.45 m

3.11 Location Of Valves

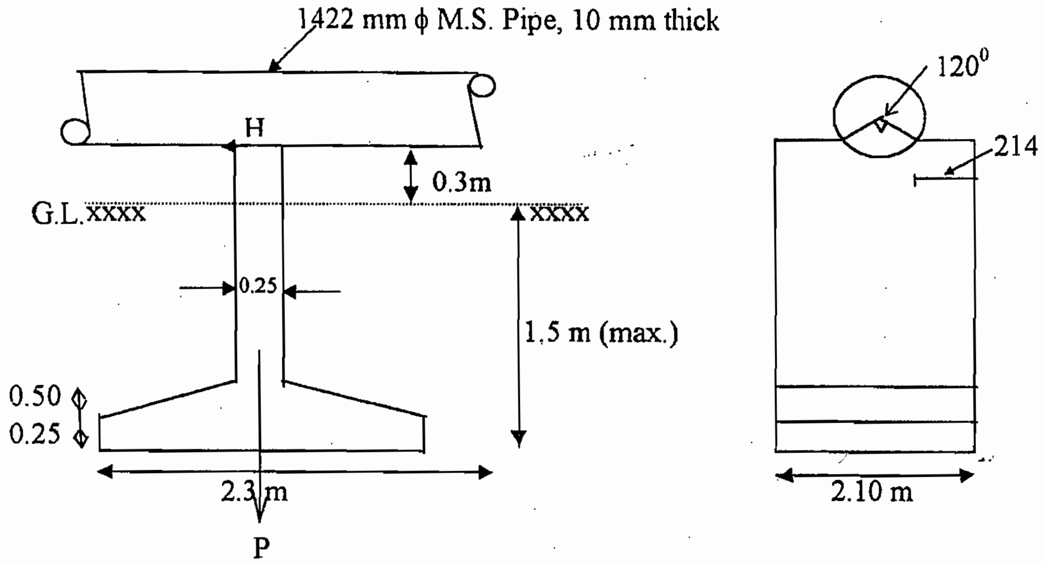
Locations of Air Valves			
S.No.	Chainage (m)	S.No.	Chainage (m)
1	750	29	13980
2	1250	30	14480
3	1680	31	15000
4	2180	32	15480
5	2460	33	15840
6	2960	34	16320
7	3420	35	16740
8	3950	36	16920
9	4450	37	17190
10	4950	38	17790
11	5610	39	18060
12	5970	40	18740
13	6330	41	19200
14	6830	42	19980
15	7290	43	20700
16	7790	44	21120
17	8190	45	21750
18	8400	46	22050
19	8760	47	22530
20	9400	48	22980
21	9480	49	23100
22	10170	50	23725
23	10860	51	23850
24	11460	52	24330
25	11670	53	24660
26	12170	54	24990
27	12670	55	25710
28	13500	56	26400

Locations Of Scour Valves	
S.No.	**Chainage(m)**
1	3610
2	6417
3	7245
4	8772
5	11490
6	12978
7	13542
8	14244
9	16170
10	17250
11	18500
12	20580
13	22856
14	24090
15	27237

Locations Of Butterfly Valves	
S.No.	**Chainage (m)**
1	8400
2	11957
3	16946
4	22540
5	25785

3.12 Design of R.C.C. Pedestal for 1422 mm (O.D.) 10 mm thick Raw Water Gravity Main

Following sizes are assumed for pedestal and footing. Length of footing required will be more due to large B.M.



Vertical load (Pipe empty condition)

weight of pipe = $\frac{\pi}{4} \times (1.422^2 - 1.402^2) \times 7.85 \times 6 = 2.089$

weight of pedestal = $0.25 \times 2.10 \times 1.8 \times 2.5 + 2 \times (\frac{0.25 + 0.75}{2}) \times 1.025 \times 2.10 \times 2.5 = 7.744 Ton$

Total vertical load = 9.833 Ton

Horizontal forces due to temp. changes acting at top of pedestal:-

H = 0.6 x 2.089 = 1.253 T

Taking moments @ Pt. A,

ε M @ A = $9.833 \times \frac{2.3}{2} - 1.253 \times 1.8$

= 9.082 T.M.

e = $\frac{2.3}{2} - \frac{9.082}{9.833} = 0.226 < \frac{b}{6} (\frac{2.3}{6} = 0.3833)$

No tension at the base

Hence O.K.

Factor of Safty against overturning = $\frac{9.833 \times \frac{2.3}{2}}{1.253 \times 1.8}$

= 5.014 > 2.5

Hence O.K.

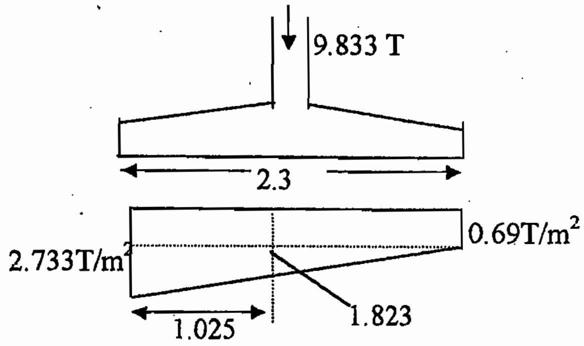
Factor of safty against sliding $= \dfrac{\mu W}{H}$

$$= \frac{0.6\times 9.833}{1.253}$$

$$= 4.709 \quad > \quad 2$$

Hence O.K.

For checking depth of footing



$$\text{Stress} = \frac{P}{bd} \pm \frac{6M}{bd^2}$$

$$= \frac{9.833}{2.3\times 2.5} \pm \frac{6\times 2.255}{2.5\times 2.3^2}$$

$$= 1.710 \pm 1.023$$

$$= 2.733 \text{ or } 0.69$$

BM @ critical section

$$= \left(\frac{1.823+2.733}{2}\right)\times 1.025\times 2.1\times\left(\frac{2\times 2.733+1.823}{2.733+1.823}\right)\times\frac{1.025}{3}$$

$$= 2.68 \text{ T.M.}$$

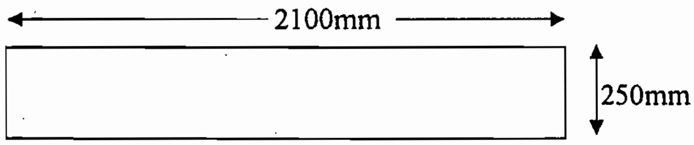
$$d_{reqd} = \sqrt{\frac{2.68\times 10^5}{0.92\times 210}}$$

$$= 37.245 \text{ cm}$$

$d_{prov} = 75 - 5 = 70\text{cm} > 37.245\text{cm}$

Hence OK

Section of pedestal is subjected to combined axial force & B.M.
Assumed section for pedestal (i.e. 2100 x 250 mm) is checked for combined AF & BM
Check for section of pedestal



Nominal Steel = 0.8 % of column area

$$= 0.8 \times \frac{2100}{100} \times 250 = 4200\,mm^2$$

Provide 11 nos. on each side 16mm ϕ

Using M20, Fe 415

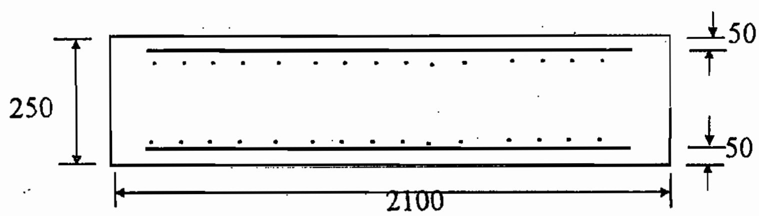
Vertical steel $= \frac{\pi}{4}(1.422^2 - 1.402^2) \times 7.85 \times 6 + 0.25 \times 2.1 \times 1.025 \times 2.5$

= 3.435 T

Horizontal force at top = M x 2.089 = 0.6 x 2.089 = 1.253 T

BM = 1.253 x 1.025 = 1.284 Tm

Asc = 11 nos. 16 ϕ = 2200 mm^2



Compressive stress in extreme fibre of conc.be σ_{cbc} & neutral axis depth from top be 'n'

Compression in concrete:

$$Cc = \frac{\sigma_{cbc}}{2} \times n \times 165$$

Compression in steel:

$$Cs = \frac{n-5}{n} \times \sigma_{cbc} \times (m-1) Asc$$

n-5

$$= \frac{n-5}{n} \times \sigma_{CbC} \times 13 \times 18$$

Tension in steel Tst $= \frac{20-n}{n} \times \sigma_{CbC} \times 14 \times 18$

Vartical load P = Cc+Cst-Tst

$$\therefore P = \sigma_{CbC}[\frac{165n}{2} + 18\{(\frac{n-5}{n}) \times 13 - \frac{(20-n)}{n} \times 14\}]$$

$$= \sigma_{CbC}[82.5n + \frac{18}{n}(13n-65-280+14n)]$$

$$= \sigma_{CbC}[82.5n + \frac{18}{n}(27n-345)] \qquad -1$$

External moment

M = ε moments @ C.g.

$$M = \sigma_{CbC}[\frac{165n}{2} \times (12.5 - \frac{n}{3}) + 18(\frac{(n-5)}{n} \times 13 \times 7.5 + \frac{20-n}{n} \times 14 \times 7.5)]$$

$$= \sigma_{CbC}[82.5n(12.5 - \frac{n}{3}) + \frac{18 \times 7.5}{n}(13n-65+280-14n)]$$

$$= \sigma_{CbC}[82.5n(12.5 - \frac{n}{3}) + \frac{135}{n}(215-n)] \qquad -2$$

$$\frac{M}{P} = \frac{1.284 \times 10^5}{3.435 \times 10^3}$$

$$37.38 \text{ cm} = \frac{82.5n(12.5 - \frac{n}{3}) + \frac{135}{n}(215-n)}{82.5n + \frac{18}{n}(27n-345)}$$

$$3083.843n + 18166.638 - \frac{232129.258}{n} = 1031.25n - 27.5n^2 + \frac{29025}{n} - 135$$

$$3083.843n^2 + 18166.638n - 232129.258 = 1031.25n^2 - 27.5n^3 + 25025 - 135n$$

$$+207.593n^2 + 18301.638n - 257154.258 = 0$$

By trial & error method

n = 7.413

$$\sigma_{CbC} = \frac{3.435 \times 10^3}{82.5 \times 7.413 + \frac{18}{...}(27 \times 7.413 - 345)}$$

$$= 13.219 \text{ kg/cm}^2 < 71.4 \text{ kg/cm}^2$$

(as per IS 456:2000 Table 21)

Hence O.K.

Since stresses are well within limits, section of pedestal provided is sufficient.

4.1 WATER TREATMENT PLANT

4.1.1 Preamble

A water treatment plant of 115 MLD capacity is to be constructed at Godhani. Treated water is to be pumped through 1422 mm x 12 mm m.s. pipeline about 9 km. to existing MBR near Governor House.

Important unit processes in water treatment plant consist of;

- Coagulation
- Flocculation
- Sedimentation
- Filtration
- Disinfection

The design report consists of three parts.

A discussion on unit processes, coagulation, flocculation, sedimentation & filtration in Part 1 and our choice to maximize overall efficiency and to minimize maintenance costs has been indicated for each of these processes.

Part 2 gives design of a conventional water treatment plant. This is generally based on GoI Manual on Water Supply & Treatment 3rd (May 1999) edition.

Part 3 gives a broad sizing of various units on the basis of discussions in Part1.

We are of the opinion that as far as possible we should not go in for any patented processes. A general approach for invitation of tenders is to invite offers (compulsorily) on the basis of a conventional design & to give an option to the tenderers to quote for acceptable alternatives as given in Part 1.

PART 1 : DISCUSSION ON UNIT PROCESSES

4.1.2 Coagulation

Coagulation is defined as the destabilization of charge on colloids and suspended solids, including bacteria & virus by a coagulant.

Flash mixing is an integral part of coagulation & its purpose is to disperse water treatment chemicals quickly and uniformly throughout the process.

When metal coagulants are used, their hydrolysis occurs within a second and subsequent adsorption to colloidal particles is almost immediate. The dispersion of metal coagulants should therefore be completed in a fraction of a second. The ratio of liquid alum volume to raw water volume is 1:50000. Instantaneous dispersal of such a small amount of alum into the raw water is thus a very unique situation.

The items to be evaluated while designing an effective flash mixing system are;

- Type of coagulant
- No. of chemicals to be fed & characteristics of each
- Local conditions
- Raw water characteristics
- Type of chemical diffusers
- Available head loss
- Variations in plant flow rate
- Subsequent process
- Cost

Selection of an appropriate chemical application sequence is vital in case where the raw water does not have sufficient alkalinity. The most reasonable application sequence in this case is first to lower the pH of the raw water through the addition of alum, thus allowing divalent and trivalent aluminium hydro complexes to form; these complexes effectively reduce colloidal charge.

The next step is to adjust the pH of the water to the range of minimum aluminium solubility to allow aluminium hydroxide flocs formation.

The design of the coagulation process is determined by the raw water characteristics. The most common problem associated with the process of coagulation is clogging of the chemical diffuser orifices & feed lines. This is related directly to the hardness of the process water and in part to dissolved & suspended solids. If the water hardness exceeds 30 mg/l, the metal salt & alkali chemical feed lines & the diffuser orifices become clogged within several months. The design of the system has therefore facilitated simple clearing of the feed lines, injection nozzles & orifices.

Water treatment chemicals are fed to the flash mixing system in either of the two forms; solutions or slurry. For both pipe and channel flow applications, the chemical diffuser is often pipe with multiple orifices. If the chemicals are in slurry form, two types of diffuser may be used. For pipe application, open end of the diffuser pipe acts as a diffuser, while channel flow application uses a trough with notches or holes at the bottom.

A head loss of 0.6 m to 0.9 m. is generally required.

The mixing energy of the hydraulic flash mixing must also change in proportion to the plant flow rate. Recent studies in effective flash mixing have shown that values of the producer of mixing energy G (expressed in seconds) and mixing time t (in seconds) should range from approx. 200 to 1600. If the seasonal plant fluctuation flow is too quet to satisfy the proper G x t range, the design must provide two parallel hydraulic flash mixing systems.

Selection of flash mixing system

The order of preference is based on effectiveness, reliability, minimal maintenance & cost.

The order of choice is;

1. Diffusion mixing by pressure jets
2. Inline strata mixing
3. Inline mechanical mixing
4. Hydraulic mixing
5. Mechanical flash mixing
6. Diffusion by pipe grid

Diffusion mixing by pressured water jets

The advantage of this type of system is that there is essentially no additional head loss by the mixer. It is very effective. It has a controllable degree of mixing and the power consumption is less than half that of a mechanical mixer system. It is cost effective.

The source of pressured water is settled / filtered water at a pressure of minimum 0.3 kg/ cm^2.

The disadvantage of this alternative is the potential for coagulant and debris present in pumped water to clog the nozzles. A second disadvantage is difficulty of applying it to a system with extra large pipes or channels.

In general, alum solutions should not be diluted beyond one percent.

Inline Stratic Mixers

The advantage of these mixers are their lack of moving parts & that they do not require external energy to be input into the system.

The disadvantages:

- The degree of mixing & the mixing time are a function of flow rate.
- The units are proprietory items & the designer has to rely on the performance claims of the manufacturer. A mixing time 1 to 3 seconds

and a maximum head loss of 0.6 to 0.9 m are normally acceptable to water treatment. The plant design should have an intake screen upstream of static mixer so that large debris will not obstruct the static mixer.

Hydraulic Mixing

Parshall flumes, venture metals and weirs are categorized as hydraulic mixing devices.

When raw water flows into a plant, flow can be metered by either a Parshall or Palmes. Bowles flume since they provide hydraulic jumps & large scale turbulence.

The draw back to these procedure is that the degree of turbulence is a function of plant flow rate & there is no positive control over the degree of mixing.

Mechanical Flash Mixing

The mechanical flash mixer consists of a tank or channel with one or more mechanical mixers. The common design parameters are; G=300 S^{-1}, a mixing time of 10 to 30 seconds & power requirements of 0.85 to 1 HP per 3.84 x 10^6 litres per day.

Recent studies indicate that this type of rapid mixing is not preferred for use in a continuous flow process because of;

- The lack of instantaneous mixing characteristics
- The production of significant flow short circuiting.
- A mixing period that is too long for metal salt coagulants
- Back mixing which may adversely affect coagulation.

Further, there is a same difficulty in analysizing the various forces acting on the mixer shaft and impeller resulting in shaft problems and gear drive failures in many large installations.

Diffusion by Pipe Grid

This type of flash mixer depends on the water turbulence created by pipe grids: Coagulants are added to the flow stream through injection orifices in the grid. A majority of actual installations employing pipe grid diffusers have experienced problems with scale clogging of the orifices after several months of plant operation.

Our recommendations are to adopt pump diffusion as the flash mixer.

4.1.3 Flocculation

Flocculation is the gentle mixing phase that follows the rapid dispersion of coagulant by the flash mixing unit. Its purpose is to accelerate the rate of particle collisions causing the agglomeration of electrolytically destabilized colloidal particles into settleable & filterable sizes.

The factors that are taken into consideration in designing flocculation process are;

- Raw water quality and flocculation characteristics
- Treatment process & finished water quality goals
- Available head loss & plant flow variations
- Choice of flocculation tank inlets
- Local conditions
- Cost

Raw water quality & flocculation characteristics

The seven important water quality aspects are: turbidity, total organic compounds, pH, alkalinity, colour, algae counts & temperature.

Flocculation characteristics can be evaluated by the Jar test.

Treatment process & finished water quality goads

The finished water quality goals influence the degree of flocculation.

Allowable head loss & plant flow variations

If the allowable head loss is limited, hydraulic flocculation methods are ruled out. If the fluctuation is in the order of 50 percent variation from the daily average flow rate, hydraulic flocculation will perform effectively.

Choice of flocculation tank inlets

Most of the proprietory reactor-clarifiers are designed with a single pipe inlet into the flocculation zone.

There are two basic choices when designing the tank inlet: a series of identical individual weirs set at the same elevation or a series of submerged orifices each fitted with an isolation valve or gate.

The weir inlet has four basic problems associated with it;

- The inlet channel must be large enough to maintain nearly equal water surface elevation for the entire length of the channel.
- Heavy suspended solids accumulate in the channel due to the large size & low flow velocity in the channel.
- Each tank is often isolated by means of stop logs which are not leak tight & create extra work for plant operations.
  If down-opening slide gates are used the down-opening slides do not reliably reset at exactly the same elevation after they are raised for isolation.
- Slight changes in water depth in the channel result in significant changes in flow over the weir whenever they are set at the same elevation.

Submerged orifices has two drawbacks;

- Slightly higher capital cost
- Slightly more loss of head

This design has four advantages over weir inlet;

- The flow rate is not significantly affected by slight changes in one end of the influent channel to the other.
- The size of the influent channel may be much smaller and a flow velocity of 0.6 to 0.9 m/s. may be allowed.
- There is minimum deposition of suspended solids in the influent channel due to higher flow velocity & the flow exists near the bottom of the channel.
- The isolation valves provide virtually drop tight closure.

Alternatives

The typical categories of mixing systems are;

1. Mechanical mixing

   - Vertical shaft with turbine or propeller blades
   - Paddle type with horizontal / vertical shafts
   - Proprietory units

2. Baffled channel basins

   - Horizontally baffled channels
   - Vertically baffled channels

3. Reactor clarifier proprietory systems

4. Contact flocculation (gravel-packaged filter)

5. Diffused air or water jet agitator

Order of preference

1. Vertical-shaft flocculators in either direct flow horizontal tanks with compartmentalization in each flocculation stage or a serpentine flow path.

2. Paddle flocculators in horizontal flow tanks with proper compartmentalization in each stage.

3. A combination of baffled channel (heli coidal flow) in serpentine flow path with flocculators in the last stage of flocculation process.

4. Baffled channel flocculation process (around the end type) provided that the mixing criteria G x t exceeds 3 x 10^4 during the low plant flow period.

Mechanical Mixing Systems

The mixer should have following characteristics:

- It must deliver the G values specified for each stage of flocculation.
- It must provide sufficient eddies and turbulence so that required velocity gradients are produced.
- It must provide low sheer forces at the edges of the mixing blades, especially during the last two stages of flocculation.
- It should have low maintenance & operation costs.

Regardless of the type of flocculator, tapered mixing across the flocculating tank is always an important consideration. The last stage of flocculation requires a delicate and gentle mixing condition to promote the growth of flow size. For this reason, an infinitely variable control unit (frequency control) is specified for the final stage flocculation. The first & second stages do not require frequent changes in speed & a two speed control mixer may be used.

Vertical-shaft flocculation tanks contain a large number of mixer units. Failure of one or two of the flocculator drive units does not significantly effect the overall efficiency of the system.

The horizontal-shaft paddle flocculators generally have only one drive unit for several paddles; failure of one drive will terminate the movement of several flocculator paddles.

The vertical shaft flocculators are the first choice for the following reasons:

- Minimal maintenance
- Operational flexibility
- Low head loss across the tank
- Easy control of mixing intensity
- Effectiveness
- Minimal impact to the overall performance if one unit malfunctions.

The drive units should have hydrofoil mixing blades & all the shaft bearings should be located above the water surface of the basin.

Baffled Channel Basins

When designed properly, both the horizontal baffled (around-the-end flow) and the vertically baffled (cover & underflow) channels perform well & exhibit plug flow characteristics. There is significant head loss 0.6 to 1 m. across the tank and the mixing intensity is a function of plant flow rate. In general good flocculation occurs when G x t ranges from 3×10^4 to 2×10^5.

Baffled channels & flocculators combination system

This concept combines the best features of both systems. It offers a large reduction in mechanical flocculator units so that there is saving in capital & maintenance costs & increased reliability. The flocculator units are located in the final stage of flocculation process.

Contact Flocculation

The advantage of contact flocculation is its compact size & lack of moving parts. Hydraulic loadings 25 to 33.5 m/h are possible & the system requires an empty bed contact time of 3 to 5 minutes to produce a floc with the proper characteristics. This type of flocculation requires minimal variations in flow rate and water temperature for adequate mixing intensity. Contact flocculation also requires frequent backwashing with air scours.

Diffused Air or Water Jet Agitation

The diffused air system is characterized by a high rate of energy consumption & is also an inefficient flocculation, process use of water jet mixing system is not recommended for flocculation because of the high sheering force on the jet path restricts the growth of floc size.

Our recommendations

Mechanical mixing – Vertical shaft with hydrofoil mixing blade system.

4.1.4 Sedimentation

Sedimentation (clarification) is broadly defined as the separation of a suspension into a clarified fluid and a more concentrated suspension. The sedimentation process is designed to remove a majority of settleable solids by gravitational settling thereby maximizing the downstream unit processes such as filtration.

The sedimentation process is divided into two classifications: grit chamber (plain sedimentation) and sedimentation tanks (clarifiers).

Important considerations that directly affect the design of the sedimentation process are;

- Overall treatment process
- Nature of suspended matter within the raw water
- Settling velocity of particles to be removed
- Local climatic conditions
- Raw water characteristics
- Geological characteristics of the plant site
- Variations in the plant flow rate
- Occurrence of flow short circuiting within the tank
- Type & overall configuration of the sedimentation tank
- Design of inlet & outlet
- Type & selection of high rate settling modules
- Method of sludge removal
- Cost
- Shape of the tank

High Rate Settling Modules

The term high rate settler refers to any small inclined tubes or tilted parallel plates which permit gravitational settling of suspended particles within the modules. The detention time in the settling modules ranges from 5 to 20 minutes depending on the type of module & the surface loading rate. Surface loading, calculated from the area of the basin covered by the settling module is generally 5 to 8.8 m/h. The settling efficiency of modules with such high hydraulic loading valves is equivalent to a conventional sedimentation basin with a designed detention time of 3 to 4 h and a surface loading of 1.3 m/h.

Although the high rate settlers are designed to deliver a certain level of performance, they do not always function according to their specifications. The reasons are;

- Poor flocculation
- Uneven flow distribution to the inlet of the settler module
- Heavy algal growth in the modules
- Heavy scale ($CaCo_3$) deposits on the module.

In parallel-plate settling modules, water enters either horizontally and parallel to the parallel to the plate or upward along the 60° tilted plates. In the tube settlers, the direction of flow is always upward at 60° to the horizontal plane.

Under the normal circumstances, the settled floc slides down the inclined plates or tubes to the tank bottom for subsequent mechanical sludge removal.

The design of the high rate settler modules must address the following issues;

- Settling velocity and characteristics of the suspended matter
- Flow velocity within the module
- Selection of appropriate sludge collection unit
- Spacing of launder when installed above the settling module
- The support system

Depending on the surface area of the tank that is covered by the settler modules, the maximum surface loading is limited to 7.5 to 8.8 m/h for warm to hot regions.

The preferred material is thin steel plates because of the structural strength and non-corrosive nature with a smooth surface to minimize the adherence of floc & algal growth.

In the tube settler modules an average flow velocity of 0.15 to 0.2 m/ min. is normally used in settling most alum floc. An approach flow velocity of 0.6 m/min. should be used in the tank upstream of the module installation.

The Reynolds & Froude numbers are not considered to be part of the design criteria, yet they act as good guides in designing the high rate settlers. The Reynolds number for the settler should be below 200, preferably around 50 and the Froude number should be greater than 10^{-6}.

Sludge removal Method

The three continuous sludge removal systems that have been proven and widely used are;

- The centre-pivoted rakes
- The chain & flight collector
- The travelling bridge

High rate settlers can be effective if they are properly designed & installed.

Upflow & Reactor Clarifiers

The upflow & reactor clarifiers are proprietory units that have their basic size & blue prints pre established by the equipment manufacturers based on the flow rates.

The units are grouped in three categories;

- Simple upflow clarifiers
- Reactor clarifiers
- Sludge blanket reactor clarifiers

The upflow & reactor clarifiers offer several advantages over the conventional basins

- Compact design & economical use
- Simpler sludge removal
- Efficient clarification due to the seeding effect achieved through recirculation of the floc & adsorption of the floc by the sludge blanket as long as the flow rate & raw water quality are constant.
- Better clarification efficiency due to improved flocculation and adsorption effect by the sludge blanket.
- Capability of delaying degradation of the effluent water quality, in case of improper coagulant dosage or even a short interruption of coagulant feed due to the buffering effect of the sludge blanket zone.

The disadvantages are;

- Stringent operational control is required
- There is a rapid loss of efficiency during hydraulic & solids overloading & hydraulic shock loading
- Frequent temperature fluctuations induce distinct flow short circuiting
- If the unit is not equipped with positive raking mechanism, it is difficult to remove sludge during periods of high turbidity
- More time is required to produce the sludge blanket whenever the sludge blanket is drained
- A significant amount of metal is used on the interior of these tanks posing problems of maintenance & corrosion.

A summary of selection guide of proprietory clarifiers is given below;

Sl.	Type of Unit	Advantages	Disadvantages
1.	Detritus tank	Low capital cost	Flow short circuiting, potential clogging of grit removal pipe, corrosion of raking system.

Sl.	Type of Unit	Advantages	Disadvantages
2.	Control feed & peripheral collection	Low capital cost, easy sludge removal	Flow short circuiting, limitations on practical size of the unit, less tolerant of shock loading.
3.	Peripheral feed & peripheral collection	Good performance for raw water with a high suspension of solids	Potential for flow short circuiting, performance relies on manufacturer's design, limitations on practical size of the unit.
4.	Reactor clarifier with high recirculation & mechanical sludge plow	Compact & economical tolerant of shock loading, good clarification due to a seeding effect.	Corrosion of under water metal parts, less reliable due to its dependency on one drive unit, requires extensive yard piping to connect each unit, practical size limitations.
5.	Reactor clarifier with sludge blanket zone & mechanical sludge plow	Good lime softening & turbidity removal, compact & economical design	Very sensitive to shock loading, requires 2 to 4 days to buildup the necessary sludge blanket, requires greater operational skills, corrosion of under water metal parts.
6.	Reactor clarifier with hydraulic flocculation & sludge removal	Good performance under proper conditions, no maintenance of mechanical equipment	Sludge will choke the unit if heavy solids are present in the raw water, no operator control over the flocculation process, process function will terminate if the water dosing system fails, patented.

Order of Preference

The order of preference among the various types of plain sedimentation tanks is

(1) A long rectangular tank
(2) A rectangular tank containing high rate settler modules
(3) Proprietory units

The order of preference among the clarifiers is;

(1) A long rectangular tank
(2) A rectangular tank containing high rate settler modules
(3) A reactor clarifier

The use of reactor clarifiers should be considered & evaluated if;

- The plant flow rate & raw water quality are relatively constant
- The raw water quality is relatively constant, particularly with no sudden changes in water temperature
- The raw water turbidity is always between 5 & 200 NTU.
- There are time constraints on design, construction & budget
- The owners prefer their use.

4.1.5 Granular Medium Filtration

The most common filtration process employs a granular medium of a certain size and depth. The pretreated water passes through the filter bed, where a majority of the particulates are removed in the top portion, as well as throughout the entire depth of the bed.

Factors that are taken into consideration in designing a granular medium filtration process are;

- Local conditions
- Design guidelines set by regulatory agencies
- Site topography
- Plant size
- Raw water quality
- Type of pretreatment process
- New & proven types of filter
- Provision for future modification or addition of filters
- Type of filter wash system
- Control of filtration rate
- Type of filter bed
- Chemical application points

Local Conditions

Availability of qualified technicians and raw materials, the local climate, the soil & geotechnical characteristics of the plant site affect the design of the granular medium filtration process.

Guidelines set by the regulatory agencies include maximum filtration rate, continuous monitoring of filters effluent, turbidity, wash water requirements and the types of filters that can be employed.

Site Topography

The site topography determines the location, type & arrangement of each unit in the-filtration process. Topography also dictates the type of backwash facility that may be used.

Plant Size

Plant size dictates the number of filters, the size of each filter, the degree of instrumentation of the filter control system & the method by which the filtration rate is controlled.

The total number of filters may be limited if either the size of each filter is increased upto a practical limit of 100 m^2 or if a high filtration rate such as 20 m/h is adopted or if both methods are implemented.

Raw Water Quality & the Type of Pretreatment

The presence or lack of a high concentration of suspended solids in the raw water requires special consideration when selecting the type of filter bed. Filtration of algae-laden water is very difficult even after flocculation and sedimentation due to rapid clogging of the filters by algae. Use of a coarse deep bed or reverse graded filter bed is evaluated under such circumstances. Conversely, a common monosand bed may be considered when the filter influent is very good, the result of a conservatively designed pretreatment process.

The filters are subjected to many different conditions that cannot be duplicated in either a laboratory or a piloting facility.

Filter Washing System

These are four basic systems in filter washing;

- Elevated wash tank
- Direct pump
- Self back wash
- Continuous backwash

The first two systems are the traditional and proven filter washing systems. The self backwash / continuous backwash filters are proprietory items.

Basic alternatives of the wash system are backwash alone, a combination of surface & backwash, ordinary air scour wash & simultaneous air & water wash. Backwash alone cannot adequately maintain clean filters bed conditions unless coagulation & flocculation are achieved with a minute amount of alum without polymers. Rapid sand filters, ordinary dual media beds are cleared effectively by backwash supplemented by surface wash. Coarse deep bed filters are more suited to ordinary air scour wash or simultaneous air & water wash.

Filtration Rate Control

There are basically two modes of filtration; constant rate filtration & declining rate filtration. Both are capable of producing filtrates with less than 0.1 NTU turbidity.

Four basic types of rate-control systems give consistent & reliable performance;

- Constant rate filtration with a flow meter & flow modulation value
- Constant level filtration with equal flow splitting inlet weirs, a water level sensor and a flow modulator valve.
- Declining rate filtration with a submerged inlet & flow restriction in each effluent pipe that may / may not be fitted with a weir to control the effluent level.
- Constant rate filtration with equal flow splitting weirs and a weir to control the common effluent level.

The first has the highest maintenance cost & requires frequent operator attention. The filtration mode changes from constant rate filtration to declining rate filtration when the control system fails.

The declining rate filtration system is very simple to design & build and generally produces good quality water. However, this mode of filtration requires vigilant plant operators because water level in the filter cells tends to fluctuate widely & creates potential for partial drainage, overflow & potential turbidity break through at the beginning of the filtration cycles.

One operational problem associated with declining rate filters is that there are no clear parameters for filter washing; the head loss for all the filters on-line is nearly equal. There is no flow metering device to indicate the filtration rate of each filter and the turbidity of the filtered water does not increase with time. Thus operators usually wash the filters based on the length of the filter run.

The fonron system is capable of backwashing a filter by using the effluent from the rest of the filters online. These are commonly referred to as salt backwash filters. The major draw backs of the self backwash filters are the limited flexibility on adjusting the backwash rate, the lack of filter to waste capacity. The deeper filter cells (at least 1.2 m deeper than normal filter design). The plus points : the lock of a flow modulation valve, the simple opening & closing of the inlet & waste wash valve to initiate filter washing. The ability to function without the system of backwash pumps, tanks & wash lines & easy determination of head loss through the filter. Since the water depth increases with the duration of the filtration, the problem of air building is minimized. The self backwash system is particularly suited on situations where the raw water is saturated with air entrained in the water.

Type of Filter Bed

Sand and gravel are the primary filter materials. Sand & combination of sand & anthracite coal are the two basic & proven alternatives with reference to ordinary water purification.

The direct & inline filtrations require filter beds with large floc holding capacity. A reverse graded filter bed such as dual media or coarse deep bed satisfies this requirement.

Rapid sand filters with rate of filtration 5 to 7.5 m/h usually have medium sized sand 0.5 mm e.s. High rate filters with filtration rates of 12.5 to 25 m/h always consist of a reverse graded filter bed or a deep large-grain monomedium bed.

Chemical Application Points

Disinfectants, filter aids, adsorbents for taste & odour control and alkali chemicals for pH control are the most common chemicals added to the filter influent.

It is necessary to minimize the number of chemical application points, recognize that certain chemicals have the potential to 'break through' into the filtered water, and ensure that the chemicals are adequately distributed in the water.

High rate filtration often employs a polymer as filtration aids. Polymer and chlorine are fed to the filter influent to promote filter efficiency & keep the filter bed clean. Where there are several passages between the settled water channel & the filters, it is necessary to distribute the chemicals to several application points with the use of additional chemical feeders & flow-splitting equipment.

The potential break through of the added chemical into the filtered water degrades the quality of filtered water. Some treatment plants routinely add alkali chemicals such as lime or sodium hydroxide to the filter influent to raise the pH to 8 & above, following flocculation with alum & sedimentation. This practice produces a high aluminium concentration in the finished water due to the pH & basic characteristic of aluminium hydroxide.

Adequate mixing of chemicals at the application point can be ensured by using an appropriate type of diffuser pipe in conjunction with a baffled channel or an inline static mixer.

Potential feeding points are: the filter influent, the filter effluent and the backwash line.

Chemicals that may be fed into the influent are chlorine / polymers / PAC chlorine, alkali chemicals, corrosion inhibitors should ideally be applied after filtration. The chemicals that may be fed to the backwash water to disinfect & condition the filter bed are chlorine & polymers.

Miscellaneous Items

These are; use of wash troughs, the amount of allowable head loss for filtration and the type of filter under drain, type of filter & waste-wash water handling facility.

Gravity filters generally have available head loss of 2.5 to 3 m. Proprietory, valve less or monovalve packaged filters do not provide more than 1.8 m of available head loss. Automatic backwash provide a maximum of 0.3 m. available head loss.

Regardless of the type of filter 2 to 3% of the plant flow rate is waste flow.

Type & Selection

Filters can be grouped as;

- Gravity filters: slow sand, rapid sand and high rate filers containing multimedia or a coarse deep medium bed.
- Pressure filters: proprietory items such as the horizontal single cell, vertical single cell, vertical bi-flow filters.
- Automatic backwash filters: exclusively proprietory items.
- Custom designed to include standard rapid sand filters, multi media high rate filters, coarse deep bed high rate filters, self backwash gravity filters, constant rate gravity filter, declining rate gravity filters, GAC adsorption filters & ion exchange resin filters.

Our Recommendations:

Rapid sand filters with a design filtration rate of 7.5 m/h.

Designed head loss 2.4 to 3 m.

The effluent turbidity of gravity filters begins to increase when the net head loss is over 1.8 m. Consequently the filters must be backwashed, despite the available head loss of 2.4 m. or more, if the turbidity of filtrate is to be maintained at less than 0.25 NTU.

Filter washing to be initiated by any of the following : turbidity break through, filter run time or terminal head loss.

Since constant rate filtration system provides better operational control over the filters, has proven performance & is preferred by the plant operators. We will propose the same.

We will propose sequential air-scouring wash. The wash begins with 0.9 m/min. of air scouring without backwash for 2 to 5 minutes followed by backwash 10-15 minutes at 20 to 30 m/h.

PART 2 : DESIGN OF 115 MLD CONVENTIONAL WATER TREATMENT PLANT

4.1.6 Units in WTP

(i) Aerator
(ii) Parshall Flume
(iii) Distribution Chamber
(iv) Flash Mixer
(v) Clariflocculator
(vi) Rapid Sand Filters
(vii) Chlorination

4.1.7 Cascade Aerator

a) Inlet Shaft

Water velocity in the inlet shaft is assumed to be 1.0 m/sec

Design flow = 1.2 x 115

= 5750 m^3/h

= 1.597 m^3 / Sec

$\therefore$ Area of the shaft = $\frac{1.597}{0.75} = 2.1296\ m^2$

$\therefore$ Dia of the shaft = $\sqrt{\frac{4 \times 2.1296}{\pi}} = 1.65$ m

= Say 1.7 m

$\therefore$ The shaft has bell mouth with 1.9 m diameter

(b) Size & number of shaft

Assume 0.03 $m^2 / m^3 / h$ as area requirement for cascade aerator.

$\therefore$ Area of cascade = 0.03 b x 4791.7

= 143.751 m^2

If Dc is Dia of cascade , then

$$143.751 = \frac{\pi}{4}\left[Dc^2 - (1.9)^2\right]$$

$\therefore$ Dc = 13.662 m

Assume number of steps = 5 Nos.

Size of tread = $\frac{13.662 - 1.9}{5 \times 2}$ = 1.176 m Say 1.2 m

$\therefore$ Actual size of aerator = 1.2 x 10 + 1.9 = 13.9 m

Assume height of each step = 0.3 m

Amount of total rise of steps = 0.3 x 5 = 1.5 m

(c) Size of collecting launder

The collecting peripheral launder is designed for 20 % overload

$\therefore$ Flow of launder = $\frac{Q}{2} = \frac{1.2 \times 115}{2} = 69$ MLD

= 0.7986 m^3 / Sec

Assume velocity in the launder is 0.8 m / Sec.

$\therefore$ Area of launder = $\frac{0.7986}{0.8} = 0.9982\ m^2$

Provide width of launder = 1.5 m

$\therefore$ Height of launder = 0.6655

Provide 0.3 m as free board

$\therefore$ Depth of launder = 0.6655 + 0.3 = 0.9655 m say 1 m

$\therefore$ Size of launder = 1.5 m x 1.0 m height

4.1.8 Parshall flume

The dimension of the Parshall flume is taken as

W	=	300 mm	F	=	600 mm
A	=	1350 mm	G	=	900 mm
B	=	1322 mm	K	=	75 mm
C	=	600 mm	Z	=	225 mm
D	=	831 mm			

Depth of water u/s of hydraulic jump is

$$Q = 2.42\ W(hu)^{2.58}$$

Where Q = Discharge over 20 % load

W = 0.30 m

h_V = Depth of water @ u/s of hydraulic jump

$$\therefore \quad 1.3310*1.2 = 2.42 \times 0.30 \times h_U^{2.58}$$

$$h_U = \left(\frac{1.3310*1.2}{2.42\times0.30}\right)^{\frac{1}{2.58}} = 1.357$$

$$\approx 1.36\text{m}$$

Assume depth of water, hd, down stream of hydraulic jump as 0.6 h_U

$$\therefore \quad h_d = 0.6 \times 1.36 = 0.816 \text{ m}$$

4.1.9 Channel : Upstream of parshal flume

Length of channel = 5 m (Assumed)

Depth of water upstream of flume is

$h_U + Z = 1.36 + 0.225$ = 1.585 m

If velocity of flow is 0.8 m /sec

Then Q = V[h x b] = 0.8 [1.585 x b]

1.597 = 0.8 [1.675 x b]

b = 1.26 m

4.1.10 Channel downstream of parshal flume to distribution chamber

Assume length of channel = 5.0 m

Depth of water in D/s = 0.816 m

Velocity in the channel = 1 m / sec

$\therefore$ Q = 1.0 (0.816 x b)

$= \dfrac{1.597}{1.0 \times 0.816} = 1.957$ m

Say 2.0 m

4.1.11 Distribution chamber

The unit is to be provided d/s of parshall flume will be minimum 4, hence a distribution chamber to divide the flow equally.

Assume 10 sec. Detention time, the volume of the chamber

= 1.3308 x 10 = 13.308 m^3

Assume depth of water = 1.0 m

$\therefore$ Area of the chamber = 13.308 m^3

Assume L/B = 1.5

$\therefore$ B = 3.0m

L = 4.5 m

$\therefore$ Size of the tank = 4.5 m x 3.0 m x 1.0 m

4.1.12 Channel b/t distribution chamber & flash mixer

2 units of flash mixers & clariflocculators are proposed,

Hence, flow will be divided in 2 parts

$\therefore$ Flow through each channel = 57500*1.2 / 2*3600*24 = 0.7986 m^3/Sec

Assume velocity in the channel = 1.5 m / sec

$\therefore$ Area of the channel = 0.7986/1.5 m^2

Assume width of channel = 0.6 m

$\therefore$ Depth of flow in channel = $\dfrac{0.7986/1.5}{0.5} = 0.887$ m

4.1.13 Flash mixer

There will be two flash mixers each consisting of three parts.

a. Inlet Chamber

b. Flash Mixer Chamber

c. Outlet Chamber

a) Size of Chamber

Flow per each unit	=	57.5 MLD
	=	0.6655 m^3 / Sec
Assume Detention time	=	60 Sec
∴ Volume of flash mixer	=	0.6655 x 60
	=	39.93 m^3
Adopt depth to dia ratio	=	as 1.5 i.e. (between 1 to 3)

$$\therefore \frac{\pi}{4} d^2 \times 1.5d = 39.93 \text{ m}$$

$$d = 3.24 \text{ m}$$

Depth of water = 3.24 x 1.5 = 4.86 m

b) Inlet and Outlet Chambers

They shall be of size 1.0 x 1.0 m. The depth of inlet chamber will be same as that Flash mixer as 4.86 m water depth. The openings in the inlet chamber will be @ the bottom while the depth of the outlet chamber will be upto the outlet pipe joining the flash mixer on the central shaft of the clariflocculator.

c) Power requirement

$$G = \sqrt{\frac{P}{\mu}(VOL)}$$

G = Gradient = 300 Sec^{-1} for DT of 60 Sec

P = Total / Power Input (watts)

μ = Viscosity (Kg / m /sec) = 0.89 x 10^{-3} Kg/m/sec

V = Volume of flash mixer (m^3)

$$\therefore 300 = \sqrt{\frac{P}{0.89 \times 10^{-3} \times 39.93}}$$

= 3198.4 = 3.198 Kw ≈ 3.20 Kw

d) **Outlet pipe**

Let the velocity in the outlet pipe be 1.5 m / sec

$$\therefore \quad 0.6655 \times 1.2 = 1.5 \times \frac{\pi}{4} \times d^2$$

$$d = 0.823 \text{ m} \approx 0.85 \text{ m}$$

4.1.14 Clariflocculator

No. of Units = 2 Nos.

a) **Central Shaft**

Let the velocity of water in the central shaft of each unit is 1.2 m /sec

$$\therefore \text{Dia. of Shaft} = \left[\frac{4Q}{V.\pi}\right]^{\frac{1}{2}} = \left[\frac{4 \times 0.7986}{1.2 \times \pi}\right]$$

$$= 0.921 \approx 1.0 \text{ m}$$

Assume outside Dia of pipe = 1200 mm (Assumed)

Ports for water outlet have to be provided at the top partion of the shaft.

Assume velocity through parts= 1.0 m/sec

$$\text{Total area of opening of parts} = \frac{0.7986}{1.0} = 0.7986 \text{m}^2$$

Provide 3 rows of 8 parts of total 24

$\therefore$ Area of each part = $\frac{0.7986}{24} = 0.0333 \text{m}^2$

$\therefore$ Size of each part = 0.222m x 0.15 m height

$\therefore$ c/c distance of parts = $\frac{\pi}{d} = \frac{1.2 \times \pi}{8} \approx 0.47 \text{m c/c}$

b) **Flocculator**

(i) **Design Parameters**

Detention time = 30 min

Velocity gradient = 40 Sec $^{-1}$

Side water depth = 4 m

Paddle Tip velocity = 0.4 m / Sec

Water velocity @ paddle Tip = 0.1 m / Sec

Water temp = 25 ^{0} C

(ii) Design calculations

Volume of flocculator= 0.6655 x 30 x 60

= 1197.9 m^3

The outer Dia. of Centre Shaft = 1200 m (Assumed)

$$\therefore \text{ Area of flocculator} = \frac{1197.9}{4} = 299.475 \text{ m}^2$$

If D_f is the Dia. of flocculator, then

$$299.475 = \frac{pi}{4}[Dp^2 - 1.08^2]$$

$$D_f = 19.56 \approx 19.57 \text{ m}$$

$$\therefore \text{Power requirement } P = G^2\mu$$

$$= 40^2 \times 0.89 \times 10^{-3} \times 1197.9$$

$$= 1705.81 \text{ W}$$

$$= 1.706 \text{ Kw}$$

$$\text{Also } P = \frac{C_D . A_p . \rho(V-u)^3}{2}$$

$$1706 = \frac{1.8 \times Ap \times 997(0.4-0.1)^3}{2}$$

$$\therefore A_P = 70.42 \text{ m}^2$$

If there are 4 drive units, then the area of blades per unit.

$$= \frac{70.42}{4} = 17.60 \text{m}^2$$

If there are 4 blades per drive unit and height of each blade is 3 m (Assumed)

Then width of each blade = $\frac{17.60}{3 \times 4}$ = 1.46 m

There are 4 blades per arm and 4 arms per drive unit then total number of blades for 4 drive units will be 64

$\therefore$ Area of each blade = 3 x 1.46 = 4.38 m^2

Velocity of blade edge, V = $\frac{2 \pi r n}{60}$

The placing of four blades on each of 4 arms supported by each shaft will be such that the edge of the blades will be @ 4, 3, 2 and 1m from centre of shaft.

$$\therefore 0.4 = \frac{2 \times \pi \times 2 \times n}{60} = 2 \text{ rpm}$$

c) **Clarifier**

i. **Design Data**

Detention time = 2.5 h

Surface overflow rate = 36 $m^3/m^2/day$

Weir loading = 300 $m^3/m/day$

Size water depth = 3.0 m

ii. **Design Details**

Volume of tank = 2395.84 x 2.5

= 5989.58 m^3

Area of clarifier = $\frac{5989.58}{3}$ = 1996.5 m^2

If Dc is the Dia of clarifier and 0.2 m thickness of the partition wall b/t the flocculator.

$= 19.57 + 0.4 = \quad 19.97\ \text{m}$

$$\therefore \quad 1996.5 = \frac{\pi}{4}\left(Dc^2 - (19.97)^2\right)$$

$$Dc = 54.23\ \text{m} \approx 54.23\ \text{m}$$

Check the surface overflow rate= $\dfrac{57500}{1996.5}$

$= 28.8\ \text{m}^3/\text{m}^2/\text{day} < 30\ \text{m}^3/\text{m}^2/\text{day}$

Hence O.K

Check for weir loading for 20% overload:

$$W.L. = \frac{57500 \times 1.2}{\pi \times 54.23} = 434.06 > 300\ \text{m}^3/\text{m}/\text{day}$$

$\therefore$ Additional length of weir required.

$$= \frac{57500 \times 1.2}{300} - (\pi \times 54.23) = 230 - 170.37$$

$= \quad 59.63$

$\therefore$ Provide weir protection of size 1.0 m (width) x (1.5 m length), 20 in number, giving additional weir length of

3 x 20 = 60 m

$>$ 59.63 m, Hence O.K.

For uniform weir loading, provide 90^0 - V - notches @ the periphery of the launder.

iii. Design of V-notches

$$q = \frac{8}{15}(C_d)\sqrt{2g}\left(\text{Tan}\frac{\theta}{2}\right)h^{\frac{5}{2}}$$

Where q = Flow on each notch, (m^3 / s)

h = Depth of flow over notch (m)

C_d = 0.6

θ = V notch angle

$$g = 9.81\ (m/s^2)$$

For 90 ^{0} V notch, the above equation reduces to

$$\therefore \quad q = 1.417\, h^{5/2}$$

If the total depth of the V notch is 10 cm and water head is 8 cm then

$$q = 1.417\,(0.08)^{5/2}$$

$$= 2.565 \times 10^{-3}\ m^3/s$$

$\therefore$ Flow on each weir = $0.705\ m^3/$ Sec.

Total number of V notches

$$\frac{Q}{q} = \frac{0.6655 \times 1.2}{2.565 \times 10^{-3}}$$

$$= 311.34$$

and their spacing will be

$$= (0.6)\left[\frac{\pi(0.08)^2}{4}\right] \times \sqrt{2 \times 9.81 \times 0.04}$$

$$= 0.738\ m\ c/c$$

But to achieve more uniform flow over the weir, provide v notches at 0.3 m c/c

(Fig. 23.7 b)

$$\therefore \text{No. of V Notches} = \frac{(54.23 \times \pi) + 60}{0.3}$$

$$= 768$$

(iv) Design of Orifices

(Note: Orifices in place of V notches could be recommended provided actual weir length, π Dc, is equal to or greater than the theoretical weir length, hence in the present case it can not be recommended, but it is mentioned here for the design purpose)

Provide diameter of the orifices as 8 cm

$$\therefore \quad q = Cd(a)\sqrt{2gh}$$

Where, C_d = 0.6

a = area of orifice

In the worst case water level in the clarifier will be at the orifice top level,

Thus,

h = head over orifice

= 4 cm

$$q = \frac{54.23 \times 20}{312}$$

= $0.6 \times (5.027 \times 10^{-3}) \times 0.886$

= $2.672 \times 10^{-3}\ m^3/s$

$\therefore$ No. of orifice $= \frac{Q}{q}$

$$= \frac{0.6655 \times 1.2}{2.672 \times 10^{-3}}$$

= 299

But to achieve more uniform flow among the weir, provide orifices at 0.3 in c/c

(Fig.23.7c)

d) **Peripheral Launder**

Let the velocity of flow in the launder be 0.6 m/sec. and width of launder be 0.8 m

$$\therefore \quad \frac{0.6655 \times 1.2}{2} = 0.6[0.8 \times h]$$

h (SWD) = depth of water in the launder

= 0.832

Provide 0.3 m as free board

(Note: If velocity of water in channel is not mentioned, then the channel can be designed ith flate bottom, S = 0 and free fall, in which case equation Q = $1.375\ bh_0^{3/2}$ can be used)

4.1.15 Rapid Gravity Filters

Data:

Flow	=	115 MLD
Rate of filtration	=	5 $m^3/m^2/h$
No. of Beds	=	10 Nos.

Design Details:

	Flow per bed	=	11.5 MLD
		=	479.17 m^3/h
		=	0.133 m^3/Sec
∴	Area of the bed	=	$\frac{479.17}{5} = 95.834\ m^2$
	Provide size of bed	=	11 x 8.8 m^2
	Ratio L/W	=	10.5 / 8 m^2
		=	1.25 m

This is in range of 1.11 to 1.66, Hence O.K.

(a) Sand

Provide depth of sand as 75 cm, it's effective size 0.5 mm and uniformity Coefficient 1.5

∴	d^{10} size	=	0.50 mm
	d^{60} size	=	0.75 mm

(b) Gravel

Depth of Gravel	=	0.45 m
Size of Gravel @ top	=	2 to 5 mm
Size of Gravel @ bottom	=	50 mm

(c) **Depth of Water**

Depth of water above sand surface = 2.0 m

Free board = 0.5 m

Total depth of filter box = 0.75 + 0.45 + 2 + 0.5

= 3.7 m

(d) **Under Drain System**

Provide two sections per filter bed. Hence provide 2 units of under drain system per bed.

Area of filter per under drain section = 11 x 4.4 = 48.4 m^2

Orifice area required = 0.3% of filter area

$$= \frac{0.3 \times 48.4}{100} = 0.1452 \text{ m}^2$$

Lateral area = 2 x orifice area

= 0.4356 m^2

∴ A pipe of 800 mm diameter could be used as manifold

Diameter of lateral = 80 mm (assumed)

$$\therefore \text{Area of lateral} = \frac{\pi(0.08)^2}{4} = 5.0265 \times 10^{-3} \text{m}^2$$

$$\therefore \text{No. of laterals} = \frac{0.2904}{5.026 \times 10^{-3}} = 58 \text{ Nos.}$$

So provide 29 numbers of laterals on either side of manifold.

Provide 12 mm dia orifice

$$\therefore \text{Area of each orifice} = \frac{\pi(0.012)^2}{4} = 1.13 \times 10^{-4} \text{ m}^2$$

$$\text{No of orifice / lateral} = \frac{0.1452}{58 \times (1.311 \times 10^{-4})}$$

= 22.15 say 22

∴ Size of pit for 800 mm dia manifold will be 0.8 m(width) x 0.8m(ht)

Size of Pit for 750 mm dia manifold will be 900 m x 900 mm

$$\therefore \text{Length of each lateral} = \frac{4.4 - 0.8}{2} = 1.8 \text{ m}$$

$$\frac{\text{Length of lateral}}{\text{Dia.of lateral}} = \frac{1.8}{0.08} = 22.5 < 60$$

Hence O.K.

If twin orifice are provided per c/s of the lateral @ an angle of 30^0 to vertical.

Spacing of orifices = $\frac{1.8}{11} = 0.164\text{m} \cong 165$ mm c/c

Thus, Size of manifold = 800 mm dia.

Spacing of laterals = $\frac{11}{29} = 0.379$ m = 379.3 mm c/c

To Summaries

No of laterals on either side = 29

Size of laterals = 80 mm

Size of manifold = 800 mm

Size of orifice = 12 mm

No. of orifice per lateral = 22

Spacing of twin orifices per c/s = 165 mm c/c

Size of pit for manifold of 800 mm dia. = 0.8 m x 0.8 m

Plan is shown in Fig. 23.9

(e) Black Washing of Filter

Assume backwash water rate as 600 l/m^2 / minute

Rate of air wash = 750 l/m^2.minute @ 0.35 kg/cm^2 pressure

(f) Wash Water Troughs And Central Gullet

Assume backwash water rate as 600 lt/m^2 / minute

Backwash water required per bed = 600 x 11 x 8.8

= 58080 lt/m

= 0.968 m^3 / Sec

Design of troughs

No. of troughs in either size of gullet = 5 (Assumed)

Total number of troughs = 10 Nos.

Flow per troughs = 0.0968 m^3/s

Assume flat bottom trough & zero slope and free fall

Hence q = $1.376\ bh_0^{3/2}$

Assume width of trough as 0.3 m

$$\therefore ho \quad (\frac{0.0968}{1.376\times 0.3})^{\frac{2}{3}} = 0.3802 \approx 0.40\text{ m}$$

Add free board as 0.15 m :

$\therefore$ Depth of trough = 0.55

$$\text{Clear spacing b/t trough} = \frac{11-5\times 0.3}{5} = 1.9m$$

There is less than 2 m. Hence O.K.

The bottom of the trough will be 100 mm above the 50 % expanded bed.

$\therefore$ The trough bottom height above unexpanded sand bed.

= 750 x 0.5 x 100

= 375 + 100

= 475 mm or 0.475

Design of Gullet

Assume that bottom Gullet with zero slope and free fall.

Assume width of Gullet = 0.6 m

Q = $1.376\ bh_o^{3/2}$

$$ho \left(\frac{0.968}{1.376\times 0.6}\right)^{\frac{2}{3}} = 1.11\text{m}$$

But adopt 1.2 m depth. Add free board as 0.3 m

$\therefore$ Depth of gullet = 1.5 m

Plan and c/s of troughs and gullet are shown in Fig.23.8

Air Scouring

Air flow rate per section = 750 ltr x 48.4 m^2

= 36300 ltr / min

= 36.3 m^3/min

∴ Air flow rate per bed = 36.3 x 2

= 72.6 m^3/min. @ 0.35 kg/cm^2 pressure

No. of air blowers = 2 (1working + 1 standby)

Capacity of blower for washing both sections at a time.

= 72.6 x 1.5 for 50% overload

= 108.9 say 110 m^3/min @ 0.35 kg/cm^2

New size of filter bed: The gullet is quiet deep thus will penetrate the sand bed, therefore provide gullet depth upto the filter bottom. Hence the width of each bed will be 4.4+4.4+0.8=9.6 m measuring 0.1 m assuming 0.1 m is the thickness of the gullet.

∴ Size of each bed = 11 x 9.6 m

Various filter details are shown in Fig.23.10

(g) Wash Water Tank

Volume of water required for 10 minutes back-wash of filter bed.

= 58080 x 10

= 580800 ltr

= 580.8 m^3

Volume of water for 10% extra quantity (assumed)

= 580.8 x 1.1

= 638.88 m^3

Provide water depth as 4 m

∴ Area required = 159.72 m^2

If 35 m is the length of tank then width of tank is 4.56 m. The tank will be divided in two parts by a partition wall. Hence over all inner dimensions of tank will be 35 m x 5m

The clear distance between bottom slab of the tank and roof top of filter will be 2 m and the effective head required at the under drain will be about 7 m for back wash.

(h) Wash Water Pumps

Since there are 10 filter beds to be back washed in 24 hrs. The interval of backwash between any two filter beds is 24/10=2.4 hours
Hence the wash water tank has to be filled up in 2 hours time.

Thus rate of pumping = $\frac{580800}{2\times3600}$ = 80.67 ltr / s
= $0.08067\ m^3/s$

The height of wash water tank bottom should be to give a head of 6 to 8 m at the underdrain. Assume 7 m head and add 10 % other losses.

$$\therefore\ 7 + 0.7 = 7.7 \text{ Say } 8 \text{ m}$$

Assume suction head and SWD in the tank as 4 m each.

Thus static head = Suction head + height of tank + SWD in tank + free board of tank
= 4 + 8 + 4 + 0.5 = 16.5 m

If the delivery pipe of 25 m length (assumed) and 150 mm diameter (assumed) delivers 70 ltr/s of water then frictional losses will be 4.335 m as per Table 23.2

$\therefore$ Total head 16.5 + 4.335 = 20.835 m ≈ 21 m

$$\therefore \text{Pump BHP} = \frac{(m^3/s)\rho\times h}{75\times\eta_1\times\eta_2}$$

Where η_1 and η_2 efficiencies of pump and motor respectively.

$$\therefore \text{BHP} \quad \frac{80.67 \times 21}{75 \times 0.7 \times 0.9}$$

$$= \quad 35.745 \quad \approx \quad 40 \text{ BHP}$$

Provide two pumps (one as standby) each of 40 BHP

(i) Filter Water Inlet Channel

The outlet channel from each clarifier will serve for half number of filter beds i.e. for 5 filters i.e. for five filters as shown in Fig. 23.1

Let velocity in the channel be 1 m/s and the flow in the channel will be 57500 x 1.2 m^3/d (for 20 % overload).

$\therefore$ Q = 57500 x 1.2
= 69000 m^3 / d
= 2875 m^3 / h
= 0.7986 m^3/s

Let width of channel be 1.0 m and h the SWD

$\therefore$ 0.7986 = 1.0 [1 x h]
$\therefore$ SWD in channel = h
= 0.7986
Free Board = 0.3 m
$\therefore$ Total depth of channel = 0.7986 m + 0.3 m
= 1.0986 m say 1.1 m

(j) Inlet Pipe For Each Filter Bed

Inlet flow per bed = 11500 m^3/d
$\therefore$ for 20% overload
Q = 11500 x 1.2 m^3 / d
= 13,800 m^3 / d
= 575 m^3 / h

$= 0.1597\ m^3 / s$

For velocity of flow of 1.0 m/s

$$0.1597 = 1.0\left[\pi\frac{d^2}{4}\right]$$

$\therefore$ Dia. of pipe $= d$

$= 0.451\ m$

Say 500 mm

(k) Filter Water Outlet Pipe Per Section Of Filter Bed

Outlet flow per section $= 5750\ m^3 / day$

$\therefore$ for 20% overload

$Q = 5750 \times 1.2\ m^3 / d$

$= 6900\ m^3 / d$

$= 287.5\ m^3 / h$

$= 0.07986\ m^3 / s$

For velocity of flow of 1.2 m/s

$$0.07986 = 1.2\left[\pi\frac{d^2}{4}\right]$$

Dia of pipe $= d$

$= 0.2911\ m$

Say 300 mm

(l) Filter Water Outlet Pipe Per Bed

The filtered water from each section will be coming to the outlet chamber where it will pass over the rectangular notch, and the combined flow from each section will be carried to the pure water pipe/ channel through a pipe. (Fig.23.10)

$\therefore$ flow through pipe, Q for 20% overload

$= 11{,}500 \times 1.2\ m^3/d$

$= 0.1597\ m^3/s$

For velocity of flow of 1.2 m/s

$$0.1597 = 1.2\left[\pi \frac{d^2}{4}\right]$$

$$\therefore \quad d = 0.4117m$$

Say 450 mm

(m) Pure Water Pipe For All The 10 Beds

Total flow = 115,000 m^3/d

$\therefore$ for 20% overload

$$Q = 115,000 \times 1.2 \; m^3/d$$

$$= 1.597 \; m^3/s$$

Here the flow is basically gravity flow, not under high pressure. Hence the pure water pipe could be assumed to run 2/3 rd full.

$\therefore$ Designed flow = 1.597 x 1.5

= 2.3958 m^3/s

$\therefore$ for a velocity of 1.2 m/s

$$2.3958 = 1.2\left[\pi \frac{d^2}{4}\right]$$

$$d = 1.597$$

Say 1600 mm

(n) Pure Water Channel For All The 10 Beds

Let width of channel be 1.5 m and velocity of flow be 1.2 m/s

$$\therefore 1.597 = 1.2 \, (1.5 \times h)$$

$$\therefore \text{SWD in channel} = h$$

$$= 0.887 \text{ m}$$

If freeboard is 0.3 m, then

Total depth of channel is 0.887 m + 0.3 m

= 1.187

Say 1.2 m

(o) **Filter Wash Water Inlet Pipe From Overhead Tank**

It is assumed that one filter bed will be washed a time. Wash water required to clean

one bed of 2 sections.

$$= \frac{600\times(11\times8.8)}{1000\times60} m^3/s$$

$$= 0.968 \quad m^3/s$$

$\therefore$ for 20% overload

$$Q = 0.968 \times 1.2$$

$$= 1.1616\ m^3/s$$

For velocity of flow of 3 m/s

$$\text{Then } 1.1616 = 3\left[\pi\frac{d^2}{4}\right]$$

$\therefore$ Wash water pipe dia= d

= 0.702 m

$\therefore$ Adopt 800 mm dia. pipe =

This pipe will from the wash water tank and will be the main pipe for backwashing the filter beds located in the pipe gallery. There will be branches from main pipe to each section of the filter bed.

(p) **Filter Wash Water Inlet Pipe Per Section Of Filter**

$$Q = 1.1616/2$$

$$= 0.5808\ m^3/Sec$$

$\therefore$ Wash water dia per section = 0.4965 m

$\therefore$ Adopt 500 mm dia pipe

(q) **Filter Waste Water Outlet Pipe**

It is assumed that maximum two sections will be backwashed at a time though actually only one section will be backwashed at a time.

The dia of waste water pipe will be the same as the wash water inlet i.e. 800 mm dia pipe.

(r) Filter Backwash Water Storage Lagoon

The backwash water generated per filter per day for 10 minutes duration of back wash.

$$= \frac{600 \times (11 \times 8.8)}{1000} \, m^3/d$$

$$= 580.8 \, m^3/d$$

∴ Backwash from 10 beds

$$= 580.8 \times 10$$

$$= 5808 \, m^3/d$$

Provide 3 days detention time in the storage lagoon

∴ Volume of tank $= 5808 \times 3 \, m^3$

$= 17424 \, m^3$

If SWD is 3.5 m, then area of lagoon

$= 4979 \, m^2$

Provide two compartments to the lagoon each of size 60 m x 42 m. The side bank of the lagoon will have slope of 1 : 2

The supernatant will be pumped back to the outlet channel from the cascade aerator, while the settled sludge will be taken to the drying beds.

4.1.16 Clarifier Sludge Storage Lagoon

Normally the sludge wasted from the clarifier is 3% of the total volume of water.

∴ Volume of sludge produced per day

$$= \frac{1,15,000 \times 3}{100} = 3450 \, m^3/d$$

$$= 3450 \, m^3/d$$

Provide 4 days detention time.

∴ Volume of lagoon $= 3450 \times 4$

= 13,800 m^3

If SWD of lagoon is 3 m, then

Area of lagoon= 4600 m^2

Provide 2 compartments each of size 70 x 33 m^2

Provide two pumps, normally vertical, non clog, open impeller type (one as stand by) per compartment of the sludge lagoon to pump the settled sludge to the drying beds. Rate of pumping of settled sludge will be such that it will pump the settled sludge say within about 3 to 4 hours.

The supernatant could be either discharged into a natural nallah or could be pumped back in the channel before flash mix.

4.1.17 Sludge Drying Beds

The settled sludge in the lagoon will be pumped to the drying beds. Assuming this volume as 20% of the inflow to the lagoon.

∴ Volume of settled sludge = 3950 x 0.2

= 690 m^3/d

Let dewatering, drying and sludge removal cycle be of 10 days and depth of application of sludge be 0.3 m

∴ Total plan area of sludge drying bed = $\frac{690 \times 10}{0.3}$=23000 m^2

Provide 20 number of beds

∴ Area of each bed	=	1150 m^2
	=	50 m x 23 m
Provide Sand Depth	=	0.3 m
E.S.of sand	=	0.5 to 0.75 mm

Depth of gravel	=	3 to 6 mm
Bottom slope of bed	=	1%
Outlet pipe from each bed	=	200 mm dia

The filtrate could be pumped back to the sludge lagoon or to the flash mix inlet channel depending upon the filtrate quality and the intensity of water scarcity.

4.1.18 Pure Water Sump

Let detention time in sump be 1 hour

$\therefore$ Volume of sump = $\frac{1,15,000}{24} = 4792 \text{ m}^3$

Provide SWD of sump = 4 m

$\therefore$ Area of sump = 1198.75 m^2

= 40 m x 30 m

Having two compartments each of size 40 x 15 m. Both compartments will be provided with pits for suction pipes of the pumps.

4.1.19 Chlorination Units

(a) Chlorinators

Total flow to be disinfected = 115 MLD

Dose of chlorine = 2mg/l (assumed) to achieve 0.2 mg/l at the far end of the distribution system.

Chlorine requirement = $\frac{1,15,000 \times 2}{1000} = 230 \text{ Kg/d}$

Provide suitable chlorinators of 230 kg / d (or 9.58 kg/h) capacity. In addition to the above, provisions of booster / injector pumps is necessary in some cases.

(b) **Emergency Chlorination**

It is done by TCL

Provide number of tanks	=	2
Capacity of each tank	=	for 12 h

Assume 25% is available chlorine then bleaching powder required per day.

= 230 x 4 = 920 kg/d

Or 460 kg for 12 h

Assuming 10% strength of solution

∴ Volume of solution tank	=	460 x 10
	=	4600 ltr
	=	4.6 m^3
∴ Size of Tank	=	2.3 m x 2 x 1 (SWD)
Provide free board	=	0.3 m
∴ Actual Size of Tank	=	2.3 x 2 x 1.3 m

(c) **Chlorine Room And Chlorine Tonner Room**

Chlorine requirement for 7 days

= 230 x 7

= 1610 kg

∴ 2 No. of toners each of 900 kg will be installed and 2 toners will be as stand by.

The toner room is normally adjoining the chlorine room.

4.1.20 Alum Requirement

Let the average dose of alum requirement for various seasons be

70 mg/l	=	Monsoon season
30 mg/l	=	winter season
70 mg/l	=	summer seas

The variation is because of the variation in the turbidity as per season.

The capacity of the store house will be decided on the basis of ultimate stage requirement for the worst (i.e. monsoon) season.

If 75 % purity is assumed for alum cakes, then alum requirement for worst season

for 115 MLD

$$\frac{115 \times 10^6 \times 70}{10^6 \times 0.75} = 10733.33 \text{ Kg/d}$$

$\therefore$ Alum requirement for 90 days – storage

$$= 10733.33 \times 90$$

$$= 9{,}66{,}000 \text{ kg}$$

(a) Alum Solution Tank

Provide minimum 3 number of alum solution tanks, each to serve for 8 hours. Two of the tanks will be used alternatively for 8 hours while the third will be as a standby.

Alum requirement for 8 hours= $\frac{10733.33}{3} = 3577.78$ Kg for 8 hours

(b) Preparation of Slolution

The solution should be prepared not in terms of weight of chemical per unit volume of water. Table from "Operation and Control of Water Treatment Process" by Cox (1969) gives the weights of chemical per unit volume for various percent solutions.

Table 23.1 : Weight of Coagulant per unit Volume for Various Percent Solutions.

%Solution	Alum, $Al_2(So_4)_3$ gm/l
1	10.9
2	20.39
5	52.70
8	86.70
10	110.60
12	135.50
16	188.30

Assuming strength of solution is 5%, the weight of the alum cake required after taking into account the purity factor.

$$= \frac{52.70}{0.75} = 70.27 \text{ gm/l}$$

The quantity of water required per shift for the solution.

$$= 3577.78 \times \frac{10^3}{70.27} = 50.91 \times 10^3 \text{ ltr}$$

$\therefore$ Adopt tank size = 5m x 3.5m x 3m (SWD)

Requirement of Alum for 7 days temporary storage

= 10733.33 x 7 = 75133 kg

The solution tanks should be of material which is acid resistant. Steel or concrete or asbestos cement concrete tanks with fiber glass, rubber, lead or asphat lining can be used. But PVC tanks (Such as Sintex etc.) are better. The alum solution is normally conveyed to flash mixer through a non corrosive pipe such as PVC. Drains of adequate capacity are provided for cleaning and flushing residual waste. A perfoarated channel of about 1 m width along one side of the solution tank is provided to dissolve the alum cakes with the help of spray of water. The bottom of the channel is above the FSL of solution of the tank.

(c) **Alum and TCL Storage Space**

(i) **Space For Alum**

Alum requirement for 90 days and 7 days temporary storage

$$= 966000 + 75133$$

$$= 10{,}41{,}133 \text{ kg}$$

Assuming 1m^3 of alum weighs 1700 kg, volume of alum

$$= \frac{905333}{1700} = 612.43 m^3$$

(ii) **Space for TCL**

TCL required for 7 days storage

$$= 920 \times 7$$

$$= 6440 \text{ kg}$$

Assuming 1m^3 of TCL weighs 1400 kg, volume of TCL

$$= \frac{5600}{1400} = 4.6 m^3$$

(iii) **Total Volume of Chemicals**

$$= 612.43 + 4.6$$

$$= 617.03 \text{ m}^3$$

Add 20% extra volume

Volume of chemicals $= 617.03 \times 1.2$

$$= 740.436 \text{ m}^3$$

If 4m is the height of building and 3.5 m is the height of stacking then area required is about 212 m^2

4.1.21 Chemical House

(a) Overall building can be of RCC framed structure with brick panels in two floors.

(b) Ground 1C : floor

- i) Space for chemical storage,
- ii) Space for laboratory
- iii) Space for toilet
- iv) M.C.C. Room
- v) Space for office

(c) First Floor:

- i) Space for 3 alum solution tanks
- ii) Space for 2 TCL solution tanks
- iii) Space for chain pulley block.

(d) Height of building
Ground floor -4m (normally)
First Floor -5m (normally)

4.1.22 Filter House and Annex

i) A block of 10 filter beds, 5 in each row with 8.8 m wide pipe gallery (operating platform in between. Each filter has two sections, the size of each section is 11 x 4.4 with 0.8 m outer width of the gullet between two sections of the bed. Thus size of each bed is 11 m x 9.6 m

ii) An annex building will have ground and first floor.

4.1.23 Full Supply Levels Of Water In Various Units

The reduced levels (R.L.s) of the bottom of various units and the full supply levels of water in those units are to be so designed that the flow of water from cascade aerator to flash mixer, clariflocculator and filters and finally to the pure water sump is by gravity. The equations to calculate the hydraulic

i) Hydraulic Gradient for Channels in Table 1

$$S = \left[\frac{q.n(B+2D)^{2/3}}{(B\times D)}\right]$$

ii) Hydraulic Gradient for Channels in Table 2

$$S = \left[\frac{3.5875.Q}{C.D^{2.63}}\right]^{1.852}$$

4.1.24 Calculations For Head Losses In Various Units

Velocities (Max, limits, m/s)

a.

Filter piping	=	1.0 m/s
Filter inlet	=	1.0 m/s
Filter outlet	=	1.2 m/s
Filter up wash	=	3.0 m/s
Filter waste water	=	3.0 m/s
Air inlet	=	0.6 m/min

b. Other systems

Collecting channel in cascade aerator	=	1 m/s
Channel from aerator to flash mixer	=	1.5 m/s
Flash mixer to flocculator (Pipe)	=	0.8 to 1.8 m/s
Clariflocculator launder	=	0.6 m/s
Channel after launder	=	1.0 m/s
Filter feed channel	=	0.9 m/s
Pure water channel	=	1.5 m/s

Details of flow, velocity, length and size of the channels and the corresponding hydraulic gradients are shown in Table 23.2 while that for pipes are shown in Table 23.3

Reduced levels of various units

(i) Cascade Aerator

R.L. of lip of cascade aerator = 200 m (assumed)

Rise of each step = 0.3 m

Total number of rises = 5

Free fall in collecting launder = 0.3 m

∴ TWL of collecting channel at the start of the channel

= 330 – 0.3 x 6

= 328.200 m

Total of launder at outlet = 328.200 – 0.0116

= 328.188 m

R.L. of launder bottom at start = 328.200 – 0.6655

= 327.5345 m

R.L. of launder bottom at outlet = 328.188 – 0.6655

= 327.5225 m

(ii) Channel U/S of Parshall Flume

Water level at the start of the channel is 50 mm below TWL at cascade outlet.

∴ TWL at start of the channel = 328.188 – 0.050

= 328.138 m

∴ R.L. of channel bottom at start = 328.138 – 1.585

= 326.553 m

Length of channel = 5 m (assumed)

∴ R.L. of channel bottom at the end = 326.553 – 0.0155

= 326.538 m

∴ TWL at the end of the channel = 326.538 + 1.585

= 328.123 m

(iii) Channel D/S of Parshall Flume

∴ TWL at start of the channel = 3289.123 – 0.544

= 327.579 m

R.L. of channel bottom at start = 327.579 – 0.816

$$= \quad 326.763 \text{ m}$$

R.L. of end of the channel = 326.763 – 0.002351

= 326.760 m

∴ TWL at the end of the channel = 326.760 + 0.816

= 327.576 m

(iv) Distribution Chamber

Provide a drop of 50 mm to TWL in the chamber

∴ TWL of water in the distribution chamber

= 327.576 – 0.050

= 327.526 m

SWD in the chamber is 1 m

∴ R.L. of chamber bottom = 327.526 – 1.0

= 326.526 m

From the chamber two channels are bifurcated by gates to connect the flash mixer. Provide gates of size 800 mm x 800 mm size.

$$\text{Velocity through gate} = \frac{0.6655 \times 1.2}{0.8 \times 0.8}$$

= 1.248 m/s

< 1.5 m/s. Hence O.K.

Head loss through gate is

$$\frac{kv^2}{2g} = \frac{0.5(1.25)^2}{2 \times 9.81}$$

= 0.0398 m say 0.04

∴ Theoretical TWL of channel to flash mixer at start

= 327.526 – 0.04

= 327.486 m

But keep R.L. of channel bottom same as bottom of distribution chamber

∴ R.L. of channel bottom at start = 326.526 m

∴ Actual TWL in channel at start = 326.526 + 0.887

= 327.413 m

This is less than 327.486, Hence O.K.

$\therefore$ R.L. of channel bottom at the end of 12 m long channel to flash mixer

$$= 326.526 - 0.0369$$

$$= 326.489 \text{ m}$$

$\therefore$ T.W.L. at the end of the channel $= 326.489 + 0.887$

$$= 327.376 \text{ m}$$

(v) Flash Mixer

Assume FSL in the flash mixer 300 mm below 197.376 m

$\therefore$ FSL in flash mixer $= 327.076$ m

$\therefore$ R.L. of flash mix bottom $= 327.076 - 4.86$

$$= 322.216 \text{ m}$$

(vi) Clariflocculator

Length of pipe from flash mixer = 30 m (assumed)

$\therefore$ Losses in pipe = (Frictional + entry + bend + exit) losses

$$= 0.101 + \frac{(1.5)(1.5)^2}{2 \times 9.81}$$

$$= 0.101 + 0.172$$

$$= 0.273 \text{ m}$$

Losses in central shaft $= 0.008$ m

$$= 0.273 + 0.008$$

$$= 0.281 \text{ m}$$

But provide a drop of 0.3 m in place of 0.281 m

$\therefore$ FSL in clariflocculator $= 327.076 - 0.300$

$$= 326.776 \text{ m}$$

$\therefore$ R.L. of flocculator bottom at partition wall $= 326.776 - 4$

$$= 322.776 \text{ m}$$

R.L. of clarifier bottom at peripheral wall $= 326.776 - 3.0$

$$= 323.776 \text{ m}$$

Provide a drop of 0.3 m between FSL of clariflocculator and TWL in launder at start.

$\therefore$ TWL in launder at start	=	326.776 – 0.300
	=	326.476 m
R.L. of launder bottom at start	=	326.476 – 0.832
	=	325.644 m
$\therefore$ TWL in launder at end	=	326.476 – 0.0331
	=	326.443 m
$\therefore$ R.L. of launder bottom at the end	=	326.443 – 0.832
	=	325.611 m

(vii) Channel between clarifier and Filters

Provide a drop of 100 mm at the start of the channel.

$\therefore$ R.L. of channel bottom at start	=	325.611 – 0.1
	=	325.511 m
$\therefore$ TWL in channel at start	=	325.511 + 0.7986
	=	326.310 m

This is less than 326.443 m, Hence O.K.

$\therefore$ TWL in channel outlet	=	326.310 – 0.04477
	=	326.265 m
$\therefore$ R.L. at channel outlet	=	326.265 – 0.7988
	=	325.466 m

(viii) Inlet Pipe to Filter

Losses in inlet pipe to filter = (Frictional + due to gate valve + entry + exit)

$$= \left[0.0011 + (0.2+1+1)\frac{v^2}{2g}\right]$$

$$= \left[0.0011 + (0.2+1+1)\frac{1^2}{2\times 9.81}\right]$$

$$= 0.1136 \text{ m}$$

$\therefore$ FSL in filter bed	=	326.265 – 0.1136
	=	326.151 m
But provide FSL in filter	=	326.000 m

Depth of filter box = depth of [gravel + sand + water] + free board

= 0.45 + 0.75 + 2.0 + 0.5

= 3.70 m

∴ R.L. of filter bottom = 326 – 3.20 (i.e. without free board)

= 322.80 m

and R.L. of manifold pit = 322.80 – 0.8

= 322.000 m

Assume head loss through filter = 1.2 m

∴ T.W.L. of upstream of control chamber = 326.00 – 1.2

= 324.8 m

(ix) Head loss in various components of Filter

$$H_{Total} = h_f+h_g+h_u+h_p$$

$$= l_e(l-f_e)(\frac{e_s-e}{e})+0.03(L_g)V_b+\frac{1}{2g}[\frac{V_b}{\alpha.\beta}]^2+\frac{f1Q^2}{12.1d^5}+\text{other losses}$$

$$H_{Total} = (0.75\times1.5)(1\text{-}0.6)(\frac{2.65\text{-}1}{1})+0.03\times(0.45)\left(\frac{0.6}{60}\right)+\frac{1}{2\times9.81}[\frac{0.6}{60}\times\frac{1}{(0.8)(0.003)}]^2+\text{losses in pipes}$$

= 0.7425 m + 1.34 x 10^{-4} + 0.885 + 0.4541 + 0.0993 from Table 21.2

= 2.1814 m

(x) Weir in control chamber

There will be one weir per section of the bed

∴ Q = 0.0665 m^3/s per section

Assume width of rectangular weir as 0.7 m

$$\therefore \quad Q = 1.84\, bh^{3/2}$$

$$\text{or } h = \left(\frac{Q}{1.84(b)}\right)^{\frac{2}{3}}$$

$$= \left(\frac{0.0665}{1.84(0.7)}\right)^{\frac{2}{3}}$$

$$= 0.139 \text{ m}$$

Say 0.14

$\therefore$ Depth of water over the crest is 0.14 m

Provide 50 mm drop below crest for down stream water with respect to crest.

$\therefore$ TWL of downstream = 324.80 – 0.13 – 0.05

= 324.62 m

$\therefore$ TWL at outlet for combined flow = 324.62 m

A 1m length and 400 mm dia pipe is provided for carrying the flow from both the sections to pure water channel.

$\therefore$ TWL at the end of the pipe = 324.62 – 0.0038

= 324.616 m

A further drop of 50 mm is provided in the pure water channel at the start.

$\therefore$ TWL of pure water channel at start= 324.616 – 0.050

= 324.566 m

$\therefore$ R.L. of pure water channel bottom at start = 324.566 – 0.887

= 323.679 m

Length of pure water channel is 45 m (assumed)

$\therefore$ TWL at the end of the pure water channel = 324.566 – 0.0400

= 324.526 m

R.L. of channel bottom at it's end = 324.526 – 0.887

= 323.639 m

The pure water channel is inside the filter house. At the end of the filter house, a collecting chamber is provided to collect the filtered water. The filtered water is then carried to the sump through a M.S. or R.C.C. pipe of diameter 1500 mm.

A gate valve is provided at the start of pipe.

$\therefore$ Total losses in the pipe = Frictional losses + loss due to valve

$$= 0.0111 + \frac{0.5(v^2)}{2g}$$

$$= 0.0111 + \frac{0.5(1.2)^2}{2 \times 9.81}$$

= 0.04775 m

If water level in the pipe is 50 mm below that in chamber then total losses in the pipe.

= 0.04775 + 0.05

= 0.09775 m

$\therefore$ TWL of water at sump = 324.526 – 0.09775

= 324.428 m

Assume a free fall of 0.3 m at the sump, so FSL of pure water sump

= 324.428 – 0.30

= 324.128

Say 324.0 m

Relative FSL in various units along with water depths is shown in Fig. 23.11

Table 1 Details of Head Losses in various channels for 120% of Average Flow

Sr. No	Channel Description	Flow	Velocity	Channel width	Liquid Depth	Hydraulic Radius	Hydraulic gradient	Length of channel	Head losses
		m^3/s	m/s	M	m	m/m	m/m	m	m
1.0	Collecting Launder of Aerator	0.7986	0.8	1.5	0.6655	0.35261392	0.0004342	24.19	0.0116
2.0	Aeration launder to flume	1.597	0.8	1.26	1.585	0.45081264	0.0003129	5	0.0017
3.0	Flume to distribution chamber	1.597	0.8	2.0	0.816	0.44933921	0.0003143	5	0.0017
4.0	Distribution chamber to flash mixer	0.7986	1.5	0.6	0.887	0.2241786	0.0027922	12	0.0369
5.0	Peripheral launder of clariflocculator	0.3993	0.6	0.8	0.832	0.27012987	0.0003484	86.44	0.0331
6.0	Channel between launder & filter inlet channel including filter bed channel	0.7986	1.00	1.00	0.7986	0.30748498	0.0008143	55	0.0493
7.0	Pure water channel	1.597	1.2	1.50	0.887	0.40638363	0.0008085	45	0.0400

Table 2: Details of Head Losses in Various Pipes for 120% of average Flow

Sr. No	Pipe Location	Flow	Velocity	Diameter of pipe	Hydraulic gradient	Length of Pipe	Head losses (H x 1.1)
		m^3/s	m/s	m	m/m	m	m
1.0	Inlet pipe from flash mixer to clariflocculator	0.7986	1.5	0.85	0.0031	30	0.101
2.0	Central shaft of clariflocculator	0.7986	1.2	1	0.0014	5	0.008
3.0	Filter inlet	0.159	1.0	0.5	0.0020	0.5	0.0011
4.0	Filter outlet upto weir chamber per channel	0.07686	1.2	0.3	0.0064	5	0.0353
5.0	Filter outlet from chamber to pure water channel per bed	0.159	1.2	0.45	0.0034	1.0	0.0038
6.0	Pure water pipe	1.59	1.2	1.6	0.0005	20	0.0111
7.0	Wash water pipe from wash water tank	1.1616	3	0.8	0.0083	50	0.4541
8.0	Wash water inlet pipe per filter section	0.5808	3	0.5	0.0226	4	0.0993
9.0	Waste water outlet per bed	1.1616	3	0.8	0.0083	54	0.4904
10.0	Rising main to wash water tank	0.07		0.15	0.1577	25	4.3373

Note: Normally pipe material is RCC, C.I., M.S. or D.I. etc., the average value of c is assumed as 100. The exact value of C will depend upon the pipe specified by the authorized.

* 10% extra head loss is considered to cover minor losses, # Figures in bracket are m^3/d

PART 3 : ALTERNATE DESIGN OF WATER TREATMENT UNITS

Capacity : 115 MLD

4.1.25 Flash Mixer: "Pump Diffusion"

Assumptions

G	=	750 Sec^{-1}
Gt	=	1000
Pipe Dia (D)	=	1000 mm
Diffusion jet velocity	=	6 – 7.5 m/s
Min water temp	=	10°C

Design

D	=	1 m
Length of mixing zone (L)	=	1.5 D
	=	1.5 m

$$\text{mixing volume (V)} = \frac{\pi}{4}D^2L$$

$$= \frac{\pi}{4}(1)^2(1.5) = 1.18\ m^3$$

Flow Rate (Q) = 115 MLD

= 1.33 m^3/s

$$\text{Mixing Time} = \frac{1.18}{1.33} = 0.895\ s$$

Power Requirement

$$P = G^2.\mu.V$$

$$= (750)^2 \times 1.33 \times 10^{-3} \times 1.18$$

[$\mu = 1.33 \times 10^3$ Pa.s at 10°C]

$$= 0.89 \text{ Kw}$$
$$= 1.19 \text{ hp}$$
$$\cong 1.2 \text{ hp}$$

To achieve satisfactory diffusion of primary coagulant in a given mixing time, designed pump flow rate should be 2 to 5 % of rated flow rate.

$$\therefore \quad Qp = 1.33 \times 0.03$$
$$= 0.0399 \text{ m}^3/\text{s}$$
$$\cong 0.04 \text{ m}^3/\text{s}$$

Design of orifice: The velocity head of the flow issued from the blending nozzle is used in computing the mixing energy.

Let head developed by Pump = H

$$P = \frac{Q.H.\rho.g.}{\eta}$$

η : Pump efficiency – to be taken as 100 % as theoretical water horsepower is used to determine orifice (nozzle) size.

$$\therefore \quad 890 = 0.04 \times H \times 1000 \times 9.81$$
$$\therefore \quad H = 2.27 \text{ m}$$

Corresponding velocity head = $\frac{1}{2}\frac{v^2}{g}$

$$\therefore 2.27 \frac{1}{2}\frac{v^2}{9.81} =$$

$$\therefore v^2 = 44.5$$

v = 6.67 m/s ---- OK(within range of 6-7.5 m/s)

= 21.88 ft/s

One nozzle that sprays a full cone pattern of 90° is used.

Nozzle dia = d_0

$$(\frac{\pi}{4}d_0^2)\times V = Q$$

$$\therefore \frac{\pi}{4}d_0^2 \times 6.67 = 0.04$$

d_0^2 $\therefore$ = 0.007635

d_0 $\therefore$ = 0.087 m

= 8.7 cm

= 0.285 ft

Check for energy input at nozzle

$$P(\text{in hp}) = \frac{0.97.Cd.a.v^3}{550}$$

Cd = 0.75

$$\therefore P = \frac{0.97\times 0.75\times(\frac{\pi}{4}\times 0.285^2)(21.88)^3}{550}$$

= 0.88 hp

< 1.2 hp

v for 1.2 hp = 7.33 m/s

A full jet nozzle with 92 % full cone spraying, 8.7 cm nozzle dia (3.42"), min. free passage of 1.9" solids, 8" flange pipe connections and 0.04 m^3/s capacity at 7 Psi

break pressure. (0.5 kg/cm^2).

Pump motor hp

TDH : Required pressure at nozzle + exit loss of jet water + pipe friction loss

Pipe friction loss assumed to be 1 ft.

$$\therefore \text{TDH} = +\left(\frac{1}{2}\times\frac{7.33^2}{9.81}\right)+0.3028$$

$$\left(0.5\ \text{kg/cm}^2\times10^4\frac{\text{cm}^2}{\text{m}^2}\times\frac{1}{1000}\frac{\text{m}^3}{\text{kg}}\right)$$

$$= 5 + 2.74 + 0.3028$$

$$= 8.04$$

$$\cong 8\ \text{m}$$

$$\text{BHP} = \frac{Q.H.\rho.g.}{\eta} = \frac{0.04\times8\times1000\times9.81}{0.85}$$

$$= 3.68\ \text{Kw}$$

$$\cong 4.93\ \text{hp}$$

Provide 5 HP Motor.

4.1.26 **Flocculator :** Mechanical mixing – vertical shaft with hydrofoil mixing blade system.

Data

Flow Rate (Q)	=	1.33 m^3/s
Detention time (t_d)	=	20 min
No. of tanks	=	2 (rectangular)
No. of stages / tank	=	3
Assuming Energy input	=	60 S^{-1} for stages 1 & 2
		30 S^{-1} for stage 3
Flocculator Blade	=	hydrofoil propeller blade
Min water Temp.	=	10°C

Design

(1) Volume of each tank

$$V\left(\frac{Q}{2}\right)\times td$$ = ... [flow divided in 2 tanks]

$$= \left(\frac{1.33}{2}\right) \times (20 \times 60)$$

$$V = 798 \text{ m}^3$$

Average water depth = 4 m (Assumed)

Total tank area required = $\frac{798}{4} = 199.5\text{m}^2$

Let tank dimensions be (18 m x 11 m x 4 m)

L=18 m; W= 11 m

Each tank is divided into 3 stages, each stage of length 6m.

Arranging, 2 impellers per stage

Total no. of impellers = 12

- **Power for impellers**

For stage 1 & 2

$$P_{(1/2)} = G^2.\mu.V$$

$$= (60)^2 \times (1.3 \times 10^{-3})\ (6 \times 4 \times \frac{11}{2})$$

Volume of tank = 11 x 18 x 4

Divided into 3 stages length wise

Volume of each stage = 11 x 6 x 4

2 impellers / stage

$\therefore$ volume per impeller = 11 x 3 x 4

$\therefore P_{(1/2)}$ = 617.8 W per flocculator

= 0.83 hp

Let efficiency (% η) be 75%

$\therefore$ motor hp = 1.1 hp

for stage 3

$$P_3 = (30)^2 \times (1.3 \times 10^{-3})\ (5.5 \times 4 \times 6)$$

$$= \frac{P_{1/2}}{4} = 0.21 \text{ hp}$$

Considering 75 % eff. Motor hp $= \frac{1.1}{4} =$ 0.28 hp

Baffles

There will be 3 baffles:

	B.W.1	B.W.2	B.W.3
Max.flow velocity (m/s)	0.55	0.45	0.35 (Assumed)
Total orifice area ($^{Q}/_{v}$)	2.42	2.96	3.8

Let orifice dia for each baffle be 15 cm (do = 0.15 m)

	B.W.1	B.W.2	B.W.3
No. of Orifices	137	168	215
Head loss (m)	0.024	0.016	0.0097

$$Q = C.A. (2\,gh)^{0.5}$$

$$Q = 1.33 \text{ m/s}$$

$$C = 0.8$$

$$h = \frac{Q^2}{C^2A^2(2g)}$$

Flocculator dimensions: Two tanks in parallel with each having

L x W x H = 18 x 11 x 4 (m)

Divided in 3 stages in series (6 m each)

4.1.27 Sedimentation Tank

1. Rectangular Tank

$$Q = 1.33 \text{ m}^3\text{/S}$$

Suspended solids to be removed = Alum floc

Design

Assuming No. of tanks = 2

Surface loading rate = 1.3 m/h [Conventional value]

$$\therefore \text{ Surface are required per tank} = \frac{1.33 \times 60 \times 60}{2} / 1.3$$

$$= 1841.5 \text{ m}^2$$

Assuming width of each tank as 18 m.

$$\text{Length of each tank} = \frac{1841.5}{18}$$

$$= 102.25 \text{ m}$$

$$\cong 105 \text{ m}$$

Assuming Water depth in each tank = 4 m

$$\text{Detention time (td)} = \frac{(18 \times 105 \times 4)}{(1.33 / 2)}$$

$$= 11368.4 \text{ s}$$

$$= 3.15 \text{ hr.}$$

$$\frac{\text{Tank Length}}{\text{Width}} = \frac{105}{18} = \frac{5.83}{1} > 4:1$$ ....OK

$$\frac{\text{Tank Length}}{\text{Water Depth}} = \frac{105}{4} = 26.3:1 > 15:1$$ ....OK

$$\text{Mean Flow Velocity} = \frac{Q}{A}$$

$$= \left(\frac{1.33}{2}\right) / (4 \times 18)$$

$$= 0.009236 \frac{m}{s}$$

$$= 0.5541 \frac{m}{\min} < 1.1 \text{m/min} \text{ -- OK}$$

$$Re = \frac{R.v.\rho}{\mu}$$

$$R = \text{hydraulic radius} = \frac{4 \times 18}{(2 \times 4) + 18} = 2.77 \text{ m}$$

$$\therefore Re = \frac{0.009236 \times 2.77 \times 1000}{1.3 \times 10^{-3}}$$

$$= 19679.7$$

$$> 18000$$

$$Fr = \frac{V^2}{gR} = \frac{(0.009236)^2}{9.81 \times 2.77}$$

$$= 3.139 \times 10^{-6} \leq 10^{-5}$$

$\therefore$ design can't be accepted

Flow characteristics can be improved by adding longitudinal baffles in tank.

No. of Baffles	**R**	**Re**	**Fr**
1	2.12	15061	4.1×10^{-6}
6	1.1	7815	7.9×10^{-6}
10	0.7346	5219	1.18×10^{-5}

This makes it clear, that a tube settler / parallel plate settler is preferable.

Length	=	105 m
Width	=	18 m
Water depth	=	4 m
Detention time	=	3 Hr. 9 Min.
Surface loading	=	1.3 m/h
Mean flow velocity	=	0.009236 m/s

Rectangular tank with tube settler:

No. of tanks : 2

The tank area to be covered by tube settler module, can be calculated using following relationship:

$$So=\frac{Q}{A}=\frac{W}{hCos\alpha+wCos^{2}\alpha}$$

α = $60°$

$\therefore$ So = $\frac{\alpha}{A}=\frac{W}{0.5h+0.25w}$

Where,

So = Avg. settling velocity of floc.

A = Surface area of tank covered by settler module.

A standard tube settler module has dimensions:

h = 0.55 m

w = 0.05 m

avg. settling velocity of floc = 0.00025 m/s.

$$\therefore 0.00025 = \frac{1.33}{A}\frac{0.05}{(0.5\times0.55)+(0.05\times0.25)}$$

A = 925.2 m^2

$\therefore$ 2 tanks in parallel are to be used

area per tank = $\frac{925.2}{2}=462.8m^{2}$ for each tank

width of tank = 18 m

$\therefore$ Length of tank = $\frac{462.8}{18}=25.7m \simeq 26m$

Flow velocity in settler module:

$$vo = \frac{Q}{A \text{ Sin } \alpha} = \frac{(1.33/2)}{(468)\text{Sin}60}$$

$$= 0.00164 \text{ m/s}$$

The hydraulic radius of settler module is

$$R = \frac{a}{p} = \frac{(0.05)^2}{4 \times 0.05}$$

$$= 0.0125 \text{ m}$$

$$Re = \frac{(0.00164) \times 0.0125 \times 1000}{1.3 \times 10^{-3}}$$

$$= 15.77$$

$$< 50$$

$$Fr = \frac{(0.00164)^2}{(9.81 \times 0.0125)}$$

$$= 2.2 \times 10^{-5}$$

$$> 10^{-5}$$

Standard size module has tubes that are 0.61 m long,

$$\text{detention time} = \frac{0.61}{0.00164} = 6.2 \text{ min}$$

75 % tank area is covered by settler module

$$\therefore \text{Actual length} = \frac{26}{0.75} = 35 \text{ m}$$

Water depth = 4m

With one longitudinal baffle wall in each tank.

Dimension = (2 No. of tanks)

Width = 18 m Length = 35 m

Water depth = 4 m

Tube settler modules are installed over 75% tank area.

Tank inlets: Submerged ports at bottom elevation of inlet channel by means of butterfly valves Provide 3 submerged holes with butterfly valves as tank inlet

Dia of each hole = 0.5 m (24")

Flow velocity through each orifice = $\frac{Q}{\sum a} = \frac{1.33}{(6\times\frac{\pi}{4}0.4^2)}$

v_0 = 1.12 m/s

$\Delta h = \frac{1}{2g}\left(\frac{q}{ca}\right)^2 = \frac{1}{2\times9.81}\left(\frac{1.33/6}{0.7\times0.196}\right)^2$

= 0.132 m

OK

The diffuser wall should provide approximately 0.23 m/s of flow velocity through each port.

$\therefore$ Port area = $\frac{Q}{V} = \frac{1.33}{0.23} = 5.78m^2$

$\therefore$ Total no. of 0.12 m dia ports required

$= \frac{5.78}{(\frac{\pi}{4}0.12^2)} = 511.2 \approx 500$

Per tank = 250 No of ports

Depth = 4m

10 rows of ports depth wise at 0.4 m c/c width wise 25 rows.

Flow velocity in each port = $\frac{1.33}{5.65}$=0.235m/s<0.25m/s

Head loss = $\frac{1}{2g}\left(\frac{1.33}{0.7\times5.65}\right)^2 \cong$ 0.0057 m

<u>Skimming system</u>: 6 launder troughs for each basin

Length of each launder = 26 m

$\left(\frac{1.33/2}{6}\right)$=0.11m^3/s

Flow rate in each launder trough = For a trough with rectangular section & a level invert

$$Q = 1.38\, b.ho^{1.5}$$

$$b = \text{width} = 0.5\text{ m}$$

$$\therefore ho^{1.5} = \frac{0.11}{0.5 \times 1.38}$$

$$ho = 0.29\text{ m}$$

$$= 0.5\text{ m (with free board)}$$

Rapid Sand Filter

Data

Flow : $1.33\ m^3/S$

No. of Beds = 10

Design

Flow per bed = $0.133\ m^3/S$

Rate of filtration = 7.5 m/h

$$\therefore \text{Area per bed} = \frac{0.133 \times 3600}{7.5} = 63.84\ m^2$$

$$= (7 \times 9)\ m^2$$

L/W = 1.29 (Between 1.11 to 1.66) -- OK

4.2 MECHANICAL WORKS - PURE WATER PUMPING STATION

4.2.1 Scope

The scope covers following:

(1) Providing 115 MLD (Immediate) pumping station at Water Treatment Plant Site with provision for future expansion upto 146 MLD capacity pumping station (for future requirements).

(2) Sump and pump house

(3) Vertical turbine pumps

(4) Lifting equipments

(5) Valves

(6) Delivery piping

4.2.2 References

Following references have been considered in the design of pumping station and equipments.

(i) Hydraulic design of pumps, sumps & intakes -MJ Prosser

(ii) Pump Handbook -Karasik, Messing, Cooper, Heald

(iii) Water Works Engineering (planning, design & operation) -Quasim, Motlay, Zhu.

(iv) CPHEEO Manual

(v) Hydraulic design of pump sumps and intake -IS -15310 -2003

(vi) Pumping station design -Robert L. Sanks

(vii) Relevant B.I Standards

4.2.3 Pumping Station

Design considerations

(i) Size of sump to avoid vortex, starvation etc.
(ii) Adequate submergence to prevent cavitation at lowest water level
(iii) Keeping velocity within limits
(iv) Selection of pumps to suit to requirements of the system at better efficiency for immediate & future.
(v) Materials of construction to suit the quality of water pumped
(vi) Smooth operations, easy maintenance, control and monitoring.
(vii) Working space, loading, unloading facility, easy access to all equipments for operation & maintenance.
(viii) Noise and vibration level within permissible limits and safety

The G.A drawing covering all above points as proposed is enclosed.

The pumping station designed shall be at the end of 40 m. x 30 m. sump and shall be constructed as a pat of sump with pump house above it as a normal and standard practice so that no separte space is required for this.

The salient points are as under:

4.2.5 Sump and Pump House

Present requirement	-	115 MLD
Future requirement	-	146 MLD
Designed capacity	-	146 MLD

Capacity of sump for one hour	-	6083 m^3 (146 MLD)
Size of sump	-	40 m. x 30 m. x 4 m.

There shall be two compartments of the sump for isolation during maintenance.

Capacity of sump with two compartments (with effective water depth of 4 mtrs.)	-	4800 m^3 which is about 43 minutes of capacity and hence O.K.

Size of Pump House

(a) Length of Pump House - The length of the pump house shall be 30 mtrs and adjusted according to width of sump (30 mtrs.)

(b) Width of Pump House

(i)	Rear clearance between wall & panel	-	1000 mm.
(ii)	Width of 3.3 kV panel	-	1800 mm.
(iii)	Draw out space on platform & railing	-	2700 mm.
(iv)	Walk way	-	1750 mm.
(v)	Pump foundation dismantling joint, NRV, SV, BFV	-	5250 mm.
	Total	-	**12750, Say 12800**

Height

The effective depth of water will be 4 meters and should have a free board of 0.50 mtr.

Levels

(i)	Lowest water level in Sump	:	320 Mtrs
(ii)	Strainer level	:	319 Mtrs
(iii)	Floor level of Sump & pumphouse	:	318 Mtrs

(iv)	F.S.L. in Sump	:	324 Mtrs
(v)	Pump Floor Level	:	324.80 Mtrs.
(vi)	Panel Floor (5500 mm width) Level	:	326.50
(vii)	Top of corbel	:	331.00 Mtrs.
(viii)	Invert level of pump house roof	:	333.50 Mtrs.

The pump house is spacious, well ventilated, having space for movements of operators, working space etc. The delivery header is taken outside the pump house for easy maintenance.

Following facilities are provided in the pump house:

(i) Sloping Floor

The bottom of the sump shall have slope of 7^0 to 10^0 towards the pump house and the flat floor for the entire width of pump house i.e. 12.8 meters.

(ii) Pump Floor (at 324.8 MRL)

The pumps will be installed on a floor at R.L. 324.8 m and as shown in the drawing. The space between pumps, clearance and submergence is as per hydraulic institute standard and references. The discharge head shall be mounted on a base frame fabricated out of 400 x 200 mm. ISMC / suitable ISMB rigidly grouted on the RCC beam for which a slot of 1500 mm x 1500 mm is required.

(iii) Operating floor (Panel floor at 326.50 MRL)

The control panels both H.T. & L.T. shall be installed at 326.5 MRL. This floor shall be raised for the entire length of pump house 30 meters and 5500 mm wide so that cables can be conveniently laid from 325 MRL to 326.5 MRL

(iv) Operators Room (5500 mm x 4000 mm x 4000 mm)

Control room is provided at one end for effective operation, supervision, monitoring and control.

(v) Battery , Store Room

Battery and Store Rooms of 300 mm x 4000 mm x 4000 mm shall be provided on the operating 324.8 MRL

(vi) Vortex prevention cones

Such cones are not required in this case.

(vii) Loading unloading bay at 325 MRL

6500 mm loading, unloading space is provided at with approach on both sides with rolling shutters.

(viii) Space for Wash Water Pumps

Two square slots of 600 mm x 600 mm are provided at one end of pump house for two wash water pumps on floor at 325 MRL one working and one standby.

(ix) EOT crane shall be installed on rails / square bars mounted on

Corbel at 331 MRL and shall have free access upto 333.5 MRL for working and movements.

(x) Valve Operating Pads

8 working pads of about 2500 mm x 600 mm x 300 mm (or suitable) shall be provided on 325 MRL for valve operation.

(xi) Portable working stools

- Two sets of portable working stools of M.S. fabricated shall be provided for maintenance and operation of motors as and when required. The size will be decided as per the height of motor stool and motor.

(xii) Adequate light & ventilation

Adequate light and ventilation has been provided.

(xii) Toilet & Bathroom

The toilet and bathroom for operators, visitors is absolutely necessary. The same may be accommodated in the close vicinity of WTP at suitable place.

Pure Water Pumps

1. Governing Levels

i	Minimum water level in Sump	320.0 MRL
ii	Full supply level of Sump	324.0 MRL
iii.	FSL of MBR at Government House (Discharge Point)	345.95 MRL
iv.	Nearest ground level at proposed pump station	324.0 MRL

2. Type of Pumps

Vertical turbine pumps and centrifugal pumps are normally used for water supply schemes. Vertical turbine pumps are considered to prevent submergence of pumps and motor as observed / experienced in many cases due to leakage of pipeline in centrifugal pumps.

Since this is pure water, self water lubricated vertical turbine pumps are preferred over oil lubricated pumps for ease of maintenance and do not require any consumables for operation.

3. Pump Nominal Speed

Pump size reduces with increase in the nominal speed, however higher speeds result in increased wear and tear and thus higher maintenance cost. High speed pumps are also susceptible to higher vibration and noise levels. Considering the above aspects, general engineering practice and size of pumps involved it is proposed to provide pumps with a nominal speed of 980 RPM (1000 RPM syn.).

4. Pump Specific Speed

Pump specific speed is an important criterion for deciding the number of operating pumps and number of stages of pump. Minimum number of stages are preferred. Pumps with low specific speeds have unstable performance characteristics whereas pumps with very high specific speeds are sensitive to the variations in total head of pumps. The preferred range of specific speed is 3000 to 4000 in US units or 58 to 77 in SI units.

5. Duty Conditions

a. Designed Discharge

Capacity of the scheme	=	115 MLD (Immediate)
	=	146 MLD (Ultimate)
Discharging capacity Q (I)	= (i)	4791.67 m^3/hr (115 MLD)
	=	1331 liters / second
Say	=	1332 litre / second
Q(U)	=	6083.34 m^3/hr (146 MLD)
	=	1689.81 m^3 litres /Second
Say	=	1690 litres /Second

b. Total Head on Pumps

Static head = 345.95 – 320 = 25.95 Mtr.

(Level of discharge point in MBR – 345.95-Lowest water level in sump 320 m)

Hence the total head on pumps worked out as under:

Static head	=	25.95 m.
Frictional losses in pipeline, valve, including entrance, exit & station losses	=	6.615 meters
Therefore Total head on pumps	=	32.565 meters Say 33 mtrs.

6.1 Working Pumps

a. The total capacity of 115 MLD will be pumped by operating 2 pumps in parallel.

b. stand-bye pumps -2 nos. 100 % standby since it is absolutely necessary.

c. Future needs – The provision for 4 pumps for the present with additional 2 pumps of 31 MLD each for future is made in pump house.

The space for 2 Nos. of wash water pumps is also considered here.

d. Single stage, VT Pump (self water lubricated)

Specific speed	-	3000 (U.S. units)
Nominal speed	-	1000 (syn)
Stage	-	Single stage

7. Horse Power

The 425 HP (320 kW) pumps are required.

8. Column dia. = 600 mm. for velocity 2.35 meters/sec. which is within permissible limits of2.75 m/secs.

9. Bell mouth dia. = 900 mm. with velocity of 1.04 m/sec.

10. Column thickness = 10 mm. thick.

11. Shaft dia. = 90 mm.

Discharging capacity	=	666 liters/second
Total head	=	33 mtrs.
Submergence	=	1000 mm.
Head range	=	24 mtrs to 36 mtrs.
Shut off	=	Above 42 mtrs.
Efficiency	=	80%

4.2.6 Codes and Standards

The design, manufacture and performance of the V. T. Pumps shall comply with all currently applicable statues, regulations and safety codes in the locality area where the equipment will be installed. The equipment shall also conform to the latest applicable Indian standards as under

IS 1710	Vertical turbine pump for clear cold, fresh water
IS 5120	Technical requirements for roto-dynamic special purpose pumps.

Where the above standards are in conflict with the stipulation of this specification, this specification supersedes them.

4.2.7 Design Requirements

The equipment shall be capable of developing the required total head at rated capacity for continuous operation. The total head discharge curve shall be continuously rising towards the shut off with highest shut off point. Pumps shall be identical and shall be suitable for parallel operation with equal load division. Impellers shall preferably be of non over-loading type. Pumps shall run smooth without undue noise (85 db) and vibrations. The magnitude of peak to peak vibration at slip will be limited to 100 microns at the bearing housing.

4.2.8 Features of Constructions

Pumps shall be vertical Turbine type with required number of stages not exceeding the requirement given above and suitable for the service condition stipulated.

4.2.9 Bowl Assembly

A pump bowl/bowls shall be flanged with machined matching of faces. The suction bell mouth to bowl assembly, to column and to discharge head i.e. all joints shall be flange joints. The bowls shall be capable of withstanding a hydrostatic pressure equal to twice the duty head or 1.5 times shut off head whichever is greater.

4.2.10 Suction Bell Mouth & Strainer

A cast iron/M.S. bell mouth not less than 950 mm dia. Shall be fitted to the suction nozzle to limit the velocity. The suction strainer shall be of S.S. Net opening area in strainer shall not be -less than 3 times of entrance area of bell mouth. The shape and curvature of the bell mouth shall be designed to streamline the flow of bowl suction. The thickness of bell mouth shall not be less than 10 mm.

4.2.11 Impeller

The impeller/s shall be dynamically balanced so as not to cause any vibrations during operation. The impellers shall be closed type and shall be made in one piece and securely fixed to the stainless steel shaft, to assure accurate adjustment of each impeller. The water passage will be finished smooth by hand. Balancing holcs / device for reducing hydraulic thrust shall not be provided.

4.2.12 Wearing Rings

Wearing rings shall be renewable type. These shall be held in place by screwing against rotation, press fit or locked with pins, flanged and screwed. Wearing rings shall be provided on both easing and impeller.

Hardness of wearing rings shall be less by atleast 50 BHN than the impeller.

4.2.13 Shaft

The shaft shall be of stainless steel and finished to the close tolerance at the impeller / bearing fixing sizes.

The design of the shaft shall also take into consideration the critical speed of the shaft, which shall be at least 20% above and below the operating speed.

The shaft shall be properly balanced so as not to cause any vibrations during operation and shall have bush bearings of stainless steel, water lubricated. Extra long bearing shall be provided for suction and discharge bowls. The hardness of bush bearing shall be less by atleast 50 BHN than that of shaft.

4.2.14 Column Pipe Assembly

Column pipes shall be of M.S. Fabricated heavy weight, flanged type each in 1.5 m length or less so that after complete erection of the pump/s the bottom of stainer shall be at RL 319. m and length of strainer shall be adjusted accordingly. The total length of column assembly, bowl assembly, bell mouth and strainer shall be 6.5 mtrs. for each pump.

The column assembly length (including column pipes, bowl, assembly, bell mouth and stainer) shall be adjusted considering, the pump floor, levels, as given above. A matching piece shall be provided if required. The stiffeners shall be provided to all pipe flanges. The discharge head/tee and column pipe dia shall be same. The discharge head/tee incorporate full diameter elbow.

4.2.15 Line Shafts

These shafts shall be of solid circular section, prepared from stainless steel machined and ground thoroughly and coupled with screwed or muff couplings. The shaft sections shall be provided with non-corrosive and abrasion resisting wearing surfaces particularly at the location ot" each guide bearing. Length of line shaft shall not be more than 1.5 m. each.

4.2.16 Line Shaft Bearings

These shall be designed to be water lubricated by the pumped water and shall be placed in bearing holders located in position at the joint of columns. Line shaft bearing shall be of cutless hard rubber designed for efficient water lubrication. Composite design of line shaft material and it's diameter and bearing centres shall ensure that the entire rotating assembly is brought from *stand-still* to full speed without any vibrations and shaft deflection and to ensure that first critical speed is not within 80% to 120% of full speed.

Reverse Rotation

The unit shall be suitable for reserve operation during power tripping of adequate or provision to prevent non reversible ratchet shall be provided.

4.2.17 Discharge Head & Motor Stool

The discharge head shall be fabricated from M.S. and shall incorporate mounting flange for motor stool for solid shaft motor, shuffling box with renewable gland packings and tapping for pressure gauge mounting etc. The discharge head shall be of robust construction and shall be designed to support entire load of pump assembly, water column and motor etc. and shall withstand all static and dynamic, torsional loads, hydraulic thrust imposed during operation from shut off to stipulated operating conditions and thrust due to change in direction of flow, without any vibrations. The discharge head shall be installed on sole plate with ISMB / ISMC frame and entire load of motor and pump shall be on the lower floor as given below:

Pump floor level	324.8 MRL
Operating floor level	326.5 MRL

Drain arrangement for gland leakage water shall be provided at bottom of discharge head with G.I. Pipe. The base of the discharge head shall not be less than 1500 mm x 1500 mm. The power shall be transmitted from motor to vertical shafting through a flexible coupling. Both halves of the coupling shall *be* machined all over, securely keyed to their respective shafts. The pins shall be of stainless steels. The arrangement of two halves shall be suitable to check alignment and parallelism. A self aligning thrust bearing shall be housed in the head gear adequately designed to accommodate entire weight of rotating parts and hydraulic thrust and shall be suitable for reserved rotation up to atleast 150% normal forward speed. Bearing shall be designed for 30,000 hours life. The bearing shall be of oil lubricated type and shall be provided with oil level gauges and suitably positioned temperature probes. Two sets of adjustable contacts shall be provided one for an alarm and other for tripping the Raw water pump motor. This shall be connected to scanner panel so that digital temperature can be read with alarm and tripping.

Motor stool shall be provided for mounting the electric motor. The motor stool shall accommodate the pump thrust bearing and pump motor coupling. The motor stool shall be robust construction and of fabricated mild steel and adequately sized with opening to work on the flexible coupling. Height of pump supporting girder/channel, discharge head and motor stool shall be adjusted to have motor base at or marginally above panel floor level.

4.2.18 Miscellaneous

The pump shall be provided with non reversible ratchet or similar mechanism to prevent them from rotation in reverse direction. Pressure gauge to each pump and manifold pipe shall be provided. Pressure gauge shall be 150 m~ dia. 0 -15 kg/cm^2 and least count shall be 0.05. Each pressure gauge shall be fitted with restrictor nozzle of brass and G.!. Pipe and U tube. Pressure gauge on manifold shall also be provided. All pressure gauges shall be installed in pump house on wall with necessary G.I. pipe connections from manifold to pump house. The pressure gauges shall be installed at suitable height so that the reading can be taken accurately.

4.2.19 Sole Plate

The M.S. Sole plate arrangement as shown in the drawing shall be provided under the discharge head for precise horizontal and vertical alignment. Thickness of sole plate shall not be less than 40 mm. It shall be independent of base plate integral with the discharge head. The contact surfaces of the sole plate arrangement as under shall be machined for precise leveling and shall ensure vibration free operation of the pump.

i) Corner plates and sole frame
ii) Sole frame and sole plate
iii) Sole plate and discharge head

All joints between machined contact surfaces shall be with nut bolts /tapped studs / bolts. All contact surfaces shall be blue-matched to ensure proper contact to the extent of 60% of contact area after necessary site finish if required. The opening in the sole-plate/frame shall be of adequate size to pass the bowl assembly etc. very easily. M.S. base frame shall be anchored in the floor ensuring complete rigidity. Entire structural fabrication and foundation arrangement shall be designed and submitted for approval. M.S. Plates shall be grouted on pump supporting R.C.C. beams provided in structure. The fixing of M.S. Plates on the R.C.C. beams and subsequent anchoring of M.S. sole frame in proper level shall. The minimum size of sole plate shall be 1.5 mx 1.5mx 0.04 m. (40 mm)

4.2.20 Air Release Arrangement

An air valve of dia 80 mm shall be provided on M. S. Tee or on the discharge head. For expelling the while starting and admitting air

4.2.21 Water Lubrication Tank and other Accessories

In order to lubricate line shaft bearing of the pump, lubrication arrangement comprising the following shall be provided.

i) Lubrication tanks 2 Nos. interconnected with each other and common for all pumps fabricated from sheet metal of thickness not less than 5 mm and of capacity not less than 2 M^3. The tank shall be cylindrical and shall be installed on panel mounting floor with at least 6 concrete saddles at a suitable place.

ii) Each lubrication tank shall be equipped with the following:-

a) W L sight gauge
b) Overflow lead to sump
c) Drain valve lead to sump
d) G.I. pipe connection with isolating valve and non-return valve to each pump column assembly for lubrication. The valve shall be located near the tank. The size of individual pipe and valve to pump shall be 40 mm. dia
e) Inlet connection with solenoid operated valve and suitable removable strainer by suitable tapping from common header.
f) Float valve in the tank for control of overflow.
g) Any other item necessarily required for proper functioning.

4.2.22 Materials of Construction

a)	Discharge and suction case, Bowls	C.I.I.S. 210 Gr. FG 200
b)	Discharge head, Bell mouth and motor stool.	M.S. Fabricated.
c)	Impeller	Stainless Steel of CF 8M
d)	Impeller Shaft	High grade carbon steel/stainless steel AISI 410/416
e)	Column Pipes	ERW Heavy Duty / MS Fabricator

f)	Shaft Sleeve	Stainless steel AISI 410/416
g)	Line shaft	Stainless steel AISI 410/416
h)	Nut bolt and washer	Stainless Steel AISI 410
i)	Wearing ring	Bronze
j)	Line shaft bearing	Cutless hard rubber.

Minimum Sizes

a)	Column Pipe diameter	600 mm
b)	Thickness of column pipe and bell mouth	10 mm
c)	Impeller and line shaft dia.	90 mm or nearest commercial size
d)	Bell mouth diameter	900 mm
e)	Thickness of sole plate	40 mm
f)	Length of each column pipe (flanged)	1.5 mtrs. For 6 mtrs length excluding bowl assembly, bellmouth and strainer
g)	Flanges of columns	Conforming to 1538 not less than 25 mm thick
h)	Discharge head	Flat bottom

i)	Discharge Elbow	600 mm dia
j)	Noise level	Not more than 85 db
k)	Vibration	below 100 microns

4.2.23 Non-Return Valve - 600 mm

i. The non-return valve will be swing reflux valve type with single multiple doors. The valve will be generally conform to IS 5312 Part I / Part II.

ii. The valve will be suitable for mounting on a horizontal pipeline and flow direction will be clearly embossed on the valve body.

iii. Valves will possess high speed closing characteristics and be designed for minimum slam when closing.

iv. PN Rating shall be 1

v. Material of construction will be as follows :-

Body and door	:	CI grade FG 260 conforming to IS 210 / S.G. Iron grade 400/12 to IS 1865 / Cast steel grade B conforming to IS 1030
Hinge pin & Face and seat rings	:	Stainless steel 04 Cr17 Ni 12 Mo2 / 04 Cr 18 Ni 10 to IS 6603
Bearing bushes	:	Leaded Lin Bronze grade, LTB 2 to Is 318

4.2.24 Sluice Valve

4.2.24.1 Design requirements

a. Sluice valves are generally conforms to IS 14846. Additionally they should also meet specific requirements as stated.

b. Spindle thrust collar and operating arrangement including hand wheel should be designed in such a way that one man is able to operate the valve against full different pressure by exerting not more than 40KGF.

4.2.24.2 Feature of construction

a) Valve shall have non-rising spindle.

b) Valve shall be with bushing arrangement for replacement of packing without leakage.

c) Valves sizes 450mm and above shall be provided with renewable CI channel & shoe arrangement and clearance being controlled between 2 to 3 mm throughout the travel.

d) Valves size 450mm and above shall be provided with grease packed enclosed spur/worm gearboxes.

e) All valve doors when fully closed would ensure door faces are riding on body seat ring by at least 50% of the width seat rings and there is sufficient room for wear travel.

f) All face and seat rings will be force/ press fitted and riveted to the recess in the CI casting

g) Nominal size of the valve, make, pressure rating shall be cast on the body of the valve.

Data

1. Size	:	600 mm dia
2. Design rating	:	PN 1
3. Drilling	:	IS 1538 PART IV & VI
4. Material of construction	:	
Body	:	CI IS 210 GR FG 260
Disc	:	CI IS 210 GR FG 260
Spindle	:	St. Steel IS 6603 GR 12 CR 12
Seat & Face Rings	:	Bronze IS 318 LTBII
Channel & Shoe	:	Cast Iron
Drain & Plugs	:	Bronze IS 318 LTB II
Gear Box Housing	:	CI
Gears	:	SG IRON IS 1865 GR 500/7
Ball Thrust Bearing	:	Bronze
Bushing Arngmt	:	Bronze.
Rivets	:	Soft Annealed Brass
Gland Packing	:	Grease Hemp
Fastners	:	MS.

4.2.25 Butterfly Valve – 600 mm dia

- The butterfly valve will be double flanged long body rated for PN 1.0 conforming to IS 13095 of 600 mm dia. The valve will be suitable for horizontal mounting. Bypass is not required.

- Resilient seat will be provided as per IS 13095.

- The face to face dimensions of the butterfly valve will be as per IS 13095 for double flanged long body BFV.

- Material of construction will be as follows :-

- Body & Disc.	:	CI grade FG 260 conforming to IS 210 / S.G. Iron grade 400 / 12 conforming IS 1865 / carbon steel as per class / grade in IS 13095
- Shaft	:	Stainless steel 12 Cr 13 / 15 Cr 16 Ni2 / 04 Cr 18 Ni10 / 04 Cr 17 Ni 12 Mo2
- Sealing ring / seal retaining ring	:	Stainless steel 04 Cr 18 Ni 10 / 04 Cr 17 Ni 12 Mo2
- Elastomers	:	Nitrile / Neoprene / EPDM rubber
- Internal fasteners	:	Stainless steel

4.2.26 Electric Actuator (for sluice valves)

4.2.26.1 Components / Accessories

The Electro mechanical actuator for sluice valve will be suitable to comprise motorized gear train to transmit drive to the valve stem. The actuator will be supplied with the following accessories.

a. A.C. electric motor.

b. Reduction gear unit.

c. Torque switch mechanism complete with set of torque switches.

d. Limit switch mechanism complete with set of limit switches.

e. Handwheel for manual operation.

f. Hand-auto changeover lever with suitable locking arrangement.

g. Local control switch / push buttons

h. 415 V / 240 V AC control transformer

4.2.27 Kinetic Air Valve

- The air valve of 80 mm and 200 mm diameter will be designed for PN 1.0 rating

- The valve will be capable of exhausting air from column assembly automatically when the pipeline is being filled and air being released at a sufficiently higher rate to prevent the restriction to Inflow. Similarly the valve will be capable of ventilating column assembly automatically when being emptied. The air inflow rate will be sufficiently high to prevent the development of a vacuum in pipeline. The valve will be automatically release air accumulated in pipe line work during normal working condition.

- Air valve will be of kinetic double orifice type with a large orifice for ventilation and exhausting air from the pipeline and small orifice for releasc of air under working pressure. The valve will be suitable for maximum working pressure in the system. The air valve will be provided with isolating valve and flanged end connection.

- A separate sluice valve of 80 mm diameter and PN 1.0 rating will be provided for isolation of air valve.

- Air Valve shall confirm to IS 14845 : 2000

4.2.28 Pipe work and Fabricated Platform

4.2.28.1 General Requirements

Material of steel pipes and fittings will conform to IS:2062. Fabrication and testing will be in accordance with IS:3589 for pipes and IS:6392. The thickness shall be 20 mm and dia shall be of 2032 mm. The individual delivery pipe of pump shall also be 15 mm thick and 600 mm dia and supported by suitable MS/ RCC support and connected to common header with readial tee with pressure gauge. The header shall also have 200 mm dia sluice valves for scovering the pipeline during maintenance. Two 1200 mm dia NRV shall also be installed on this header to prevent back flow of water. The thickness of pipeline is suitable to withstand water hammer pressure.

All the piping will be suitably supported by RCC chairs.

4.2.29 Dismantling Joint

Dismantling joint one for each pump will be provided in delivery side to facilitate removing valves.

The dismantling joint will be designed for hydro static test pressure of 1.6 kg/m^2. The dismantling joint will be in MS/ SS construction.

4.2.30 Supports, Thrust Blocks, Pads

Designed RCC/CC/structural steel support will be provided underneath pipeline in the pump house, wherever required and pads/ fabricated platforms to operate the valves.

4.2.31 Lifting Equipment

4.2.31.1 Electrically Operated Traveling Crane

The crane will be electrically operated, single girder bridge type complete with all accessories including down shop conductor, crane rails and fixtures, and will conform to IS:3177.

- Safe working load : 7.5 MT
- Class : 2
- Lift : 6 meters
- Suitable for : lifting, lowering, long travel, cross travel

4.2.32 Annexure

1. Specific speed

115 ml capacity by 4 pumps each with 81.25 ml.

Specific speed $= N_s = \frac{N\sqrt{Q}}{H^{.75}}$

Where;

N = Speed of pump

Q = US gallons / minute

H = Total head in feet

Assuming single stage pump and speed as 980 rpm

Q = 666 litrs./sec.

H = 104.96 feet (32 mtrs.)

$$= 980 \times \frac{\sqrt{\frac{666 \times 60}{3.782}}}{104.96^{0.75}}$$

$$= \frac{980 \times 102.77}{32.79}$$

$= 3073.39$

Say 3100 O.K

2 working and 2 standbye sets are therefore adopted.

2. Column pipe dia.

Flow, Q = $0.666\ m^3/sec.$

Q = A x V

V = 2.75 m/sec. (permissible limit)

A = $\frac{\pi}{4}\times d^2 = \frac{Q}{\mu} = \frac{0.666}{2.75}$

= $0.242\ m^2$

A^2 = $\frac{\pi}{4}\times d^2$

d^2 = $\frac{0.242\times 4}{3.14}$

= 0.3085

d = 555 mm.

Adopt 600 mm. dia.

v = $\frac{Q}{A} = \frac{0.666}{0.7854\times 0.6\times 0.6}$

= 2.355 m/sec. is which in m acceptable limits.

4. Bell Mouth Dia., D

D = About 1.5 d.

Say 600 x 1.5 = 900 mm.

(Velocity) $v = \frac{0.666}{0.7854\times0.9\times0.9}$

$= 1.04$ m/sec.

$D / d = \frac{900}{600} = 1.5$ O.K

3. Column thickness

$$P = \frac{2st}{D}$$

Where,

s = Yield stress = 235 mpa.

P = 32 mtrs. = 3.2 kg/cm^2

$$4.2 = \frac{2\times0.6\times235\times t}{600}$$

t = 6.80 m.

Provide 2.00 mm for corrosion allowance

t = 8.80 mm.

next commercial size t = 10 mm (adopted)

HEAD LOSS IN;

(i) Bell mouth, $Hf = \frac{k\times v^2}{2g}$

k = 0.05

$$= \frac{0.05\times1.08}{2\times9.81}$$

$= 2.75^{-03}$

$= 0.00275$

Say 0.003 mtrs.

(ii) Discharge Head $= \frac{kV^2}{2g}$

$= \frac{0.5 \times (2.35)^2}{2 \times 9.81}$

$= 0.140$ m.

(iii) Non return valve (600 mm dia)

k $= 2.5$

$h_f = \frac{kV^2}{2g}$

$= \frac{2.5 \times (2.35)^2}{2 \times 9.81}$

$= 0.703$ mtrs.

(iv) Sluice valve (600 mm dia)

k $= 0.19$

$h_f = \frac{0.19 \times (2.35)^2}{2 \times 9.81}$

$= 0.053$ meters

(v) Butterfly valve (600 mm dia)

$$k = 3.00$$

$$h_f = \frac{3\times(2.35)^2}{2\times9.81}$$

$$= 0.804 \text{ mtrs.}$$

(vi) Radial Tee (Bend) (600 mm dia)

$$k = 0.38$$

$$h_f = 0.38\times\left(\frac{2.35}{2\times9.81}\right)^2$$

$$= 0.106 \text{ meters}$$

(vii) Head loss through rising main 1422 mm OD, 9300 m long as per Hazen and Williams formula

12 mm. thick and 12 mm. mortar lining

$$hf = \frac{10.676}{D^{4.87}}\times\left(\frac{Q}{C}\right)^{1.852}\times1.1$$

Where,

Q = Discharge in m3/Sec

D = Internal diameter in meters

L = Length of pipeline in meters

$$hf = \frac{10.676}{1.374^{4.87}}\times\left(\frac{1.332}{130.0}\right)^{1.852}\times9300\times1.1$$

$$= 4.806 \text{ meter (for 115 MLD)}$$

$$= \frac{10.676}{1.374^{4.87}}\times\left(\frac{1.690}{130}\right)^{1.852}\times1.1\times9300$$

= 7.466 meter (for 146 MLD)

(viii) 1200 mm NRV = $h_f = k \times \frac{V^2}{2g} = \frac{2.5 \times (0.898)^2}{2 \times 9.81} = 0.102$ meter

Total head = Static head + frictional losses

= 25.95 + 0. 003 + 0.140 + 0.703 + 0.053 + 0.804 + 0.106 +4.806 (115 MLD)

= 32.565 (115 MLD) mtrs. Say 33 mtrs.

= 35.723 (146 MLD) say 36 meters

Horse Power

BHP = $\frac{Q \times H}{75 \times \eta}$

Q in literes/ second = 666 l/s.

H = 32 mtrs.

Efficiency 80%

= $\frac{666 \times 33}{75 \times 0.80} \times 1.15$

= 421.25

(80% efficiency and 15 % margin)

Say = 425 HP (317 kW say 320 kW)

Or 317 KW say 320 KW

(ix) Shaft dia.

$$N = 980$$

$$HP = 425$$

$$HP = 2\pi \times NT$$

$$425 = 2 \times \pi \times 980 \times T$$

$$T = \frac{425}{2 \times \pi \times 980} = 0.0690$$

$$fs = 630\ \text{kg/cm}^2$$

$$= \frac{\pi}{16} d^3 \times fs = 0.690$$

$$d^3 = \frac{0.690 \times 16}{\pi \times 630}$$

$$= 5.5^{-04}$$

$$d = 0.0823\ \text{m.}$$

$$= 82.35\ \text{mm.}$$

Say d = 90 mm

<u>Cross check</u>

$$HP = \frac{fNd^3}{321000}$$

$$f = 7000\ \text{lb/in}^2$$

$$\sqrt[3]{\frac{425 \times 321000}{7000 \times 980}}$$

d =

= 2.70 in.

= 68.8 mm say 70 mm

With corrosion allowance say 80 mm

Hence adopt 90 mm which is higher and safe.

Dynamic Weight of Pump

1.	Weight of bowl assembly (900 mm)	=	1800 kgs
2	Weight of strainer	=	108 kg
3	Weight of 900 mm dia bellmouth	=	98.00 kg
4	Weight of 600 mm dia 7 mtrs. Long column pipes	=	1035 kg
5.	Weight of Flanges – 8 numbers (800 mm dia OD 20 mm thick)	=	276 kg
6	Weight of Water	=	1979 kg.
	Total (1 to 6)	=	**5296** kgs

Say 6000 kgs

Capacity of EOT Crane = 7500 kg.

≈ 7.5 MT

Weight of discharge head + motor = 3500 kg.

Dynamic weight = 3 x Pump weight + 2 x Motor weight (as per IS 2974 Part 4)

3 x 6 + 2 x 3.5 = 25 Tonnes

Say 30 Tonnes

Maximum and minimum head on pumps

Minimum head	=	Discharge level in MBR – FSL in Sump + h_f
	=	345.95 – 324 + 6.615 = 28.565 mtrs.
Or	=	24 mtrs. (25% less as per IS)
Maximum head	=	Discharge level in MBR – lowest water level of the reservoir + h_f
	=	345.95 – 318 + 6.615 = 34.565 mtrs.
Or	=	33 + 3.3 (10% higher as per IS)
	=	36.3 mtrs.

Say 36 m

4.3 ELECTRICAL WORKS (PUMPING STATION AT GODHANI)

4.3.1 HT Panel Design

Fault level is 93.46 MVA (4.91 kA for 3 sec) for three phase fault as per M.S.E.B.

System Voltage	Nominal ---	11 kV
	Highest ---	12 kV (1.1 times nominal voltage)

4.3.2 Design Basis

Clear water pumping station, comprises 4 Nos. potable water pumps and total 2 Nos. pumps will be run to deliver the required capacity and two pump will be standby. This along with the aux. load for the pumping station and treatment plant will be the total load of the pumping station. (For details of the aux load refer to LV section of this document). This load caters for future expansion Incomer is sized based on this philosophy.

Main Transformers 11 / 3.6 kV

Capacity

i. Total HT motor load (4 x 325) = 1300 kW

HT load in kVA (considering three pumps) = $\frac{1300 \times 0.75}{0.88 \times 0.95}$

(Assume Diversity factor, PF& Efficiency) = 1166.27 kVA

ii. Total LT load in KVA = 426 kVA

(Refer Item 3.0 –Aux. Transformer capacity for details)

Total load = 1910.72 kVA

∴ Two 1600 kVA 11/3.6 kV transformers for H.T load and two nos. 630 kVA, 11/0.433 kV transformers for L.T load are proposed.

Load Current = 11 kV Side - 105 Amps
3.3 KV Side - 350.00 Amps

Water Treatment Plant receives power supply from MSEB at 11 kV by two express feeders. We have considered one (1) No. 11 kV VCB / switchboard to receive the power supply and feed the pump motors and auxiliary load through suitable step down transformers. The switchboard shall consist of 2 incomers each rated for 100 % capacity with bus coupler and suitable outgoing feeders. Both the feeders can operate independently with the bus section breaker open. When one of the feeders trip on under voltage the other incomer feeder caters for the total pumping station load by closing the bus-section breaker automatically.

Suitable auto changeover scheme is employed to implement this. Auto change over scheme shall ensure that the residual voltage is within safe value, before closing & voltage is less than 20 % (no volt condition) on the faulty feeder / bus for tripping and voltage available on the healthy bus/feeder shall be more than 80 %. For this suitable under voltage relays are used.

VCBs of suitable rating are considered with necessary protection for the transformer outgoing feeders.

4.3.3 Breaker Design

4.3.3.1 11 kV switchboard shall include

a) 2 Nos. Incomers
b) 1 No. Bus Coupler
c) 2 Nos. outgoing feeders for 1500 kVA transformers
d) 2 Nos. outgoing feeders for 630 kVA transformer

2 Nos. panels for O.L.T.C. for 1600 KVA, 11 kV Transformers

Maximum load Current Rating at 11 kV breaker	=	84 Amp
Rated continuous current of Breaker chosen	=	400 Amp. (Minimum Standard)
Fault Level at 11 kVAs per M.S.E.B.	=	93.46 MVA
Maximum Fault Current as per 93.46 MVA	=	symmetrical breaking current
Fault Level/(√3 x Line Voltage)	=	4.91 kA
Considering Line Voltage	=	11 kV
Rated interrupting current rating	=	12.5 kA

Making current = 1.8 x √2 x symmetrical breaking current

Chosen making capacity (peak) = 50 kA

Conclusion :

The maximum sinusoidal r.m.s. current, symmetrical breaking current and making current are within the rating of chosen breaker.

4.3.3.2 Current transformer for 11 kV circuit breaker:

Current rating at 11 kV incomer	=	84 Amp.
Nearest standard C.T. Rating available	=	100 Amp.
Secondary current rating for protection and metering	=	1 Amp.

The fault current at 192 MVA fault level is 4.91 kA = $\left(\frac{93.46}{\sqrt{3}\times 11}\right)$

Accuracy class for metering C.T. core I is = Class 1

Accuracy class for protection C.T. core II is = 5 P 20

VA Burden of Core I = VA Burden of Digital power Meter: < 5 VA

VA Burden of Ammeter = 5 VA

= 10 VA

VA Burden chosen = 15 VA

VA Burden of Core II = Over Current & Earth Fault Relay Element

= 10 VA

Rated burden chosen for both core = 15 VA

CT Ratio for outgoing feeder = 100/1A,
Class 5P10, 15VA

4.3.3.3 Voltage transformer for 11 kV circuit breaker

Transformer Ratio is (11 / √3 kv) / (110/ √3)/ (110/ √3)

VA rating = 50 VA /phase, Accuracy Class = 1

VA Burden of Digital power monitor meter = 10 VA

VA Burden of voltmeter = 5 VA

VA Burden of undervoltage relay = 5 VA

VA Burden of Indicating Lamps	=	15 VA
Total Burden in VA	=	35 VA

4.3.4 Protection

Protection of the Incomer feeder shall be provided by means of IDMT relay with two over current elements having range 50 to 200 % of 1 Amps. With definite minimum time of 1.3 Sec. at 10 times the current setting. Earth fault shall be IDMT with 10 to 40% setting range.

Suitable instantaneous under voltage relays (2 Nos.) with adjustable setting range and adjustable time delay shall be provided on each incomer and bus-section for the auto change over scheme.

Type of relays shall be as follows:

- Under voltage relays with 1 No. timer, GEC ALSTOM type VAGM 22. with a range (40-80%) to check the healthiness of the voltage
- Under voltage relays with 1 No. timer, GEC ALSTOM type VAG 21 with a 20% fixed setting to check the no voltage condition

4.3.4.1 Outgoing Transformer feeder

Instantaneous short circuit protection on HT side and back up over current protection for the transformer is considered for the Transformer outgoing feeder by means of IDMT relay with two elements having range 50 to 200 % of 1 Amps. with definite minimum time of 1.3 Sec. at 10 times the current setting and instantaneous high setting over-current range (500-2000%)

Earth fault protection on HV side is achieved by means of instantaneous Earth fault element with external resistance for stability against magnetizing current inrush having range as 10-40%. Back up ground fault relay for the LV system by means of restricted earth fault IDMT element having range 10-40% is also provided.

4.3.5 3.3 kV Incomer feeders

Max load current rating at 3.3 kV incomer breakers	=	280 Amps
Rated continuous current of breaker chosen	=	630 Amps
Fault level at 3.3 kV switchboard	=	
Considering line voltage	=	3.3 kV
Rated interrupting current rating	=	16 kA
Making current = 1.8 x √2 x Symnetrical breaking current		
	=	15.78 kA
Closer making capacity (peak)	=	50 kA

4.3.5.1 Current transformer for 3.3 kV C.B.

Current at 3.3 kV Incomer	=	280 A
Nearest standard C.T. rating available	=	300 A
Secondary current rating for protection & metering	=	1 Amp
Fault current	–	
Accuracy class for metering - core I	=	Class - I
Accuracy class for protection C.T. core II	=	5 P 20
VA Burden of digital power meter	=	< 5
VA Burden choosen	=	15 VA

VA Burden for Core II	=	Over current & Earth Fault Relay
	=	10 VA
Rated Burden chosen for both cone	=	15 VA

4.3.6 Voltage Transformer for 3.3 Kv C.B.

Transformer Ratio 3.3 / √ 3 / (110 / √3) / (110 / √3)

VA rating 50 VA / phase, Accuracy Class – I

VA Burden of Digital Power Monitor meter	-	10 VA
VA Burden of Volt meter	-	5 VA
VA Burden of under voltage relay	-	5 VA
VA Burden of indicating lamps	-	15 VA
Total Burden in VA	-	35 VA

4.3.7 Outgoing feeders to starter panels

3.3 kV Vacuum Circuit breakers for controlling motor operations shall be provided before FCMA soft starters as per SLD.

Starter panels

i) 3.3 kV FCMA Soft Motor starter with vacuum contactors

Full Load Current (I) of Pump Motor =

$$KW/(1.732 \times kV \times p.f. \times eff.) \frac{325}{1.732 \times 3.3 \times 0.9 \times 0.9}$$

$$= \quad 70.2 \text{ Amp}$$

The HRC fuse capacity for the starter is considered to give fault protection to the motor and connecting cable. The capacity of the HRC fuse is to be arrived at by considering motor starting time/ current characteristic curve, motor thermal withstand characteristic, power fuse permissible current/ time curve, power fuse total clearing current time curve, short time current of contactor and HRC fuse manufacturer's recommendation. The standard size of HRC fuse for starter in this case will be 200 Amps. Motor duty.

Vacuum contactor shall be 3.3 kV, 400 amps. Suitable for AC-4 duty with making current 4 kA and breaking current 3.2 kA and short time current rating 8 kA for 1 sec. and 40 kA for 200 ms.

ii) Current Transformer:

CT Ratio : 110/1 amps. 5P10 for motor protection

iii) Protection for motors

A solid state motor protection relay is proposed for the protection of the pump motor (325 kW). Motor protection relay shall provide the following protections as a minimum:

- Thermal overload
- Instantaneous overcurrent
- Stalling protection
- Phase unbalance
- Earth fault

To protect the motors from operating at lower than desired voltage two Nos. instantaneous under voltage relays with adjustable setting range of 20 to 80% of 110 volts shall be provided in the starter panels. The under voltage relays even though instantaneous shall act through time delay relay and trip the contactors.

4.3.8 Capacitors for improvement of power factor for the main pump motors

Assuming a p.f. of motors as 0.85 and the same has to be improved to 0.95

The capacity can be worked out as below :

kVA of motor at 0.85 p.f. $= \dfrac{325}{(0.85\times 0.9)}$

$= 424.84$ kVA

kVA of motor at 0.95 p.f. $= \dfrac{325}{(0.85\times 0.9)}$

$= 380.12$ kVA

KVAR of Capacitor required =

$\sqrt{(\text{sq.(kVA 0.84)} - \text{sq.(kW)})} - \sqrt{\text{sq.(kVA 0.95)-sq.(kW)}}$

= 76.47 kVAR

KVAR rating at 3.6 kV = 83.42 kVAR

The nearest round size = 85 kVAR

Capacitor current at 3.3 kV = $85/\sqrt{3} \times 3.3$

= 14.87 Amp.

Magnetizing current of the motor is normally 90% of no load current. From manufacturer's data for 3.3 kV 400 kW motor I No load / I full load	=	0.3
I no load	=	0.3 x 70
	=	21 Amp
Hence magnetizing current of motor	=	0.9 x 21
	=	18.9

Since, the capacitive current is less then the motor magnetizing current, we can use 85 kVAR capacitor for the purpose of power factor improvement from 0.85 to o.95.

4.3.9 HT Cable Design

11 kV incomer feeder cables from MSEB structure are laid under ground and outgoing transformer feeder cables are laid partly underground. A de-rating factor of 0.7 is considered for HT cable sizing. 11 kV cables are sized for a fault current of 12.5 kA for 1 sec. Based on this minimum size of the cable shall be 185 sq.mm.

i) Cable for Incomer

After applying de-rating factor of 0.7 current rating 84/07 = 120 Amp. Cable size of 3C x 185 sq. mm. Size XLPE with 17.46 kAmp. rating for 1 sec. is sufficient for the incomer.

ii) Cable for 11/0.433 KV Transformer incomer

Current for 630 VA Transformer = 34.00 Amp.

After applying de-rating factor = 34.00/0.7

= 49.00 Amp

Cable size selected is 3C x 95 sq. mm. Size XLPE with 8.96 k. Amp rating for 1 sec

iii) Cable for 3.3 kV 325 kW motor

Full load current = 71 Amp.

After applying de-rating factor = 101.43 Amp.

Motor cables are protected by fuses. Hence, it is sufficient to consider a duration of 0.25 sec. Hence, cables size of 1 No. 3C x 70 sq. mm., 3.3 kV (UE) cable is proposed.

Sr. No.	Load Description	Rating kW	Full Current Amps	Current Devating Factor	Cable Size	Cable nins	Cable Type
1 a)	Transformer	1600 kVA	84	120	3 x 185	1 x 2	11/11 XLPE
b)	Transformer	630 kVA	34	49	3 x 150	1 x 2	3.3 XLPE
2	Transformer to 3.3 kV S.B.		280	400	2 x 3 x150	2 x 2	3.3 kV XLPE
3	3.3 kV SB to motor	325 kW	71	101.5	3 x 70	1 x 4	3.3 kV XLPE
4	3.3 kV Capacitors	85 kVA	15	22	3 x 35	1 x 4	3.3 kV XLPE

4.3.10 DC battery sizing philosophy

48V DC system shall feed following loads in the pumping station :

Closing coils, trip coils, protective relays, auxiliary relays, timers, indicating lamps, annunciator, etc. on 11 & 3.3 kV & 415 V circuit breaker feeders.

4.3.11 Considerations for the battery sizing

Battery capacity has been sized to feed continuous load for 2 hours duration and in addition, momentary load for 1 minute duration.

Lead acid maintenance free Battery bank of 48V DC has been considered.

4.3.12 Estimation of continuous and momentary loads of battery

Following loads have been considered for calculation of battery capacity :

a. LED Indication lamps: 1W
b. Aux relay : 3W as per GEC ALSTOM type VAA11
c. Trip supervision relay : 6W as per GEC ALSTOM type VAX
d. Trip relay : 5W as per GEC ALSTOM type VAJH13 [low burden]
e. Tripping coil of 33 kV VCB : 200W
f. Tripping coil of 415V CB: 250W as per GE ALSTOM type M-Pact
g. Tripping coil of 3.3 kV vacuum contactor: 615W as per ALSTOM
h. Closing coil of 3.3kV vacuum contactor: 615W as per ALSTOM
i) Continuous Load

a) Indication for 2 I/C 1 B/C, 4-O/G in SWGR 14 x 1 = 14 Watt [2 Nos/ panel]

b) Aux. Relay in 11 kV switchboard [1 No. in each panel -Assumed]. 7 x 3 = 21 Watt

c) Trip supervision relay for 11 kV incomers 6 x 2 = 12 Watt

d) Trip relay operated [2 Nos assumed] 5 x 2 = 10 Watt

e)	Annunciation facia [2 nos assumed]		
f)	Indication for 3.3 kV starters –6 x 2 [2 Nos /panel assumed]		12 Nos
g)	Aux. Relay in 3.3 KV starters [2 No. in each panel Assumed] 12 x 3	=	36 Watt
h)	Emergency Lamps 50 x 30	=	1500 Watt

Continuous load current : 15 AMP FOR 2 HOURS

ii) Momentary Loads

a)	11 KV switchboard Tripping of 1 incomer & one outgoing 615 x 2	=	1230 Watts
b)	3.3 KV starters- Tripping of 4 contactors 615 x 4	=	2460 Watts
c)	Hooter [1 for all system] 100 x 1	=	100 Watts
d)	Annunciator lamps – 4 Nos (1 x 4)		4 Watts

Momentary load current : 62 AMP FOR 1 MIN

Type of battery	=	Lead Acid Maintenance free
End cell voltage considered	=	1.75 V/cell
Discharge rate considered	=	10 hrs.

Based on above, Lead-Acid maintenance free battery of 80 AH at 8 Hrs. discharge rate of is calculated. This sizing is arrived taking into consideration ageing factor, design margin, temperature correction factor etc., by the manufacturer. However, the battery manufacturer shall confirm the battery sizing based on the discharge performance characteristics of the batteries offered.

4.3.13 Auxiliary Transformer Capacity

The load on auxiliary transformer is as below :

Sr. No.	Description	Rating Kw	Qty No. working + stand by	Total connected Load in kW	Working load in kW	Demand factor	Demand in kW
I)	**Clarifiers**						
1	Blowers	12	2 + 2	48	24.0	1.0	24.0
2	Desuldging Pump	7.5	2 + 2	30	15.0	0.9	13.5
3	Sample Pump	0.1	2	0.2	0.2	1	0.2
4	Building Services and External lighting	5	-	5	5	1	5.0
II)	**Chemical House**						
1	Alum Storage Stirrer	3.73	2 + 2	14.92	7.46	1	7.46
2	Alum Pumps	3.73	2 + 2	14.92	7.46	1	7.46
3	Flash Mixer	2	2 + 2	8	4	0.9	3.6
4	Caustic Soda Stirrer	2	2 + 2	8	4	0.9	3.6
5	Caustic Soda Pump	3	2 + 2	12	6	0.9	5.4
6	Building Services and External lighting	10	2 + 2	10	15	1	10
III)	**Filter House**						
1	Air Compressor	5.6	2 + 2	22.4	11.2	0.9	10.08
2	Blowers	56	1 + 1	112	56	0.9	50.35
3	Wash Water Pump	25	2 + 1	75	50	0.9	45.0
4	Building Services and External lighting	20	-	20	20	1	20.0
IV)	**Chlorination House**						

Sr. No.	Description	Rating Kw	Qty No. working + stand by	Total connected Load in kW	Working load in kW	Demand factor	Demand in kW
1	Pre Chlorination Pumps	2	1 + 1	4	2.0	1	2.0
2	Post Chlorination Pumps	3.75	1 + 1	7.46	3.75	1	3.75
3	Crane	5.0	-	5.0	5.0	0.9	4.5
4	Building Services and External lighting	10.0	-	10.0	10.0	1	10
V)	**Sludge Thickener**						
1	Stirrer	5.0	2	10	10	0.9	9
2	Sludge Pump	7.5	2 + 2	30	15	0.9	13.5
3	Building Services and External lighting	5.0	-	50	5.0	1.0	5
VI)	**Pump House**						
1	Sump Pump	11.0	1 + 1	22.0	11	0.9	9.1
2	E.O.T Crane	15.0	-	15.0	150	0.9	13.5
3	Hub Motor Pump	7.5	2 + 1	22.5	15.0	0.9	13.5
4	Valve Actuators	2.0	12	24.0	2.0	1	2.0
5	Ventilation	20.0	-	20.0	20.0	0.9	18.0
6	Building Services and External lighting	10.0	-	10.0	10.0	1	10.0
VII)	**Administrative Building**						
1	Building Services	10.0	-	10.0	10.0	1	10.0
VIII)	**Instrumentation**						
1	Instrumentation	3.0	-	30.	3.0	1	3.0
IX)	**Compound Lighting and Street Lighting**						
1	Compound Lighting and Street Lighting	7.5	-	7.5	7.5	1	7.5

Hence the demand in Kw	=	**340.7 KW**
Demand in kVA @ 0.8 power factor	=	**425.87 kVA**
Add 20% extra capacity hence transformer capacity	=	**511.05 kVA**
Considering 97% transformer efficiency final Transformer capacity	=	**526.86 kVA**

The nearest standard rating recommended is **630 kVA** Hence we will go for **630 kVA** auxiliary transformer.

All motors are small in rating, as compared to transformer rating hence there is no severe current demand on transformer hence voltage regulation is not a concern.

The primary current of the transformer will be (630 / (1.732 x 11)) = 34.0 Amp.

For 630 kVA transformer 11 kV 400 A Vacuum Circuit Breaker, overload and short circuit protection as shown in the single line diagram (SLD) of pumping station we propose to go for Vacuum Circuit Breaker for transformer primary protection and isolation for following reasons:

- The SLD suggests relay protection, which may not be feasible with Fuse and isolator.
- There are No. of draw out type contactor in one pumping station and in all together in two pumping station. Hence standardization of contactor will help in long way to maintain spares as well as emergency replacement.

4.3.14 433 Volts AC Distribution panel

The secondary current of 630 KVA transformer is $= \dfrac{630}{1.732 \times 0.433}$

= **840.05 Amps**

Other system details are not known

The fault MVA at 11 kV is around 94 MVA known, but max. fault current a 630 kVA transformer with 6.25% impedance can supply is

$$840.05 \times \frac{100}{4.5} = 18667.76 \text{ AMPS}$$

$$= 18.67 \text{ KA.}$$

Hence we recommended 40 KA rating for LV panel components and LV panel bus bar. For cables even 15 KA rating for 1 second shall be adequate as protected by fuses.

It is recommended to have 1250 amps, 40 KA rating ACB with microprocessor based release as incomer the micro processor based release shall have following protections:

1. Overload protection.
2. Short circuit protection (with short time delay)
3. Short circuit protection (instantaneous)
4. Earth fault protcction

The bus bar shall be rated for 1250 A, 40 KA for 1 second.

All out going distribution feeders shall be SDFs of appropriate rating.

All motor starter feeders for motors upto and including 7.5 kw shall have DOL starters and motors above 7.5 KW shall have star delta starters.

The selection of SDFs, HRC back-up protection, contactor rating and over load relay range shall be as per type – II co-ordination chart recommended by manufacturer. The contactors shall be one size higher than that recommended for normal life by the manufacturer to have long trouble free operation.

4.3.15 LT Side power factor improving capacitor

The total working load on any one of the two transformers at a time is 340.7 kW at 0.8 power factor (assumed)

The calculation can be worked out as below :

KVA of load at 0.8 p.f. $= \dfrac{340.70}{0.8}$

$= 425.88$ kVA

KVA of motor at 0.98 p.f. $= \dfrac{340.70}{0.98}$

$= 347.65$ kVA

KVAR of Capacitor required

$= \sqrt{(\text{sq.(kVA 0.80)} - \text{sq.(kW)})} - \sqrt{\text{sq.(kVA 0.98)} - \text{sq.(kW)}}$

$= 186.36$ kVAR

Considering maximum demand, it is recommended to connect 2 No. 50 kVAR capacitor with manually controlled SDF on each bus section.

4.3.16 LT Cables

Derating factors	:	0.75 for 6 cables in a tray touching each other.
	:	0.90 for 45°C ambient temperature.

: Overall derating factor = 0.675.

Sr. No.	Load Description	Rating Kw	Full load current IL	Current / derating factor	Cable size	Cable runs	Cable type
1.	Transformer	630 kVA	876.48	1298.50	3.5 x 400	2 x 4	AYFY
2.	Blowers	12	26.0	39.0	3 x 10	1 x 4	AYFY
3.	Desludging Pumps	7.5	14.0	21.0	3 x 2.5	1 x 4	YWY
4.	Sample Pumps	0.1	0.5	0.75	2 x 1.5	1 x 2	YWY
5.	Building Services	5	10.0	15.0	3 x 2.5	1	YWY
6.	Alum Stirrer	3.73	7.5	11.0	3 x 2.5	1 x 4	YWY
7.	Alum Pumps	3.73	7.5	11.0	3 x 2.5	1 x 4	YWY
8.	Flash Mixture	2	50	7.5	3 x 2.5	1 x 4	YWY
9.	Caustic Soda Stirrer	2	5.0	7.5	3 x 2.5	1 x 4	YWY
10.	Caustic Soda Pumps	3	6.2	9.2	3 x 2.5	1 x 4	YWY
11.	Building Services	10	20.0	30.0	3 x 10	1	AYFY
12.	Air Compressor	5.6	11.0	16.0	3 x 2.5	1 x 4	YWY
13.	Blowers	5.6	100.0	148.0	3 x 70/3x3.5	1 x 2	AYFY
14.	Wash Water Pumps	25	46.0	68.0	3 x 25/3x10	1 x 3	AYFY
15.	Building Services	20	43.0	64.0	3 x 16/3x6	1	AYFY
16.	Pre-chlorination Pumps	2	50.0	7.5	3 x 2.5	1 x 2	YWY
17.	Post-chlorination Pumps	3.73	7.5	11.0	3 x 2.5	1 x 2	YWY
18.	E.O.T. Crane	5	10.0	15.0	3 x 2.5	1	YWY
19.	Building Services	10	20.0	30.0	3 x 10	1	AYFY
20.	Sludge Stirrer	5	10.0	15.0	3 x 2.5	1 x 2	YWY
21.	Sludge Pumps	7.5	14.0	21.0	3 x 2.5	1 x 4	YWY
22.	Sump Pumps	11	21.0	31.0	3 x 10	1 x 2	AYFY
23.	E.O.T. Crane	15	28.0	42.0	3 x 10	1	AYFY
24.	Lubricant Water Pumps	7.5	14.0	21.0	3 x 2.5	1 x 3	YWY

Sr. No.	Load Description	Rating Kw	Full load current IL	Current / derating factor	Cable size	Cable runs	Cable type
25.	Valve Actuators	2	5.0	7.5	3 x 2.5	1 x 12	YWY
26.	Ventilation	20	43.0	64.0	3 x 16	1	AYFY
27.	Building Services	10	20.0	30.0	3 x 10	1	AYFY
28.	Administration Building Services	10	20.0	30.0	3 x 10	1	AYFY
29.	Instrumentation	3.0	6.2	9.2	3 x 2.5	1	YWY
30.	Compound Lighting	7.5	14.0	21.0	3 x 2.5	1	YWY
31.	Capacitors	50 KVAR	70.0	103.0	3 x 70	1 x 4	AYFY

4.3.17 Earthing Design

4.3.17.1 Design Basis

4.3.17.1.1 Max fault current at 415 V = 40 kA

4.3.17.1.2 Duration of fault current = 0.5 Sec

4.3.17.1.3 Max earth resistivity = 8 Ω m [as per Drg. No.DRA/NMC/PENCH- 4/11].

4.3.17.1.4 Mat. at earth electrode = Galvanised Iron for Pipe & Copper for Plate

4.3.17.1.5 Type at joint = Bolted

4.3.17.1.6 Reference = IS 3043-1987

4.3.17.1.7 If required, calculations will be revised based on actual measurement of soil Resistivity figure during the installation stage.

4.3.18 Determination of Size of Earth Grid Conductor [MEL]

The size of earth grid conductor is decided as per IS 3043 formula [Pg. 29].

$$\frac{I}{S} = k\frac{1}{\sqrt{t}}$$

Where,

S = Cross Sectional area of grid in mm^2

I = Value of a. c. rms. fault current in Amperes.

t = Duration of fault in Secs. [operating time of disconnecting device]

k = Factor dependent on the material of the protective conductor , the insulation & other parts ; initial & final temperatures.

k = 80 for steel material [table 6A of IS 3043] [Pg.31]

I = 40 kA

t = 0.5 Sec.

$$S = \frac{I\sqrt{t}}{k}$$

$$S = \frac{40000\sqrt{0.5}}{80}$$

S = 353.55 mm^2

Since two No. earth connections are given for each & every equipment, considering two parallel paths,

$$S = \frac{353.55}{2} = 176.775mm^2$$

GI strip Conductor of size 50 x 6 sq.mm can be used which has cross-sectional area of 300 mm^2 as MEL. Strip between Transformer Neutral & Neutral Earth Pit shall be same but insulated.

4.3.19 Determination of No. of Earth Electrodes [EP]

4.3.19.1 As per IS 3043 [pg 27] dissipation of fault current of electrode surface is:-

$$I = \frac{7.57x10^3}{\sqrt{dt}} Amp/m^2$$

Where,

I	=	Current density in AMP / m^2
t	=	Duration of fault current is 0.5 Sec
d	=	Resistivity of soil in Ω m. is 8 Ω -m.

$$I = \frac{7.57x10^3}{\sqrt{8x0.5}} Amp/m^2$$

$$I = 3785 \text{ AMP/m}^2$$

In order to dissipate fault current of 40 kA the total area of electrode required is

$$Area = \frac{40x10^3}{3785} = 10.57m^2$$

Area of 1 No. Plate earth electrode [both sides of plate]

A_E = $2[L \times B]\ m^2$

Where

L = Length of plate electrode in mtr. [600 mm.]

B = Width of plate electrode in mtr. [600 mm.]

A_E = $2[0.6 \times 0.6]$ = $0.72\ m^2$

Total Area for 8 Nos. of plate Electrode = $8 \times 0.72 = \mathbf{5.76\ m^2}$
[For Transformer Neutral]

4.3.19.2 Area of 1 No. Pipe earth electrode

A_E = $\pi \times D \times L\ \ m^2$

A_E = $\pi \times 0.04 \times 3$

= $0.377\ m^2$

Where

D = Diam of pipe electrode in mtr. is 40 mm.

L = Length of pipe electrode in mtr. is 3 mtr.

Allowing 5% reduction in area due to perforation

A_E = $0.377 \times 0.95 = 0.36\ m^2$

Total Area for 6 Nos. of pipe Electrode = 6×0.36

$$= \quad \mathbf{2.16\ m^2}$$

4.3.19.3 Area of 300 mtrs of 50 x 6 mm GI strip [main earth loop] which is buried directly underground.[both sides of strip]

$$A_E = 2 \times (300 \times 0.05) = \mathbf{30\ m^2}$$

4.3.19.4 Total Area of Electrodes = 5.76 +2.16 +30 = **37.92 m^2** which is more than required Area of 10.57 m^2 as calculated in clause 9.3.1 above. Hence No. of Electrodes provided are adequate.

4.3.20 Calculation of Earth Resistance

4.3.20.1 Pipe Electrodes --- 6 Nos. provided [Ref. Overall Earthing layout]

The earth resistance of pipe electrode is calculated as per formula given is IS 3043 [page 20]

$$R = \frac{100\delta}{2\pi L}\log_e \frac{4L}{D} \ \Omega$$

Where,

L	=	Length pipe electrode in cm	-	[300]
D	=	Diam of pipe electrode in cm	-	[4cm]
δ	=	resistivity of soil in Ω m.	-	[8 Ω -m]

$$R = \frac{100x8}{2\pi 300}\log_e \frac{4x300}{4}\Omega$$

$$= 2.422\ \Omega$$

Hence Effective resistance [Re. 1] for 6 Nos. pipe electrodes provided will be,

$$1/Re_1 = 6/R$$

$$1/Re_1 = 6/2.422$$

$$Re_1 = 2.422/6$$

$$Re_1 = 0.40\Omega$$

4.3.20.2 Plate Electrodes

8 Nos. for Transformer Neutral as required by CEI [Ref. Overall Earthing layout]

The earth resistance of copper plate electrode [600mm X 600mm] is calculated as Per formula given in IS 3043 - [page 19]

$$R = \frac{\delta}{4}\sqrt{\frac{\pi}{A}}\ \Omega$$

Where,

A	=	Area of both sides of plate in sq.m.	[0.72 sq.m]
δ	=	resistivity of soil in Ω m.	[8 Ω -m].

$$R = \frac{8}{4}\sqrt{\frac{3.14}{0.72}}\Omega$$

$$R = 4.177\Omega$$

Hence Effective resistance [Re. 2] for 8 Nos. plate electrodes provided will be,

$$1/Re_2 = 8/R$$
$$1/Re_2 = 8/4.177$$
$$Re_2 = 4.177/8$$
$$Re_2 = 0.522\Omega$$

4.3.21 Main Earth loop Resistance---- 300 mtr length.

The resistance of earth grid will be further reduced due to burial of 50 x 6 mm GI strip. The earth resistance of Main Earth Loop is calculated as per formula given is IS 3043 - [page 21]

$$R_g = \frac{100\delta}{2\pi L}\log_e\frac{2L^2}{wt}\,ohms$$

Where

L	=	Length of strip in cm	[30000cm]
w	=	Depth of burial of strip in cm	[60cm]
t	=	Width of conductor in cm.	[5cm]
δ	=	resistivity of soil in Ω m.	[8 Ω -m]

$$R_g = \frac{100x8}{2\pi 30000}\log_e\left(\frac{2x(30000)^2}{60x5}\right)$$

$$R_g = 0.066\Omega$$

4.3.21.1 Combined resistance of 16 Nos. electrodes & main earth loop is

$$1/Rcomb=1/Re_1+1/Re_2+1/R_g$$

$$\frac{1}{Rcomb}=\frac{1}{0.40}+\frac{1}{0.122}+\frac{1}{0.066}$$

$$\frac{1}{Rcomb}=2.5+1.92+15.15=19.57$$

$$Rcomb=0.05\Omega$$

4.3.21.2 Thus quantity of 40mm Φ, GI pipe Earth Electrodes provided = 6 nos. & 600mm x 600mm copper plate Earth Electrodes provided = 8 nos. for Transformer Neutral, that is **total 14 No. Earth Electrodes** provided, are adequate for achieving Earth Resistance less than 1Ω as stipulated by IS 3043.

4.3.22 Building Services

4.3.22.1 Scope

The Contract shall include the design supply, delivery to Site, off-loading, storage, erection, testing and setting to work the complete building services installation including but not limited to:

(a) Internal main and emergency lighting;
(b) External walkways and floodlighting;
(c) Roadway lighting;
(d) Small power;
(e) Air conditioning;
(f) Ventilation;
(g) Fire Detection System.

The building services installation shall comply with Standard Specification and the following clauses herein.

Internal Lighting

4.3.22.2 Internal main lighting

Internal lighting shall be designed to provide the following minimum service illuminance, measured at floor level:-

(a)	Process plant/pump hall areas	:	200 lux
(b)	Chemical preparation areas	:	300 lux
(c)	Switch rooms	:	300 lux
(d)	Control room	:	350 lux
(e)	Workshop areas	:	300 lux
(f)	Laboratory	:	500 lux
(g)	Offices	:	350 lux
(h)	Staff rooms and reception areas	:	150 lux
(i)	Toilets, washrooms, mess rooms corridors and staircases	:	100 lux

Luminaires shall be fixed directly to, or suspended from, the underside of roof slabs, ceilings or fixed to walls as appropriate.

Pump halls and other high bay areas shall be provided with high or low bay energy efficient lighting. The contractor shall provide all necessary equipment to ensure lighting maintenance can be performed in a safe and efficient manner. Where special provision would have to be made for accessing luminaires supported from the underside of the roof slab for maintenance, luminaires shall be wall mounted.

Luminaires for the control room and offices shall be designed to minimise glare.

Light switches shall be located adjacent to doorways. Multi-way switching shall be provided for rooms and areas with more than one point of access. For large area light switching or high/low bay lighting, contactors shall be provided to switch lighting in blocks from each entry point.

4.3.22.3 Internal emergency lighting

Emergency lighting shall be provided and shall comprise exit and escape route luminaries to facilitate safe movement of personnel in or from any building or major dry structure in the event of a mains supply failure. Exit luminaries shall be provided above all doors leading to or accessible to an outdoor area.

Emergency lighting shall also be provided in areas where essential operations may be required during a mains supply failure, for example, switch room and control rooms.

4.3.22.4 External lighting

Luminaries shall be provided to illuminate all external personnel walkway areas around buildings and structures. The lighting shall be designed to provide an even minimum service illuminance measured at ground level of 15 lux.

Lighting shall be switched at personnel access doors. Multi-way switching shall be provided where there is more than one point of access.

4.3.22.5 Floodlighting

Floodlighting shall be provided for the entrance to the site, raw water intake, chlorine cylinder stores, clarifiers, all site pumping stations and wet wells, sludge thickening areas, loading/unloading areas, the contact/ treated water tank and the ground level balancing reservoir. Floodlighting shall also be provided at all locations requiring inspection.

Floodlights shall be mounted on galvanized steel poles or on structure walls as appropriate.

Floodlighting shall provide a minimum service illuminance of 50 lux measured at the working plane.

Floodlighting shall be locally switched.

4.3.22.6 Roadway lighting

Roadway lighting shall comprise tubular steel columns with semi cut-off high pressure sodium type luminaires complete with control gear. The roadway lighting shall provide a minimum illuminance at ground level of 25 lux.

Minimum 4c x 6sq mm, 1.1 kV, Cu., PVC, Annoured cables shall be used for power supply from distribution board up to the individual junction boxes of each street light pole. From the junction boxes up to the luminaries 2.5sq mm Cu flexible wire shall be used.

Roadway lighting shall be solar time switch controlled. The time switch shall be located adjacent to the point of supply. An over-ride switch shall be provided to manually over- ride the solar time switch controller. This shall be located at the low voltage switch room for the raw water pumping station.

4.3.27 Small power

Industrial switched type 230 Vac socket outlets with residual current devices for the connection of electric tools shall be installed in convenient places in all plant and workshop areas.

Suitable rated 415 Vac/ 230 Vac socket outlets with residual current device shall be provided for all water retaining structures for the water treaemtment works, intake structure and raw water pumping station. The socket outlets shall be located in an IP65 weatherproof enclosure fixed to the structure wall.

For process plant areas, industrial type socket outlets shall be spaced so that any location within the area is no greater than 20 m from an outlet. A minimum of two socket outlets shall be provided in each area.

Commercial type 230V 15A and 5A socket outlets shall be installed throughout all administrative office areas including the associated corridor areas. A minimum of two socket outlets shall be provided in each room to allow each desk to be serviced with a power supply without the need for extension leads. Additional socket outlets to suit the particular requirements of the main control room and the laboratory shall be provided.

Low voltage and extra low voltage supply transformers shall be provided for hand held power tools and lights adjacent to all below ground structures which require maintenance access.

4.3.27.1 Ventilation

Mechanical ventilation shall be provided as follows:-

Location		Air changes/hour (ACH):
Chlorine Building		
- Cylinder Store	:	12
- Chlorine Room	:	10
- Monitoring Room	:	6
- Pump Room	:	16
Miscellaneous:		
- Toilets and Washrooms	:	6
- Mess rooms and Kitchen	:	6
- Sludge Galleries	:	10
- Electrical switch rooms	:	10

For further details of ventilation requirements refer to the mechanical specification.

4.3.27.2 Ceiling Fans

All administrative areas such as the control room, all offices and building entrance areas at water treatment works and raw water pumping station shall be provided with ceiling fans to provide 4 ACH. The fans shall be provided with local speed controllers and switches adjacent to each individual unit.

4.3.27.3 Air conditioning

As a minimum control room and laboratory shall be air conditioned. The contractor shall also provide additional air conditioning units to meet the requirements of his design.

The air conditioning shall be designed to maintain a dry bulb temperature of 22 °c and relative humidity of 50% under the outside mean monthly maximum shade temperature and humidity specified elsewhere.

4.3.27.4 Fire detection system

A fire detection system shall be provided in accordance with BS 5839: Fire detection and alarm systems for buildings, the local fire regulations and the following requirements:

(a) Fire detectors

Optical smoke type detectors shall be installed in switch rooms, stores containing flammable materials and the control rooms.

The detectors shall be locally resettable and shall be detachable from their installation position to facilitate maintenance and replacement. Detectors shall have light-emitting type operation indication and shall be suitable for fixing direct to circular conduit boxes.

(b) Manual call points

Manual call points shall be located strategically throughout the plant. A call point shall be located adjacent to each external door and at personnel doors to switch rooms, chemical areas and stores of flammable materials. For multi-storey buildings, call points shall additionally be located at stairwell landings on each floor.

(c) Control panel

Wall mounted addressable type control panels shall be located in the control room of the administration building for the water treatment works and in low voltage switch room at the raw water pumping station.

A system-test facility and a power supply failure indication shall be provided.

Each control panel shall be provided with voltage-free changeover contacts to be monitored by the DCS for the following conditions:

(i) system fault
(ii) normal supply failed
(iii) system operated.

The contacts shall be wired to cable terminations.

A correctly-oriented plan of the premises showing the locations of the fire zones and exits, and instructions for the actions to be taken in the event of fire or fault indication, shall be positioned adjacent to the control and indicating equipment. They shall be in an approved durable form.

(d) Fire alarm devices

Sounder and visual fire alarm devices shall be installed in switch room and on each floor of multi-storey buildings. The fire alarm sounder/strobe device locations shall be audible or easily observed from all parts of the water treatment works and raw water pumping station.

(e) Power supplies

The normal supply for each control panel shall be derived from the normal site power supplies. A standby supply shall be provided by an integral sealed-type battery complete with an automatic charger. The battery shall be of the nickel- alkaline or lead-acid type and shall have a life of not less than 4 years and shall be capable of automatically maintaining the system operational for a minimum period of 24 hours.

The battery charger shall be fitted with a milli-amp meter to indicate the rate of charge.

The normal site power supply for each control panel shall be from a dedicated outgoing MCB. The outgoing unit shall be coloured red and shall be fitted with a label inscribed "Fire alarm -do not switch off".

(f) Wiring

Wiring shall be carried out using the red covered fire resistant cabling in accordance with the local fire regulations.

4.3.27.5 Telephone facilities

A complete telephone system shall be provided for the raw water pumping station. The system shall comprise a site EPABX located in the filter building control room. The site telephone system shall be connected to the telephone company network to provide off-site communications. The contractor shall make all necessary arrangements with the telephone company for provision of the lines into the works (minimum 2 lines)

Telephone handsets shall be provided in the control room, each electrical switch room and each office. Locations of handsets shall be agreed with the Engineer.

The EPABX shall be sized to provide 50% spare capacity for additional telephone handsets and external telephone lines.

The treatment works telephone cable network shall be used for telephones only and not instrumentation signals.

4.3.28 Site Intercom

The Contractor shall provide a site intercom system comprising of a externally mounted call- point at the site entrance gates for the water treatment works and raw water pumping station which shall be limed to the control room in the filter house.

The external call-point shall be provided with in-built call button, a microphone and speak push-button, and a speaker all located in a weather proof enclosure adjacent to each site entrance.

The control room shall be provided with a desk mounted microphone and speak push- button. An audible call alarm shall be provided which is audible in all parts of the administration area of the filter building.

4.3.29 Distribution boards

A distribution board shall be installed on each floor of each building and shall provide distribution to lighting, socket outlets, heating, ventilation and air conditioning. Circuits shall be arranged to provide a balanced load on each phase of the supply.

The fire detection system shall be supplied from a dedicated feeder unit on the appropriate 415V motor control centre.

4.3.30 Wiring

Internal wiring on concrete and block work surface shall be carried out using single core PVC insulated non-sheathed cables installed in surface mounted heavy duty galvanized steel conduit and / or trunking. Wiring in plastered and tiled areas shall be installed in concealed steel conduit.

External wiring shall be carried out using single core PVC insulated non-sheathed cables installed in heavy duty galvanized steel conduit or PVC covered mineral insulated copper sheathed cables.

Wiring associated with lighting and ventilation fans in the chlorine and chemical buildings shall be carried out using heavy duty PVC or GRP conduits/ trunking and / or cable tray ladder as necessary.

4.3.31 Ventilation System Design

4.3.31.1 Introduction

In any industrial building where industrial processes are carried out a large amount of heat is evolved. If such heat is not removed from industrial building, it will affect efficiency of the workers working therein and it will also affect the life of the machinery especially electrical one. Similar is the case of Nag pur Water Supply and Sewerage Project wherein following pumping station will be installed & commissioned.

1. Clear Water Pumping Station

4.3.31.2 Method of Ventilation

Ventilation can either be carried out by natural or mechanical way.

In the present cases of all four installations the natural ventilation is neither practicable nor adequate enough to remove the heat generated during pumping operation. Natural ventilation also depends upon pressure exerted by the wind outside, stack action generated in the building, cross ventilation through the building configuration and roof of the building and hence airflow cannot be controlled consistently thorough out all the seasons.

In view of above, it is essential to adopt mechanical ventilation. Mechanical ventilation may be either (a) by exhaust ventilation whereby air is removed from a building by means of fan while fresh air is introduced from windows and other openings, or (b) by positive ventilation whereby air is supplied by means of a fan or blower from outside or (c) by combination of both exhaust and positive ventilation. In case of positive ventilation, it is possible, where necessary, to cool the air before being brought into the building either by way of evaporation cooling or by air conditioning.

a. Exhaust ventilation

Ventilation by this method can be effected in case of narrow buildings. Exhaust fans are provided in walls on one side of the building and roofs to draw large volumes of air through the building from the opposite side. Adequate inlet openings for air are provided so as to minimise draughts caused by high inlet velocities. In this case short circuiting of air should be avoided.

b. Positive Ventilation

Positive ventilation affords better control of atmospheric conditions inside the factory building. It is useful where exhaust ventilation cannot be used due to wider processing area. In positive ventilation method, air is forced into the building by means of centrally located supply fans and distributed air through the duct. The duct may carry cooled or conditioned air. Unit ventilators may be provided for individual roofs and may be placed against outside wall. The air supply outlets are many times more than what is possible by exhaust.

c. Combined System

In this system the air is forced into the area of working at lower level and hot air which takes natural upward path is removed by roof extractors provided preferably over the heat producing machines or processes.

d. Selected Method

The method of Exhaust Ventilation mentioned above amongst the offer, it is found to be useful in the installation taking into account the number of air charges required at the installation are less.

4.3.31.3 Data

4.3.31.4 General

Ambient temperature (max.)	=	45^0 C
Humidity (max.)	=	77 %
Altitude	=	< 1000 m.

4.3.31.5 Clear Water Pumping Station

i. Clear Water Pump Room

No. of pumps	=	4
Motor capacity	=	325 kW
Motor efficiency	=	94.5 %

Lighting fittings	=	16 Nos.
Wattage of fitting	=	250 Watts each
Pump room size (LxWxH)	=	25 m x 12 m x (EL 333 – EL 325)

4.3.32 Design Criteria and Assumptions

It is essential to find out total quantity of air required for ventilation for maintaining temperature in the area of ventilation within a limit.

For this purpose following assumptions are taken into account.

i. Maximum temperature difference between outside air and inside air should not exceed 5°C as the maximum ambient temperature is given as 45° C.

ii. Temperature of outlet air should not exceed 50° C for more than one hour, as it will be injurious to the worker.

iii. Wet bulb temperature during 45° C dry bulb temperature shall not exceed 27°C.

iv. Sufficient elevation level difference between intake air and outlet air is present.

v. It is assumed that the roof top of the building is painted with heat reflecting paint and wherever possible it is insulated.

vi. Heat from the Sun affects comparatively less as inside the building heat developed due to the electrical motors is more and temperature inside the building is more than outside temperature.

vii. During high ambient temperature, the electrical lighting heat load will be nil in the pump rooms. However, for safer side it is considered in the calculations.

viii. Electrical loads viz. auxiliary pumps are not considered for heat load calculations, as these pumps will not be operated continuously.

ix. Doors and windows provided to the building are shielded with sunglass film etc. so as to reduce heat entering inside the building due to sun rays.

x. Formula used for requirement of air for ventilation is,

$$Q = \frac{3.462 \times Ks}{t}$$

Where,

Ks = Sensible heat gained in kcal/hr.

t = Allowable temperature difference in °C

Q = Quantity of air in m^3/hrs.

1 KWH = 860 Kcal/Hr.

4.3.33 Detailed Design for Ventilation

4.3.33.1 Clear Water Pump Room

A. Pump Room

i. Volume of room = 25.0 x 12.0 x 7.5.

= 2250 m^3

ii. Heat loss due to motor Kcal/hr = Rating of motor x No. of motors x (1-efficiency)

= 325 kW x 3 x (1.0 – 0.945) x 860

= 46117.5 Kcal/hr

iii. Heat loss due to lighting = No. of fittings x wattage x 0.86

= 16 x 250 x 0.86

= 3440.00 Kcal/hr

iv. Total heat loss in Kcal/hr. = 46117.50 + 3440.00

= 49557.50 kcal/hr.

v. Air requirement for ventilation in m^3/hr = $Q = \dfrac{3.462 \times Ks}{t}$

Ks = 49557.50 kcal/hr.

t = 5°C

$= \dfrac{3.462 \times 49557.50}{5}$

= 34313.61 m^3/hr.

vi. Air changes per hour = $\dfrac{34313.61}{2250}$

≈ 16

vii. No. of exhaust fans required $= \frac{34313.61}{10400}$

$= 3.3$

Say 4 Nos.

Each of size 600 mm, 3 phase, capacity of 10400 m^3/hr. and db level not exceeding 65.

viii. Power requirement of fans,
Power of each fan is 550 W.

Total Power $= 550 \times 4$

$= 2200$ Watts

$= 2.2$ kW

4.3.34 Installation Details

Typical sizes of exhaust fans (refer sketch) are as follows (all dimensions are in mm):

Size (Dia.)	A	B	C	D	E	F	G
600 mm.	720	598	635	11.5	405	162	600

Exhaust fan shall be protected with wire guard and provided with louvers.

Marking of Exhaust Fan locations are provided in the following drawings.

1. Ventilation system for Clear Water Pumping Station

APPENDIX – I

A) Transformer Capacity for Direct on line starting 325 kW motor

1) Fault Level = 93.46 MVA

≈ 4.91 kA

V_1 = 3.3 Kv

= 1905.3 Volts/ Phase

V_m = 0.85 V_1

= 1619.5 Volts / Phase

Cos ∅ = 0.15, Sin ∅

= 0.988, k = 6

Starting enment of 325 kW motor Is = $\text{In} \times k \times \frac{V_m}{V_1}$

V_{bs} = 0.9 x 1905.3

= 1715 volts / phase

$$V_1^2 = \left[V_m \text{Cos}\varnothing + \frac{k\text{In}VmRC_1}{V_1}\right]^2 + \left[V_m \text{Sin}\varnothing + \frac{k\text{In}Vm(XC+X_{50})}{V_1}\right]^2 - \text{I}$$

$$V_{bs}^2 = \left[V_m \text{Cos}\varnothing + \frac{k\text{In}VmRC_2}{V_1}\right]^2 + \left[V_m \text{Sin}\varnothing + \frac{k\text{In}VmXC}{V_1}\right]^2 - \text{II}$$

$$I_n = \frac{325}{1.732 \times 3.3 \times 0.9 \times 0.9}$$

	=	70.2 Amps
Tr. To Bus	=	2 x 3 x 150 Sq nl
Bus to Motor	=	3 x 70 Sq.mm
Xc_{150}	=	0.0953 / km
	=	0.0020/40mL
Rc_{150}	=	0.263 / km
	=	0.00524 / 40 mtrs
Xc_{70}	=	0.107 / km
Rc_{70}	=	0.576 / km
Motor cable length	=	40 m
Xc_{70}	=	$\frac{0.107}{1000}\times 40$
	=	0.00428Ω
Rc_{70}	=	$\frac{0.576}{1m}\times 40$
	=	0.023Ω

V_{bs}^2

$$=\left[Vm\times 0.15+\frac{6\times 70.2\times Vm\times 0.023}{1905.3}\right]^2+\left[Vm\times 0.988+\frac{6\times 70.2Vm\times 0.00428}{1905.3}\right]^2$$

$$= (0.1551\ Vm)^2 + (0.98895\ Vm)^2$$

$$= 0.0241\ Vm^2 + 0.9780\ V^2$$

$$= 1.002\ Vm^2$$

$$\therefore Vm = \frac{Vbs}{\sqrt{1.002}}$$

$$= \frac{1715}{1.002}$$

$$= 1713.19 \text{ volts}$$

Putting this value of Vm in equation I

$$(1905.3)^2 = \left[1713.19\times0.15+\frac{6\times70.0\times1713.19\times X_{50}}{1905.3}\right]^2$$

$$+$$

$$\left[1713.19\times0.988+\frac{6\times70.2\times1713.19\times X_{50}}{1905.3}\right]^2$$

$$= 66037.92 + 194651.29\ X_{50} + 143436.95X_{50}^2$$

$$+$$

$$2859616 + 28 + 1575190.23\ X_{250} + 216919.78\ X_{50}^2$$

$$3630168.09 = 2865002.14 + 1282103.19\ X_{50} + 143536.95X_{50}^2$$

$$= 2931040.06 + 1476754.48\ X_{50} + 286873.19\ X_{50}^2$$

$$\therefore 0 = X^2_{50} + 1575190.23\ X_{50} - 697722.25 \div 216919.78$$

$$= 286873.91X_{50}^2 \quad +1476754.48 \quad X_{50}-699128.03(\div286873.91)$$

$$= X^2_{50} + 5.1477\ X_{50} - 2.4371$$

$\therefore$ a = 1

b = 5.1477

c = -2.4371

b^2 = 26.4993

4ac = 9.7484

$$X_{50} = \frac{-b \pm \sqrt{4ac}}{2a}$$

$$= \frac{-5.1477 \pm 6.0206}{2}$$

$$= 0.4364\Omega$$

$$\therefore \sqrt{b^2 - 4ac} = \sqrt{36.2477} = 6.0206$$

$$Xs = X_{50} - Xc$$
$$= 0.4364 - 0.00628$$
$$= 0.43012$$

$$Xs(pu) = \frac{0.43012}{E^2}$$

$$= \frac{0.43012}{E^2}$$

$$= \frac{0.43012}{3.3^2}$$

$$= 0.039497$$

$$Xg = \frac{1}{93.46}$$

$$= 0.0106998$$

$$\therefore X_5 = X_{5(pu)} - X_g$$

$$= 0.028797$$

Reactance of transformer = 6.25 %

$\therefore$ X_{5pu} = 0.0625

$\therefore$ MVA rating of Transformer = $\dfrac{0.0625}{0.028797}$

= 2.17035 MVA

= 2170.35 kVA

$\therefore$ Transformer rating is 2500 kVA. Hence it can take starting current load of 325 kW motor

B) Transformer load when last motor i.e. third motor started when other load was in service (with D. O. L. Starter)

Load in service = 2 x 325

= 650 kW

$\therefore$ Current = $\dfrac{650}{1.752 \times 3.3 \times 0.9 \times 0.9}$

= 140.40 Amps.

Starting current of 3rd motor = 6 x I_{f1}

= 6 x 70.2 = 421.2

$\therefore$ Total current = 140.40 + 421.2

= 561.6 Amps

Plus treatment plant load – 300 kva ≈ 53 Amps

Full load current of 2500 kVA Transformer

$$= \frac{2500}{1.732 \times 3.3}$$

$$= 437 \text{ Amps}$$

$$\therefore \frac{\text{Total current}}{\text{Tr. Full load current}} = \frac{561.6}{437}$$

$$= 1.285$$

i.e. 28.5 % over loading

Actual transformer capacity required for running max. three 325 kW pumps single transformer is in service is 1250 kVA. For providing D.O.L starters capacity of transformer required is 2500 kVA, which is quite high. Hence it is proposed to provide two transformers of 1600 kVA, 11/36 kV taking into consideration future expansion. 3.3 kV, 34 kW motors shall be provided with FCMA soft starters to limit the starting current.

5.0 PURE WATER RISING MAIN FROM WTP AT GODHANI TO MBR AT GOVERNOR HOUSE

5.1 DESIGNS

5.1.1 Hydraulic Design

Internal diameter	=	1422 mm
Cement mortar lining	=	12 mm
Plate thickness	=	10 mm
C.C. out coating	=	20 mm

For flow of 115 MLD

$$Q = \frac{115 \times 1000}{24 \times 3600}$$

$$= 1.3310 \text{ m}^3/\text{s}$$

$$\text{Velocity} = \frac{Q}{A}$$

$$= \frac{1.3310}{\frac{\Pi}{4} \times 1.374^2}$$

$$= \mathbf{0.8976 \text{ m/s}}$$

Maximum Water Hammer Pressure

$$a = \frac{1425}{\sqrt{1 + \frac{kd}{Ect}}}$$

$$= \frac{1425}{\sqrt{1 + \frac{2.07 \times 10^8 \times 1.410 \times 1000}{2.1 \times 10^{10} \times 12}}}$$

$$= \frac{1425}{\sqrt{1 + 1.1582142}}$$

$$= \frac{1425}{1.469086207}$$

$$= \mathbf{969.990}$$

Maximum Water Hammer Pressure

$$= \frac{a \times v}{g}$$

$$= \frac{969.990 \times 0.8976}{9.81}$$

$=$ **88.752 m** **head of water**

Hydraulic Test Pressure at Factory
IS 3589 : 2001 C1.20.1
For Fe 410 Steel

$$P = \frac{2\,St}{D}$$

$$= \frac{2 \times 0.6 \times 235 \times 12}{1422}$$

$=$ 2.37974 MPa

$=$ **237.974 m** **head of water**

Operating head= F.S.L. of BPT at Gorewada – L.W.L. in sump at Godhani

$=$ 345.950 - 320.000

$=$ 25.95 m

For 185 MLD operating head + max water hammer pressure

$=$ 25.95 + 88.752

$=$ 114.702 < 280 m ---------- OK

Review of Hydraulic Design of Raw Water Pumping Main

Internal diameter 1400 mm

Q = 115 MLD

$$V = \frac{Q}{A}$$

$$= \frac{115 \times 1000}{24 \times 3600}$$

$=$ **0.8976 m/s**

Frictional Losses

$Q = 7.436 \times 10^{-9} \times C \times D^{2.63} \times hf^{0.54}$

$115 = 7.436 \times 10^{-9} \times 130 \times 1374^{2.63} \times hf^{0.54}$

$\therefore$ hf = 0.469153

hf = **0.469153** **say 0.470m / 1000m**

Length of main = 9285 m

Loss of head in friction = 9.285 x 0.470

= **4.36395 m**

5.1.2 Structural Design Calculations

Check for Deflection

Iowa Spangler Equation

$$\frac{\Delta}{D} = \frac{k\left(D_L\ Pb + Ps\right)}{8\dfrac{EI}{D^3} + 0.061\,E^1} \times D_R$$

Where

Δ	=	Linear deflection of pipe vertical diameter
D	=	Pipe diameter
D_L	=	Deflection lag factor
D_R	=	Re-rounding factor
Pb	=	Vertical pressure due to backfill
Ps	=	Vertical pressure to surcharge loads
EI/D^3	=	Pipe stiffness
E^1	=	Modulus of passive resistance of pipe zone fill material
k	=	Bedding constant 0.1 for sand

Load on pipe due to backfill

= w x H x Bc

= 18 x 1 x 1.462

= 26.316 kN/m.

$$Pb = \frac{26.316}{1.462}$$

= $18\ kN/m^2$ or 18 kPa

Ps

Wheel load IRC class AA = 6.25 T

IS 783-85 Cl. 11.2

Cover > 900 mm, Impact factor 1

$$Wc = CP\frac{P\alpha}{l}$$

Where l = 1.15H + 2D + S

= 1.15 x 1 + 2 x 1.462 + 0

= 1.15 + 2.924

= 4.074

$$\frac{l}{2H} = 2.037, \quad = \frac{D}{2H} \quad \frac{1.462}{2H} = 0.731$$

From fig. 3, IS 783 – 1985 for $\frac{l}{2H} = 2.037$, $\frac{D}{2H} = 0.731$

Cp = 0.675

$$wc = \frac{0.675 \times 6.25 \times 1}{4.074}$$

= 1.0355 T

= 10.158 kN/m.

$$Ps = \frac{10.158}{1.462}$$

= 6.948 kN/m²

or 6.948 kPa

Pipe stiffness = EI / D³

$$= \frac{2 \times 10^5 \times \frac{1}{12} \times 12^3}{1410^3} \times (1000)^2$$

= 10273.895 N/m²

or

10.2738 kPa

$$\frac{\Delta}{D} = \frac{k\left(D_L\, Pb + Ps\right)}{8\dfrac{EI}{D^3} + 0.061\,E^1} \times D_R$$

k	=	0.1
D_L	=	1
E^1	=	3000 kPa
D_R	=	1

$$= \frac{0.1(1+18+6.948)}{8\times 10.2738+0.061\times 3000}$$

$$= \frac{0.1\times 25.948}{82.1904+183}$$

$= 0.009784$ or $0.9784\ \%$

This is within permissible limit of 2 % for cement mortar lined and coated pipes

Horizontal Deflection (As per M-11)

$$\Delta x = Dl\left(\frac{kWr^3}{EI + 0.061\,E'r^3}\right)$$

Where,

Δx	=	Horizontal deflection of pipe (inches)
Dl	=	Deflection lag factor (1)
k	=	Bedding constant (0.1)
W	=	load / unit length (lb/inches of pipe)
r	=	radius (inches)
EI	=	Pipe wall stiffness (inches – lb)
E	=	Modulus of elasticity (30000000 p.s.i. for steel)
I	=	Transverse moment of inertia, per unit length of pipe wall
E'	=	Modulus of soil reaction (lb/inches^2)
W	=	load due to back fill + load due to live load

$= 26.316 + 10.158$ kN/m.

$= 36.474$ kN/m

$= 2498.70$ lb/ft.

$= 208.225$ lb/in.

$$I = \frac{t^3}{12} \qquad r = \frac{55.5118}{2}$$

$$= \left(\frac{12}{25.4}\right)^3 / 12 \qquad = 27.755 \text{ inches}$$

$$= 8.7874915 \times 10^{-3}$$

$$EI = 30000000 \times 8.7874915 \times 10^{-3}$$

$$= 263622.5745$$

$$\Delta x = Dl\left(\frac{kWr^3}{EI + 0.061 E'r^3}\right)$$

$$\Delta x = 1\left(\frac{0.1 \times 208.225 \times 27.755^3}{263622.5745 + 0.061 \times 400 \times 27.755^3}\right)$$

$$= 1 \times \frac{0.1 \times 208.225 \times 20910.51887}{263622.5745 + 521691.2124}$$

$$= \frac{445201.4455}{785313.7869}$$

$$= 0.566 \text{ inches}$$

$$\frac{\Delta x}{D} = \frac{0.566}{55.518} \times 100$$

$$= 1.019 \text{ percent}$$

This is within 2 % allowed for cement mortar lined and coated pipes.

Check for Vacuum Conditions

Shell thickness required for collapsing pressure is calculated by,

$$e = D \times 3\sqrt{\frac{SF}{C}(Patm\text{-}Pv)}$$

Where,

e	=	Shell thickness (inches)
D	=	Outer Diameter of Pipe (Inches)
SF	=	Factor of Safety
Patm	=	Atmospheric Pressure at an attitude of @ 1000 feet
Pv	=	Vapour Pressure (1b/in^2)
C	=	s x 10^7

$$e = 55.984 \times \sqrt[3]{\frac{2}{S \times 10^7}(14.2\text{-}0.09)}$$

= 0.4626574 inches

Hence,

e = 11.75 mm

Shell thickness adopted

= 12 mm

Minimum Wall Thickness

Minimum plate or sheet thickness for handling for pipe sizes greater than 54 in. ID is given by

$$t = \frac{D+20}{400} \ \textit{Inches}$$

$$1398 = 1400 \div 25.4$$

$$= 55.0393$$

$$t = \frac{55.12+20}{400}$$

$$= 0.1875 \text{ inches or } 4.76 \text{ mm.}$$

Check Against Buckling

Allowable buckling pressure p.s.i

$$qa = \left(\frac{1}{Fs}\right)\left(32\ Rw\ B'\ E'\ \frac{EI}{D^3}\right)^{1/2}$$

FS	=	Design factor	$\frac{h}{D} \geq 2$	2.5
			$\frac{h}{D} < 2$	3.0
h	=	ht. of ground surface above top of pipe in		
D	=	diameter of pipe inches		
Rw	=	water hougency factor		

$$1 - .33\frac{hw}{h}, \quad 0, < hw \leq h$$

Where hw = ht of water surface above top of pipe in

B` empirical coefficient of elastic support

$$= \frac{1}{1 + 4e^{-(.065H)}}$$

Where H = ht of fill above pipe ft.

$$D = 1422 + 40$$

$$= 1462 \text{ mm}$$

$$= 57.56 \text{ Inches}$$

$$h = 1000 \text{ mm} = 39.37 \text{ inch.}$$

$$\frac{h}{D} = 0.684 < 2$$

$$Fs = 3.0$$

$$Rw = 1 - 0.33\frac{hw}{h}$$

Assuming that ground water table reaches the ground level

$$Rw = 1 - 0.33\frac{1}{1}$$

$$= 0.67$$

$$B^1 = \frac{1}{1 + 4e^{(-0.065H)}}$$

$$= \frac{1}{1 + 4e^{-.065 \times 3.28}}$$

$$= \frac{1}{1 + 4e^{-.2132}}$$

$$= \frac{1}{1 + 4 x .807994522}$$

$$= 0.236926119$$

$$I = \frac{t^3}{12}$$

$$= \left(\frac{12}{25.4}\right)^3 \div 12$$

$$= 8.77741915 \times 10^{-3}$$

$$\frac{EI}{D^3} = \frac{30 \times 10^6 \times 8.78741915 \times 10^{-3}}{57.56^3}$$

$$= 1.38235708$$

$$\text{Say} = 1.382$$

Allowable buckling pressure

$$qa = \left(\frac{1}{Fs}\right)\left(32\ Rw\ B'\ E'\frac{EI}{D^3}\right)^{1/2}$$

$$= \frac{1}{3}\ (32 \times 0.67 \times .236926119 \times 400 \times 1.382)^{1/2}$$

$$= \frac{1}{3} \times 52.99109306$$

$$= 17.603 \text{ p.s.i.}$$

Load on pipe due to backfill = 26.316 kN/m

= 1802.818 lb/ft.

Load due to line load = 10.158 kN/m

= 695.8471 lb/ft.

$$\wp w \times hw + Rw\frac{Wc}{D} + \frac{W_L}{D} < qa$$

$$\wp w \times hw + Rw\frac{Wc}{D} + \frac{W_L}{D} = 0.0361 \times 3.28 \times 12 + \frac{0.67 \times 1802.818}{12 \times 57.56} + \frac{695.8471}{12 \times 57.56}$$

$$= 1.42 + 1.748 + 1.0074$$

$$= 4.1754 \text{ p.s.i.} < 17.603 \text{ p.s.i.}$$

5.2 CALCULATION OF ECONOMICAL PIPE SIZE FOR PURE WATER RISING MAIN

Design of Economic Size of PUMPING MAIN

D A T E
24/3/2005

Project: NAGPUR PENCH-4
From : Sump At Godhani WTP
To : HBR At Governor House

INPUT DATA

		Year	Discharge	
1)	Water requirement :			
	A. Initial	2005	115.000	mld
	B. Intermediate	2011	146.000	mld
	C. Ultimate	2021	146.000	mld
2)	Pumping main	LENGTH	9300	M ✓
3)	Static head for pump (345.950 - 320.000)+2.0	ST.HEAD	27.000	M ✓
4)	Design period	YEAR	30	yr.
5)	Combined eff. of pump set	EFF. %	80.000	%
6)	Cost of pumping unit	Rs./KW	25000.000	Rs
7)	Interest rate	INTEREST	8.00	%
8)	Life of elec. motors	P.Yrs	15	yr.
9)	Energy charges	P/KWH	350.00	paise
10)	Pumping hours for discharge	PUMPING-HOURS	24	hrs

25.95+2 = 27.95

PIPE DATA

DIAMETER MM.	MATERIAL	CLASS	HWC	RATE Rs/M
1104	MS	10.000	130	14872.00
1175	MS	10.000	130	15506.00
1277	MS	10.000	130	16814.00
1374	MS	10.000	130	18109.00
1480	MS	10.000	130	19418.00
1592	MS	10.000	130	20726.00
1679	MS	10.000	130	21570.00

PRESS <ALT>M for MENU

CALCULATIONS:

		1st 15 years		2nd 15 years	
1)	Discharge at Start OF PERIOD	115.00	mld ✓	146.00	mld ✓
2)	Discharge at the end of 15 yrs	146.00	mld ✓	146.00	mld ✓
3)	Average Discharge	130.50	mld	146.00	mld ✓
4)	Ave.pumping hours during the period	21.45	hrs ✓	24.00	hrs ✓
5)	KW required at combined efficiency of pumping set	20.71	* H1	20.71	* H2
6)	Ave.annual charges for electrical energy Rs.	27423.02	* KW1	30680.16	* KW2

TABLE 1 - VELOCITY AND HEADLOSSES FOR DIFFERENT PIPE SIZES

Total head(m) for 9300.00 m length including 27.00 m static head

B	Pipe Size in mm.	Frictional Head loss per 1000 m: 1st stage flow	Frictional Head loss per 1000 m: 2nd stage flow	Velocity in m/s: 1st stage flow	Velocity in m/s: 2nd stage flow	1st stage flow: Frictional loss	1st stage flow: Other* losses	Total losses H1	2nd stage flow: Frictional loss	2nd stage flow: Other* losses	Total losses H2
1.0	1124.000	1.94	1.94	1.70	1.70	18.05	1.81	46.86	18.05	1.81	46.86
2.0	1175.000	1.56	1.56	1.56	1.56	14.54	1.45	43.00	14.54	1.45	43.00
3.0	1277.000	1.04	1.04	1.32	1.32	9.70	0.97	37.66	9.70	0.97	37.66
4.0	1374.000	0.73	0.73	1.14	1.14	6.79	0.68	34.47	6.79	0.68	34.47
5.0	1480.000	0.51	0.51	0.98	0.98	4.73	0.47	32.20	4.73	0.47	32.20
6.0	1582.000	0.37	0.37	0.86	0.86	3.42	0.34	30.76	3.42	0.34	30.76
7.0	2150.000	0.27	0.27	0.47	0.47	2.56	0.26	29.81	2.56	0.26	29.81

>>> * Other losses = 10% of frictional loss

TABLE 2 - KILOWATTS & COST OF PUMP SETS REQUIRED FOR DIFFERENT PIPE SIZES AND PIPE COST

1st stage flow of 146.00 liters/day; 2nd stage flow of 146.00 n liters/day

PIPE Size in mm	Class of PIPE	1st stage: H1 Total head in meters	1st stage: Kw req'd plus % 50.000 standby	1st stage: Pump Cost @ Rs 25000.00 per kw Rs THS	2nd stage: H2 Total head in meters	2nd stage: Kw req'd plus % 50.000 standby	2nd stage: Pump Cost @ Rs 25000.00 per kw Rs THS	Cost of pipe per unit length (Rs)	Cost of 9300.000 meter pipe line THS (Rs)
1 1124.000	10.000	47.00	1460.000	36500.0	47.00	1460.000	36500	14852.000	138123.600
2.0 1175.000	10.000	43.00	1336.000	33400.0	43.00	1336.000	33400	15506.000	144205.800
3.0 1277.000	10.000	38.00	1180.000	29500.0	38.00	1180.000	29500	16814.000	156370.200
4.0 1374.000	10.000	34.00	1056.000	26400.0	34.00	1056.000	26400	14109.000	131213.700
5.0 1480.000	10.000	32.00	994.000	24850.0	32.00	994.000	24850	19418.000	180587.400
6.0 1582.000	10.000	31.00	963.000	24075.0	31.00	963.000	24075	20726.000	192751.800
7.0 1679.000	10.000	30.00	932.000	23300.0	30.00	932.000	23300	21970.000	204321.000

TABLE 3 - COMPARATIVE STATEMENT OF OVERALL COST OF PUMPING MAIN FOR DIFFERENT PIPE SIZES

	1st stage flow 146.00 mld				2nd stage flow 146.00 mld					
	Cost of pump sets THS (Rs)	Annual Energy Charges THS (Rs)	Capital-ised Energy Charges THS (Rs)	Capital-ised Total Cost THS (Rs)	Cost of pump sets THS (Rs)	Annual Energy Charges THS (Rs)	Capital-ised Energy Charges THS (Rs)	Capital-ised Total Cost THS (Rs)	GRAND TOTAL of Capital-ised cost for 30 yrs THS (Rs)	PIPE SIZE in (mm)
1.0	36500	26692	123394	298018	36500	29862	138048	109995	408013	1124.000
2.0	33400	24425	112914	290520	33400	27326	126325	100654	391174	1175.000
3.0	29500	21573	99729	285599	29500	24135	111573	88900	374499	1277.000
4.0	26400	19306	89249	246863	26400	21599	99850	79559	326422	1374.000
5.0	24850	18172	84007	289444	24850	20331	93988	74888	364332	1480.000
6.0	24075	17606	81390	298217	24075	19697	91057	72553	370770	1582.000
7.0	23300	17039	78769	306390	23300	19063	88126	70217	376607	1679.000

***. TABLE 3 shows that the most economical size of MAIN is :1422 (OD), 1374 mm (ID) costing :CAPITALISED Rs. 326422 thousands

5.3 Calculations of Restrained Length for Horizontal bends for Clear Water

Inner diameter (D)	=	1374 mm
Thickness of Outlining	=	20 mm
Thickness of steel shell	=	12 mm
Inner lining	=	12 mm

If the soil prism above the pipe is restrained from movement:

$$L = \frac{PA\sin^2\frac{\Delta}{2}}{f\,(2w_e + w_p + w_w)}$$

Where

L	=	Restrained length in cm		
P	=	Internal pressure in kg/sq. cm		
A	=	Cross section area of pipe in sq. cm		
Δ	=	Bend deflection in degrees		
We	=	Weight of prism of soil over the pipe in kg/cm		
Wp	=	Weight of pipe in kg/cm		
Ww	=	Weight of contained water in kg/cm		
f	=	Friction between pipe and soil	=	0.4

Weight of steel shell (W1)	=	4.22 kg/cm
Weight of Outer lining (W2)	=	2.412 kg/cm
Weight of inner coating (W3)	=	1.505 kg/cm
Total weight of pipe (Wp)	=	W1 + W2 + W3
	=	8.137 kg/cm
Outer diameter (Bc)	=	1462 mm

Weight of prims of soil over the pipe(W $\gamma_s \times H \times B_c$

where,	=	Density of soil	= 18 kN/m^3
H	=	Minimum depth of cover = 1 m	
We	=	26.826 kg/cm	
Weight of contained water (Ww)	=	14.833 kg/cm	
$2w_e+w_p+w_w$	=	76.622 kg/cm	
Area of pipe (A)	=	14827.4 sq.cm	
Maximum pressure (P)	=	12.000 kg/sq.cm	

Δ in degrees	90	60	45	30	22.5	15
sin(Δ/2)	0.707	0.500	0.383	0.259	0.195	0.131
$sin^2(\Delta/2)$	0.500	0.250	0.147	0.067	0.038	0.017
L in m	29.03	14.51	8.53	3.89	2.21	0.99
L say	30	15	9	4	3	1

5.4 Calculation of Restrained length for vertical downward bends for clear water.

Inner diameter (D)	=	1374 mm
Thickness of Outlining	=	20 mm
Thickness of steel shell	=	12 mm
Thickness of Inner lining	=	12 mm

If the soil prism above the pipe is restrained from movement:

$$L = \frac{S_f P A Tan\frac{\theta}{2}}{F_f}$$

Where,

Ff	=	Frictional force = (πBc/2)*C+(2We+Wp+Ww)Tanδ		
L	=	Restrained length in cm		
P	=	Internal pressure in kg/sq. cm		
A	=	Cross section area of pipe in sq. cm		
q	=	Bend deflection in degrees		
We	=	Weight of prism of soil over the pipe in kg/cm		
Wp	=	Weight of pipe in kg/cm		
Ww	=	Weight of contained water in kg/cm		
ϕ	=	Angle of friction	=	30 Degrees
Fϕ	=	Ratio of pipe friction angle to soil friction angle	=	0.75
Tanδ	=	Friction between pipe and soil =Tan(Fϕ*ϕ)	=	0.4
C	=	Cohision	=	0.00 kg/cm^2
S_f	=	Factor of safity	=	1.5

Weight of steel shell (W1)	=	4.22 kg/cm
Weight ofOuter Lining (W2)	=	2.412 kg/cm
Weight of Inner lining (W3)	=	1.505 kg/cm
Total weight of pipe (Wp)	=	W1 + W2 + W3
	=	8.138 kg/cm
Outer diameter (Bc)	=	1462 mm

Weight of prims of soil over the pipe(We)	=	$\gamma_s \times H \times B_c$		
where,	=	Density of soil	=	0.001835 kg/cm^3
H	=	Minimum depth of cover	=	1.0 m
We	=	26.8 kg/cm		
Weight of contained water (Ww	=	14.8 kg/cm		
$2w_e+w_p+w_w$	=	76.6 kg/cm		
Area of pipe (A)	=	14827.3 sq.cm		
Maximum pressure (P)	=	12.0 kg/sq.cm		
Frictional force (Ff)	=	31.7 kg/cm		

θ in degrees	90	60	45	30	22.5	15	10
Tan(θ/2)	1.000	0.577	0.414	0.268	0.199	0.132	0.087
L in m	84.13	48.58	34.85	22.54	16.74	11.08	7.36
L say	85	49	35	23	17	12	8

5.5 Calculations of Restrained Length for Vertical Upward Bends for clear water.

Inner diameter (D)	=	1374 mm
Thickness of Outlining	=	20 mm
Thickness of steel shell	=	12 mm
Inner lining	=	12 mm

If the soil prism above the pipe is restrained from movement:

$$L = \frac{S_f PA Tan\frac{\theta}{2}}{F_f + (1/2)R_s}$$

Where,

Ff	=	Frictional force = (πBc/2)*C+(2We+Wp+Ww)Tanδ		
L	=	Restrained length in cm		
P	=	Internal pressure in kg/sq. cm		
A	=	Cross section area of pipe in sq. cm		
θ	=	Bend deflection in degrees		
We	=	Weight of prism of soil over the pipe in kg/cm		
Wp	=	Weight of pipe in kg/cm		
Ww	=	Weight of contained water in kg/cm		
φ	=	Angle of friction	=	30 Degrees
Fφ	=	Ratio of pipe friction angle to soil friction angle	=	0.75
Tanδ	=	Friction between pipe and soil = Tan(Fφ*φ)	=	0.4
C	=	Cohision	=	0.00 kg/cm^2
γs	=	Unit weight of soil	=	0.001835 kg/cm^3
S_f	=	Factor of safity	=	1.5
Rs	=	Unit Bearing Resistance	=	Kn*Pp*Bc
Pp	=	Passive soil presure = γ*Hc*Nφ +2*Cs*sqrt(Nφ)		
Kn	=	Reduction Constant	=	0.6
Nφ	=	$Tan^2(45+\phi/2)$	=	3.00
Hc	=	Height between center line of the pipe to GL	=	173.1 cm

Weight of steel shell (W_1)	=	4.22 kg/cm
Weight of Outer lining (W_2)	=	2.412 kg/cm
Weight of Innert coating, W_3	=	1.505 kg/cm
Total weight of pipe (Wp)	=	W1 + W2 + W3
	=	8.138 kg/cm

Outer diameter (Bc)	=	1462 mm			
Weight of prims of soil over the pipe(We)	=	$\gamma s \times H \times Bc$	=	1.0	m
Where,					
H	=	Minimum depth of cover			
We	=	26.828 kg/cm			
Weight of contained water, W_w	=	14.833 kg/cm			
$2w_c+w_p+w_w$	=	76.627 kg/cm			
Area of pipe (A)	=	14827.34 sq.cm			
Maximum pressure (P)	=	12.00 kg/sq.cm			
Frictinal force (Ff)	=	31.7 kg/cm			
Passive presure (Pp)	=	0.95 kg/cm^2			
Unit bearing resistence (Rs)	=	83.6 kg/cm			

θ in degrees	90	60	45	30	22.5	15
Tan(θ/2)	1.00	0.577	0.414	0.268	0.199	0.132
L in m	36.30	20.96	15.04	9.73	7.22	4.78
L say	37	21	16	10	8	5

5.6 Typical Design of Horizontal Thrust Block for Clear water

Inside Diameter of the Pipe (D)		=	137.4 cm
Outline Coating		=	2.0 cm
Steel Plate Thickness		=	1.2 cm
Internal Coating		=	1.2 cm
Outer diameter of the pipe (Bc)		=	146.2 cm
Field Test Pressure (P)		=	12.00 kg/cm^2
Angle of Bend (θ)		=	60 Degree
Horizantal Bearing Capacity of Soil		=	15.29 T/m^2
Cross Section Area of Pipe	A	=	14827.38 cm^2
Trench Depth	H	=	261.2 cm
Resultant Thrust	T	=	$\frac{2 \text{ x P x A x Sin} \frac{\theta}{2}}{1000}$
		=	178.0 MT

Thrust Block Dimentions

Contact area of thrust block		=	$\frac{AppliedThrust}{Horz.BearingCapacityofsoil}$
		=	11.64 m^2
Height of block	B	=	Trench depth - 20
		=	241.2 cm
	Say	=	2.41 m
Length of block	L	=	$\frac{ContactAreaofThrustBlock}{HeightofBlock}$
		=	482.99 cm
	Say	=	4.83 m
~~Width of block~~	~~d~~	~~=~~	~~0.5 m~~

5.7 Typical Design of Vertical Downward Thrust Block for Clear water

Inside Diameter of the Pipe (D)	=	137.4 cm
Outline Coating	=	2.0 cm
Steel Plate Thickness	=	1.2 cm
Internal Coating	=	1.2 cm
Outer diameter of the pipe (Bc)	=	146.2 cm
Field test pesure (P)	=	12.00 kg/cm^2
Unit weight of the concrete (W_m)	=	24 kN/m^3
	=	0.002446 kg/cm^3
Factor of safety (Sf)	=	1.0
Angle of Bend (θ)	=	60 degree
Horizontal bearing capacity of the soil (qh)	=	3000 lb/ft^2
	=	143.692 kN/m^2
Cross section area of pipe (A)	=	14827.34 cm^2
Upward thrust (T_v)	=	P x A x Sinθ
Volume of the block required (Vg)	=	$\frac{S_f \times P \times A \times \sin\theta}{W_m}$
	=	62.9844 m^3
Horizontal thrust (T_h)	=	P x A x (1- cosθ)
	=	88964.1 kg
Required vertical surface area	=	$\frac{T_h \times S_f}{q_h}$
	=	6.07 m^2

Size of Thrust Block

Width of the Block,	B	=	3.50 m	2.086
Height of the Block,	H	=	Trench Depth-20	
			2.44 m	
Vertical Surface Area of the Block		=	8.54 > 6.1 m^2	
			Hence safe	
Length of the Block,	l	=	$\frac{VolemeofConcreteBlock}{verticalSurfaceArea}$	
		=	7.375 m	
	Say	=	7.400 m	

5.8 Typical Design of Vertical Upward Bends for Clear water

Inside Diameter of the Pipe (D)	=	137.4 cm
Outline Coating	=	2.0 cm
Steel Plate Thickness	=	1.2 cm
Internal Coating	=	1.2 cm
Outer diameter of the pipe (Bc)	=	146.2 cm
Field Test Pressure (P)	=	12.00 kg/cm^2
Unit weight of the concrete (W_m)	=	24 kN/m^3
	=	2.45 t/m^3
Angle of Bend (θ)	=	60 degree
Angle of Repose (ϕ)	=	30 degree
Outer diameter of the pipe (Bc)	=	197 cm
Cross section area of pipe (A)	=	14827.3 cm^2
Horizontal Thrust (Th)	=	‹ (1-cos θ)
	=	88.96 MT
Vertical Thrust (Tv)	=	A x Sin θ
	=	154.09 MT
Height of Ground level above the centre of the Pipe (hc)	=	ver + Bc/2
	=	1.731 m
Minimum Height of Thrust Block (H)	=	Trench depth-20
	=	2.4 m

Size of Thrust Block:

L	=	6.00 m
b	=	2.50 m
H	=	2.32 m

Passive resistance Coefficient (kp) = $\frac{1 + \sin \phi}{1 - \sin \phi}$

= 3

Unit weight of soil (γ) = 1.8 t/m3

Friction Coefficient (μ) = 0.3

Passive Resistance by soil (Fp) = : γ x H x L

= 129.89 MT

Frictional Resistance betweenWeightandconcrete(Ff)riction coefficient

= 25.497 MT

Total Horozontal Resistance (Fh) = Fp + Ff

= 155.39 MT > 88.96 MT

Hence Safe

Bearing Capacity of the soil (qv) = 15 t/m^3

Total Vertical Resistance offered by the soil (Qv) = ırust block

= 225 MT > 154.09 MT

Hence Safe

Therefore provide Thrust Block of size6.0m X 2.5 m X 2.32 m

5.9 Dimentions for Pipe Elbows

For Two Piece Elbow : $0^0 < \blacktriangle <= 22.5^0$

Deflection Angle = 10 Degree

D	=	OutSide Diameter of the Pipe	=	57.6 Inches
R	=	Radius of Elbow	=	2.5D
			=	143.90 Inches
Δ	=	Deflection Angle of Bend	=	10 Degree
θ	=	Segment Deflection Angle	=	Δ
			=	10 Degree

S.No	Deflection Angle(Δ)	Dimentions (Inches)	
1	10^0	S=4D Tanθ/2	20.17
2		L=0.5D Tanθ/2	2.52
3		T=2.5D TanΔ/2	12.61
4		E=2.5D Tanθ/2	12.61
5		Z_2=f	16.00
6		L1=L+Z_2	18.52

Deflection Angle = 15 Degree

D	=	OutSide Diameter of the Pipe	=	57.6 Inches
R	=	Radius of Elbow	=	2.5D
			=	143.90 Inches
Δ	=	Deflection Angle of Bend	=	15 Degree
θ	=	Segment Deflection Angle	=	Δ
			=	15 Degree

S.No	Deflection Angle(Δ)	Dimentions (Inches)	
1	15^0	S=4D Tanθ/2	30.35
2		L=0.5D Tanθ/2	3.79
3		T=2.5D TanΔ/2	18.97
4		E=2.5D Tanθ/2	18.97
5		Z_2=f	16.00
6		L1=L+Z_2	19.79

Deflection Angle = 22.5 Degree

D	=	OutSide Diameter of the Pipe	=	57.6 Inches
R	=	Radius of Elbow	=	2.5D
			=	143.90 Inches
Δ	=	Deflection Angle of Bend	=	22.5 Degree
θ	=	Segment Deflection Angle	=	Δ
			=	22.5 Degree

S.No	Deflection Angle(Δ)	Dimentions (Inches)	
1	22.5^0	S=4D Tanθ/2	45.86
2		L=0.5D Tanθ/2	5.73
3		T=2.5D TanΔ/2	28.66
4		E=2.5D Tanθ/2	28.66
5		Z_2=f	16.00
6		L1=L+Z_2	21.73

5.10 Design of Pipe for Nalla Crossing

When the pipe passes through the canal or Nalla, the pipe is under floatation, because buoyant force is more than pipe weight, is as shown in figure - i. To prevent floatation. concrete encasement is required for getting negative buoyant force. The forces acting on pipe after concrete encasement in shown in figure - ii. The thickeness of concrete required depends on negative buoyance required on pipe.

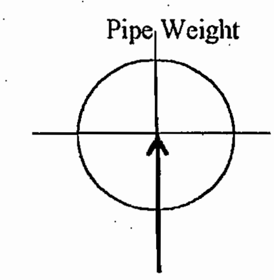


Fig.(i) Pipe is in floatation

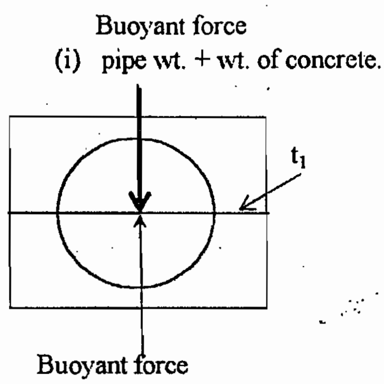


Fig.(ii) Pipe is in steady condition

Outer Diameter of the pipe	=	1462 mm
	=	57.6 inches
Wall Thickeness	=	10 mm
	=	0.4 inches
Buoyancy of the pipe (without encasement)	=	$D/3\ (D - 32t) + 11\ t^2$
B	=	864 lb/ft^2

Buoyancy of pipe is possitive. Therefore the pipe is in floating condition.

Therefore concrete coating will be required to give negative buoyancy.

Assume the negative buoyancy on pipe = 864 lb/ft^2

Therefore, concrete thickness required (t_1) can be calculated by,-

$$B = \frac{D}{3}(D-32\,t_1)+t_1 D\left(\frac{63-wc}{48}\right)$$

t_1 = Thickness of Concrete coating in inches

Wc = Unit Weight of concrete = 146 lb/ft^3

$\therefore\ t_1$ = 17.4 inches

= 0.44 m

5.11

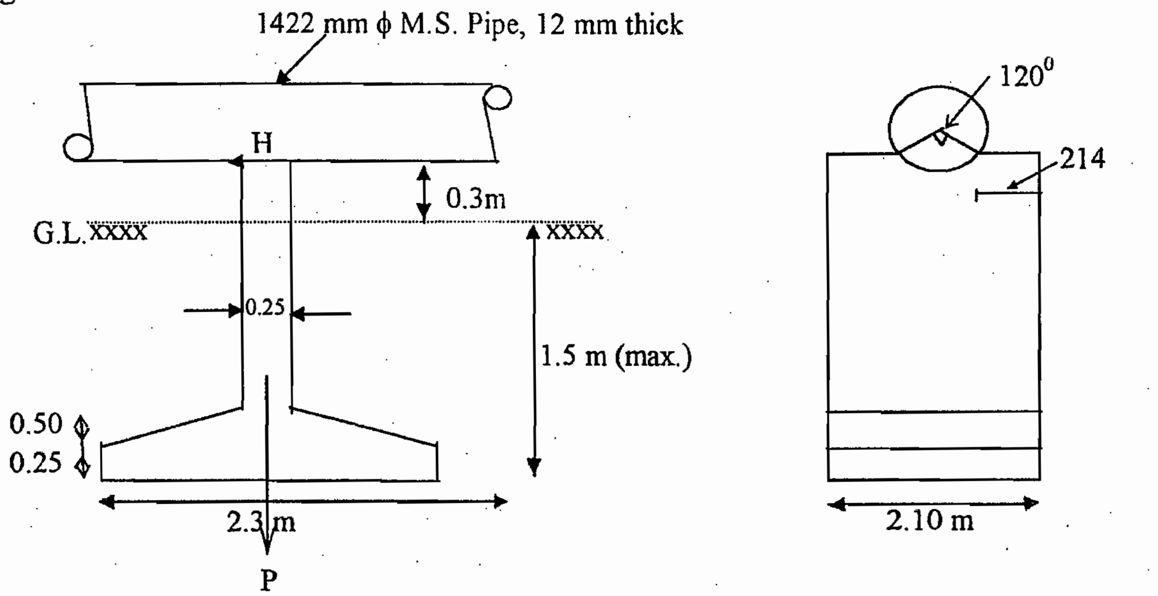
Location Of Valves			
Locations of Air Valves			
S.No.	Chainage (m)	S.No.	Chainage (m)
1	750	29	13980
2	1250	30	14480
3	1680	31	15000
4	2180	32	15480
5	2460	33	15840
6	2960	34	16320
7	3420	35	16740
8	3950	36	16920
9	4450	37	17190
10	4950	38	17790
11	5610	39	18060
12	5970	40	18740
13	6330	41	19200
14	6830	42	19980
15	7290	43	20700
16	7790	44	21120
17	8190	45	21750
18	8400	46	22050
19	8760	47	22530
20	9400	48	22980
21	9480	49	23100
22	10170	50	23725
23	10860	51	23850
24	11460	52	24330
25	11670	53	24660
26	12170	54	24990
27	12670	55	25710
28	13500	56	26400

Locations Of Scour Valves	
S.No.	**Chainage(m)**
1	3610
2	6417
3	7245
4	8772
5	11490
6	12978
7	13542
8	14244
9	16170
10	17250
11	18500
12	20580
13	22856
14	24090
15	27237

Locations Of Butterfly Valves	
S.No.	**Chainage (m)**
1	8400
2	11957
3	16946
4	22540
5	25785

5.12 'Design of R.C.C. Pedestal for 1422 mm (O.D.) 12 mm thick Pure Water Rising Main

Following sizes are assumed for pedestal and footing. Length of footing required will be more due to large B.M.



Vertical load (Pipe empty condition)

weight of pipe = $\frac{\pi}{4}\times(1.422^2-1.398^2)\times 7.85\times 6=2.504$

weight of pedestal = $0.25\times 2.10\times 1.8\times 2.5+2\times(\frac{0.25+0.75}{2})\times 1.025\times 2.10\times 2.5=7.744\,Ton$

Total vertical load = 10.248 Ton

Horizontal forces due to temp. changes acting at top of pedestal:-

H = 0.6 x 2.504 = 1.502 T

Taking moments @ Pt. A,

ε M @ A = $10.248\times\frac{2.3}{2}-1.502\times 1.8$

= 9.082 T.M.

e = $\frac{2.3}{2}-\frac{9.082}{10.248}=0.264<\frac{b}{6}(\frac{2.3}{6}=0.3833)$

No tension at the base

Hence O.K.

Factor of Safty against overturning = $\frac{10.248\times\frac{2.3}{2}}{1.502\times 1.8}$

= 4.359 > 2.5

Hence O.K.

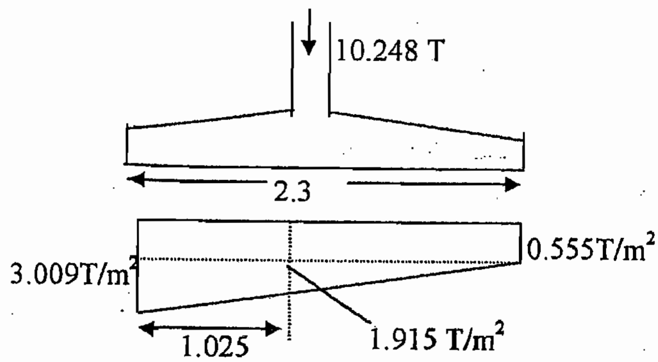
Factor of safty against sliding $= \frac{\mu W}{H}$

$= \frac{0.6 \times 10.248}{1.502}$

$= 4.094 \quad > \quad 2$

Hence O.K.

For checking depth of footing



$$Stress = \frac{P}{bd} \pm \frac{6M}{bd^2}$$

$$= \frac{10.248}{2.3 \times 2.5} \pm \frac{6 \times 2.704}{2.5 \times 2.3^2}$$

$$= 1.782 \pm 1.227$$

$$= 3.009 \quad or \quad 0.555$$

BM @ critical section

$$= \left(\frac{1.915+3.009}{2}\right) \times 1.025 \times 2.1 \times \left(\frac{2 \times 3.009 + 1.915}{3.009 + 1.915}\right) \times \frac{1.025}{3}$$

$$= 2.917 \text{ T.M.}$$

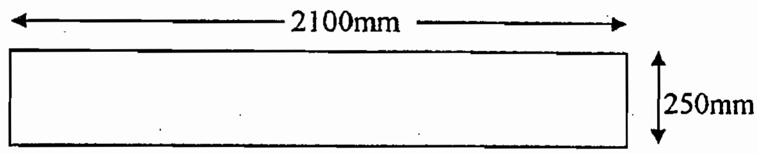
$$d_{reqd} = \sqrt{\frac{2.917 \times 10^5}{0.92 \times 210}}$$

$$= 38.86 \text{ cm}$$

d_{prov} = 75 - 5 = 70cm > 38.86cm

Hence OK

Section of pedestal is subjected to combined axial force & B.M.
Assumed section for pedestal (i.e. 2100 x 250 mm) is checked for combined AF & BM
Check for section of pedestal



Nominal Steel = 0.8 % of column area

$$= 0.8 \times \frac{2100}{100} \times 250 = 4200\text{mm}^2$$

Provide 11 nos. on each side 16mm ϕ

Using M20, Fe 415

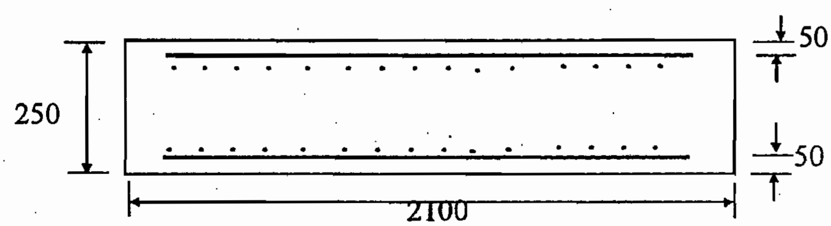
Vertical steel = $\frac{\pi}{4}(1.422^2 - 1.398^2) \times 7.85 \times 6 + 0.25 \times 2.1 \times 1.025 \times 2.5$

= 3.849 T

Horizontal force at top = M x 2.504 = 0.6 x 2.504 = 1.502 T

BM = 1.502 x 1.025 = 1.540 Tm

Asc = 11 nos. 16 ϕ = 2200 mm^2



Compressive stress in extreme fibre of conc.be σ_{cbc}& neutral axis depth from top be 'n'

Compression in concrete:

$$Cc = \frac{\sigma_{cbc}}{2} \times n \times 165$$

Compression in steel:

$$Cs = \frac{n\text{-}5}{n} \times \sigma_{CbC} \times (m\text{-}1)Asc$$

$$= \frac{n\text{-}5}{n} \times \sigma_{CbC} \times 13 \times 18$$

Tension in steel Tst $= \frac{20\text{-}n}{n} \times \sigma_{CbC} \times 14 \times 18$

Vartical load P $=$ Cc+Cst-Tst

$$\therefore P = \sigma_{CbC}[\frac{165n}{2} + 18\{(\frac{n\text{-}5}{n}) \times 13 - \frac{(20\text{-}n)}{n} \times 14\}]$$

$$= \sigma_{CbC}[82.5n + \frac{18}{n}(13n\text{-}65\text{-}280\text{+}14n)]$$

$$= \sigma_{CbC}[82.5n + \frac{18}{n}(27n\text{-}345)] \qquad \text{-1}$$

External moment

$$M = \varepsilon \text{ moments @ C.g.}$$

$$M = \sigma_{CbC}[\frac{165n}{2} \times (12.5\text{-}\frac{n}{3}) + 18(\frac{(n\text{-}5)}{n} \times 13 \times 7.5 + \frac{20-n}{n} \times 14 \times 7.5)]$$

$$= \sigma_{CbC}[82.5n(12.5 - \frac{n}{3}) + \frac{18 \times 7.5}{n}(13n\text{-}65\text{+}280\text{-}14n)]$$

$$= \sigma_{CbC}[82.5n(12.5 - \frac{n}{3}) + \frac{135}{n}(215\text{-}n)] \qquad \text{-2}$$

$$\frac{M}{P} = \frac{1.540 \times 10^5}{3.849 \times 10^3}$$

$$40.01 \text{ cm} = \frac{82.5n(12.5 - \frac{n}{3}) + \frac{135}{n}(215 - n)}{82.5n + \frac{18}{n}(27n - 345)}$$

$$3300.857n + 19445.051\frac{248464.536}{n} = 1031.25n\text{-}27.5n^2 + \frac{29025}{n} - 135$$

$$3300.857n^2 + 19445.051n - 248464.536 = 1031.25n^2 - 27.5n^3 + 25025 - 135n$$

$$2269.607n^2 + 19580.051n - 277489.536 = 0$$

By trial & error method

$$n = 7.35$$

$$\sigma_{CbC} = \frac{3.849\times10^{3}}{82.5\times7.35+\frac{18}{7.35}(27\times7.35-345)}$$

$$= 15.553 kg / cm^2 \quad < 71.4 \text{ kg} / cm^2$$

(as per IS 456:2000 Table 21)

Hence O.K.

Since stresses are well within limits, section of pedestal provided is sufficient.

6.0 COST ESTIMATE

6.1 VALVE COMPLEX AT MAHADULA (BIFURCATION ARRANGEMENT)

Item No.		Description	Quantity	Unit	Rate	Ammount
		MATERIAL				
1		Supplying Butterfly valves including packing, nuts, bolts, washers and storing in the stock yard.				
	i	1400 mm dia. Butterfly valves (In line) P.N 1.0	1	Nos.	500000	500000
	ii	1200 mm dia. Butterfly valves (In line) P.N 1.0	2	Nos.	400000	800000
2		Fabricating specials and fixtures from the steel plates and stacking the same in the fabricating yard.The rate to include cutting the plates, rolling, tack welding, etc. complete	10	MT	50000 High // [illegible]	500000
3		Welding in all positions with required number of runs for M.S. pipes internally and / or externally including gauging wherever nessasaty, fixing appurtenences and other accessories in connection with pipe laying work as per specification	50	m	385	19250
4		Lowering ,laying joining and fixing in position valves including cost of conveyance, cost of all materials and giving factory hydraulic test.				
	i.	1400mm dia butterfly valves	1	Nos	50000	50000
	ii.	1200mm dia butterfly valves	2	Nos	40000	80000

Item No.		Description	Quantity	Unit	Rate	Ammount
5		Providing and constructing valve chambers with RCC 1:2:4 walls with footings, foundation concrete 300mm thick in C.C 1: 3: 6 using trap metal 25 to 40 mm size 20mm cement plaster in C.M 1: 3 inside and outside with precast RCC slab 150mm thick, including cost of reinforcement as directed by engineer in charge including all taxes, complete including cost of excavation and refilling with ramming , watering and curing of civil works.Construction of RCC valve chambers for butterfly valves as per detail specifications of size 3.5 x 4 x 3 m.	3	Nos	120000 unit estimate ?	360000
6		Mass concrete M-20 with 20 mm max aggregate size, for embeddment, anchor blocks and thrust blocks etc. including form work, embedding puddle flange, etc. complete as per drawing.				
	i.	Plain cement concrete (M-10)	34.2	m^3	1500	51300
	ii	R.C.C (M-20)	101	m^3	2400	241320
7		Reinforcement steel for RCC works with deformed high yield steel bars conforming to IS 1786. (Nominal bar size from 6 mm to 12 mm), including anticorrosive treatment as specified.	6	Tonnes	30000	180000
8		Drain arrangement at scour valve locations including approx.20m .of RCC drain pipe size of 300mm dia and NP2 class from chamber to near by water course and outfall Arrangement.	300	m	500	150000
9		Providing uncoursed rubble masonry of trap stones in cement mortar 1:6 in foundation and plinth of inner wall, including bailing out water manually, striking joints on unexposed faces and watering complete.	113.4	Cu M	880	99792
10		Providing Second Class Burnt Brick masonary with conventional/I.S . Type bricks in cement mortar 1:6 in superstructure, including striking joints,racking out joints, watering and scaffolding complete.	74.52	Cu M	1350	100602

Item No.	Description	Quantity	Unit	Rate	Ammount
11	Providing cement plaster 12mm thick in a single coat without neeru finish to concrete or brick surface in all positions including racking out joints, scaffolding and curing complete.	648	SqM	66	42768
12	Providing and constructing W.B.M. road in layers of 75/100 mm compacted thickness, preparation of subgrade with murum screenings necessary testing including supplying and conveying all materials with all leads and lifts, spreading, sectioning, artificial watering and compacting in layer with vibratory roller as directed by Engineer-incharge including maintenance of diversion road during construction etc. complete. (2 to 7 metre width) 0.38x375	118.56	CuM	450	53352
13	Providing and fixing mild steel grill gate with angle iron frame 65 x 65 x 10 mm with iron bars at 150 mm c/c and diagonal flats as per the detailed drawing, including hinges, pivot blocks, locking arrangement, welding, reveting with three coats of approved colour shade. (Weight of gate 35 Kg/ Sq M)	16	SqM	1400	22400
14	Construction of operator room with a provision of sufficient space , complete as per specifications, drawings, design and instruction of Engineer-in-charge.	25	SqM	6500 Plinth area	162500
					3413284
	Cost Contingencies (@ 10 %)				**341328**
	Physical Contingencies (@ 5 %)				**170664**
	TOTAL				**3925277**

6.2 RAW WATER GRAVITY MAIN FROM MAHADULA TO WTP AT GODHANI

WORK - M.S PIPES WITH INTERNAL CEMENT CONCRETE LINING AND EXTERNAL COATING OF CEMENT CONCRETE INCLUDING EXCAVATION, BEDDING, LAYING, JOINTING, BACKFILLING, SPECIALS, LINE VALVES, WASHOUTS, APPURTENANCES, CHAMBERS, THRUST AND ANCHOR BLOCKS, ENCASEMENT HYDRAULIC TESTING etc. COMPLETE.

Item No.		Description	Quantity	Unit	Rate	Ammount
		MATERIAL				
1		Manufacturing, Providing and Supplying Spirally welded /ERW/SAW/fabricated M.S.Pipes of following diamer as per IS - 3589 including procurements of plates, gas cutting to required size rolling,tack welding assembling in suitable lenghts to form pipes welding on automatic welding machine and forming V edge on both ends of pipes including all taxes.				
	i	M.S 1422 mm (OD), 10mm Shell thickness Inlining - 12mm thick C.C Outcoating - 20mm thick C.C	2900	m	18000	52200000
2		Supplying mild steel specials for M.S. pipes for internal dia. and thickness as item wised below, suitable for butt welding, specials with C.M. mortar lining and 2.4 mm thick external coal tar enamel coating.				
	a	Outer Dia of 1422mm with outer lining of 20 mm CC Coating and 12 mm inling.				
	i	Bends as specified below.				
		10° deg. Bends	5	Nos.	22574	112870
		15° deg. Bends	1	Nos.	24508	24508
		22.5° deg. Bends	1	Nos.	27438	27438
		30° deg. Bends	1	Nos.	54266	54266
		45° deg. Bends	1	Nos.	76805	76805
3		Supplying double flanged Scour valves,Butterfly valves & Air Valve including packing, nuts, bolts, washers and storing in the stock yard				-
	i	1200 mm dia. Butterfly valves (In line) P.N 1.0	2	Nos.	500000	1000000
	ii.	400 mm dia. Sluice valves (Scour valves) P.N 1.0	1	Nos.	32682	32682
	iii	Double Flanged Kinetic Air Valve with Isolating Sluice	5	Nos.	29158	145790

Item No.		Description	Quantity	Unit	Rate	Ammount
4		Fabricating manholes as per drawing and specifications from M.S. flats. sheets etc.. supplied free of cost and assembling the same on the pipe and tack welding etc. complete as per directions.	4	Nos.	10000	40000
		EARTH WORK				
5		**Excavation** Clear cover = 1000 mm Dia. of Pipe =1462 mm bedding = 150 mm. Depth of excavation = 2.612m. Width of trench = 2.062m				
	i	Excavation for pipe trenches in earth, soils of all types, **sand, gravel and soft murum,** including removing the excavated material upto a disstance of 50m , stacking na d spreading as directed, normal dewatering, preparing . the bed for foundation and excluding backfilling etc., complete.	6248	m^3	34	212432
	ii	Excavation for pipe trenches in **hard murum,** including removing the excavated material upto a disstance of 50m , stacking na d spreading as directed, normal dewatering, preparing the bed for foundation and excluding backfilling etc., complete.	4686	m^3	43	201498
	iii.	Excavation for pipe trenches in **Hard rock** including removing the excavated material upto a disstance of 50m , stacking na d spreading as directed, normal dewatering, preparing the bed for foundation and excluding backfilling etc., complete.	4686	m^3	220	1030920
6		Providing and filling in sand boxing in pipe line or for foundation with sand of approved quality including watering compaction etc. complete.	2129	m^3	300	638700
7		Lowering, laying and jointing M.S pipes in trenches on prepared formation including marginal cutting wherever required, assembling and Butt Welding, preliminary air testing of each field joint and final hydraulic testing to required pressures etc. as per specification and drawings.				

Item No.		Description	Quantity	Unit	Rate	Ammount
	i.	*In Trench* OD 1422 mm. 10 mm shell thickness with CC 20mm lining. MJP DSR PUNE 2004-2005 Item No.XIII 5 (b) V	2900	m	343	994700
8		Welding in all positions with required number of runs for M.S. pipes internally and / or externally including gauging wherever nessasaty, fixing appurtenences and other accessories in connection with pipe laying work as per specification	1296	m	374	484704
9		Lowering, laying and jointing M.S pipe Specials including marginal cutting wherever required, assembling and Butt Welding, The rate to including unloading, hoisting etc. complete as specified.				
	a.	Outside dia. 1422 mm, 20 mm outer lining with shell thickness 10mm	72	Nos.	374	26928
10		Lowering ,laying joining and fixing in position valves including cost of conveyance, cost of all materials and giving factory hydraulic test.				
	i.	1200mm dia butterfly valves	2	Nos	50000	100000
	ii.	200mm dia kinetic air valves with isolating sluice.	5	Nos	220	1100
	iii.	Scour Valve of 400 mm dia.	1	Nos	2570	2570
11		Providing, fabricating and fixing expansion joints for pipe line of diameter as per the drawing. The rate to include machining the strakes and steel ring as shown in the drawing and welding on either automatic welding machine or manually. Rate includes plates and flats required for expansion joint and all other materials such as synthetic rubber, rubber ring etc., complete. Including packing as per specifications, grease, blots and nutsetc., including local handling, all types of taxes and duties etc. commplete.	2	Nos	300000	600000

Item No.		Description	Quantity	Unit	Rate	Amount
12		Providing and constructing valve chambers with RCC 1:2:4 walls with footings, foundation concrete 300mm thick in C.C 1: 3: 6 using trap metal 25 to 40 mm size 20mm cement plaster in C.M 1: 3 inside and outside with precast RCC slab 150mm thick, including cost of reinforcement as directed by engineer in charge including all taxes, complete including cost of excavation and refilling with ramming , watering and curing of civil works.				
	i.	Construction of RCC valve chambers for butterfly valves as per detail specifications of size 2.5 x 4.2 x 4 m.	2	Nos	130000	260000
	ii.	Construction of RCC valve chambers for scour valves as for detail specifications of size 2.5 x 2.3 x 3.3 m.	1	Nos	76100	76100
	iii.	Construction of RCC valve chambers for Kinetic air valves as for detail specification of size 3.1 x 2.5 x 1.3 m.	5	Nos	56600	283000
13		Mass concrete M-20 with 20 mm max aggregate size, for embeddment, anchor blocks and thrust blocks etc. including form work, embedding puddle flange, etc. complete as per drawing.				
	i.	Plain cement concrete (M-10)	29	m^3	1500	43500
	ii	Concrete for pre cast works (M-20) of Highway crossings, Nalla & Canal Crossings and thrustblocks	250	m^3	2400	600000
14		Reinforcement steel for RCC works with deformed high yield steel bars conforming to IS 1786. (Nominal bar size from 6 mm to 12 mm), including anticorrosive treatment as specified.(for road crossings)	6	Tonnes	30000	180000
15		Backfilling trench with available excavated stuff in layers not exceeding 200 mm, including watering and compaction as directed.(including road crossings)	8622	m^3	16	137952
16		Providing and fixing indicator posts along pipe line routes, post to be of precast concrete M20 of as for drawing.	6	Nos	1000	6000

Item No.	Description	Quantity	Unit	Rate	Ammount
17	Drain arrangement at scour valve locations including approx.20m .of RCC drain pipe size of 400mm dia and NP2 class from chamber to near by water course and outfall Arrangement.	50	m	500	25000
18	R.C.C. Pedestal	18	Nos	15000	270000
	Hydraulic testing	2.9	km	20437	59267.3
19	Providing and applying coal tar epoxy paint, externally,including cleaning the surface of pipe, etc.complete.	3320	SqM	20	66400
					60015130
	Cost Contingencies (@ 10 %)				**6001513**
	Physical Contingencies (@ 5 %)				**3000757**
	TOTAL				**69017400**

6.3.1 Cost Estiamtes for Water Treatment Plant (Civil Works)

Sl. No.	Item	Quantity	unit	Rate	Amount
1	**V. T. Pumps** Designing(aesthetically) ,providing and constructing state of art/ultramodern water treatment plant of capacity 115 MLD .Including civil .mechanical and electrical works.including necessary hydraulic testing.structural testing.eqipment testing etc. as directed by engineer -in-charge (Turnkey Job)		LUMPSUM		23,00,000.00=00
			TOTAL		23,00,000,00=00

RUPEES TWENTY THREE CRORE ONLY.

High cost

6.3.2 Cost Estiamtes for Mechanical Works (Pure Water)

Sl. No.	Item	Quantity	unit	Rate	Amount
1	**V. T. Pumps** Providing, erecting, commissioning and giving test and trial of V.T. Pumps, water lubricated type and capable of discharging raw water 666 LPS at total head of 42 mtrs. Operating at 1000 RPM synchronous speed including providing fixing / BMC ISMB, etc. as per detailed specifications	4	Nos.	2044000	8176000.00
2	**Reflux Valve** Providing, erecting, coomissioning and giving test and trail of reflux valves of sizes and rating as mentioned below and as per specifications.				
a)	600 mm dia PN 1.0 rating CIDF Non-Return valve with buepass arrangement (on delivery side of each pump)	4	Nos.	231205	924820.00
b)	1200 mm dia PN 1.0 rating Non- Return valve as per detailed specifications	1	Nos.	1664000	1664000.00
3	**Sluice Valve** Providing, erecting, commissioning and giving test and trail of CIDF Sluice Valve PN-1 rating as per detailed specifications				
a)	Slucice Valve 600 mm dia with Actuator (for pump delviery) PN - 1.0 rating	4	Nos.	417720	1670880.00
b)	Sluice valve 200 mm dia for scouring arrangement (PN-1.0 rating)	2	Nos.	25000	50000.00
4	**Butterfly Valve** Providing, erecting, commissioning and giving test and trail of Butterfly Valve as per detailed specifications of size 600 mm dia PN1.0 rating (Additional control valve on pump delivery).	4	Nos.	113472	453888.00
5	**Kinetic Air Valve** Providing, erecting, commissioning and giving test and trail of Kinetic Air Valve of 80 and 200 mm dia PN1.0 rating isolating sluice valve as per detailed specifications.				
a)	80 mm dia (for expelling air in column pipes of pumps)	4	Nos.	16855	67420.00
b)	200 mm dia (on delivery header)	3	Nos.	61262	183786.00

Sl. No.	Item	Quantity	unit	Rate	Amount
6	**M.S. Pipe Work and Fabricated platforms** Providing fabricating, erecting, jointing and testing MS flanged pipes and specials and fabricated platforms as per detailed specifications including painting with epoxy paint	39958	kg	50	1997900.00
7	**RCC/CC Work for Pipes,Valves, Thrust Blocks and Pads** Designing, providing RCC/CC supports, thrust blocks for manifold pipes, valves in M-200 concrete with necessary reinforcement including excavation in all types of strata, frame work, curing plastering etc. complete as per detailed specifications.				
	RCC and PCC work in M-200 with excavation etc.	Job	LS	500000	500000.00
8	**Dismantallig Joints** Designing, Providing, erecting, commissioning and testing MS fabricated dismatalling joints 700 mm dia with required hardware as per detailed specifications.	4		58400	233600.00
9	**Lifting Equipments**				
	EOT CRANE Providing, erecting, commissioning and testing single girder EOT crane of 7.5 tonnes capacity complete with all accosiated electrical equipment, rail/sq. bar, DSL system, wire rope etc. as per detailed specifications.	Job	LS	1010950	1010950.00
	Total				**16933244.00**
	Physical Contingencies (@5%)				846662
	Cost Contingencies (@10%)				1693324
	Grand Total				**19473231**

6.3.3 ELECTRICAL WORKS

Sr. No.	Description	Unit	Qty.	Unit Rate Rs.	Total Rs.
1	SUPPLY AND INSTALLATION OF OUTDOOR STEEL STRUCTURE FOR 11 KV INCOMING TWO LINES	No	1	250000.00	250000.00
2	INDOOR HT SWITCHGEAR SUPPLY, INSTALLATION, TESTING AND COMMISSIONING OF FOLLOWING SWITCHBOARDS SCOPE INCLUDES UNLOADING SHIFTING ERECTION, LEVELLING AND FIXING THE PANELS TO THE CHANNEL BASE FRAME INSERT PLATE PROVIDED ON THE FLOOR. SCOPE ALSO INCLUDES TESTING OF ALL THE RELAYS, CTS. PTS. AND METERS (THIS SCOPE SHALL BE APPLICABLE FOR INSTALLATION OF ALL PANELS).				
2.1	11 KV VCB / SWITCHBOARD AS PER SINGLE LINE DIAGRAM.	No.	1	2950000.00	2950000.00
2.2	**3.3 Kv VCB SWITCHBOARD** SUPPLY AND INSTALLATION, TESTING AND COMMISSIONING OF 3.3 KV,250MVA VCB SWITCHBOARD COMPRISING 2 nos:630 A, BUS-SECTION, 2 nos:630 A, OUTGOING TX FEEDERS, VACUUM CONTACTOR WITH FUSE COMPLETE NITH RELAYS, 4 nos:630 A, OUTGOING FEEDERS (FOR MOTOR D.O.L STARTERS WITH VACUUM CIRCUIT BREAKER COMPLETE WITH RELAYS) '2 nos:BUS PT PANELS APPROXIMATE DIMENSIONS 12000(L)+2000(D) TESTING &COMMISSIONING OF THE ABOVE PANEL UNDER SUPERVISION OF THE MANUFACTRURER	No	1	3050000.00	3050000.00
2.3	FULLY AUTOMATIC AIR COOLED ROTOR CONTROL PANEL INCLUDING FLUX COMPENSATED MAGNETIC AMPLIFIER WITH BYPASS CONTACTOR AND ITS CONTROL CIRCUITRY	No.	4	325000.00	1300000.00
2.4	**3.3 Kv CAPACITOR PANEL** UNLOADING SHIFTING INSTALLATION TESTING AND COMMISSIONING OF 3.6 kV, 85 KVAR, POWER FACTOR IMPROVING CAPACITOR BANK COMPLETE WITH AIR COOLED SERIES REACTOR ,RVT& INSTRUMENT COMPo WITH METERS & RELAYS (TO BE CONNECTED TO EACH 3.3 Kv,325 kW MOTOR) APPROXIMATE DIMENSIONS:	Sets	4	56025.00	224100.00
3	TRANSFORMERS				
3.1	DISTRIBUTION TRANSFORMER				
	SUPPLY & UNLOADING, SHIFTING INSTALLATION, TESTING AND COMMISSIONING OF OUTDOOR TYPE RATING				
3.1.1	33/3.6 KV,2000 KVA, ONAN, O.L.T.C. 'DYN11., SUITABLE FOR HT CABLE TERMINATION	Nos.	2	1089105.00	2178210.00
3.1.2	11 KV / 0.433 KV, 630 KVA, ONAL, DYN -11 suitable for H. T. and L. T. cable termination	Nos.	2	348290.00	696580.00

Sr. No.	Description	Unit	Qty.	Unit Rate Rs.	Total Rs.
4	415V SWITCHBOARD				
4.1	SUPPLY UNLOADINC, SHIFTINC, INSTALLATION, TESTING AND COMMISSIONING OF 415 V SW BOARD [SINGLE FRONT), 415 VOLT.,50 kA TPN, AL BUSBAR, FLOOR MOUNTED.AS PER SLD AND LAYOUT APPROXIMATE DIMENSIONS : (L) x (D)	No.	1	138000.00	138000.00
	(i) Min. 415V S.B	No.	1	650000.00	650000.00
	(ii) Pump Huse 415V S.B	No.	1	30500.00	30500.00
5	LIGHTING DISTRIBUTION BOARD SUPPLY, UNLOADING,SHIFTING INSTALLATION, TESTING AND COMMISSIONING OF DISTRIBUTION BOARDS / WALL MOUNTED PANELS.				
5.1	4 WAY AC LIGHTING PANELS INCOMER- 63 A TPN MCB+ELCB OUTGOING -12 NOS: 16A DP MCB	No.	2	3400.00	6800.00
5.2	4 WAY AC LIGHTING PANELS WITH PHOTO SENSOR NCOMER- 63 A TPN MCB+ELCB OUTGOING -12 NOS: 16A DP MCB	No.	1	4000.00	4000.00
5.3	4 WAY AC POWER PANELS INCOMER- 63 A TPN MCB+ELCB OUTGOING -9 NOS: 20A DP MCB	No.	2	3400.00	6800.00
5.4	4 WAY AC POWER PANELS INCOMER- 32 A TPN MCB+ELCB OUTGOING -10A DP MCB	No.	7	3600.00	25200.00
6	DC SYSTEM				
6.1	SUPPLY, UNLOADING, SHIFTING, INSTALLATION, TESTING AND 'COMMISSIONING OF 110 V DC SYSTEM COMPRISING THE FOLLOWING: FLOAT CHARGER-1 NO BOOST CHARGER-1 NO DCDB-1 NO 48 V LEAD ACID MAINTENANCE FREE BATTERY WITH MOUNTING RACK (48V, 80 AH),2 HOURS BACK UP	Set	2		175000.00
6.2	INSTALLATION RATE SHALL INCLUDE MOUNTING OF BATTERY ADJACENT TO THE CHARGER PANEL(TO BE MOUNTED ON THE RACK)	Set	2		
7	L.T MOTORS				
	TESTING AND COMMISSIONING OF INDUSTRIAL TYPE LT SQUIRREL CAGE INDUCTION MOTORS UPTO 7.5Kw 7.5 KW TO 20 KW	Nos. Nos.			
8	HT MOTORS TESTING AND COMMISSIONING OF INDUSTRIAL TYPE WOUND ROTOR INDUCTION MOTORS 3.3Kv,	Nos.	4	825000.00	3300000.00
9	INSTALLATION OF CABLES SUPPLY AND LAYING OF AL/CU, PVC,ARMOURED CABLE RATE TO INCLUDE SUPPLY AND FIXING OF CLAMPING MATERIAL, IDENTIFICATIONTAG. CLEATS, ETC.				

Sr. No.	Description	Unit	Qty.	Unit Rate Rs.	Total Rs.
9.1	CABLES DIRECTLY IN GROUND, INCLUSIVE OF SUPPLY AND LAYING OF SAND, PROTECTIVE BRICK LAYERS AND CABLE MARKERS AND IDENTIFICATION				
A	1100V LT POWER CABLES				
	3.5C x 400 SQ MM (AYFY)	MTR	200	1316.00	263200.00
	3.5 x 300 SQ.MM (AYFY)	MTR	160	1033.00	165280.00
	3.5 x 120 SQ.MM (AYFY)	MTR	360	457.00	164520.00
	3.5 x 50 SQ.MM (AYFY)	MTR	100	218.00	21800.00
	4C x 16 SQ MM (AYFY)	MTR	100	165.00	16500.00
	3C x 16 SQ. MM (AYFY)	MTR	UR	0.00	
	3C x 10 SQ MM (AYFY)	MTR	UR	0.00	
	4C x 6 SQ. MM (AYFY)	MTR	UR	0.00	
	3C x 6 SQ. MM (A YFY)	MTR	UR	0.00	
	4C x 4 SQ. MM (AYFY)	MTR	UR	0.00	
	3C x 2.5 SQ. MM (YWY)	MTR	60	90.00	5400.00
B	CONTROL CABLES				
	PVC, ARMOURED CABLES WITH COPPER CONDUCTOR OF FOLLOWING SIZES				
	2C x 1.5 SQ.MM	MTR	40	112.00	4480.00
	3C x 1.5 SQ.MM	MTR	70	121.00	8470.00
	4C x 1.5 SQ. MM	MTR	640	133.00	85120.00
	6Cx1.5 SQ. MM	MTR	180	155.00	27900.00
	14C x 1.5 SQ. MM	MTR	40	202.00	8080.00
	3Cx2.5 SQ. MM	MTR	100	90.00	9000.00
9.2	SUPPLY AND CABLES LAID ON TRAYS, STRUCTURAL SUPPORTS PVC, ARMOURED CABLES WITH AL I COPPER CONDUCTOR, LAID IN CABLE TRAY,CLEATED ON STRUCT., PULL THROUGH PIPE SLEEVE INCLUDING SUPPLY & FIXING OF CLAMPING MATERIAL !IDENTIFICATION TAG,CLEATS ETC.,				
A	L T POWER CABLES				
	3.5C x 400 SQ MM (AYFY)	MTR	50	1266.00	63300.00
	3.5 x 300 SQ.MM (AYFY)	MTR	70	983.00	68810.00
	3.5 x 120 SQ.MM (AYFY)	MTR	120	407.00	48840.00
	3.5 x 50 SQ.MM (AYFY)	MTR	65	168.00	10920.00
	3C x 70 SQ. MM (A YFY)	MTR	50	218	10900.00
	4C x 16 SQ MM (AYFY)	MTR	100	115.00	11500.00
	3C x 16 SQ MM (AYFY)	MTR	30	91.00	2730.00
	3C x 10 SQ. MM (AYFY)	MTR	UR		
	4C x 6 SQ. MM (AYFY)	MTR	UR		
	4C x 4 SQ MM (A YFY)	MTR	UR		
	3C x 2.5 SQ. MM (YWY)	MTR	100	122.00	12200.00
B	CONTROL CABLES				
	PVC, ARMOURED CABLES WITH COPPER CONDUCTOR OF FOLLOWING SIZES				
	2C x 1.5 SQ.MM	MTR	160	112.00	17920.00
	3C x 1.5 SQ. MM	MTR	200	71.00	14200.00
	4Cx1.5SQ.MM	MTR	560	83.00	46480.00
	6Cx1.5SQ.MM	MTR	200	105.00	21000.00
	14C x 1.5 SQ. MM	MTR	20	201.00	4020.00
10	HT CABLES				

Sr. No.	Description	Unit	Qty.	Unit Rate Rs.	Total Rs.
10.1	SUPPLY AND CABLES DIRECTLY IN GROUND, INCLUSIVE OF SUPPLY AND LAYING OF SAND, PROTECTIVE BRICK LAYERS AND CABLE MARKERS AND IDENTIFICATION TAGS.				
A	33 KV (UE),3C x 185 SQ. MM	MTR	90	1959.00	176310.00
B	3.3 KV (UE),3C x 150 SQ. MM	MTR	160	1150.00	184000.00
C	3.3 KV (UE),3C x 35 SQ. MM	MTR	UR		
D	3.3 KV (UE), 3C x 95 SQ.MM	MTR	100	618.00	61800.00
10.2	CABLES LAID IN BUIIT UP TRENCH COMPLETE WITH COVER				
A	33 KV (UE),3C x 185 SQ. MM	MTR	UR		
B	3.3 KV (UE),3C x 150 SQ. MM	MTR	UR		
C	3.3 KV (UE), 3C x 95 SQ.MM	MTR	UR		
10.3	CABLES LAID ON TRAYS, STRUCTURAL SUPPORTS PVC, ARMOURED CABLES WITH AL I COPPER CONDUCTOR, LAID IN CABLE TRAY,CLEATED ON STRUCT., PULL THROUGH PIPE SLEEVE INCLUDING SUPPLY & FIXING OF CLAMPING MATERIAL IDENTIFICATION TAG,CLEATS ETC.				
A	3.3 KV (UE),3C x 150 SQ. MM	MTR	50	796.00	39800.00
B	3.3 KV (UE),3C x 70 SQ. MM	MTR	100	511	51100.00
C	3.3 KV (UE),3C x 35 SQ. MM	MTR	100	397.00	39700.00
D	3.3 KV (UE), 3C x 95 SQ.MM	MTR	50	618.00	30900.00
11	**EARTHING AND LIGHTNING PROTECTION :**				
11.1	SUPPLY AND INSTALLATION OF FOLLOWING GI EARTHING & LIGHTNING PROTECTION CONDUCTORS OF FOLLOWING SIZES, THE GROUNDING CONDUCTOR SHALL TERMINATE IN APPROVED GROUNDING FITTING, EARTH STRIP SHALL BE LAID IN CABLE TRAY CLEATED ALONG BRICK WALURCC STRUCTURES STEEL STRUCTURES. INSTALLATION RATE SHALL INCLUDE ALL HARDWARES.				
	50 x 6 MM GI STRIP[MEL]	KG	2600	53.00	137800.00
	25 x 6MM GI STRIP[LIGHTNING]	KG	413	53.00	21889.00
	8 SWG WIRE	KG	UR	-	-
	12 SWG WIRE	KG	176	53.00	9328.00
11.2	SUPPLY & INSTALLATION OF TEST LINKS FOR LIGHTINING PROTECTION CONDUCTORS	Nos.	6	UR	
11.3	SUPPLY AND INSTALLTION OF 40MM DIA 3000MM LONG HEAVY DUTY GI PIPE ELECTRODE AS PER IS 3043 WITH INSPECTION CHAMBER ALL ACCESSORIES INCLUDING CIVIL WORK PIPE ELECTRODES WITH TEST PIT	Nos.	6	1890.00	11340.00
11.4	SUPPLY AND INSTALL TION OF 600x600x6MM THK. COPPER PLATE ELECTRODE AS PER IS 3043 WITH INSPECTION CHAMBER FOR TRF. NEUTRAL ALL ACCESSORIES INCLUDING CIVIL WORK PLATE ELECTRODES WITH TEST pit	Nos.	10	1320.00	13200.00
12	**TERMINATION KITS**				

Sr. No.	Description	Unit	Qty.	Unit Rate Rs.	Total Rs.
12.1	SUPPLY & INSTALLATION OF HT HEATSHRINKABLE/ PUSH ON TYPE TERMINATION KITS FOR FOLLOWING SIZES. LUGS SHALL BE HEXAGONAL CRIMPINGTYPE. SCOPE ALSO INCLUDES PREPARATION FOR TERMINATION HIGH POT TESTING OF HT CABLE AFTER TERMINATION. '33/3.3KV(UE) TERMINATION KIT FOR XLPE INSULATED ALUMINIUM CONDUCTOR ARMOURED CABLE OF FOLLOWING SIZE				
	3C x 185 SQ. MM (OUTDOOR) 33 KV	Nos.	4	27245.00	108980.00
	3C x 185 SQ MM (INDOOR) 33 KV	Nos.	4	20065.00	80260.00
	3C x 35 SQ. MM (INDOOR) 3.3 KV	Nos.	8	4680.00	37440.00
	3C x 150 SQ. MM (OUTDOOR) 3.3 KV	Nos.	4	7750.00	31000.00
	3C x 150 SQ. MM(INDOOR) 3.3 KV	Nos.	4	5620.00	22480.00
	3C x 95 SQ.MM (OUTDOOR) 3.3 KV	Nos.	2	7260.00	14520.00
	3C x 95 SQ.MM (INDOOR) 3.3 KV	Nos.	2	5080.00	10160.00
13	**LOCAL PUSH BUTTON STATIONS**				
	SUPPLY, INSTALLATION. TESTING, COMMISSIONING OF WEATHERPROOF, DUSTPROOFCAST ALUMINUM HOUSED, INDUSTRIAL PUSH BUTTON STATION				
13.1	ONLY STOP PUSH BUTTON. (TRANSFORMER)	Nos.	4	600.00	2400.00
13.2	START/STOP PUSH BUTTON WITH KEY FOR STOP	Nos.	4	800.00	3200.00
13.3	START/STOP PUSH BUTTON WITH AMMETER.	Nos.	UR		
13.4	START/STOP PUSH BUTTON, STOP WITH KEY & AMMETER.	Nos.	UR		
13.4	**LIGHT FITTINGS**				
	SUPPLY AND INSTALLATION, TESTING AND COMMISSIONING OF FOLLOWING LIGHT FITTING WITH BULBSfTUBES INSTALLATION RATE SHALL INCLUDE PROVISION OF ALL HARDWARE SUCH AS NUTS. ANCHOR FASTENERS. BOLTS, SCREWS, CLEATS, CLAMPS,INSULATED WIRES FROM JB/ CGB FABRICATION AND INSTALLATION OF SUPPORTING STRUCTURE,BRACKETS, STEEL SHALL BE INCLUDED.				
14.1	2 x 250 W. INDUSTRIAL FLUORESCENT LIGHT FITTING WITHSTOVE ENAMELLED REFLECTOR, MOUNTING TYPE: CEILING/SUSPENDED.	Nos.	12	610.00	7320.00
14.2	1 x 400W, HPMV HIGH BAY INDUSTRIAL FITTING WITH INTEGRAL C.G. MOUNTING TYPE: CEILING/SUSPENDED.	Nos.	16	6000.00	96000.00
14.3	150 W, HPMV STREET LIGHTING FIXTURES SUITABLE FOR BRACKET MOUNTING	Nos.	16	3436.00	54976.00
14.4	70 W, HPSV STREET LIGIn'ING FIXTURES SUITABLE FOR BRACKET MOUNTING	Nos.	UR		
14.5	SELF CONTAINED EMERGENCY LUMINAIRE SUPPLY & INSTALLATION OF SELF CONTAINED EMERGENCY LUMINAIRE WITH TWO 40W FLUORESCENT TUBES& Ni-Cd BATTERIES [gaMiN BACKUP] INVERTER, RECTIFIER.EACH FITTTING TO BE PROVIDED WITH 2 NOS. ENTRIES SUITABLE FOR 3C x 2.5 Sq.mm YWY CABLE. ALL HARDWARE REQUIRED FOR MOUNTING OF ASSEMBLY TO BE INCLUDED.	Nos.	6	2500.00	15000.00
15	**CONDUIT WIRING**				

Sr. No.	Description	Unit	Qty.	Unit Rate Rs.	Total Rs.
	POINT WIRING USING 3C X 2,5 SQ.MM STRANDED CU CONDUCTOR PVC INSULATED WIRES IN GI CONDUIT ON SURFACE FOR THE ABOVE FITTINGS RATE SHALL INCLUDE SUPPLY & INSTALLATION OF CONDUITS,WIRES,JUNCTION BOXES,PULL BOXES ETC., FOR THE ABOVE FITTINGS				
	FULL POINT [FIRST FITTING FROM PANEL]	Nos.	10	665.00	6650.00
	HALF P01NT[SUBSEQUENT FITTINGS]	Nos.	34	450.00	15300.00
16	STRUCTURAL STEEL				
	SUPPLY, FABRICATION & INSTALLATION OF GALVANISED STEEL STRUCTURE FOR SUPPORTING VARIOUS ITEMS/EQUIPMENT SUCH AS VARIOUS PANELS, CABLE TRAYS, PUSH BUTTON STATIONS, JUNCTING BOXES LIGHT FITTING, DB, ETC, INCLUDING DRILLING WELDING, GROUTING, CHIPPING, BOLTING WITH SUPPLY OF REQUIRED HARDWARE.	K.G.	2100	5.00	10500.00
17	CABLE TRAYS				
	SUPPLY & INSTALLATION OF LADDER TYPE PREFABRICATED AL CABLE TRAY AS PER DRG. OF FOLLOWING SIZES				
	80 mm wide cable trays	MTR	80	64.00	5120.00
	200 WIDE CABLE TRAY.	MTR	100	126.00	12600.00
	400 WIDE CABLE TRAY.	MTR	100	246.00	24600.00
	600 WIDE CABLE TRAY.	MTR	UR		
	750 WIDE CABLE TRAY.	MTR	UR		
18	EXCAVATION				
	EXCAVATION ,PREPARATION OF SAND BEDDING BACKFILLING INCLUDING SUPPLY &INSTALLATION OF CABLE/JOINT MARKERS,PROTECTIVE COVER FOR 450MM WIDEX1000 MM DEEP ROUTE FOR INCOMING 33 kVCABLES	MTR	50	60.00	3000.00
19	CABLE GLANDS & LUGS.				
	END TERMINATION WITH Ni-Cr PLATED INDL DOUBLE COMPRESSION BRASS GLANDS AND CRIMPING TYPE COPPER LUGS FOR FOLLOWING CABLES SIZES. PVC SLEEVES SHALL BE PROVIDED OVER THE CABLE LUGS & GLANDS. SUPPLY OF GLANDS LUGS, ETC. TO BE INCLUDED. CABLES SHALL BE CU /AL.CONDUCTOR, PVC ARMOUR ED.				
19.1	L. T. POWER CABLES				
	3.5C x 400 SQ. MM (AYFY)	Nos.	12	302.00	3624.00
	3.5C x 300 SQ.MM	Nos.	6	338.00	2028.00
	3.5C x 120 SQ.MM	Nos.	24	168.00	4032.00
	3.5C x 50 SQ.MM	Nos.	10	104.00	1040.00
	3C x 35 SQ. MM (A YFY)	Nos.	UR	86.00	-
	4C x 16 SQ. MM (AYFY)	Nos.	UR		
	3C x 16 SQ. MM (AYFY)	Nos.	12	62.00	744.00
	3C x 10 SQ. MM (YWY)	Nos.	6	32.00	192.00
	3C x 4 SQ. MM (YWY)	Nos.	12	29.00	348.00

Sr. No.	Description	Unit	Qty.	Unit Rate Rs.	Total Rs.
	3C x 2.5 SQ. MM (VWY)	Nos.	50	29.00	1450.00
19.2	CONTROL CABLES				
	PVC, ARMOURED CABLES WITH COPPER CONDUCTOR OF FOLLOWING SIZES				
	4Cx 1.5 SQ. MM	Nos.	64	29.00	1856.00
	14C x 1.5 SQ. MM	Nos.	12	32.00	384.00
20	LIGHTING POLES with M.V. Lamp fittings, Bracket, Terminal box. etc	Nos.	6	8000.00	48000.00
21	SWITCH/SOCKET UNIT				
	SUPPLY & INSTALLATION OF SINGLE PHASE SWITCH SOCKET UNIT, INDUSTRIAL TYPE, (RATING- 5/15A, 240V) WITH MATCHING PLUG, CAP FOR SOCKET & MECHANICAL INTERLOCK THE ENCLOSURE SHALL BE OF CAST METAL WITH 2 NOS. ENTRIES SUITABLE FOR CONDUIT WIRING.	Nos.	16	210.00	3360.00
21.2	CONDUIT WIRING				
	POINT WIRING FOR THE ABOVE SWITCH SOCKET USING 3C X 2.5 SQ.MM STRANDED COPPER CONDUCTOR PVC INSULATED WIRES IN GI CONDUIT ON SURFACE. RATE : SHALL INCLUDE SUPPLY & INSTALLATION OF ICONDUITS,WIRES,JUNCTION BOXES,PULL BOXES ETC., FOR THE ABOVE FITTING				
	FULL POINT [FIRST SOCKET FROM PANEL}	Nos.	6	665.00	3990.00
	HALF POINT[SUBSEQUENT SOCKETS}	Nos.	10	450.00	4500.00
22	L. T. CAPACITORS				
	SUPPLY, UNLOADING SHIFTING INSTALLATION TESTING AND COMMISSIONING OF 430 VOLTS, 50 KVAR. APP POWER FACTOR IMPROVING	Sets	4	5900.00	23600.00
23	TPN WELDING SOCKET				
	SUPPLY & INSTALLATION OF TPN, WELDING SWITCH SOCKET UNIT, INDUSTRIAL TYPE, '(RATING- 30A, 415V) WITH MATCHING PLUG, CAP FOR SOCKET & MECHANICAL INTERLOCK THE ENCLOSURE WILL BE OF CAST METAL WITH 2 NOS. ENTRIES SUITABLE FOR	Nos.	4	2300.00	9200.00
	3.5C x 25 Sq.mm AYFY CABLE.				
24	JUNCTION BOXES				
	SUPPLY, INSTALLATION OF INDUSTRIAL TYPE SHEET STEEL ENCLOSED JUNCTION BOXES SUITABLE FOR 4 NOS. 3C x 1.5/2.5 Sqmm COPPER CONDUCTOR CABLE. JUNCTION BOX SHOULD HOUSE 12 NOS. STUD TYPE TERMINALS	Nos.	UR		
25	SAFETY EQUIPMENT FOR SWGR. ROOMS				
	ALL ITEMS OF SAFETY EQUIPMENT SHALL BE INCLUDED IN THE RATE QUOTED.				
25.1	SUPPLY & INSTALIATION OF RUBBER MAT.				
	RUBBER MAT SHALL BE CHEQURED TYPE AS PER IS 5425. RUBBER MAT OF 415V GRADE OF WIDTH 900 MM.	MTR	6	200.00	1200.00
	RUBBER MAT OF 11 KV GRADE OF WIDTH 900 MM.	MTR	20	600.00	12000.00
	RUBBER MAT OF 33 KV GRADE OF WIDTH 900 MM	MTR	20	400.00	8000.00
25.2	SHOCK TREATMENT CHART				

Sr. No.	Description	Unit	Qty.	Unit Rate Rs.	Total Rs.
	SUPPLY, FIXING OF SHOCK TREATMENT CHART IN ENGLISH AND LOCAL LANGUAGE AT SUITABLE LOCATIONS. SHOCK TREATMENT CHART BE PRINTED TYPED AND FRAMED.	Nos.	2	100.00	200.00
25.3	SUPPLY, INSTALIATION OF METALIC CAUTION				
	BOARDS AS PER IS-2551 OF VOLTAGE GRADE AS GIVEN BELOW WITH RED COLOUR BASE AND WHITE PAINTED IN ENGLISH AND LOCAL LANGUAGE CAUTION BOARDS SHALL BE FIXED FIRMLY AT SUITABLE LOCATION BY NUTS, BOLTS, ETC.				
	440V GRADE CAUTION BOARDS	Nos.	2	500.00	1000.00
	11 KV GRADE CAUTION BOARDS	Nos.	1	500.00	500.00
	3.3 KV GRADE CAUTION BOARDS	Nos.	2	500.00	1000.00
25.4	FIRE EXTINGUISHER				
	SUPPLY, INSTALLATION AND FIXING OF DRY TYPE FIRE EXTINGUISHER OF 5 KG CAPACITY AT SUITABLE LOCATIONS.	Nos.	4	1899.00	7596.00
25.5	FIRST AID KIT				
	SUPPLY AND INSTALLATION OF FIRST AID KIT TO BE KEPT IN WOODEN STAND MOUNTED ON WALL AT SUITABLE LOCATION. FIRST AID KIT SHALL BE SUITABLE FOR 10 PERSONS.	Nos.	2	290.00	580.00
25.6	SAND BUCKETS WITH SAND.				
	SUPPLY AND INSTALLATION OF SAND BUCKETS WITH SAND AT SUITABLE LOCATIONS. CONTAINING 3 NO. BUCKETS IN ONE SET WITH M.S. STAND	Sets	2	635.00	1270.00
26	WORKS STATION (CONTROL PANEL) SUPPLY, INSTALLATION, TESTING AND COMMISSIONING WORKS STATION FOR OPERATION AND CONTROL PUMP-MOTOR, TRANSFORMERS WITH ANNUNCIATOR AND INDICATOR PANEL COMPLETE WITH MATERIALS, PUSH BUTTONS, METERS, LAMPS, SWITCHES, RELAYS ETC.	No.	1	200000.00	200000.00
27	MSEB METERING PANEL COMPLETE WIH C.T.S, P.T.S ELECTRICITY MAX. DEMAND WATT METER, TRIVECTOR METER SUPPLY LINES, MARSHALLING BOX, CABLES, HARD BOXES ETC.	SET	1	130000.00	130000.00
28	PROVISIONAL ITEM FOR PROVIDING POWER SUPPLY LINES BY M.S.E.B, ELECTRICAL INSPECTOR'S APPROVAL, LIAISON WORKS ETC.	LUMP SUM			2500000.00
	SUB TOTAL				**20408127.00**
	Ventilation System				
1	**Supply, installation and commissioning of following switch gears at distribution position on angle iron frame / Teak wood board.**				
i	63 A TPN MCB and 12 way 10 AMP, TPMCB per way.	No.	1	4000.00	4000.00
ii	15 A TPN MCB and 4 way 10 Amp TPMCB per way	No.	2	2500.00	5000.00
iii	10 A MCB Tripple pole isolator with 20 Amp, 415 V, 3 P, LT control switch enclosed in metal box.	No.	6	1800.00	10800.00
2	**Supply & installation of following cables**				

Sr. No.	Description	Unit	Qty.	Unit Rate Rs.	Total Rs.
i	4/25 sq.mm, A1 conductor PVC armoured 1100 Volt grade cable with G.I earth conductor of size 8 SWG fixed on wall/laid in cable tray in approved manner complete with cable lugs / terminations etc. for mains.	MTR	30	136.00	4080.00
ii	4/4 sq.mm Cu conductor 1100 Volt grade single PVC wires in 25mm G.I pipe fixed on wall/ in cable tray in approved manner and provided with 8 SWG G.I earth conductor, complete with terminations etc. for submain.	MTR	60	90.00	5400.00
iii	i. Wiring with 3/2.5 sq.mm Cu conductor, 1100 Volt grade, single PVC wires in 25 mm G.I pipe fixed on wall in approved manner and provided with 8 SWG G.I earth conductor, complete with 3P + earth socket & plug.	No	6	500.00	3000.00
3	**Supplying Installation & commissioning of following** **Exhaust Fan complete with Loures & bird Quards**				
i	600 mm size 3 phase, 415 Volts having air delivering capacity of 10400 m3/hr (Min). Complete with suitable Cu conductor flexible cord.	No.	6	5900.00	35400.00
ii	300 mm size, 3 phase, 415 Volts having air delivering capacity of 1250 m3/hr (Min). Complete with suitable Cu conductor flexible cord.	No.	2	4225.00	8450.00
Intercom System					
1	Supply, installation & Commissioning following:	Job		59500.00	59500.00
i	2 x 16 EPABX System				
ii	Multi Core cu wire				
iii	instruments				
iv	UPS -500 Watts				
Fire Alarm System					
1	Supply, installation & commissioning of fire alarm system for Pump House and substation complete with smoke detector, wiring, annunciation system.	Job		45000.00	45000.00
	Sub Total				**180630.00**
	Grand Total				**20588757.00**
	Physical Contingencies (@5%)				1029437.85
	Cost Contingencies (@10%)				2058875.70
	Grand Total				**23677070.55**

6.4 PURE WATER RISING MAIN FROM WTP AT GODHANI TO MBR AT GOVERNOR HOUSE

WORK - M.S PIPES WITH INTERNAL CEMENT CONCRETE LINING AND EXTERNAL COATING OF CEMENT CONCRETE INCLUDING EXCAVATION, BEDDING, LAYING, JOINTING, BACKFILLING, SPECIALS, LINE VALVES, WASHOUTS, APPURTENANCES, CHAMBERS, THRUST AND ANCHOR BLOCKS, ENCASEMENT HYDRAULIC TESTING etc. COMPLETE.

Item No.		Description	Quantity	Unit	Rate	Ammount
		MATERIAL				
1		Manufacturing, Providing and Supplying Spirally welded /ERW/SAW/fabricated M.S.Pipes of following diamer as per IS - 3589 including procurements of plates, gas cutting to required size rolling,tack welding assembling in suitable lenghts to form pipes welding on automatic welding machine and forming V edge on both ends of pipes including all taxes.				
	i	M.S 1422 mm (OD), 12mm Shell thickness Inlining - 12mm thick C.C Outcoating - 20mm thick C.C	9300	m	21000	195300000
2		Supplying mild steel specials for M.S. pipes for internal dia. and thickness as item wised below, suitable for butt welding, specials with C.M. mortar lining and 2.4 mm thick external coal tar enamel coating.				
	a	Outer Dia of 1422mm with outer lining of 20 mm CC Coating and 12 mm inling.				
	i	Bends as specified below.				
		10° deg. Bends	21	Nos.	22574	474054
		15° deg. Bends	21	Nos.	24508	514668
		22.5° deg. Bends	7	Nos.	27438	192066
		30° deg. Bends	5	Nos.	54266	271330
		45° deg. Bends	3	Nos.	76805	230415
		60° deg. Bends	1	Nos.	114041	114041
3		Supplying double flanged Scour valves,Butterfly valves & Air Valve including packing, nuts, bolts, washers and storing in the stock yard				
	i	1200 mm dia. Butterfly valves (In line) P.N 1.0	5	Nos.	500000	2500000
	ii.	400 mm dia. Sluice valves (Scour valves) P.N 1.0	6	Nos.	32682	196092

Item No.		Description	Quantity	Unit	Rate	Ammount
	iii	Double Flanged Kinetic Air Valve with Isolating Sluice	19	Nos.	29158	554002
4		Fabricating manholes as per drawing and specifications from M.S. flats, sheets etc.. supplied free of cost and assembling the same on the pipe and tack welding etc, complete as per directions.	16	Nos.	10000	160000
5		**EARTH WORK** **Excavation** Clear cover = 1000 mm Dia. of Pipe =1462 mm bedding = 150 mm. Depth of excavation = 2.612m. Width of trench = 2.062m				
	i	Excavation for pipe trenches in earth, soils of all types, **sand, gravel and soft murum,** including removing the excavated material upto a disstance of 50m , stacking na d spreading as directed, normal dewatering, preparing the bed for foundation and excluding backfilling etc., complete.	20038	m^3	34	681292
	ii	Excavation for pipe trenches in **hard murum,** including removing the excavated material upto a disstance of 50m , stacking na d spreading as directed, normal dewatering, preparing the bed for foundation and excluding backfilling etc., complete.	15027	m^3	43	646161
	iii.	Excavation for pipe trenches in **Hard rock** including removing the excavated material upto a disstance of 50m , stacking na d spreading as directed, normal dewatering, preparing the bed for foundation and excluding backfilling etc., complete.	15027	m^3	220	3305940
	iv	Excavation for pipe trenches in **WBM road** including removing the excavated material upto a disstance of 50m , stacking and spreading as directed, normal dewatering, preparing the bed for foundation and excluding backfilling etc., complete.	9400	m^3	43	404200

Item No.		Description	Quantity	Unit	Rate	Ammount
6		Providing and filling in sand boxing in pipe line or for foundation with sand of approved quality including watering compaction etc. complete.	6826	m^3	300	2047800
7		Lowering, laying and jointing M.S pipes in trenches on prepared formation including marginal cutting wherever required, assembling and Butt Welding, preliminary air testing of each field joint and final hydraulic testing to required pressures etc. as per specification and drawings.				
	i.	*In Trench* OD 1422 mm, 112 mm shell thickness with CC 20mm lining. MJP DSR PUNE 2004-2005 Item No.XIII 5 (b) V	9300	m	343	3189900
8		Welding in all positions with required number of runs for M.S. pipes internally and / or externally including gauging wherever nessasaty, fixing appurtenences and other accessories in connection with pipe laying work as per specification	4155	m	385	1599675
9		Lowering, laying and jointing M.S pipe Specials including marginal cutting wherever required, assembling and Butt Welding, The rate to including unloading, hoisting etc. complete as specified.				
	a.	Outside dia. 1422 mm, 20 mm outer lining with shell thickness 12mm	520	Nos.	385	200200
10		Lowering ,laying joining and fixing in position valves including cost of conveyance, cost of all materials and giving factory hydraulic test.				
	i.	1200mm dia butterfly valves	5	Nos	50000	250000
	ii.	200mm dia kinetic air valves with isolating sluice.	19	Nos	220	4180
	iii.	Scour Valve of 400 mm dia.	6	Nos	2570	15420

Item No.		Description	Quantity	Unit	Rate	Ammount
11		Providing, fabricating and fixing expansion joints for pipe line of diameter as per the drawing. The rate to include machining the strakes and steel ring as shown in the drawing and welding on either automatic welding machine or manually. Rate includes plates and flats required for expansion joint and all other materials such as synthetic rubber, rubber ring etc., complete. Including packing as per specifications, grease, blots and nutsetc., including local handling, all types of taxes and duties etc. commplete.	4	Nos	300000	1200000
12		Providing and constructing valve chambers with RCC 1:2:4 walls with footings, foundation concrete 300mm thick in C.C 1: 3: 6 using trap metal 25 to 40 mm size 20mm cement plaster in C.M 1: 3 inside and outside with precast RCC slab 150mm thick, including cost of reinforcement as directed by engineer in charge including all taxes, complete including cost of excavation and refilling with ramming , watering and curing of civil works.				
	i.	Construction of RCC valve chambers for butterfly valves as per detail specifications of size3.5 x 4 x 3 m.	5	Nos	120000	600000
	ii.	Construction of RCC valve chambers for scour valves as for detail specifications of size 2.5 x 2.3 x 3.3 m.	6	Nos	76100	456600
	iii.	Construction of RCC valve chambers for Kinetic air valves as for detail specification of size 3.1 x 2.5 x 1.3 m.	19	Nos	56600	1075400
13		Mass concrete M-20 with 20 mm max aggregate size, for embeddment, anchor blocks and thrust blocks etc. including form work, embedding puddle flange, etc. complete as per drawing.				
	i.	Plain cement concrete (M-10)	156	m^3	1500	234000
	ii	Concrete for pre cast works (M-20) of Highway crossings, Nalla & Canal Crossings and thrustblocks	1442	m^3	2400	3460800

Item No.		Description	Quantity	Unit	Rate	Ammount
14		Reinforcement steel for RCC works with deformed high yield steel bars conforming to IS 1786. (Nominal bar size from 6 mm to 12 mm), including anticorrosive treatment as specified.(for road crossings)	9	Tonnes	30000	270000
15		Backfilling trench with available excavated stuff in layers not exceeding 200 mm, including watering and compaction as directed.(including road crossings)	27650	m^3	16	442400
16		Providing and fixing indicator posts along pipe line routes, post to be of precast concrete M20 of as for drawing.	20	Nos	1000	20000
17		Drain arrangement at scour valve locations including approx.20m .of RCC drain pipe size of 400mm dia and NP2 class from chamber to near by water course and outfall Arrangement.	300	m	500	150000
18		R.C.C. Pedestal	30	Nos	15000	450000
		Hydraulic testing	9.3	km	20437	190064.1
19		Major crossing (River,Rail,Canal)	L.S			15000000
20		Providing and applying coal tar epoxy paint, externally,including cleaning the surface of pipe, etc.complete.	42715	SqM	20	854300
21		Miscellaneous	L.S			5000000
						242255000
		Cost Contingencies (@ 10 %)				**24225500**
		Physical Contingencies (@ 5 %)				**12112750**
		TOTAL				**278593250**