DESIGN CALCULATION

OF

DRAINAGE SYSTEM

REGIONAL RUSUMO FALLS
HYDROELECTRIC PROJECT

RUSUMO POWER COMPANY LIMITED (RPCL)

Nile Equatorial Lakes Subsidiary Action Program Coordination Unit (NELSAP-CU)

CONTRACTOR:

ANDRITZ Hydro

CONSULTANT:

AECOM ARTELIA
## MODIFICATIONS TABLE

<table>
<thead>
<tr>
<th>REV</th>
<th>Drawn By</th>
<th>Checked By</th>
<th>Agreed By</th>
<th>DATE</th>
<th>MODIFICATIONS</th>
<th>STATUS</th>
</tr>
</thead>
</table>


# Table of Content

1. INTRODUCTION ................................................................................................................................. 4
2. DRAINAGE WATER VOLUME CALCULATION .................................................................................... 4
3. LINE SIZE CALCULATION: .................................................................................................................. 6
4. CALCULATION OF HEAD LOSS FOR DRAINAGE SYSTEM: .............................................................. 7
5. PUMP MOTOR CALCULATION: ............................................................................................................ 11
1. INTRODUCTION

Drainage System:-

- 2 nos. submersible pumps for drainage system common in the power house.
- Water from drainage sump will discharge to tail race above flood level.
- Drainage system includes seepage water & leakage water from cooling water floor and other power house equipment's.
- Automatic start / stop of submersible pump are considered with respect to level switches.
- Friction factor \((f)\) is considered as 0.003 for calculating head loss in pipe.

This document is read in conjunction with ANDRITZ HYDRO PVT. LTD drawing no: RU-CP2-HIP300-DWG-MDRA-FD-0010.

2. DRAINAGE WATER VOLUME CALCULATION

2.1 Total seepage area in downstream from cooling water floor to flood level:

- Cooling Water floor level : EL 1278.60 M
- Flood level : EL 1300.95 M
- Longitudinal length at downstream : 53.25 M

Total Area = 53.25 X (1300.95 - 1278.60)
= 53.25 X 22.35
= 1190.13 m²

As per standard IS: 4721, 1 liter per minute of seepage water is considered for every 6 m² of submerged wall.

Total Seepage water through submerged wall = 1190.13 / 6 LPM
= 198.35 LPM
2.2 **Leakage water calculation:**

- Leakage from shaft seal for all three units = 100 x 2 x 3 LPM = 600 LPM (Approx.)
- Leakage water from cooling water system = 150 LPM (Approx.)

As per IS: 4721 drainage pump should have a capacity to handle 150% of seepage water & 100% of continuous leakage water.

Total leakage & seepage water coming to drainage sump pit:-

\[
\text{Total flow} = 198.35 \times 1.5 + 600 + 150 = 1047.52 \text{ LPM} \\
\approx 1048 \text{ LPM}
\]

The intermittent water flow coming from the oil water drainage system in the drainage pit is the seepage water coming through the floor drain in the oil water drainage system, which is already considered in the total flow coming in the drainage pit.

Total water flow in the drainage pit = 1048 LPM

Hence, Pump flow considered taking 10% margin in the total flow = 1048 x 1.10 = 1152.8 LPM ≈ 1200 LPM

**Minimum effective sump volume to dewater the water:**

Minimum water level in sump (LS-1) for both pump off = EL 1274.50 M

Water level for pump #1 ON (LS-2) = EL 1274.80 M

**Overall sump size = 7.8 (L) x 4 (W) x 5.1 (H) meter**

So the effective sump volume = 7.8 x 4 x (1274.8 – 1274.5) m³

\[= 9.36 \text{ m}^3 \text{ or } 9360 \text{ ltrs}\]

Stop cycle time for pump motor set = 9360 / 1048 = 8.93 minutes
**Calculation of no. of start/stop per hour**

Consider pump #1 will run ‘t’ minutes before stopping.

When the water level reaches at EL 1274.8 M pump #1 will start, which dewater 9360 liters water volume in ‘t’ minutes & the same time 948.35 t liters water will come in the pit. Hence, time for pump #1 running will be.

\[
1200t = 9360 + 948.35t
\]

\[
t = 37.91 \text{ minutes}
\]

So, the total start-stop time for pump-motor set = 8.93 + 37.91 = 46.12 minute

No. of start-stop of pump motor set per hour = \( \frac{60}{46.12} \approx 1.30 \approx 2 \) nos.

(As per contract no. of start-stop of pump motor set per hour should not more than 4).

Hence pump flow, 1200 lpm for drainage system is OK.

3. **LINE SIZE CALCULATION:**

**When one pump is running:**

- Inside dia of pipe can be calculated by formula \( A = \frac{Q}{V} \)
- Flow through the pipe (Q) : 1200 LPM
- Economic velocity of water (V) : 2 m/sec.
- Calculated Inside dia of pipe (D) : 112.83 mm
- Selected inside dia of pipe (D1) : 150 mm.
- Actual Velocity of water (V1) : 1.13 m/s

**When both the pump is running:**

- Inside dia of pipe can be calculated by formula \( A = \frac{Q}{V} \)
- Flow through the pipe (Q) : 2400 LPM
- Economic velocity of water (V) : 2.5 m/sec
- Calculated Inside dia of pipe (D) : 159.5 mm
• Selected inside dia of pipe (D) : 200 mm.
• Actual Velocity of water (V1) : 1.27 m/s

4. **CALCULATION OF HEAD LOSS FOR DRAINAGE SYSTEM:**

**Input Data:-**

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Description</th>
<th>Size</th>
<th>Length</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>D</td>
<td>L</td>
</tr>
<tr>
<td></td>
<td></td>
<td>m</td>
<td>m</td>
</tr>
<tr>
<td>1.</td>
<td>Pipe line from pump discharge to drainage water header.</td>
<td>0.150</td>
<td>11</td>
</tr>
<tr>
<td>2.</td>
<td>Drainage water header to pump discharge outlet.</td>
<td>0.200</td>
<td>70</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Description</th>
<th>Pipe Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Butterfly valve</td>
<td>150 NB</td>
</tr>
<tr>
<td>2.</td>
<td>Check valve</td>
<td>2</td>
</tr>
</tbody>
</table>

**a. Head Loss Calculation in Pipes:-**

Friction factor 
\[ f = \frac{0.079}{(Re)^{\frac{1}{4}}} \]  
*Equation (i)*

Head loss 
\[ F = \frac{4 \times f \times L \times V^2}{2 \times g \times D} \]  
*Equation (ii)*

Reynold's No. 
\[ Re = \frac{V \times D}{\nu} \]  
*Equation (iii)*

Where, 
\[ V = \text{Velocity in pipe (m/s)} \]
D: Internal Diameter of pipes (m)

ν: Kinematic Viscosity of water = $0.01 \times 10^{-4}$ m$^2$/s

g: Acceleration due to gravity m/s$^2$

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Description</th>
<th>Size</th>
<th>External Dia</th>
<th>Internal Dia</th>
<th>Length</th>
<th>Velocity</th>
<th>Friction factor</th>
<th>Head Loss</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>L</td>
<td>V</td>
<td>f</td>
<td>F</td>
</tr>
<tr>
<td></td>
<td></td>
<td>mm</td>
<td>mm</td>
<td>mm</td>
<td>m</td>
<td>m/s</td>
<td>m</td>
<td></td>
</tr>
<tr>
<td>1.</td>
<td>Pipe line from pump discharge to drainage water header</td>
<td>0.150</td>
<td>0.168</td>
<td>0.154</td>
<td>11</td>
<td>1.13</td>
<td>0.0038</td>
<td>0.071</td>
</tr>
<tr>
<td>2.</td>
<td>Drainage water header to pump discharge outlet</td>
<td>0.200</td>
<td>0.219</td>
<td>0.202</td>
<td>70</td>
<td>1.27</td>
<td>0.0035</td>
<td>0.398</td>
</tr>
<tr>
<td></td>
<td>Total Head Loss</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.469</td>
</tr>
</tbody>
</table>

Head Loss in Valves & Pipe Fittings:-

Following valves, Elbow & Tees are used in the pressurized line when both pumps are working:

b. Head Loss in Valve

Formula used for head loss calculation in Valve:-

$$K_v = \frac{Q \sqrt{G}}{\sqrt{\Delta P}}$$ ..........................Equation (v)

Where,

Q: Flow Rate in m$^3$/hr
G: Specific Gravity of Liquid
∆P: Pressure Drop Across the valve, bar
### Head loss in butterfly valves

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Description</th>
<th>Pipe Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>No. of Butterfly Valves</td>
<td>150 NB</td>
</tr>
<tr>
<td>2</td>
<td>Q = Flow Rate (m³/hr)</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>G = Specific Gravity</td>
<td>72</td>
</tr>
<tr>
<td>4</td>
<td>Kv = Coefficient</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2020</td>
</tr>
</tbody>
</table>

Net Head Loss in Butterfly Valve (MWLC) 0.0012
Total Head Loss in Butterfly Valves (MWLC) 0.0025

### Head loss in check valves

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Description</th>
<th>Pipe Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>No. of Check Valves</td>
<td>150 NB</td>
</tr>
<tr>
<td>2</td>
<td>Q = Flow Rate (m³/hr)</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>G = Specific Gravity</td>
<td>72</td>
</tr>
<tr>
<td>4</td>
<td>Kv = Coefficient</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>500</td>
</tr>
</tbody>
</table>

Net Head Loss in Check Valve (MWLC) 0.0207
Total Head Loss in Check Valves (MWLC) 0.0414

### c. Head Loss in Elbows

Formula used for head loss calculation in Elbows:

\[ \Delta P = K \times \frac{V^2}{2 \times g} \]

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Description</th>
<th>Pipe size</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>No. of Elbows</td>
<td>150 NB</td>
</tr>
<tr>
<td></td>
<td></td>
<td>200 NB</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 (Approx)</td>
</tr>
</tbody>
</table>
2. \( V = \text{Avg. Velocity of water (m/s)} \)  
\[ 1.13 \quad 1.27 \]

3. \( g = \text{Acceleration due to Gravity (m/s}^2) \)  
\[ 9.81 \quad 9.81 \]

4. \( K = \text{Resistance Coefficient} \)  
\[ 0.5 \quad 0.5 \]

5. \( P = \text{Head loss in Elbow (MWLC)} \)  
\[ 0.032 \quad 0.041 \]

Net Head Loss in Elbows (MWLC)  
\[ 0.097 \quad 0.411 \]

Total Head Loss in Elbows (MWLC)  
\[ 0.508 \]

d. **Head Loss in Tee**

**Formula used for head loss calculation in Tee:**

\[ \Delta P = K \times \frac{V^2}{2} \times g \]

<table>
<thead>
<tr>
<th>Sr. NO.</th>
<th>Description</th>
<th>Pipe size</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>No. of Tees</td>
<td>1</td>
</tr>
<tr>
<td>2.</td>
<td>( V = \text{Avg. Velocity of water (m/s)} )</td>
<td>1.27</td>
</tr>
<tr>
<td>3.</td>
<td>( g = \text{Acceleration due to Gravity (m/s}^2) )</td>
<td>9.81</td>
</tr>
<tr>
<td>4.</td>
<td>( K = \text{Resistance Coefficient} )</td>
<td>0.5</td>
</tr>
<tr>
<td>5.</td>
<td>( P = \text{Head loss in Tee (MWLC)} )</td>
<td>0.041</td>
</tr>
</tbody>
</table>

Net Head Loss in Tees (MWLC)  
\[ 0.411 \]

e. **Head Loss in Reducers**

**Formula used for head loss calculation in Reducers:**

\[ \Delta P = K \times \frac{V^2}{2} \times g \]

<table>
<thead>
<tr>
<th>Sr. NO.</th>
<th>Description</th>
<th>Pipe size</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>No. of Reducer</td>
<td>2</td>
</tr>
<tr>
<td>2.</td>
<td>( V = \text{Avg. Velocity of water (m/s)} )</td>
<td>1.27</td>
</tr>
</tbody>
</table>
3. \( g = \text{Acceleration due to Gravity (m/s}^2) \) = 9.81

4. \( K = \text{Resistance Coefficient} \) = 0.5

5. \( P = \text{Head loss in Reducer (MWLC)} \) = 0.041

Net Head Loss in Reducers (MWLC) = 0.822

**Total Head Loss**: 
Total Head Loss is the sum of all the losses in pipes, valves, instruments, Elbows, Tee & Reducers.

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Description</th>
<th>MWC</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Head loss in Pipes</td>
<td>0.469</td>
</tr>
<tr>
<td>2.</td>
<td>Head Loss in Butterfly valves</td>
<td>0.0025</td>
</tr>
<tr>
<td>3.</td>
<td>Head Loss in Check valves</td>
<td>0.0414</td>
</tr>
<tr>
<td>4.</td>
<td>Head Loss in Elbows</td>
<td>0.508</td>
</tr>
<tr>
<td>5.</td>
<td>Head Loss in Tee</td>
<td>0.411</td>
</tr>
<tr>
<td>6.</td>
<td>Head Loss in Reducers</td>
<td>0.822</td>
</tr>
<tr>
<td></td>
<td><strong>Total Head Loss</strong></td>
<td><strong>2.25</strong></td>
</tr>
</tbody>
</table>

5. **PUMP MOTOR CALCULATION**: 

**Static Head Calculation**: 
Bottom level elevation of Drainage pit is at EL. 1273.50 M  
Centre line elevation of Discharge pipe is at EL. 1301.10 M. 
Total static head = Centre line elevation of discharge pipe - Bottom level elevation of drainage pit. 
Total static head = 1301.10 – 1273.50 
= 27.6 M

**Total Dynamic Head Calculation:**
Total Dynamic head is the sum of static head & all the total losses in piping including valves, bends & other equipment’s:

Total dynamic head  :  27.6 + 2.25 MWC
                      :  29.85 MWC
Net head for pump (H) :  30 MWC (say)
Total discharge      :  1200 LPM
Considering Overall pump-motor :  0.50 (approx.)*
Efficiency ($\eta_o$)

Pump-motor rating :  $H \times Q / 6120 \times \eta_o$

Where, $H$= head in meter, $Q$= discharge in lpm, $\eta_p$ = Pump efficiency, $\eta_m$ = Motor efficiency

$\therefore \quad 30 \times 1200 / 6120 \times 0.50$ (Consider)

$\therefore \quad 11.76$ kW

Selected Pump Motor rating  :  15.0 kW (Approx.)