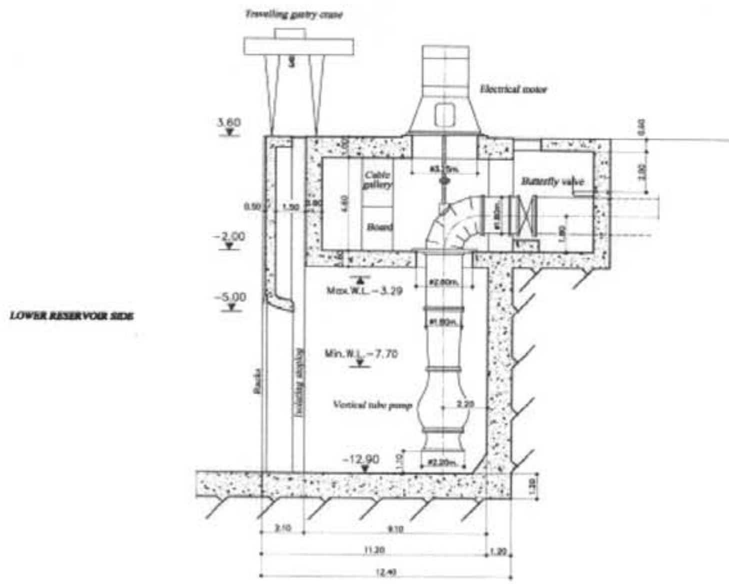
CPP Consorcio Post-Panamax

ACP
AUTORIDAD DEL CANAL DE PANAMA



SECTIONAL VIEW

Conceptual Design to Recycle Water in Post-Panamax Locks

ELECTROMECHANICAL EQUIPMENT OF THE PUMPING STATION

Final Report

R-EM-02-A

Tractebel Development Engineering · TECHNUM · COYNE ET BELLIER · Compagnie Nationale du Rhône

1. GENERAL

The recycling study is a conceptual design of a recycling system by pumping water from a lower to a higher reservoir on the Pacific side for the future Post-Panamax locks, in order to save a maximum of spilled water during periods of insufficient water resources.

This document is related to phase II of the recycling study and is including the study, conceptual design of the main electromechanical components of the pumping station as well as a brief technical description of:

- the pumping units,
- the discharge valves,
- the mechanical auxiliaries of the pumping station,,
- the electrical auxiliaries of the pumping station,
- the water intake,

This design will allow at the end of this report to make a cost estimation covering the electrical and power equipment including local substation..

Basic design assumptions

According to the TOR:

- Water levels

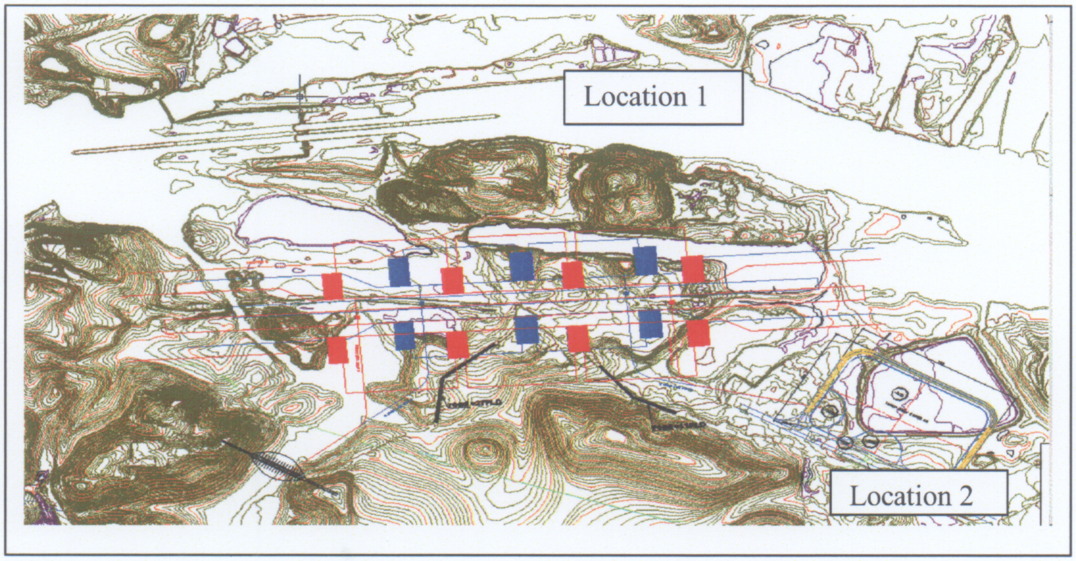
The upstream water level of lake Gatun is supposed to be constant at + 26.00m PLD. It is obvious indeed that the recycling system should be used when the water levels are low, as there is no need to save 100% of the spilled water when there is sufficient water in the lake.

The average downstream level of the Pacific Ocean is 0.04 PLD. In fact, the level is fluctuating according to the tides. The average value is based on a sinusoidal curve with maximum and minimum levels corresponding to mean low water spring and mean high water spring (-2.32m PLD and +2.40m PLD), as the extreme values do seldom occur.

- Recycling scenarios:.

As required by the TOR, three different operating scenarios will be studied:

- a baseline scenario will assume recycling water directly from the Pacific Ocean directly into Gatun Lake (see location 1 of the pumping station on the general layout hereunder),
- a second scenario will include water storage ponds at lower (ocean) end and upper (lake) end, tied into Post-Panamax locks intake and discharge system (see location 2 of the pumping station on the general layout hereunder),
- a third scenario will recycle water from a lower storage pond directly into Gatun Lake (see same location 2 of the pumping station as for the second scenario near the lower pond).



2. PUMPING STATION

2.1 TYPE OF PUMPS

As stated in the report R-EM-01 "Suitability Analysis of different types of pumps and discharge valves", the vertical tube type pump is the most suitable solution for recycling water from the Pacific Ocean or from the low pond to the Gatun lake or to the upper reservoir.

Vertical tube type pumps are mainly preferred because wet well configuration has the great advantage of simplicity. Vertical tube pumps do not require the deep and large space that is necessary for other types of pumps so that civil works are much cheaper to build. Moreover, the driving motors can be installed above the maximum water level.

Horizontal pump units must instead be installed several meters under the minimum water level (-7.7mPLD in the low reservoir and -3.60mPLD in the Pacific Ocean).

The height of the tube depends on the level range in the reservoir and on the required counterpressure on the runner to avoid cavitation effects.

As a reference, a lot of cooling systems for thermal and nuclear power plants have been equipped with that reliable type of pump. Moreover, ACP has already experience with that type of pump to empty the existing locks for maintenance.

2.2 PUMP UNIT CHARACTERISTICS

As required by the TOR, the hydraulic report has combined the three above mentioned scenarios with:

- two design of the Post-Panamax locks:. the 3-lift with 3 WSB per lift and the 2-lift with 2 WSB per lift operating with and without WSB,
- four daily traffic levels (1, 5, 10 and 15 lockages a day).

The main results regarding the size of the pumps are given in the three tables hereunder:

Direct pumping - Recycling from Pacific Ocean to Gatun Lake – L = 2390m

Number of Locks / WSB	Total flow (m^3/s)	Hmt (mWC)	Number / F of disch. pipes (m)	Pump unit characteristics Q (m^3/s) P (kW)	Driving motor P (kW)
3 / 0	60	33	3 F 2.9	Q = 9 x 6.7 P = 9 x 2,712	P = 9 x 2985
3 / 9	24	37	3 F 1.8	Q = 3 x 8 P = 3 x 3,630	P = 3 x 4000
2 / 0	75	32.9	3 F 3.2	Q = 9 x 8.33 P = 9 x 3,360	P = 9 x 3700
2 / 4	39	35	3 F 2.3	Q = 6 x 6.5 P= 6 x 2,790	P = 6 x 3070

Semi-Direct pumping - Recycling from lower pond to Gatun Lake – L = 3470m

Number of Locks / WSB	Total flow (m^3/s)	Hmt (mWC)	Number / F of discharge pipes (m)	Pump unit characteristics Q (m^3/s) P (kW)	Driving motor P (kW)
3 / 0	60	39.7	3 F 2.9	Q = 9 x 6.7 P = 9 x 3,262	P = 9 x 3590
3 / 9	24	43.9	3 F 1.8	Q = 3 x 8 P = 3 x 4,307	P = 3 x 4740
2 / 0	75	39.4	3 F 3.2	Q = 9 x 8.33 P = 9 x 4,025	P = 9 x 4430
2 / 4	39	41	3 F 2.3	Q = 6 x 6.5 P = 6 x 3,268	P = 6 x 3600

Indirect pumping - Recycling from lower pond to upper pond – L = 2500m

Locks / WSB	**Total flow Number of (m^3/s)**	**Hmt (mWC)**	**Number / F of discharge pipes (m)**	**Pump unit characteristics Q (m^3/s) P (kW)**	**Driving motor P (kW)**
3 / 0	60	40.4	3 F 2.9	Q = 9 x 6.7 P = 9 x 3,320	P = 9 x 3650
3 / 9	24	43	3 F 1.8	Q = 3 x 8 P = 3 x 4,218	P = 3 x 4640
2 / 0	75	41	3 F 3.2	Q = 9 x 8.33 P = 9 x 4,188	P = 9 x 4600
2 / 4	39	41	3 F 2.3	Q = 6 x 6.5 P = 6 x 3,268	P = 6 x 3600

Comments on the three tables above:

The 4 first columns are coming from the Hydraulic Report (see annex 4 of R-HY-001).

The 5th column is providing the number of pump units as well as the unit flow and power. The pump unit efficiency (? pump x ? motor) has been estimated to 0.80.

The recommended power of the driving motors is given in the 6th column. The power values are including a 10% reserve compared to the 5th column.

All recycling flows mentioned in the second column are the mean value corresponding to the maximum navigation traffic (i.e. 15 lockages a day) through the 3rd lane on the Pacific side.

The total heads (Hmt) of the third column are the maximum values so that all pumps operating together will always be able any time to supply the maximum flow required in the worst conditions of operation.

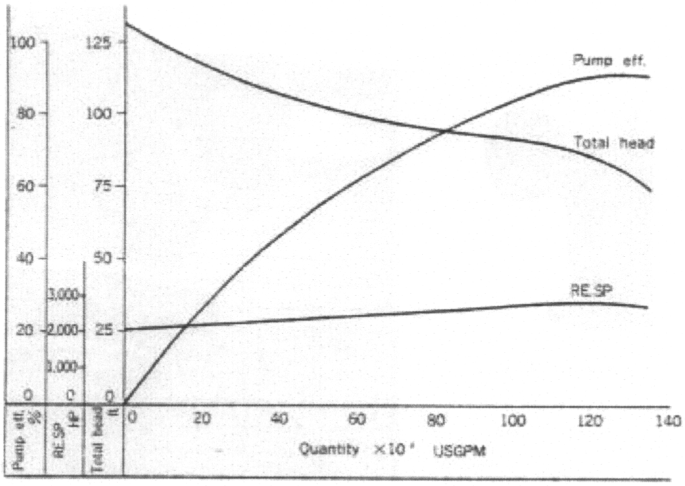
In case of reduced navigation traffic, only a part of the pumps will run to recycle the water. If there is an upper pond, the pumps will have to refill it. The pump units will start and stop according to a water level control system.

We have considered that there would be three independent discharge pipes of the same size for every alternative. In case of maintenance or incident on one discharge line, the two others will remain available.

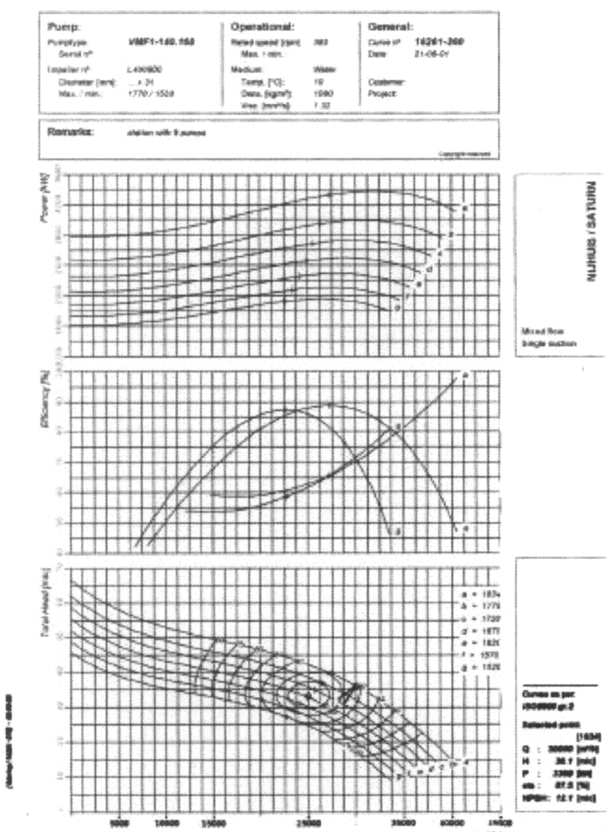
Typical curves of pumps with similar characteristics are shown hereunder (origin: Hitachi, Alstom for vertical tube pumps and Nijhuis for vertical volute type)

The aim of the diagrams is to give an idea of the shape of the curves, not to give accurate curves for recycling water in Post-Panamax locks. This has to be optimized later on and given by pump manufacturer in accordance with detailed equipment specification.

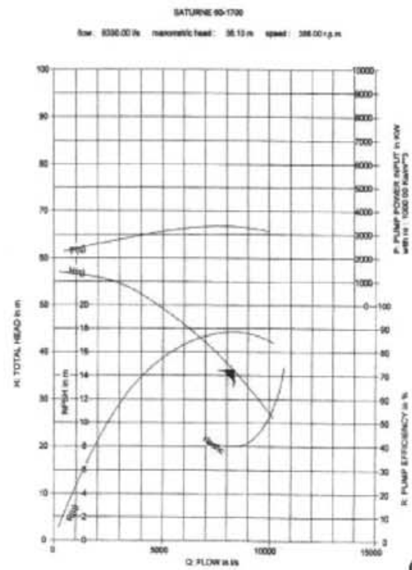
However, very preliminary contacts have been taken with Alstom and KSB for the tube pumps and with Nyhuis for the vertical axis pumps.



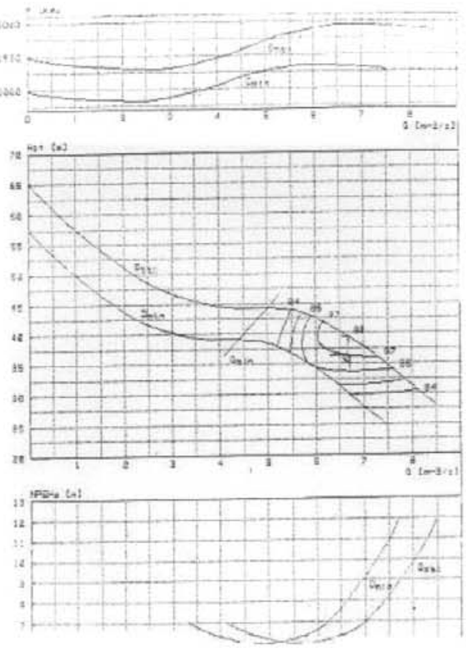
(from a leaflet of Hitachi)



(from Nijhuis)


H: TOTAL HEAD in m
NPSH in m
P: PUMP POWER INPUT in KW
R: PUMP EFFICIENCY in %
Q: FLOW in l/s
0
5000
10000
15000

(from Alstom)



(from KSB)

Comments on the above curves:

- The power remains quite constant versus Q,

- NPSH value are low at about Q = 8m³/s. The counterpressure can be limited to only a few meters to avoid unacceptable cavitation and swirling flow at the pump inlet.

- All best efficiencies (BEP) of the pump are = 88%

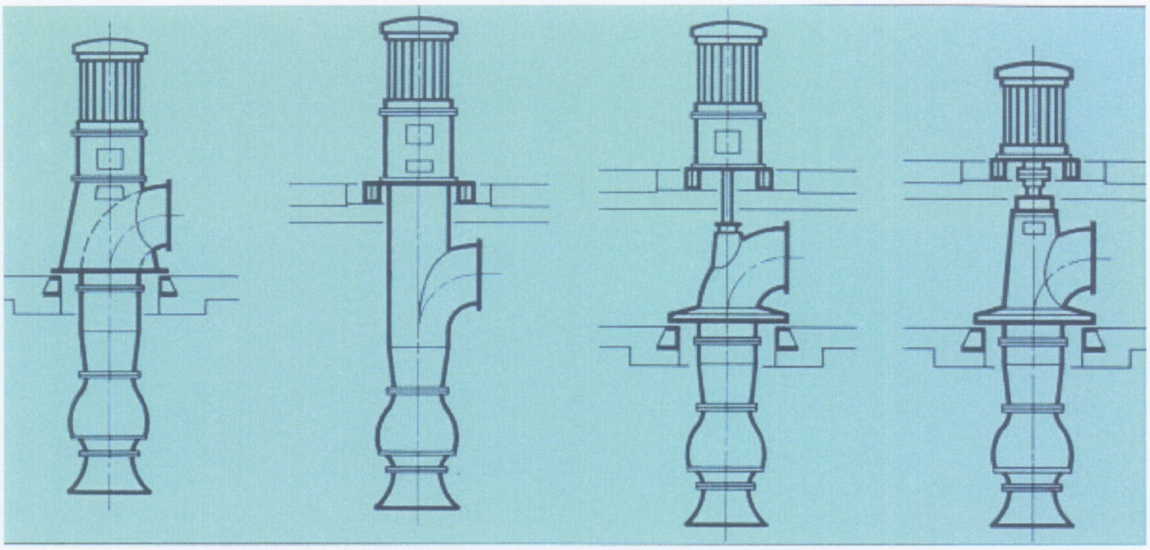
2.3 PUMP UNIT LAYOUT

A typical general layout of the pumping station to implement along the lower pond is shown on the drawings EM-001 to 004 at the end of this report. These drawings correspond to the most powerful station equipped with 9 pumping units.

The vertical tube pumps are typically suspended within the suction pit.

Although the maximum water level of the lower pond is -3.29 PLD, the access level to the pumping station has been fixed at +3.60 PLD corresponding to the maximum level of the Pacific Ocean.

The driving motors are suspended from the floor at level +3.60 PLD



. Fig.1 Fig.2 Fig.3 Fig.4

The discharge pipe can be installed above (see Fig.1) or under the upper floor. All axial forces i.e. the weights of the motor and the pump and the hydraulic thrust can be supported by one floor (Fig.1 and 2) or separately by 2 floors (Fig.3: weight of the motor and axial hydraulic thrust supported by the upper floor - weight of the pump supported by the lower floor – Fig.4: weight of the motor supported by the upper floor - weight of the pump and axial hydraulic thrust supported by the lower floor). (Sketches by Andritz).

The one-floor solution (Fig.1 and 2) is more suitable for small and middle-size vertical tube pumps. The size of the recycling pump is quite big in any case so that a double floor solution should be recommended for the recycling pumping station (similar to Fig.3).

Regarding the discharge valves, the most convenient type corresponding to the recycling pump characteristics is the butterfly type (see report R-EM-01). The butterfly valves are bolted to the discharge pipe and supported by the lower floor. On the pump side, an expansion joint has to be foreseen to facilitate the valve or pump dismantling.

The pump units are of the "outdoor" type. No building is covering the motors. This economical solution has been applied to a number of cooling water circulating pumps of that type as shown hereunder (Hitachi supply). Proper IP protection has to be specified to make this outdoor installation suitable for Panama climate.

Type: Vertical, Mixed Flow Pump
Specifications: 104", 243,320 GPM x 35 ft. x 247 rpm x 3,080 HP
Customer: Tokyo Electric Power Co., Inc. Fukushima Nuclear Plant

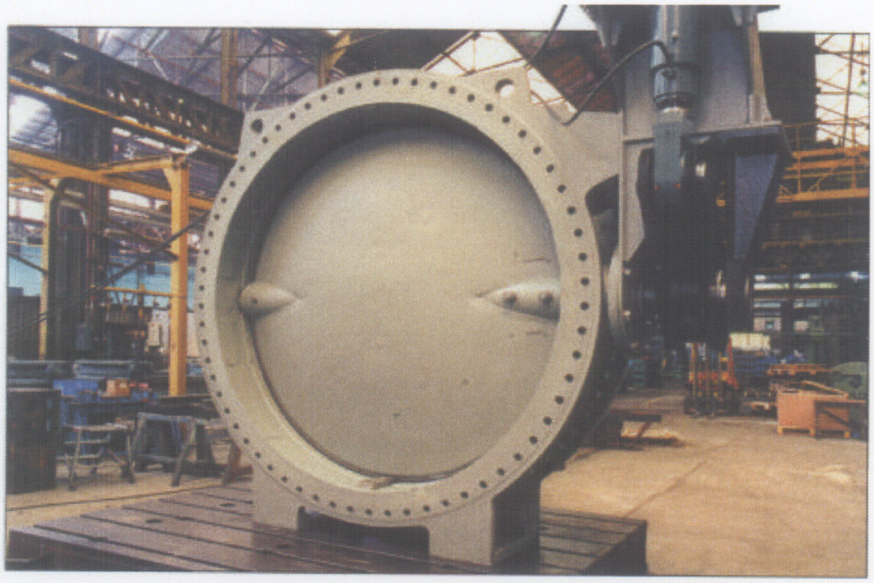
2.4 DISCHARGE VALVES

As stated in the report R-EM-01, the recommended type of discharge valve is the butterfly type (see picture by Hanrez), mainly because that type of shut-off valve is the most convenient to the rated characteristics of pressure and flow.

The butterfly valve is open by a hydraulic cylinder and closed by gravity by use of a counterweight. Opening time as well as closing time can be adjusted to avoid any unacceptable water-hammer effect. Opening and closing time are adjustable to reduce water-hammer effect.

For emptying or refilling the discharge pipe the disc can be blocked in partial opening position. In case maintenance or dismantling of the pump is required, the butterfly valve can be mechanically blocked in closed position.

An expansion joint (for example Dresser or Johnson type) has to be installed between the pump and valve to allow the complete dismantling of the valve. The casing of the butterfly valve is flanged and bolted to the discharge pipe.



The sealing system between casing and disc is composed of a 360° rubber seal in touch with stainless steel when the valve is closed. It is recommended to install the seal in the casing so that it can better be adjusted.

The one piece disc is supported by trunions rotating in self lubricated bearings.

The valve operator is mainly composed of a lever with counterweight, a hydraulic cylinder and a hydraulic power unit. A local control panel is equipped with a remote/local key selector and all necessary push-buttons and lamps.

2.5 MOTORS

2.5.1 CONSTANT OR VARIABLE SPEED

Variable speed is often the best technical solution but just sometimes economically. Investment costs are substantially higher. It was felt at this stage that the main advantage of variable speed drives of ready change in flow was not necessary in that case.

The increased capital cost, reduction in overall efficiency, relatively high maintenance costs and complicated control arrangements ruled them out. The price of a pump with variable speed indeed is typically more than the double of the constant speed solution. Installation and maintenance costs are estimated to be about 33% higher. We did not consider the variable speed solution.

2.5.2 MOTOR DESCRIPTION

Three phase squirrel-cage induction motors, 12000 V 60 Hz, power according to the selected pump unit (between 3000 and 4600 kW), fixed speed, intended to drive the lower pond water pumps.

- Vertically mounted motor (mounting arrangement: V1), with large skirt type flange and roof protection assembly.
- Motors will be cooled by means of air-to-air heat exchanger with internal and external shaft mounted fans.
- Enclosure ingress protection degree: IP55.
- Winding insulation class: F.
- Assumed motor operation mode: continuous running duty (S1) at rated output.
- Motor starting mode: direct-on-line.
- Auxiliary power supply 480/277 V required for anti-condensation heating and bearings oil cooling system.

At this stage, the efficiency of all driving motors will be considered to be the same i.e. 0.95

2.5.3 POWER FACTOR IMPROVEMENT

Individual capacitor banks will be provided for each HV electric motor in order to achieve a minimum lagging power factor value of 0.82 at the plant HV incoming feeders.

Individual detuned capacitor banks will include the following:

- Low losses star connected capacitors rated 1200 kvar, 12/17.5 kV 60 Hz.

- Self-healing metallized PP film, impregnation oil/PCB free dry-type.
- Switching off fail safe device, internal fused elements and built-in discharge resistors.
- HRC fused switch disconnector.
- Surge choke reactors
- Fan cooled and anti-condensation heated enclosure suitable for outdoor installation, ingress protection degree: IP54.

2.5.4 CHOICE OF THE MOTOR SUPPLY VOLTAGE

The 12 kV primary voltage level is recommended for the following reasons:

- Available HV motor nominal voltage range: 11 to 13.8 kV.
- 12 kV motor is only 20% more expensive than 6 kV motor.
- Smaller HV motor feeder cable section.
- Harder HV motor DOL starting due to the additional power transformer short-circuit impedance.
- More civil works required with the 6 kV, such as bigger electrical substation, additional bays and oil recovery pits for power transformers.
- Cost saving on 6 kV major electrical items, such as:
  Additional power transformers 12/6 kV.
  Additional 6 kV switchgear.
  6 kV motor feeder cables.

2.6 PLANT ELECTRICAL SYSTEM

2.6.1 ELECTRICAL POWER DISTRIBUTION

The electrical power distribution is proposed as shown on the relevant General One Line Diagram (Drawing n° EM-010).

The electrical grid is taken as made available at the lower pond pumping station and would include dual redundant overhead feeder lines.
Each feeder line would be sized for 100% plant full load.
The battery limit is located after the HV overhead line disconnectors and earthing switches.

The HV power will be distributed through a HV double bus switchgear for the supply of the HV electric motors and the step-down distribution transformers.
In normal operation, the plant is powered from both HV incoming feeder lines, 50% plant full load being balanced on each of them.
In case of failure on one incoming feeder line, the relevant 50% plant full load will be automatically transferred to the other one.

Return to the normal situation will be automatically or manually achieved with no-break transfer.
The HV incomers and HV switchgear bus coupler will be controlled by a suitable automatic transfer system.
An acceptable reliability is assumed with a such key power supply.

The LV consumers are to be powered from two step-down distribution transformers, each of them being sized for 100% full load.
HV key power supply philosophy will be applied for the LV power distribution.

2.6.2 VOLTAGE LEVELS

- HV primary power distribution.
  12 kV 60 Hz, three phases.
- LV secondary power distribution.
  480 V 60 Hz, three phases and neutral.
- Auxiliary power supply.
  110 VDC, two poles, two wires.

2.6.3 EARTHING SYSTEMS

The plant earthing systems are broken down as follows:

-Power source grounding systems.
-Protective grounding system.
-Clean earth system.

Power source grounding system.

- 12 kV power supply will be earthed by means of two grounding transformers and resistances
  to be connected to the protective grounding system in compliance with IEC standardized IT scheme.
- 480 V power supply will be grounded with the step-down distribution transformer neutral points
  solidly grounded and electrically connected to the protective grounding system in compliance with
  IEC standardized TN-C/S scheme.
- 110 VDC auxiliary power supply will be fully earth isolated in compliance with IEC standardized
  IT scheme.

2.7 DESIGN OF MAIN ELECTRICAL EQUIPMENT

2.7.1 HV SWITCHGEAR

One HV switchgear including
two incomers, two 3ph. busses, one bus coupler, one bus riser, two metering panels, two source earthing cells and required outgoings, suitable for indoor installation.

- Switchgear arrangement as per the relevant General One Line Diagram.
- Metal-clad air-insulated switchgear rated 12/15 kV 60 Hz, 4000A, 25 kA/1s.
- Full withdrawable vacuum circuit-breakers 4000/630 A.
- Fully isolated low voltage compartment.
- Separate 110 VDC auxiliary control voltage.
- Incomers and bus coupler controlled by an automatic transfer system.
- Cubicle ingress protection degree: IP41.

2.7.2 LV SWITCHBOARD/MCC

One LV switchboard/MCC including two incomers, two 3ph & neutral busses, one bus coupler and required outgoings suitable for indoor installation.

- Switchboard/MCC arrangement as per the relevant General One Line Diagram.
- Metal-clad air-insulated switchboard/MCC rated 480/1000 V 60 Hz, 1000 A, 20 kA/1s.
- Cubicle partitioned assembly
- Full withdrawable incoming and outgoing modules complete with air-insulated circuit-breaker, power switching and protection devices.
- Single phase 277 V auxiliary control voltage.
- Incomers and bus coupler controlled by an automatic transfer system.
- Cubicle ingress protection degree: IP41.

2.7.3 STEP-DOWN DISTRIBUTION TRANSFORMERS

Two cast-resin dry-type step-down distribution transformers, 630 kVA, 12000/500 V 60 Hz, 3ph+N, with two windings per phase, natural air cooled, suitable for indoor installation.

- Step-down distribution transformers arrangement as per the relevant General One Line Diagram.
- Primary/secondary windings insulation class: F.
- Off-load tap changer on the secondary side. Tappings: +/- 2x2.5%.

2.7.4 INDOOR LIGHTING

Indoor lighting will be provided for the electrical substation and the butterfly valves room.
It shall be manually controlled by dedicated switches.

- Normal lighting will include light fittings equipped with tubular fluorescent lamps and quick start electronic ballast.
- Emergency and safety lighting will be used to maintain a sufficient illumination level in case of power failure at the critical places such as switchboard front side, escape doors, safety lanes, stairs, ladders. A such light fittings will be equipped with suitable fluorescent lamps and self-contained battery charger (back-up time: 1 hour).
- All fluorescent lighting fixtures shall be compensated to achieve a lagging power factor of 0.95 min.
- Enclosure ingress protection degree: IP55.

2.7.5 OUTDOOR LIGHTING

Outdoor lighting will be provided for the following areas:

- HV electric motors area.
- Building access ways.
- Alongside the plant security fence.
- Gantry crane traveling track.

The outdoor lighting will be automatically controlled by photo-electric cell with manual override switching device.
Fluorescent light fittings similar to the lighting fixtures for indoor lighting but equipped with two lamps 36 W and mounted on 3 m high brackets 2.5" will be only used for HV electric motor area.
Lighting fixtures with HP sodium vapour lamps 150 W and short run-up time gear to be mounted on 8 m high straight pole will be intended for the other outdoor areas above.
Enclosure ingress protection degree: IP55.

2.7.6 DC POWER SUPPLY

Dual redundant battery chargers including two static solid state rectifiers and one battery set will be provided as auxiliary power supply for the HV switchgear and step-down distribution transformers control circuits.
Each rectifier and the battery will be rated for 100% full load 110 VDC, 8 kW.

2.7.7 AIR-CONDITIONING AND VENTILATION

Air-conditioning is to be provided for the electrical substation.
Split unit air-conditioners will be preferred and sized as per the following requirements:

- Min/max. temperatures: 15/30° C.
- Relative humidity: 80% max at 30°C.
- No condensation allowed.
- 10x volume renewed per hour.

Ventilation duty will be only provided in the butterfly valves room.

2.7.8 ELECTRICAL POWER & CONTROL CABLES

High Voltage 12 kV (8,7 to 15 kV):

- Single core cable
- Copper conductor (maximum temperature (steady state): 90°C)
- Inner and outer semi-conducting layer
- Tree Retardant Crosslinked Polyethylene insulation (TR-XLPE)
- Copper wire screen
- PVC outer sheath

Design according to IEC 60 502 -2.

Low voltage (up to 1 kV):

- Multicore (three, four or five cores) cable
- Copper conductor (minimum sections 2.5 mm²)
- Double steel tape armour (in some application) or no armour
- PVC outer sheath*

Design according to IEC 502

* For the control room, we propose to use halogen free material: a halogen free thermoplastic outer sheath replaces the PVC outer sheath.

Design according to:
- IEC 61034-1 + 2 (Smoke density)
- IEC 60754-2: Test of gases evolved during the combustion of materials taken from electric cables.

Safety cables:
For more security, the cables supplying safety equipment, shall be fire resistant with insulation integrity 3 h under impact of fire and mechanical chock according to IEC 60331.

Data cables:
- XLPE or PVC insulation
- Copper core (single or multicore)
- Metallic screen.

2.7.9 LOCATION OF MAIN ELECTRICAL EQUIPMENT

The main electrical equipments will be located in the following buildings and areas:

-Electrical substation.
Ref.dwg n° EM-004 Lower Pond Pumping Station, plan view level +3.60 PLD.
HV switchgear.
LV switchgear/MCC.
Step-down distribution transformers.
Dual-redundant battery chargers.
Split unit air-conditioners.
One service SO's cabinet.
Indoor/outdoor lighting panels.
Fluorescent light fittings.
Earthing bar-collectors.
A 2 m high cable room will be provided beneath the switchroom and intended for incoming and outgoing cable routings.

-Valve room
Ref. dwg n° EM-003 Lower Pond Pumping Station, plan view level -2.00 PLD.
Main electrical cable gallery and secondary cable ways.
Three ventilation fans.
Pump & valve auxiliary skid packages to be installed close the butterfly valves.
Two service SO's cabinets.
Fluorescent light fittings.
Earthing bar-collectors.

-HV motor area & traveling track for gantry crane
Ref. dwg n° EM-004 Lower Pond Pumping Station, plan view level +3.60 PLD.
HV vertical electric motors
Auxiliary skid packages for HV electric motors.
Capacitor banks.
Two service SO's cabinets.
Fluorescent light fittings for motor area.
HP sodium vapor light fittings integrated in the travelling gantry crane structure.
Earthing bar-collectors.

-Plant security fence.
Pole-mounted HP sodium vapor light fittings will be installed alongside the plant security fence.

2.8 ELECTRICAL AND POWER REQUIREMENTS

2.8.1 LOAD SCHEDULE

Loads	Absorbed power (kW)	Effic	Power factor	Demand power (kVA)	Utiliz coef	Simult coef.	Nr	Total dem Power (kVA)
HV motors MP1 to 9	4600	0.96	0.82	5843.5	1	1	9	52592
Auxiliaries MP1 to 9	5	0.80	0.87	7.2	1	1	9	65
Auxiliaries Capacitor Banks MP1 to 9	1.5	0.85	0.80	2.2	0.6	1	9	12
Auxiliaries Pumps & Valves P1 to 9	10	0.80	0.87	14.4	1	1	9	130
Battery-chargers	8	0.93	0.92	9.4	0.8	0.5	2	8
RTU	1	0.90	0.85	1.3	0.8	1	1	1
Air-conditioning Elect. Substation	5.5	0.86	0.88	7.3	1	1	3	22
Ventilation B. Valve Room	11	0.90	0.85	14.4	1	1	3	43
Travelling Gantry Crane	42	0.90	0.85	54.9	1	1	1	55

Outdoor Lighting	20	0.90	0.90	24.7	1	1	1	25
Indoor Lighting	20	0.90	0.90	24.7	1	1	1	25
Service SO's	24	0.85	0.80	35.3	1	0.5	2	35
					Total demand power:			53013
					20% spare included:			63616

2.8.2 PROPOSAL

Each plant incoming feeder line should be sized for a total continuous demand power of 63616 kVA with an overall improved lagging power factor of 0.82 and nine pumps rated 4188 kW.

In this case, attention is drawn to the fact that the max. demand peak power is achieved with eight pumps in normal running conditions and the ninth pump in starting stage, let's say 86 MVA.

The plant power distribution detailed in the present "Electrical Part" has been developed by taking into account the following assumptions and exclusions:

- Plant power distributed as per the relevant General One Line Diagram.
- The electrical grid is made available at the Lower Pond Pumping Station, including dual redundant overhead feeder lines, each one with a fault capacity of 300 MVA.
- Fixed speed HV electric motors.
- HV electric motor DOL staggered starting mode performed without means of in-rush current limiting.
- All HV electric motors can be operated at the same time.
- The systems which have been assumed as not required or handled by others are mentioned in section 2.6.13

Remark:

It should be noted that the network could have to support a total of nine pumps in service (continuous demand power : 63.6 MVA). So the direct starting of a pump (one by one) should be possible while remaining within acceptable values of voltage drops. In this case some improvements of the local electrical supply network could be necessary.

In case of a three (or six) pumps configuration, the installation of softstarter should be envisaged.

2.9 WATER INTAKE AND SUCTION PIT ARRANGEMENT

2.9.1 AT THE LOWER POND

The water intake has been divided into several channels protected from inlet of any possible debris by a rack. The length and the width of each channel is in accordance with the usual hydraulic rules in order to get an acceptable uniform flow and a water velocity not superior to 0.3m/s (see bibliography).

For maintenance purpose, each pump pit can be emptied separately by use of a stoplog lowered down by a gantry crane. Complete maintenance involves de-watering of the sump or lifting up of the pump that can be dismantled in several tube parts.

All auxiliaries (cooling water system, thrust bearing lubrication system, electrical boards,..) are located on the same floor at elevation -2.00 PLD.

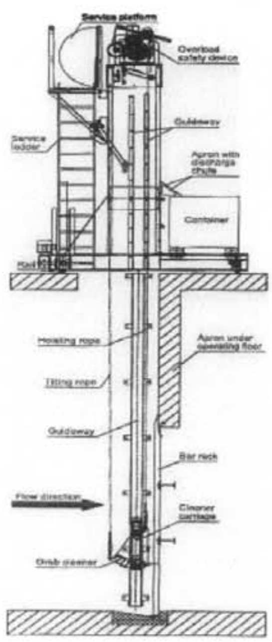
A gallery above the electrical boards is collecting all the cables from the local substation to the pump units and their auxiliaries.

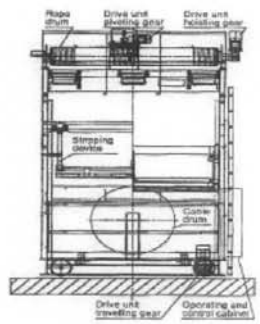
The plan view at level -2.00 PLD shows the two access galleries, one on the discharge side for easy access to the motor, pump elbow, stuffing box and auxiliaries (water cooling system of the pump unit, oil sump for the butterfly valves, lubrication system of the thrust bearing,..) all located on the same floor and one on the lower pond side to give access to the electrical equipment.

2.9.2 ON THE PACIFIC OCEAN SIDE

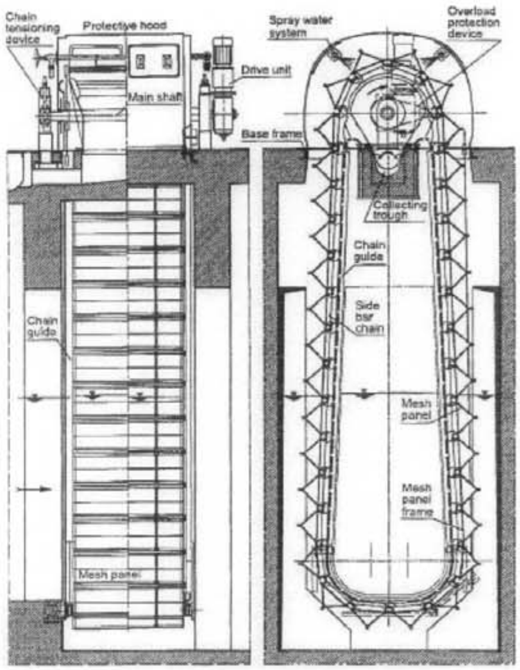
The suction pit arrangement will be the same as for the lower pond (see drawing EM-005 to EM-008) but the water intake will be substantially different because it has to be equipped with a grab cleaner and a band traveling screen (see sketches hereunder – origin Geiger) to avoid all kind of debris to enter the pump.

The grab cleaner mainly consists of a wheeled cleaner carriage with a well-shaped grab, lifting and pivoting unit, apron with discharge chute and wiper device. Tilting and raising movements of each raking grab are controlled by limit switches.





The next step for cleaning the pumped water is a traveling band screen (one per pump unit – see sketch hereunder). The raw water to be screened will centrally flow to the interior of the band screen, laterally pass through the traveling mesh panels and flow to the inlet of the pump. The total submerged screening surface is such that the recommended water velocity should not be higher than à.0.30m/sec. All debris retained inside the mesh panels are washed off by spay water into a debris collecting basin trough leading to a trash sump (one for every pump units).


Chain tensioning device
Protective hood
Drive unit
Main shaft
Base frame
Chain guide
Mesh panel
Spray water system
Overload protection device
Collecting trough
Chain guide
Side bar chain
Mesh panel
Mesh panel frame

2.10 Control System

2.10.1 Introduction

The choice between the three different operating scenarios (direct pumping, semi-direct pumping or indirect pumping) does not have any influence on the control system architecture level.

It is the same whatever the number of pumps (between three and nine). Indeed, the control system is modular: a cabinet with PLC and I/O peripheral cards for each pump.

It is simply necessary to adapt the number of PLC cabinets to the selected number of pump. The analysis described hereafter takes into account a nine-pump station.

2.10.2 Objectives of the control system

The control system shall be efficient and reliable; it will be designed with the same targets as for the main control system of the 3-rd lane of locks : safe operating conditions, decrease of shutdown time for maintenance, minimization of staff requirement, improvement of the operator interface with clear and accurate real time indications, auto-diagnosis, use of sequence, mimic displays, use of standard modules, records of the analogical values, events and alarms with sorting, zooming and archiving capabilities.

2.10.3 Selected control syst em

In order to ensure the coherence of the system and facilitate maintenance, the equipment of control will be standardized. They will be standardized as much as possible by using PLC's of the same family all over the site.

The proposal of architecture is based on nine identical systems for the control of the nine pumps. One advantage consists in the fact that the identical systems lead to greater simplicity and also contributes to easier maintenance operations.

The proposal for the pumping station control system is an extension of the 3-rd lane of locks of Panama distributed control system with several PLC's and an optical fiber network connecting all the devices.

Dedicated operator workstations shall be installed in the central control room of the 3-rd lane of locks and shall allow the control of all the installations.

This is a very open system which allows future PLC's extensions by the simple connection of new devices to the network.

2.10.4 CONTROL PHILOSOPHY

The pumping station control will be fully automated. The pumps will start and stop automatically according to the water levels in the lower and upper ponds. It could be envisaged to take into account some other parameters such as priority orders, cumulative operation time, etc

Under normal operation, this pumping station does not need human intervention. Nevertheless in the event of defect, it must be possible to control all this pumping equipment in the central control room of the 3-rd lane of locks.

For different reasons (e.g. comfort, availability), it will be better to also provide a local control equipment located in the pumping station. This backup operating station allows the same control functions and facilities as those of the central control room.

2.10.5 CONTROL LEVELS

The system will be built up with three control levels:

- At the central control station level, the system will carry out the control and supervisory functions for the overall 3rd lane of locks and all its auxiliary devices including the pumping station equipment. We envisage the addition of an operating station dedicated to the pumping station in this central control room. It is sufficient for a normal operation owing to the fact that the pumps normally start automatically in function of the water levels
- The local control level will be located in special cabinets on the -2.00 floor of the pumping station ;

  At this level, the local PLC control system will be installed in front of each functional group (such as a pump and its associated devices).

  Each pump has a dedicated PLC which ensures all these automatic control functions. All the supervisory functions of the pumping station will be carry out by a local operating station.
- Only at the test and maintenance level, a push button system for manual operation of individual items of equipment could also be available from local boxes in the field.

2.10.6 CAPABILITIES OF THE SYSTEM AT EACH LEVEL

Central control station level of the 3-rd lane of locks

At this level, all information from the whole installation is available. It is possible to control all the site equipment. All control system capabilities are available among which:

- automatic control, start / stop sequences, control of all the auxiliary systems in the entire installation ;
- display of information about the missing preliminary conditions for the initialization of an operation;
- supervision of the entire installation via mimic displays, trend-logs, bar-charts and supervision sequences;
- alarm and event management;
- statistical data and reports;
- diagnosis of the system;
- printing out of trends and mimic displays,
- data archiving...

Local PLC control level

A redundant display monitor will be provided for the pumping station. At this level, the same facilities will be available but limited to the pumping station equipment and auxiliary devices (pumps, valves, HV arrivals, etc)

Local push buttons control level

There is no conventional control panel with pushbuttons, switches, indicators, lamps or LED's to allow operating the relative functional group in case of double PLC failure.

The probability of having more than one pump out of service due to a control system failure does not justify the installation of a conventional control panel especially if we consider the following points:

- the redundancy of the PLC's;
- the N+1 redundancy at the level of number of pumps envisaged ;
- the very short time for replacement of defective equipment of a modern control system ;

Test and maintenance level

This is in fact the equipment level.

Here, there is no automation: it is only a local command on the equipment itself. This level will be used only for maintenance and tests purposes.

At this level, interlocking does not exist.

2.10.7 CONTROL SYSTEM ARCHITECTURE

Functional split

The requirements are the same ones as those of the principal system of control of 3-rd lane of locks because of use of the same type of equipment

The high modularity of the control system and an adequate functional distribution between the different PLC's minimize the common failures to a little part of the installation. For that reason, the following split is proposed; a PLC with redundant CPU is attributed to each group of equipment listed here after.

1 ? 9 **One redundant PLC on the -2.00 PLD floor for each pump** : for the control of equipment associated with each pump (drive, valve, auxiliaries, HV, LV cabinets : 50 I/O estimated for each pump)

10 **One redundant PLC in the HV technical room** : for the control of auxiliaries equipment associated with pumping station 3 and 4 right side (HV, LV cabinets, lighting, ventilation : 150 I/O estimated)

This is a structure of PLC's established in function of a functional split. This solution presents the advantage to have nine identical systems for each pump. This fact makes the control of equipment for the operating and maintenance staffs easier.

The number of I/O (600 I/O) and their functional split could be improved according to the definitive design of the pump ing station.

2.10.8 CONFIGURATION

In addition to the equipment for the 3-rd lane of locks, the configuration for the control system of the pumping station of the 3rd lane of locks of Panama will include:

- The ten (10) PLC's mentioned before with, every time, a redundant CPU associated with not redundant peripheral cards. The power supply of the PLC's is redundant;
- An extension of redundant optical fibre network connecting on one side the pumping station control system equipment together (PLC's and local operating workstation) and on the other side connecting these to the main control system (3-rd lane of locks). The redundancy is also applicable for communication nodes ;

- One (1) operating workstation, with associated electronics, situated in the same central control room as the locks' workstations; including a 20" colour flat screen with keyboard and mouse. In the central control room, from each workstation, all the installation can be controlled and every workstation is independent from the others. In practice, every screen will be allocated to the control of a part of the installation: a screen by system of double gates, a screen for the auxiliary devices and a screen for the pumping station. This makes the control easier due to the fact that the operators will find easily the equipment on their dedicated screen;
- One (1) redundant operating workstation, with associated electronics, installed in a special cabinet situated in the pumping station (-2.00 PLD floor) or in the HV room; including a 20" color flat screen with keyboard and mouse ;
- One (1) printer for alarm and events ;
- One (1) removal Engineering Station could be provided for all the equipment of the control system (3-rd lane of locks and pumping station).

This basic configuration (see drawing EM-009) allows the control of all the installations and contains redundancy at every level: automation with redundant CPU's, communication with redundant optical fiber network and supervision with redundant workstations.

On the drawing, we proposed to install a redundant operating workstation on -2.00 PLD floor for equipment proximity reasons. Indeed, these operating workstations will be more often used to carry out tests on the pumps (after a breakdown service, for checking etc) than for normal operation. The final location of the operating workstations is left to the free choice of the site operator.

2.10.9 VARIANTS AND IMPROVEMENTS

Some variants could be envisaged. Their advantages or disadvantages are described hereafter.

Redundant screens

In the central control room, there will be six (6) operating workstations available to control the whole installation (pumping units, valves, auxiliaries, etc). Redundant screens are not justified.

On the other hand, for the local workstations this solution presents an interest because individual screens for each pump are not considered. This alternative is taken into account in our proposal.

Large flat screens (rear projection system).

Large flat screens are provided for the 3-rd lane of locks. It could be envisaged to use them for the pumping station but that does not present much interest since pumping is automated.

Automatic positioning CCTV

According to the very long distances between the central control room and the pumping station, it is certainly interesting to provide a CCTV's system (Closed Circuit TeleVision).

We envisage ten cameras for the monitoring of the pumping station.

Monitor for local automatic control

However it is better to provide a local control screen. It allows having all capabilities and diagnosis tools of a modern supervision system available locally for tests and maintenance; it can also be used in case of a general failure in the central control room. As mentioned in the § 4.3.1, this monitor could be redundant.

Conventional control panel

As already mentioned a conventional backup control panel is not envisaged.

PLC's dedicated to the lighting, HV and LV cabinets

The split of the auxiliary devices (electric HV & LV distribution cabinets, lighting, etc) from the process itself (pumps, valves, etc) at the level of the PLC brings the following advantages:

- minimizes the common failures to a little part of the installation;
- simplifies the searches in case of defect (targeted defects);
- guaranties the strictly identical character for the nine PLC's for the pumping;
- ensures the separation of more "static" equipment (very few operations at the level of the electric auxiliary devices) and the functioning of locks.

The variety in the size of the PLC on the market allows indeed finding a type of PLC suited to the best functional split.

This alternative is taken into account in our proposal.

Redundant I/O's

A redundant I/O cards system as opposed to a simple I/O cards system leads to a large additional cost.

Moreover, the failures of I/O cards are rare, except during commissioning and, in any case, the replacement of modular cards is easy and fast.

Nevertheless, a logic 2 of 3 will be used for the management of the water levels (3 sensors, 3 I/O cards).

Maintenance help system

The PLC's or an additional computer could be loaded with special software which could allow statistical global calculations. Due to the automation of the pumping station and the large number of pumps, it is certainly interesting to provide this maintenance tool in the control system.

The system could :

- calculate the electrical auxiliary device consumption (1/4 hour values);
- define priorities upon the start of the pumps according to the cumulative operation times in order to balance these operation times ;
- avoid short running or stoppage time ;
- manage on-line actuators data sheets for maintenance purpose (cumulative operation time, number of starts...).

Fieldbus alternative

The fieldbus is especially used in the petrochemical environment where equipment are distributed almost everywhere on the site.

In the case of the pumping station, most of the equipment are grouped together in the same room where the PLC'S are installed. In that case a fieldbus solution is not recommended as far as it does not allow great savings of cabling.

2.10.10 DEGRADED MODES

Normal situation

In normal operation the equipment are ordered automatically by their respective PLC according to the water levels.

Simple failure

The table below resumes the various possibilities of command of equipment in case of one control system element failure.

Faulty element	Control mode
- Operating work station	- Full control: from another operating workstation. not necessary, the management of the pumps is automatic.
- Optical fibre network cut	- Full control: from the workstation dedicated to these equipment via the redundant network.
- Control Process Unit	- Full control: from the workstation dedicated to these equipment via the redundant Control Process Unit.

Double failure

In the extremely rare case of double control sys tem failure, the only constraining case is the simultaneous breakdown of both PLCs on the same pump. In this case this pump can not be operated any longer until the defective parts are replaced.

3. PRICE ESTIMATE

The equipment prices are including transport, erection and commissioning.

The prices of main equipment (pumps, valves, motors) have been based on preliminary budget price information given by manufacturers (Alstom, KSB, Geiger…) or based on similar equipment supplies.

Direct pumping - Recycling from Pacific Ocean to Gatun Lake

DESIGNATION (*Number*)	**PRICE ESTIMATE(USD)**			
	P = 9 x 2985kW	*P = 3 x 4000kW*	*P = 9 x 3700kW*	*P = 6 x 3070kW*
PUMPING UNITS Pumps including auxiliaries (9) and HV motors, auxiliary skid pack's incl. (9)	8 745 000	3 970 000	10 830 000	5 970 000
DISCHARGE VALVES Butterfly valves including oil sump, dismantling joints and auxiliaries (9)	915 000	355 000	1 120 000	610 000
WATER INTAKE EQUIPMENT				
Racks (*)	-	-	-	-
Gantry crane	150 000	140 000	150 000	135 000
Stoplogs (**)	740 000	310 000	740 000	525 000
Grab cleaner	1 690 000	655 000	1 690 000	1 175 000
Travelling band screen	2 140 000	760 000	2 140 000	1 450 000
ELECTRICAL EQUIPMENT	1 800 000	1 150 000	1 800 000	1 500 000
CONTROL SYSTEM	1 260 000	900 000	1 260 000	1 070 000
TOTAL	17 440 000	8 240 000	19 730 000	12 435 000

(*) Racks are included in grab cleaners

(**) 2 x 2 stoplog sets for 3 units, 2 x 3 sets for 6 units and 2 x 4 sets for 9 units

Semi-direct pumping - Recycling from lower pond to Gatun Lake

DESIGNATION (*Number*)	PRICE ESTIMATE (USD)			
PUMPING UNITS Pumps including auxiliaries (9) and HV motors, auxiliary skid pack's incl. (9)	*P = 9 x 3590kW* 10 600 000	*P = 3 x 4740kW* 5 040 000	*P = 9 x 4430kW* 13 730 000	*P = 6 x 3600kW* 6 960 000
DISCHARGE VALVES Butterfly valves including oil sump, dismantling joints and auxiliaries (9)	915 000	355 000	1 120 000	610 000
WATER INTAKE EQUIPMENT				
Racks	120 000	40 000	120 000	80 000
Gantry crane	120 000	110 000	120 000	115 000
Stoplogs (*)	390 000	165 000	390 000	278 000
Grab cleaner	-	-	-	-
Travelling band screen	-	-	-	-
ELECTRICAL EQUIPMENT	1 800 000	1 150 000	1 800 000	1 500 000
CONTROL SYSTEM	1 260 000	900 000	1 260 000	1 070 000
TOTAL	15 205 000	7 760 000	18 540 000	10 613 000

(*) 2 stoplog sets for 3 units, 3 sets for 6 units and 4 sets for 9 units

Indirect pumping - Recycling from lower pond to upper pond

DESIGNATION (*Number*)	PRICE ESTIMATE(USD)			
PUMPING UNITS	*P = 9 x 3650kW*	*P = 3 x 4640kW*	*P = 9 x 4600kW*	*P = 6 x 3600kW*
Pumps including auxiliaries (9) and HV motors, auxiliary skid pack's incl. (9)	10 630 000	4 980 000	14 800 000	6 960 000
DISCHARGE VALVES				
Butterfly valves including oil sump, dismantling joints and auxiliaries (9)	915 000	355 000	1 120 000	610 000
WATER INTAKE EQUIPMENT				
Racks	120 000	40 000	120 000	80 000
Gantry crane	120 000	110 000	120 000	115 000
Stoplogs (*)	390 000	165 000	390 000	278 000
Grab cleaner	-	-	-	-
Travelling band screen	-	-	-	-
ELECTRICAL EQUIPMENT	1 800 000	1 150 000	1 800 000	1 500 000
CONTROL SYSTEM	1 260 000	900 000	1 260 000	1 070 000
TOTAL	15 235 000	7 700 000	19 610 000	10 613 000

(*) 2 stoplog sets for 3 units, 3 sets for 6 units and 4 sets for 9 units

4. DRAWING LIST

- EM-01: Lower pond pumping station – Sectional view
- EM-02: Lower pond pumping station – Plan view level -12.90PLD
- EM-03: Lower pond pumping station – Plan view level -2.00PLD
- EM-04: Lower pond pumping station – Plan view level +3.60PLD
- EM-05: Seawater pumping station – Sectional view
- EM-06: Seawater pumping station – Plan view level -8.64PLD
- EM-07: Seawater pumping station – Plan view level +0.40PLD
- EM-08: Seawater pumping station – Plan view level +6.00PLD
- EM-09: Control system architecture – Pumping station
- EM-10: Lower pond pumping station – General one line diagram

5. BIBLIOGRAPHY

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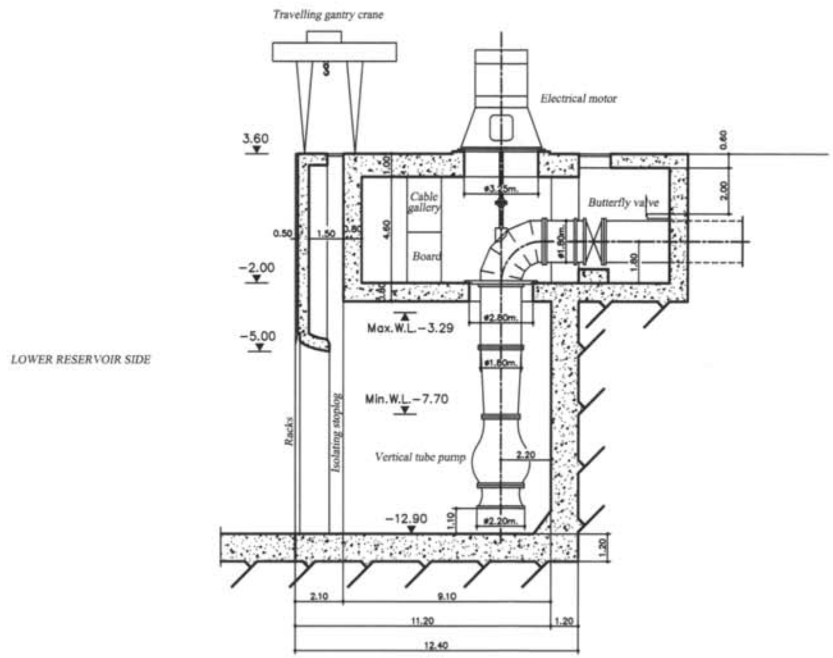
- BHRA Fluid Engineering – "The Hydraulic Design of Pump Sumps and Intakes " by M.J.Prosser



SECTIONAL VIEW

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Tractebel Development Engineering
TECHNUM
COYNE ET BELLIER
CNR PROJETS
SBE
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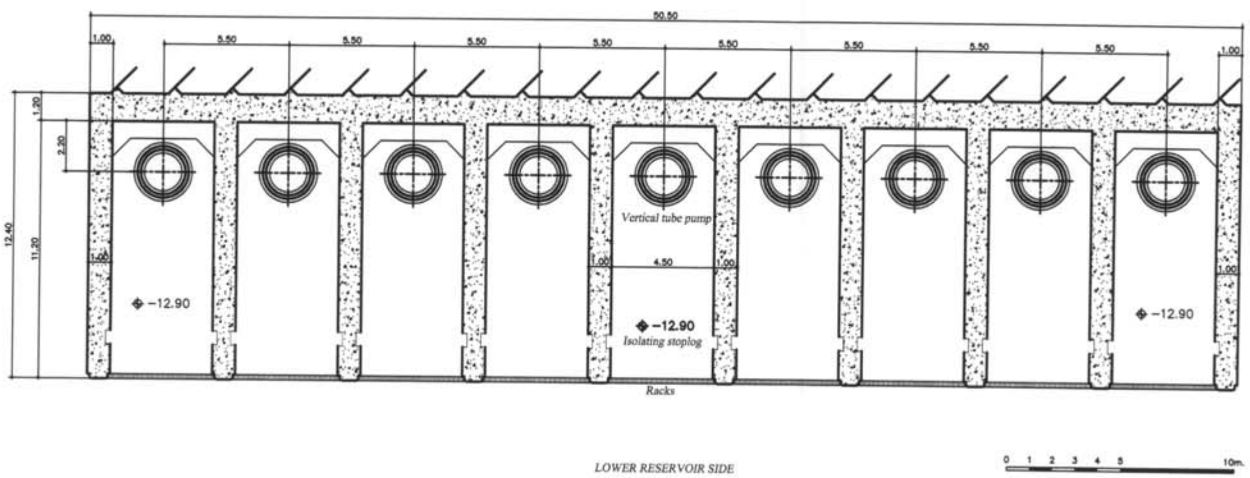
Conceptual Design of Recycling of Water in Post-Panamax Locks

LOWER POND
PUMPING STATION
SECTIONAL VIEW

Contract	Scale	Drawing n°:	Rev.	Folio
	1/200	EM - 001	A	1/1



PLAN VIEW level -12.90

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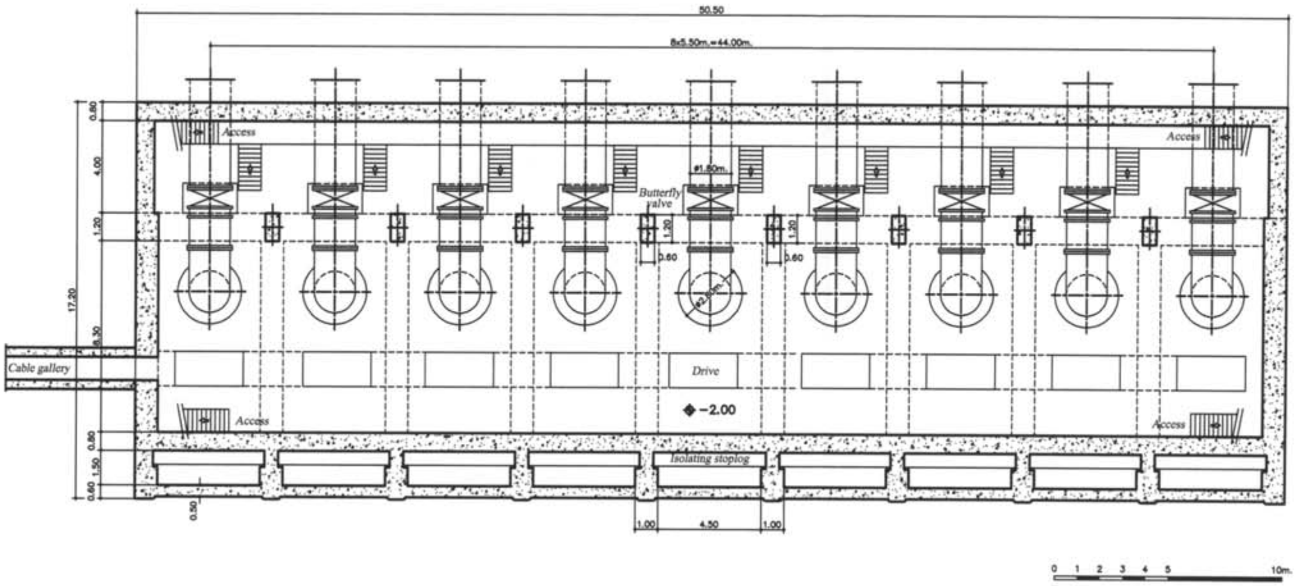
LOWER POND
PUMPING STATION
PLAN VIEW level -12.90 PLD

Contract	Scale	Drawing n°:	Rev.	Folio
[illegible]	1/200	EM – 002	A	1/1



PLAN VIEW level -2.00

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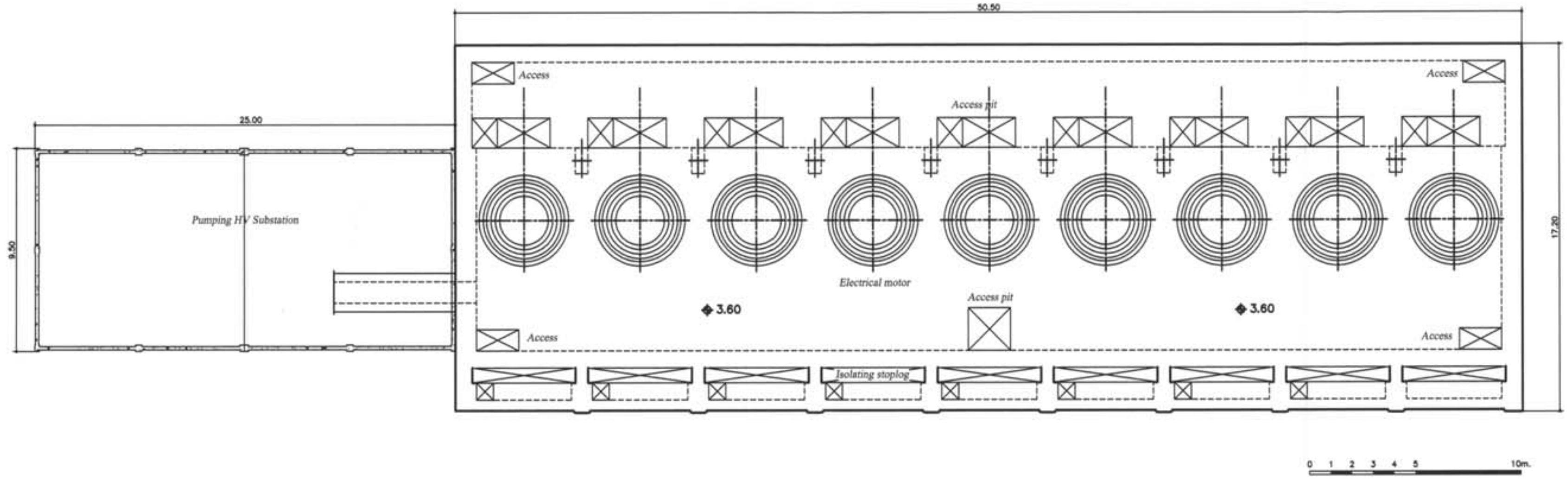
LOWER POND
PUMPING STATION
PLAN VIEW level -2.00 PLD

Drawing n°: EM - 003



PLAN VIEW level +3.60

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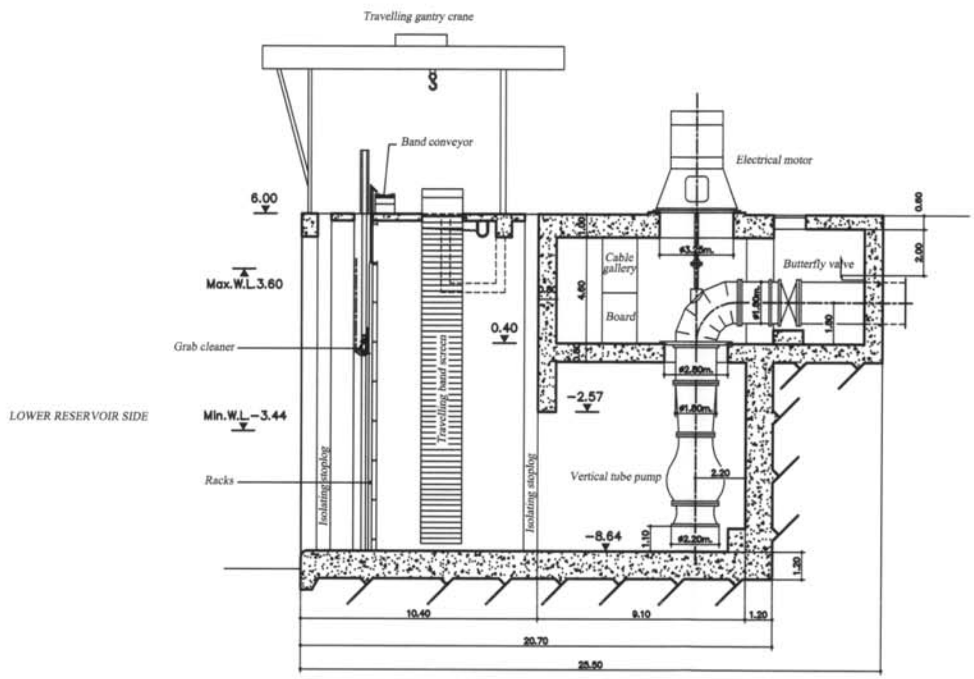
LOWER POND
PUMPING STATION
PLAN VIEW level +3.60 PLD

Drawing n°: EM - 004



SECTIONAL VIEW

0 1 2 3 4 5 10m.

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SEAWATER PUMPING STATION
SECTIONAL VIEW

Contract	Scale	Drawing n°:	Rev.	Folio
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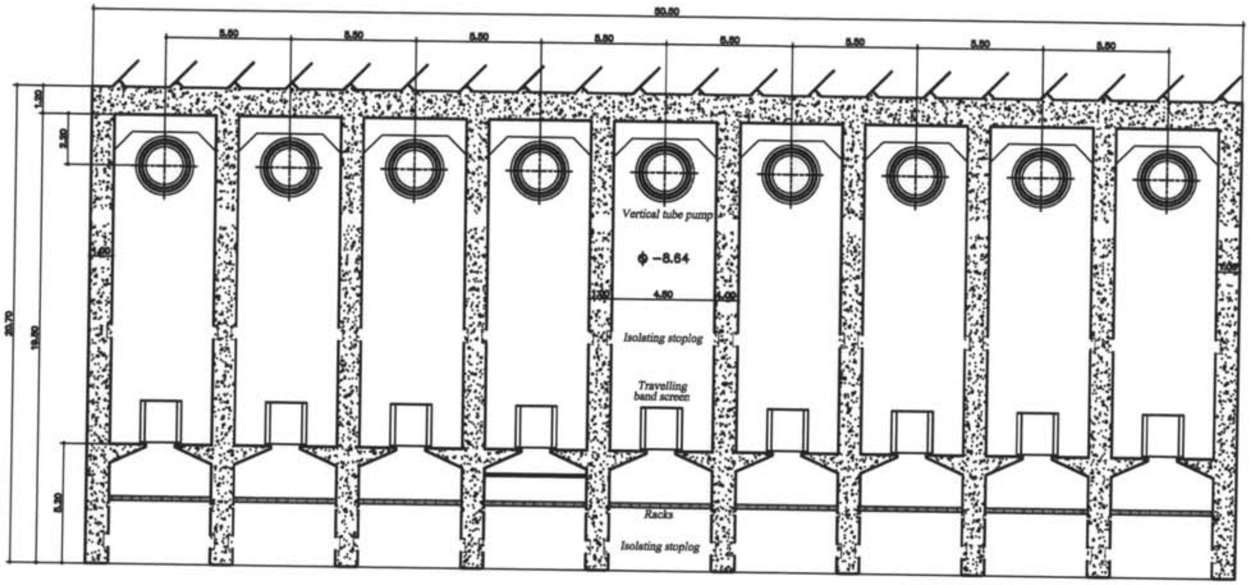

LOWER RESERVOIR SIDE

0 1 2 3 4 5 10m.

PLAN VIEW level -8.64

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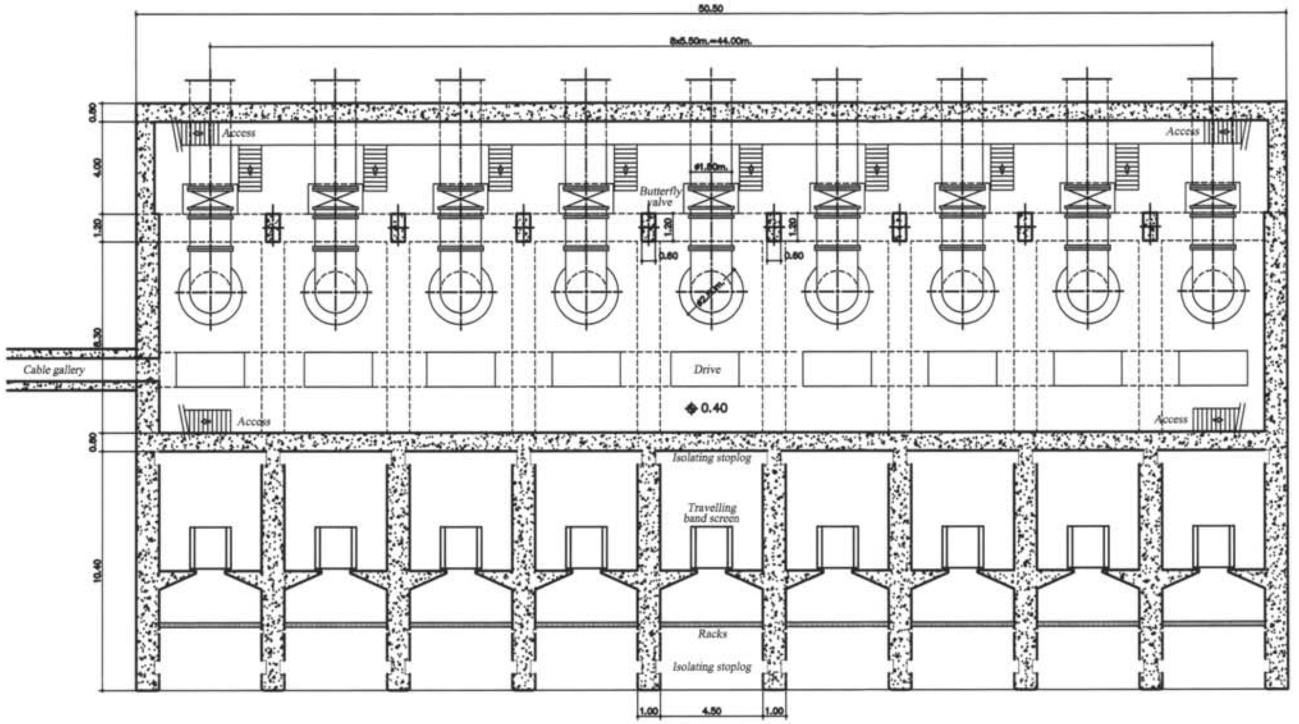
SEAWATER PUMPING STATION
PLAN VIEW level -8.64 PLD

Drawing n°: EM – 006

1/1



PLAN VIEW level 0.40

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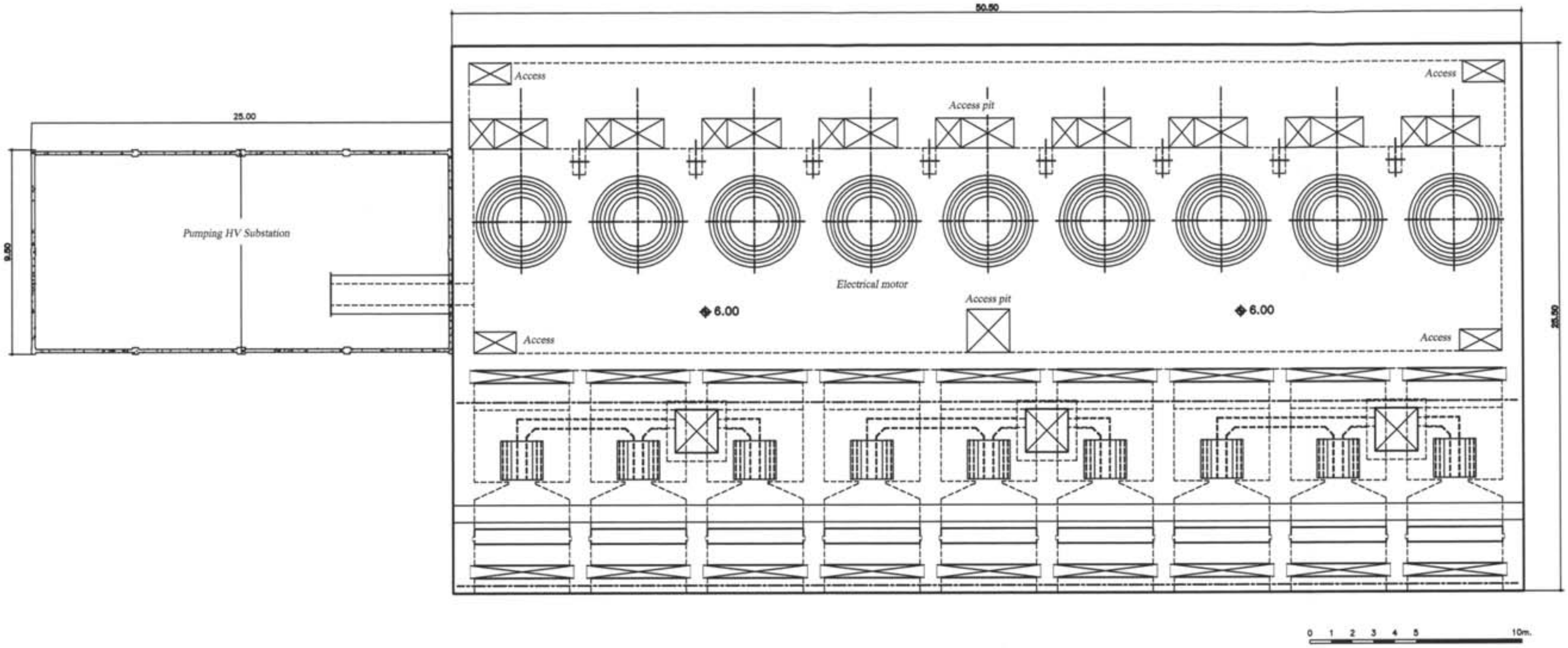
SEAWATER PUMPING STATION
PLAN VIEW level +0.40 PLD

Drawing n°: EM – 007



PLAN VIEW level +6.00

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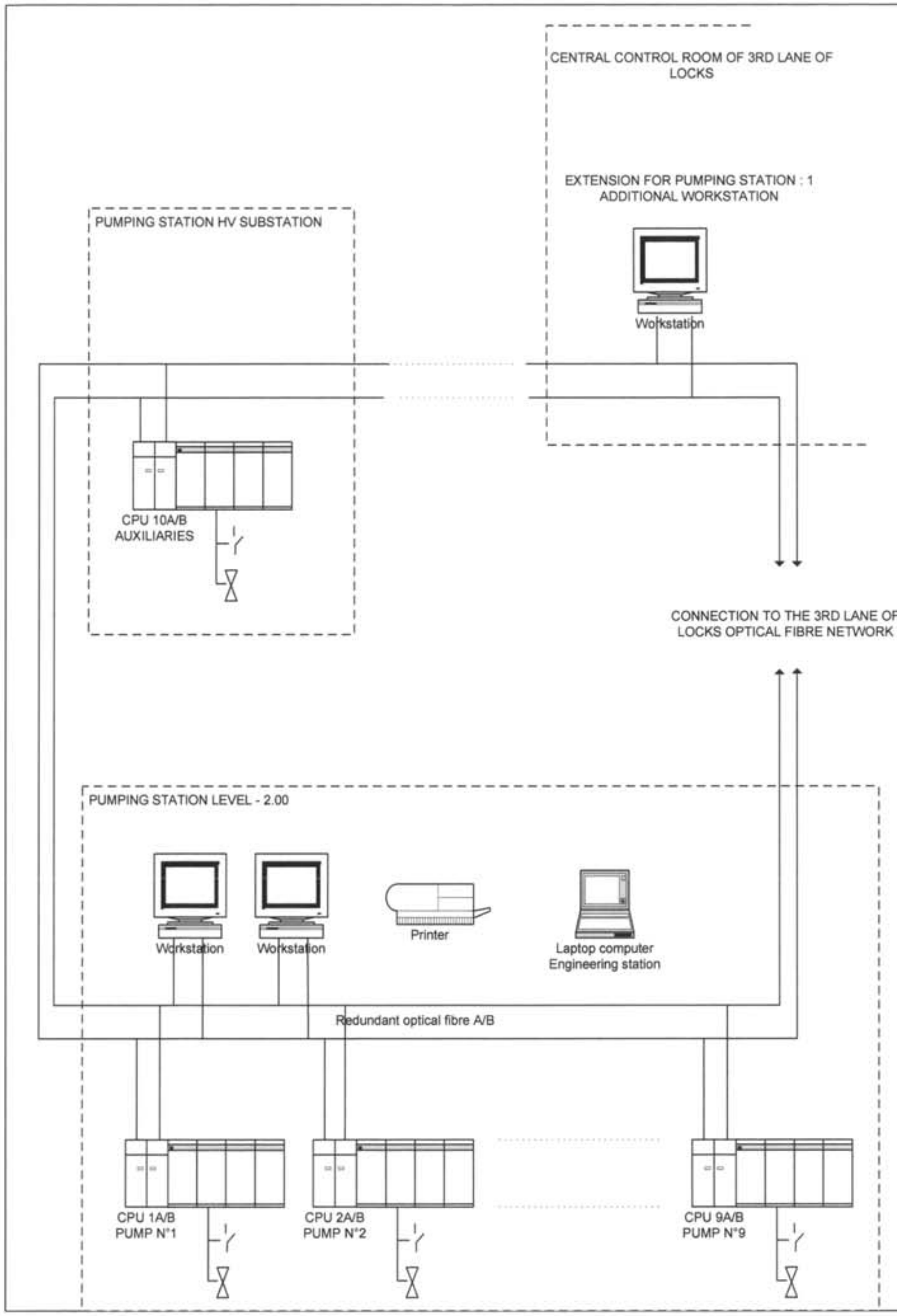
SEAWATER PUMPING STATION
PLAN VIEW level +6.00PLD

Drawing n°: EM – 008



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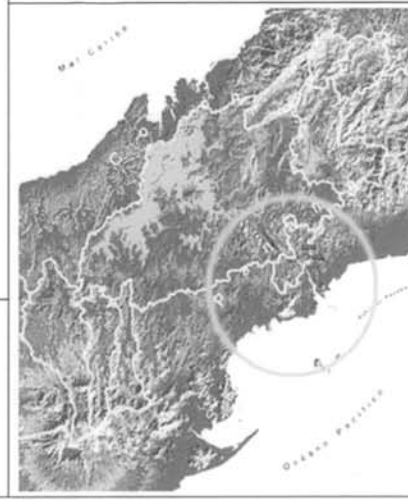
REPUBLICA DE PANAMA

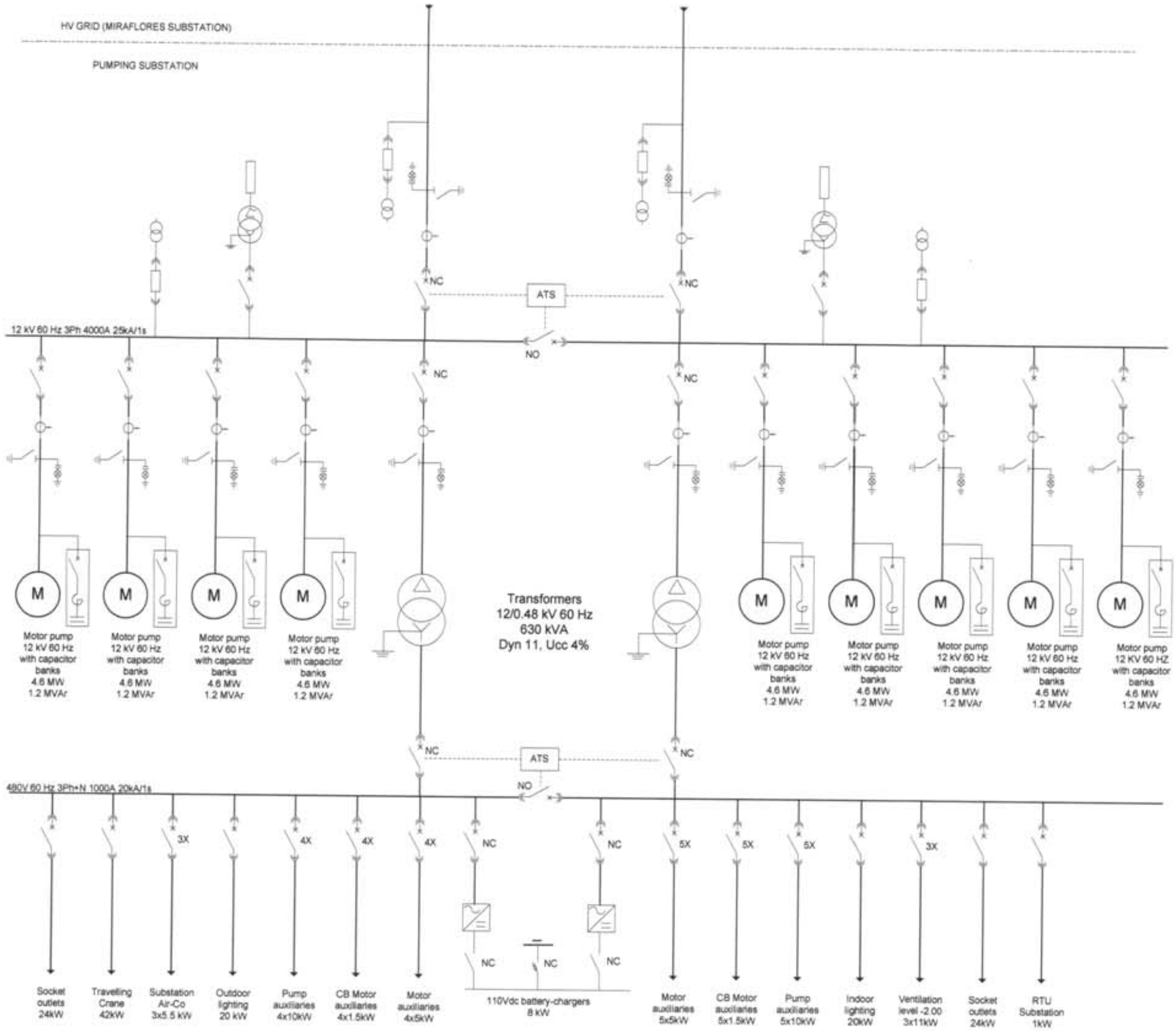


Conceptual Design of Recycling of Water in Post-Panamax Locks

CONTROL SYSTEM ARCHITECTURE PUMPING STATION

A	22 OCT 03	FIRST EDITION	FCL		VDP

Drawing n° EM-009 Rev A

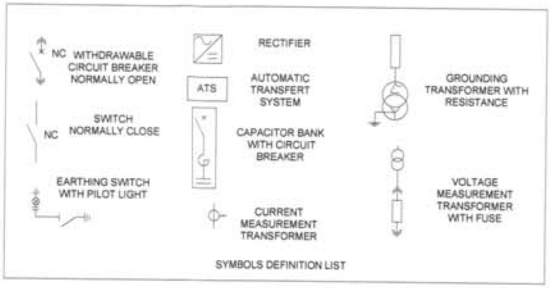


NOTES

1) THIS ONE LINE DIAGRAM IS CORRESPONDING TO THE MOST POWERFUL PUMPING STATION ALTERNATIVE

2) ASSUMED GRID FAULT CAPACITY : 300 MVA
MAXIMAL REQUIRED POWER AT THE LP PUMPING STATION :
- CONTINUOUS DEMAND POWER : 63.6 MVA
- SHORT TIME PEAK : 86 MVA
- ABOVE VALUES WITH 20 % SPARE INCLUDED

3) IN CASE OF PUMPING FROM THE OCEAN, IT IS NECESSARY TO ADD FOLLOWING CONSUMPTION :
- TRAVELLING BAND SCREEEN / 10 kW (For each pump)
- GRAB CLEANER : 10 kW (for each pump)



SYMBOLS DEFINITION LIST

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Conceptual Design of Recycling of Water in Post-Panamax Locks

LOWER POND PUMPING STATION GENERAL ONE LINE DIAGRAM

C	15 JAN 04	REMARK ACP JAN 04	FCL		RNG
B	12 NOV 03	UPDATED	FCL	PLX	VPS
A	23 OCT 03	FIRST EDITION	FCL	PLX	VPS

Drawing n° EM-010 Rev C