ELLOMAY
Pumped Storage (2014) Ltd.

PSPP MANARA

ISRAEL

Particular EM Specifications

Pumpturbine

Including Governor, MIV and Draft Tube Gate

Volume 2

Section VII

Part 1

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COMPOSITION OF RFP DOCUMENTS

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REVISION NUMBER

1.0 First edition
2.0 Second edition
3.0 Third edition with incorporated deviations and clarifications
3.1 Third edition with minor changes

1 GENERAL

Notwithstanding anything to the contrary in this document or any other Project Document, the Design and Works and Services (as applicable) shall be done and executed in compliance and shall adhere to the Israeli applicable standards. Compliance with an applicable recognized international standard shall not in no way derogate from the above requirement to comply at all times with the Israeli applicable standards. In the event that no Israeli standard is applicable the Design and Works and Services (as applicable) shall be done and executed in compliance and shall adhere to the relevant standard specified in the list included in the general specifications (Volume 2 Section IV, Section VI of the RFP Documents).

The Owner disclaims any and all liability for any errors, inaccuracies or incompleteness contained in this document. To the extent that the terms and conditions set forth herein conflict with the terms and conditions of the EPC Contract Agreement and/or O&M Contract Agreement, as applicable, the terms and conditions of the EPC Contract Agreement and/or O&M Contract Agreement, as applicable, will prevail.

1.1 Scope of Supply

This specification covers the design, manufacture, testing at the factory and site, transportation from factory to site, storage, complete erection, testing and commissioning of

- One (1) vertical single stage reversible Francis pumpturbine with approximate output/input at the shaft of 158.7 MW (turbine mode) and 151.0 MW (pump mode) for the initial mode and 217.5 MW (turbine mode) and 213.7 MW (pump mode) for the final mode at the given head conditions and operating at synchronous speed of 750.0 rpm for driving a motor-generator described in Part 2 - Motorgenerator and Excitation
- One (1) digital electronic – hydraulic governor including pressure oil system
- One (1) main inlet valve (MIV) designed as spherical valve with a diameter of 1500 mm including pressure oil system, inlet pipes and outlet pipe with dismantling/expansion joint as connection to the pumpturbine spiral case.
- One (1) draft tube gate designed in accordance to the draft tube dimensions including oil pressure system
- All relevant pumpturbine auxiliary equipment
- All connections to the cooling water system described in Part 3 – Power plant auxiliaries
- All connections to the compressed air system described in Part 3 – Power plant auxiliaries

- All dewatering pipes and valves
- Measuring pipes and instruments
- Complete oil piping for the scope of supply
- Lifting facilities and electric illumination for the pumpturbine shaft pit
- Assembly and test in the workshop for components as practicable
- Transportation and delivery to site
- Storage at site
- Site installation, commissioning and field acceptance testing of the pumpturbine by using the thermodynamic measurement method
- Corrosion protection of the whole equipment
- First lubricant fill plus 10% extra in barrels
- Tools for erection installation and maintenance
- Shop and field tests
- Training for the Operational staff
- Operation- and maintenance manuals and full documentation of supplied equipment including as built drawings.

The scope shall include all components which are required for performance, durability and satisfactory operation of the pumpturbine, governing system, Unit auxiliary equipment, main inlet valve and draft tube gate even though not individually or specially stated in this specification.

The EM1 contractor has shown a hydraulic base line model which is very similar to Manara PSP requirements. Only minor adjustments are needed for the hydraulic neat line for Manara PSP. Therefore results for the required guarantees below shall be shown and proved with a CFD calculation based on the existing base line.

Therefore if further in this document a reference is made to model test or homologous model test or model it shall be understood to be replaced by a reference to the hydraulic and CFD calculation reports.

1.2 Interfaces

The specification is outlined as functional description and therefore does not contain any technical detail design. Guidelines to internal interfaces of the main components and to other parts of the Contract are provided in the Interface Guidelines (EPC-EM Sub – O&M) Volume 2 / Section XI.

1.3 <u>General Technical Design Conditions</u>

1.3.1 General

In general all technical conditions and design criteria of the General Technical Specifications Annex A apply.

1.3.2 Operation modes and general operating conditions

1.3.2.1 General

The unit is designed for local control of unit control system as well as for remote control.

The unit shall be operated in any one of the following operating modes:

- Turbine mode,
- Pump mode,
- Electrical braking mode,
- Black start (electric island) mode,
- Synchronous condenser mode in turbine rotational direction,
- Synchronous condenser mode in pump rotational direction.

In daily routine and depending on the Israel Electric Company (IEC) grid (referred to subsequently as a grid) conditions, the unit will be started several times per day and for different operating times in the turbine or pump mode and will be operated in these modes, all according to IEC exclusive decisions.

The unit and its auxiliary, ancillary and protective devices must be designed for these modes as well as for an unrestricted continuous operation. In this continuous operation, all operating changes and load changes are included.

Operation of the power plant shall be performed from the control room of the plant. The control and supervision of the unit will normally be carried out from this control room.

The unit can be controlled by one of the following methods.

Automatic control

i.e. control of the unit including starting, automatic synchronizing, loading, changeover from bus bars and stopping where only initiation of the event is performed manually, the sequence of events following automatically. Automatic control will be performed only from the control room.

Manual electrical control

i.e. consecutive (step by step) control by individual switches on the unit local control board of the individual events which collectively constitute a starting, synchronizing, loading, change-over and stopping sequence.

Manual mechanical control, i.e. manual control of the wicket gate during maintenance will be possible via touch panel and turbine governor as well as backup governor.

Manual control of the turbine gates shall be provided at the actuator. Manual control shall be continuous over the full range of the gates' opening and gates' closing stroke. The transfer from actuator to manual control and vice versa shall be accomplished by a manual control button accessible from the front of the actuator cabinet. The manual control shall be supplied with an indicator to show the control in service.

The control system will be designed that it will be possible to change over from automatic to manual electrical control and vice versa while the unit is running, standing in process of starting, of changing over between modes of operation and of stopping without changing the condition of operation.

1.3.2.2 Definitions

<u>Turbine mode</u>

The unit delivers electrical energy to the grid powered by the water, which is stored in the upper reservoir and flows into the lower reservoir. The flow through the pumpturbine can be regulated with the wicket gate opening. In turbine operation the pump turbine will be controlled via unit specific power-frequency controller.

<u>Pump mode</u>

The unit draws electrical energy from the grid. The pumpturbine pumps water from the lower reservoir to the upper reservoir. The pumped water is stored for the turbine mode. In pump mode the power demand of the unit is defined by the given pump height. There is no possibility to control the power. To start up the unit in pump mode the pump turbine must be dewatered. After that the unit will be accelerated via static frequency converter (SFC) up to the rated speed.

<u>Electrical braking</u>

In normal operation the SFC is used for shutting down the unit and to feed the stored energy into the grid. The total apparent power of SFC is available as braking power. In case of unavailability of the SFC it is possible to brake electrically the unit through closing of the braking disconnector.

<u>Black start</u>

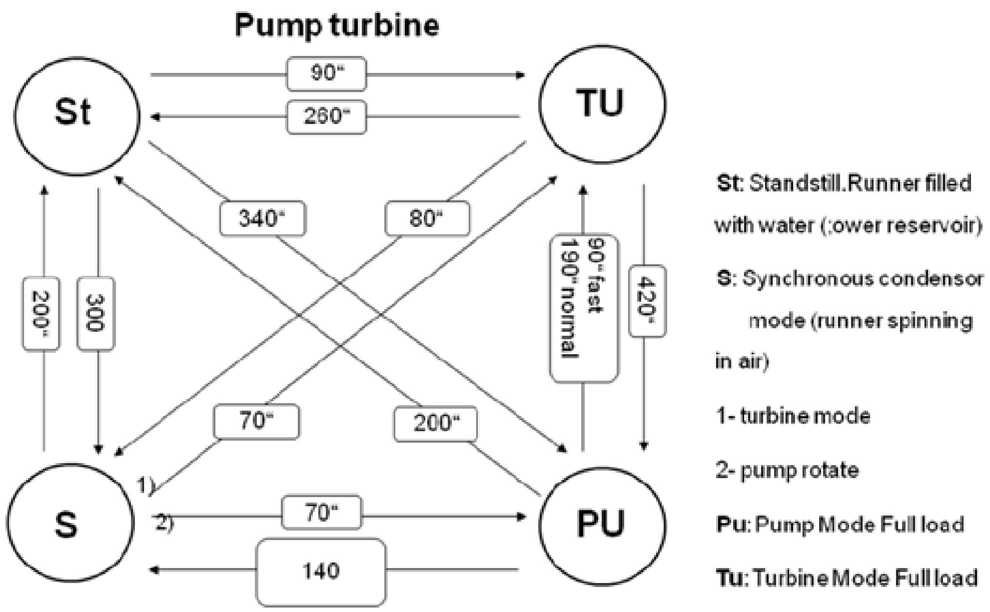
In this mode, where the grid being de-energised, the unit shall start supplied by the station service which is powered by the emergency Diesel generator. This permits the grid operator to restore power on the grid. The aim is to re-energise a certain part of the grid while limiting the frequency and voltage variations.

<u>Synchronous condenser</u>

In this mode, provided that the pumpturbine is dewatered, the unit shall operate as a synchronous motor supplied by the grid. This operating mode will be used for unit participating to the voltage adjustment of the grid by supplying or absorbing reactive power.

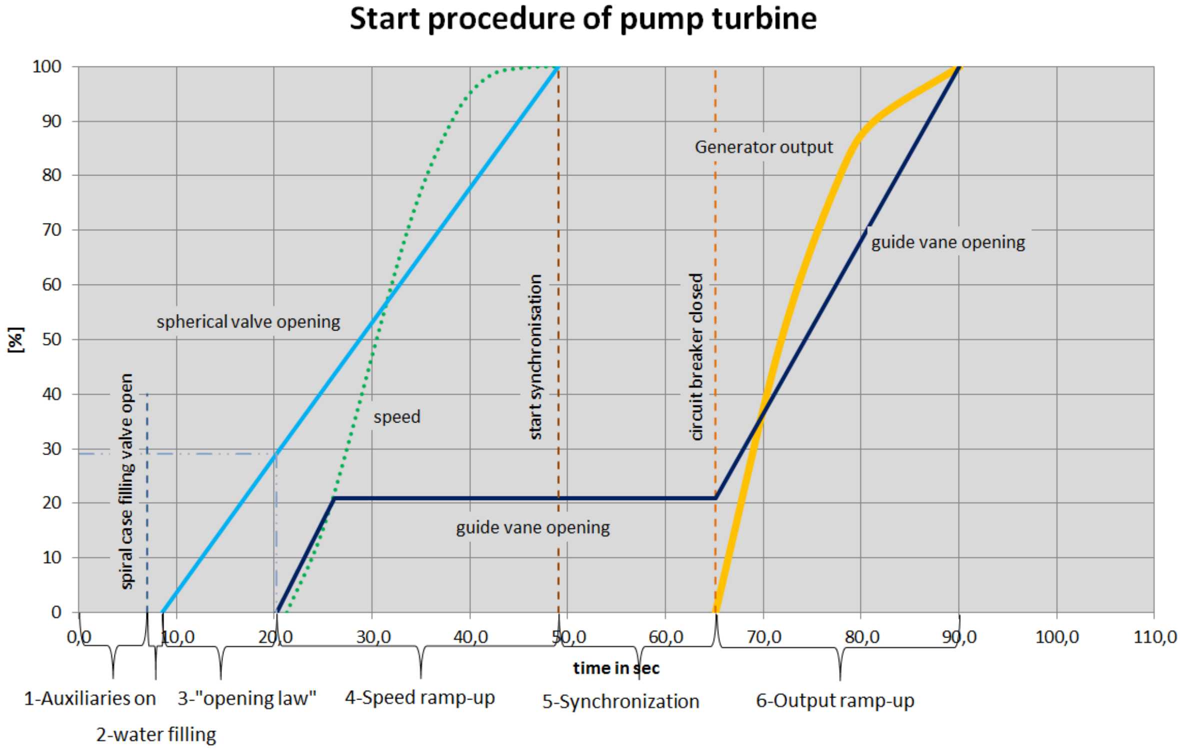
1.3.2.3 Changeover of operating modes

The unit shall be capable of safely completing the following maximum changeover times according to IEC requirements:



In order to verify the guaranteed changeover times the bidder shall supply with his bid a calculation report showing the changeover operations in similar diagrams to below shown start procedure for the turbine mode.

In the lifetime estimation an average number of 5 “fast” switchovers from Pump operation to Turbine operation mode per year shall considered.



This diagram shall be given for all changeover operations. The changeover operations to turbine mode will be part of the bonus and fines calculation referred in 1.4.

1.3.3 Grid requirements

Particular grid connection requirements can be found in the General Technical Specifications respectively in the grid connection agreement documentation.

1.3.4 Other Design Conditions

The pumpturbine shall be designed and constructed in such a way that it can be assembled and disassembled with the powerhouse crane as shown on the drawings with a total capacity of 245 tons and a minimum crane hook height of app. 10.5 m (measured from the machine hall floor) as described in Part 3 of the Technical Specification.

For the first erection also mobile cranes shall be used depending on the construction progress and project time schedule.

1.4 Bid evaluation criteria

The criteria will be assessed according to the scheme “PSPP Manara_Scoring_PPA.xls” in Volume 0, Section II, Bonus Evaluation Criteria.

1.5 Data Sheets

The data sheets in Volume 0, Section IV are a technical questionnaire to be furnished in filled-in form with the Proposal. They are an integral part of the Proposal.

2 PUMPTURBINE

2.1 Scope of supply

2.1.1 Reversible pumpturbine

This specification covers the design, calculations, technical drawings, manufacture including corrosion protection, erection at the factory, testing at the factory and site, packing, transportation from factory to site, storage, complete erection, documentation, testing and commissioning, training of operational staff. Additional tests and inspections during the guarantee period including documentation. The Contractor has sole responsibility for his deliverables, performance and services.

In this specification described scope of supply includes following main components for the reversible Pumpturbine, all parts except the runner and related components shall be designed for the 220 MW final mode:

- One Pumpturbine runner (one for 156 MW initial mode and one offered as option for 220 MW final mode)
- Turbine shaft including coupling components to the intermediate shaft including shaft preserve bushings
- Intermediate shaft including coupling components to the motorgenerator shaft
- Turbine guide bearing
- Spiral case including stay ring
- Spiral case dewatering
- Pressure test sets
- Head cover including wearing rings
- Bottom rings including wearing rings
- Draft tube steel lining
- Inspection platforms for runner inspection in the draft tube
- Shaft seals
- Pumpturbine regulating mechanism
- Pit liner
- All pipe connections for blow down air system and stabilisation air system
- Set of covers, platforms, stairs, ladders, railings and access pedestals
- Set of special tools and erection devices
- Pumpturbine governor system
- All connections to the cooling water system described in Part 3 – Power plant auxiliaries
- All connections to the compressed air system described in Part 3 – Power plant auxiliaries
- All dewatering pipes and valves
- Measuring pipes and instruments
- Site installation, commissioning and field acceptance testing of the pumpturbine by using the thermodynamic measurement method
- Corrosion protection of the whole equipment
- First lubricant fill plus 10% extra in barrels
- Tools for erection installation and maintenance

- No Model Test is required. A CFD analysis shall be delivered for the 156MW solution derived from the existing base line Model Test (see section 2.5)Shop and field tests
- Training for the Operational staff
- Operation- and maintenance manuals and full documentation of supplied equipment including as built drawings.

The outline of the deliverable and performance is structured in the following way:

2.1.2 Design

- Basic and Detail design
- As-Built design
- Training of O&M staff

2.1.3 Manufacturing

- Procurement of materials
- Workshop manufacturing
- Workshop and field assembly

2.1.4 Inspection and tests

- Material tests
- Factory acceptance tests
- Field acceptance tests

2.1.5 Transportation and Shipment

- All components carriage paid to final erection position
- Packaging
- Loading, transhipping and unloading
- Transport per rail, road, ship or plane
- Transport incurrence
- Transport monitoring

2.1.6 Erection at site

- Erection tools
- Measurement surveys
- Erection personal
- Erection insurances

2.1.7 Commissioning and trial runs

- All related documents
- As built drawings
- Operating instructions and regulations
- Inspection and test protocols

2.2 Performance requirements & operation conditions

2.2.1 General layout of the pump storage set

The general description and power plant layout is described in the Civil and E&M Basic Design report accompanied with the project drawings and schematics in Volume 3 and 4. The drawings show the general arrangement and amount of space for the different components. Changes in the arrangement are in principal allowed, if the Contractor can prove the benefits of the new arrangement. Arrangement changes can only be done with the Employer's approval.

The vertical pumpturbine unit set shall be designed in a conventional arrangement with the pumpturbine guide bearing at the head cover of the pumpturbine, a combined trust and guide bearing in the upper bracket and a guide bearing in the lower bracket of the motor-generator. The spiral case will be completely embedded in concrete. The unit will be equipped with a main inlet valve (MIV) on the high pressure side executed as spherical valve and on the low pressure side with a draft tube gate. The MIV and draft tube gate are specified in chapters 4 and 5 in this specification.

2.2.2 Main data of the pumpturbine

The main characteristic data of the pumpturbine are stated in the following table.

Number of units	1 unit with two modes (156 MW and 220 MW)
Pumpturbine type	Single stage Francis
Shaft arrangement	Vertical
Direction of Turbine rotation (when viewed from above)	Counter-clockwise
Approximately capacity at the shaft of the unit in turbine/pump mode	158.7 MW / 151.0 MW (initial mode) 217.5 MW / 213.7 MW (final mode)
Approximately discharge of one unit in turbine/pump mode	37.7 m³/s / 31.1 m³/s
Rated gross head	652.7 m

Power frequency / Synchronous speed	50 Hz / 750 rpm
Design pressure / Test pressure on the HP side	93 bar / 140 bar
Design pressure / Test pressure on the LP side	10 bar / 15 bar
Spiral case centre line	+2.00 m a.s.l.

2.2.3 Main data of the motorgenerator

For the main data of the motorgenerator see Part 2 of the PTS.

2.2.4 Main parameter of the power water way

The main parameter of the power water way are listed in the table below.

Upper Reservoir	
Full supply level (F.S.L.)	737.0 m a.s.l.
Rated reservoir level	729.8 m a.s.l.
Minimum operating level (M.O.L.)	712.5 m a.s.l.
Lower Reservoir	
Full supply level (F.S.L.)	80.7 m a.s.l.
Rated reservoir level	77.1 m a.s.l.
Minimum operating level (M.O.L.)	73.25 m a.s.l.
Head	
Maximum gross head	663.75 m
Rated gross head	652.7 m
Minimum gross head	631.8 m

2.2.5 Head losses

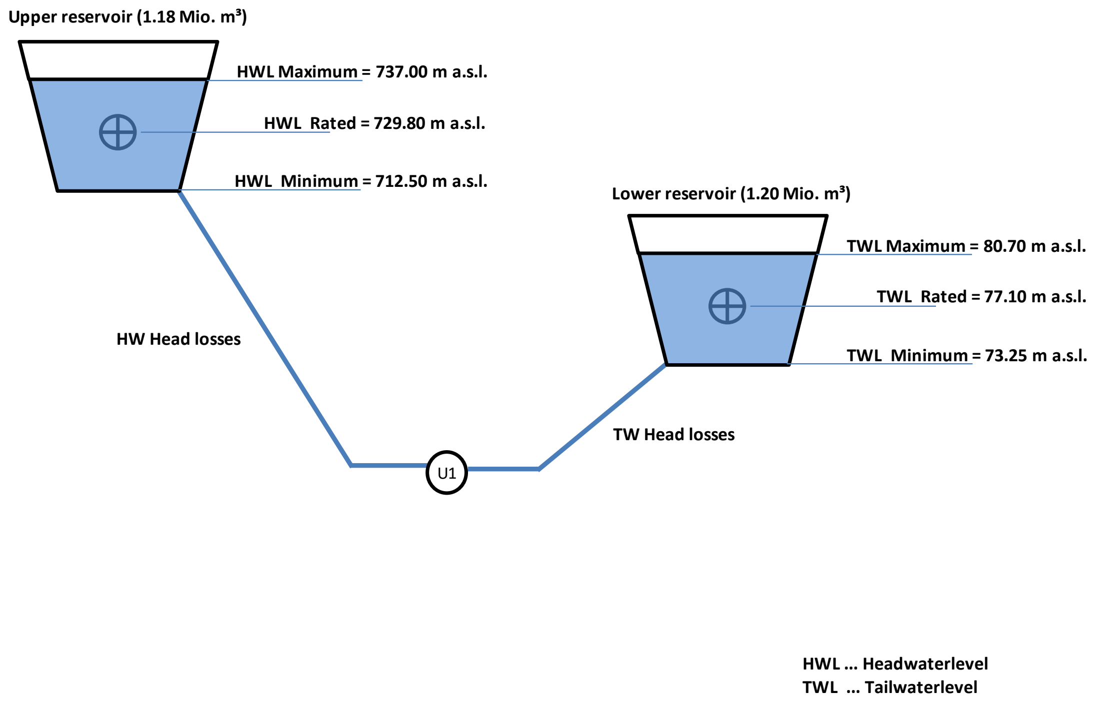
The hydraulic system of the PSPP Manara is the basis for the design of the pumpturbine. The water levels give the maximum, rated and minimum gross heads.

The net heads in the turbine and pump modes are calculated as follows:

$$H = H_g \pm k \cdot Q^2 = H_g \pm h_L$$

H…	net heads	[m]
Hg…	geodetic (gross) heads	[m]
k…	loss coefficient	[s^2/m^5]
Q…	discharge	[m^3/s]
h_L…	hydraulic head loss	[m]

were k Q^2 indicate the hydraulic head losses of the waterway. The “+” is applied in the pump mode and the “-“ symbol in the turbine mode. The final head loss values shall be recalculated after the detail design and coordinated between the related project partners. The head losses based on the basic design are stated below:



Pumpturbine in turbine mode: $h_{L,T} = 0.0109619 \times Q_{Turbine}^2$

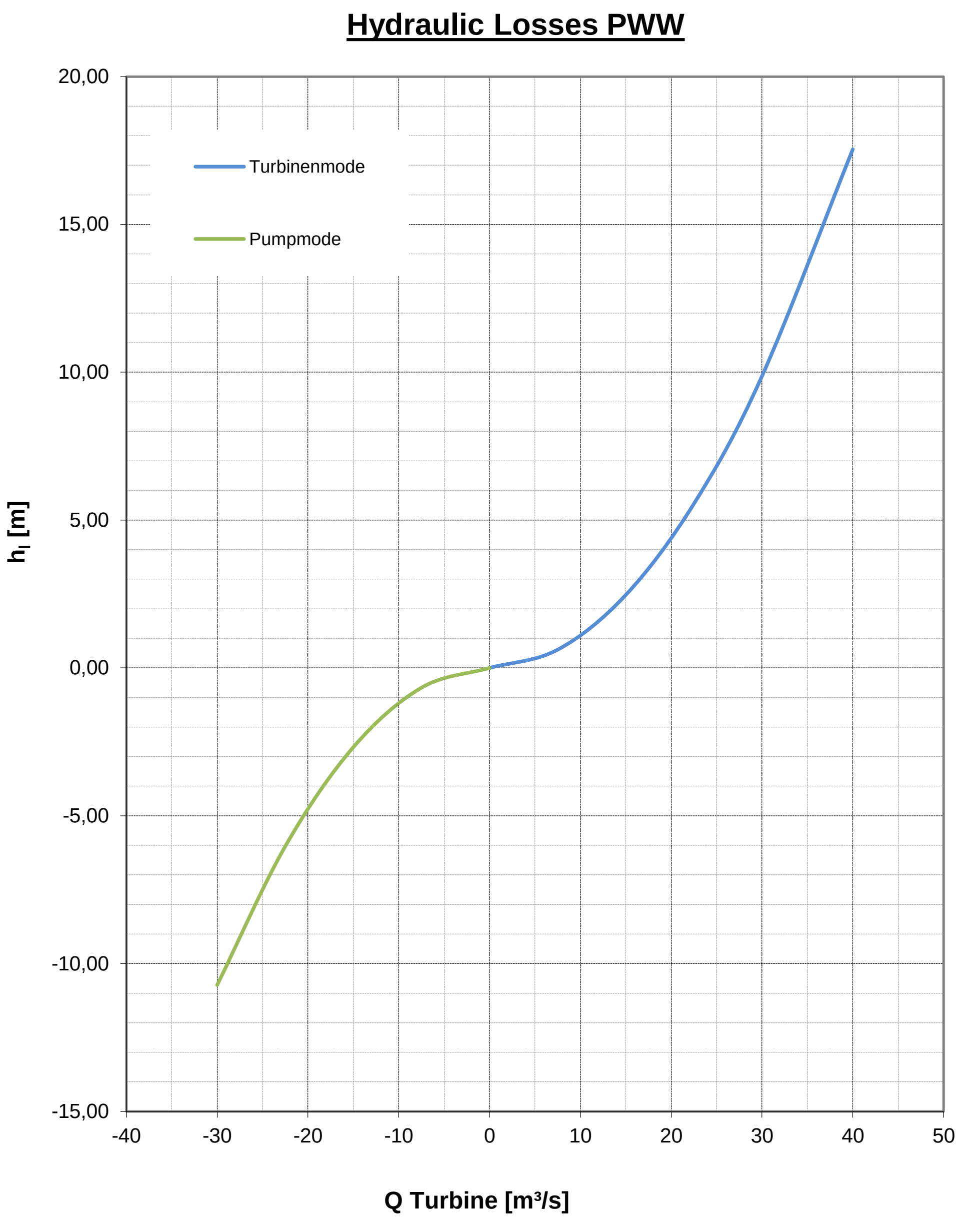
Pumpturbine in pump mode: $h_{L,P} = 0.0119165 \times Q_{Pump}^2$

Load Case	Q_r [m^3/s]	h_L [m]	% of max. gross head *
Turbine mode	36.6	14.68	2.2%
Pump mode	29.9	10.65	1.6 %

* … 737.00 masl – 73.25 masl = 663.75 m

For the head loss coefficients calculation for the waterway see the report MANARABDCR04001.

The hydraulic losses in the power water way including the losses of the main inlet valve and the draft tube gate can be summarized as follows.



The turbine mode is shown in blue and the pump mode is shown in green.

2.2.6 Weighted average efficiencies

The efficiencies of the pumpturbine be verified through a fully homology model test and measured and confirmed on the completed power plant. Therefore the efficiencies will be guaranteed values and have a great influence on the hydraulic layout of the pumpturbine.

The weighted factors for the efficiency calculation shall correlate to the expected operation pattern of the pump storage plant. As for now no information on the expected operation patterns are available, the weighted average efficiencies are based on the requirements for the cycle efficiency test required by IEC.

In the following chapters the weighted efficiencies for the pump and turbine mode are shown.

2.2.6.1 Pump mode

As the pumpturbine of the PSPP Manara is of the fixed speed type the pump capacity only depends on the related operation points head and discharge which follows the pump curve. As it is assumed that the full storage volume of the reservoirs will be used on a regular basis the weighted factors for the pumping mode are chosen equally related to 5 reference gross heads of the plant.

Weighted Average Efficiency					
	Gross head				
	663.75	657.80	649.20	640.50	631.8
Pump mode Weighted factor	20 %	20 %	20 %	20 %	20 %

2.2.6.2 Turbine mode

The turbine mode efficiencies are weighted with 5 reference gross heads between maximum and minimum head in 6 different operation load points, up from the maximum capacity (100%) down to 50 % part load operation in 10% steps.

Weighted Average Efficiency							
gross H in m	Efficiencies in part load in %						
	50	60	70	80	90	100	Σ
663.75	1.25	2.50	6.25	6.25	0	0	16.25
657.80	1.25	2.50	6.25	6.25	6.25	2.50	25.00
649.20	1.25	2.50	6.25	6.25	6.25	2.50	25.00
640.50	1.25	2.50	6.25	6.25	6.25	2.50	25.00
631.80	0	0	0	0	6.25	2.50	8.75
	5.00	10.00	25.00	25.00	25.00	10.00	100

The weighting focus is on the capacities between 90 % and 70 % in all selected gross heads.

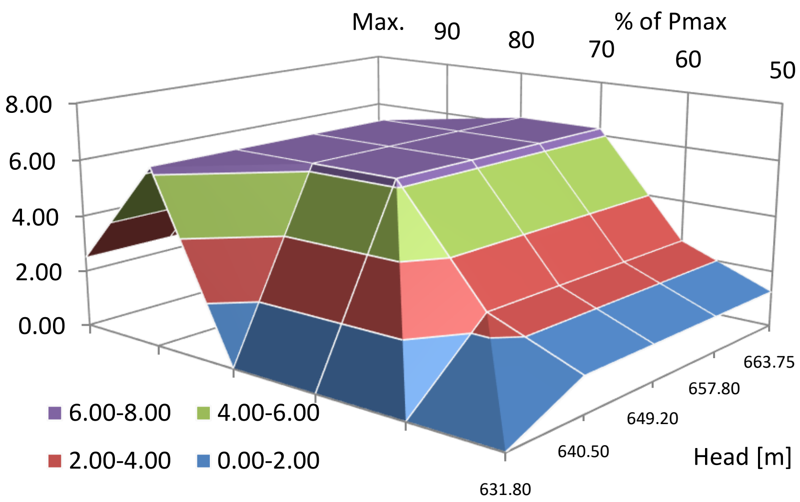


Figure 2-1: Weighted efficiency factors diagram for the turbine mode

This weighted efficiency factors are based on the requirement for the cycle efficiency test required by the PPA.

The pumpturbine shall be able to operate at guaranteed maximum unit capacity at minimum head.

2.2.7 Planned operation pattern

Refer also to related chapter in the general technical specifications.

According to IEC the pumpturbine will have following **minimal** operational requirements regarding start/stop/changeover annual quantity:

The procedures will determine that:

*(a) routinely, the grid manage will be entitled to execute up to **six (6) starts** of the generation unit each day;*

*(b) the grid manager will be entitled to execute up to **1,800 starts** of the generation unit each year;*

*(c) in the event that the number of starts executed in a given year is lower than 1,800, the grid manager is entitled to transfer 1/3 of the number of starts that were not exploited, to the following year, however no more than 600 starts, provided that the number of starts in the following year does not exceed **2,400** for that generation unit.*

2.3 Technical guarantees

The guaranteed values in chapter 2.3 are indicative. The guaranteed values are shown in Annex 11 to the EPC agreement.

2.3.1 Guaranteed IECo criteria

All criteria that are requested by IECo and stated in Volume 2, Section II shall be guaranteed.

2.3.2 Guaranteed capacity turbine mode

With the given parameters the maximum mechanical (shaft) output power of the pump turbine in turbine operation shall be approximately **158.7 MW / 217.5 MW** to fulfil the grid criteria.

The turbine capacity shall be guaranteed at all possible head conditions.

The homologous model test shall demonstrate that the prototype pumpturbine is capable of meeting the guarantee powers, however site performance tests shall be used to prove attainment of the guarantee values.

2.3.3 Guaranteed capacity pump mode

With the given parameters the maximum mechanical (shaft) input power of the pump turbine in pump operation shall be **154.0 MW / 213.7 MW** to fulfil the grid criteria.

The pump capacity shall be guaranteed at all possible head conditions at a rated grid frequency of 50 Hz.

The homologous model test shall demonstrate that the prototype pumpturbine is capable of meeting the guarantee powers, however site performance tests shall be used to prove attainment of the guarantee values.

2.3.4 Guaranteed max. pressure rise

The maximum transient pressure at the spiral inlet, following the worst case sequence of operating conditions, referenced to machine centreline, shall be guaranteed.

The maximum pressure rise shall be **≤ 93 bar**.

The likely worse case boundary conditions and sequence of operating conditions to consider are outlined in the preliminary transient calculation report as part of the basic design.

These preliminary calculations shall be updated by the Contractor on receipt of the pumpturbine 4-quadrant characteristic data from the contractual model test and shall cover in minimum the following load cases:.

General:

- All load cases using P_{max} must be performed both at H_{max} and Q_{max}

TU-operation:

- Load rejection from P_{max}
- Normal closing from P_{max} (for verification of assumed surge tank parameters during commissioning)
- Surge tank design verification (max. upsurge and down surge), including fast transition operation between PU-TU
- Closing of MIV with disabled wicket gates
- Runaway speed H_{max} and wicket gate max; Closing of MIV
- Loading (Nn, P= 0 → P_{max})

PU-operation:

- Load rejection from pump mode of operation
- Loading in pumping mode (Nn, y = 0 → rated opening)
- Normal stop from Pump mode (closing of MIV and distributor)

The expected maximum and minimum water levels in the surge shaft and surge chamber shall be stated in the data sheets.

The max. pressure rise shall be verified through on site plant measurements during the acceptance tests.

2.3.5 Guaranteed pressure fluctuation / vibrations

The design, construction, execution and erection of the pumpturbine (as well as of the motor-generator) shall be carried out with the maximum of care and accuracy.

The pumpturbine shall run smoothly throughout the normal operating range. One of the measures to judge smooth running shall be pressure fluctuations.

The Contractor shall guarantee the stable operation condition for all head conditions and for the min. and maximum grid requirements (f_{min}-f_{max}).

For the bearing vibration the Contractor shall guarantee according to ISO 10816-5 for the pumpturbine bearing following:

Operation range	Evaluation zone / max. vibration	Max. radial force at the runner [kN]
100 % to 75 %	B	
75 % to 50 %	B	
50 % to 0 %		

For the shaft vibration the Contractor shall guarantee according to ISO 7919-5 for the pumpturbine bearing following:

Operation range	Evaluation zone / max. vibration
100 % to 75 %	B
75 % to 50 %	B
50 % to 0 %	

For the bearing and shaft vibrations the evaluation zones and maximum values shall be stated in above table and in the data sheets.

The bearing and shaft-vibrations shall be measured in horizontal, vertical and in 45° to the horizontal direction. The Contractor shall furnish all required measurement equipment and sensors.

For all other bearings the Contractor shall guarantee according to ISO 10816-5 evaluation zone B, regarding the shaft vibration according to ISO 7919-5 evaluation zone B.

In the draft tube the maximum amplitude of the pressure fluctuation (H) (peak to peak) shall be guaranteed as follows:

- Pump mode $\Delta H/H < 3$ %
- Turbine mode max. capacity $\Delta H/H < 2$ %
- Turbine mode part load $\Delta H/H < 4$ %

Should for any reason the respective limits are exceeded, the Contractor shall be obliged to take immediately and completely at his own cost all steps an measures to remedy the situation and to reduce the vibration to the above-stated limits.

Related max. noise levels shall comply with the GTS.

2.3.6 Maximum overspeed

The maximum transient overspeed, following the worst case sequence of operating conditions, shall also be considered.

The maximum momentary speed rise shall not exceed **45%** of the rated speed in the most unfavourable conditions at a max. head.

The Contractor shall clearly indicate the speed rise for sudden tripping at 4/4 (guarantee), 3/4, 2/4 and 1/4 (for information purposes) of the respective full load.

The turbine supplier is responsible to consider the overspeed increase for the unit design.

2.3.7 Maximum runaway speed

The steady state runaway speed under maximum static head, and using the waterways head loss factors given in the basic design shall be considered.

The corresponding expected runaway discharge and generating net head used in the guarantee calculation shall be stated in the data sheets.

The model test shall demonstrate that this value is not exceeded.

The expected maximum transient runaway speed is stated in the data sheets.

The unit set shall withstand runaway speed safely and without any abnormal reaction.

The turbine supplier is responsible to consider the runaway speed increase for the unit design.

2.3.8 Guaranteed efficiency

The contractor has to guarantee the weighted prototype efficiency which is built by weighting the up-scaled model efficiencies.

The efficiency of the prototype shall be determined from the efficiency of the model by the current IEC (International Electrotechnical Commission) 60193 model stepped-up formula.

The guaranteed weighted efficiency for the pumpturbine shall be guaranteed in the datasheets adding the according net head depending on the required discharge.

The guarantees shall be given for water temperatures of 20°C. Mechanical losses attributable to the turbine (e.g. guide bearing losses) shall be included in the prototype efficiency.

If the tested weighted efficiency (generating and pumping values) is less than guaranteed value by greater than 1% (plus the measurement uncertainty band) then the model test shall be rejected.

The guaranteed efficiencies shall be measured during the field acceptance tests with the means of a thermodynamic efficiency measurement according to IEC code 60041.

This weighted efficiency factors are based on the requirement for the cycle efficiency test required by IEC.

The guaranteed efficiencies shall be stated in the data sheets and in the evaluation calculation sheet.

2.3.8.1 Guaranteed efficiency in turbine mode

The turbine mode efficiencies are weighted with 5 reference gross heads between maximum and minimum head in 6 different operation load points, up from the maximum capacity (100%) down to 50 % part load operation in 10% steps.

See chapter 2.2.6.2.

2.3.8.2 Guaranteed efficiency in pump mode

As it is assumed that the full storage volume of the reservoirs will be used on a regular basis the weighted factors for the pumping mode are chosen equally related to 5 reference gross heads of the plant.

See chapter 2.2.6.1.

2.3.8.3 Guaranteed average cycle efficiency

The cycle efficiency shall be guaranteed by the EPC contractor according to IEC conditions and requirements stated in Volume 2, Section II.

2.3.9 Cavitation guarantee

The Cavitation guarantee shall be in accordance with IEC 60609 latest edition and the following stipulations:

The runner shall be guaranteed against excessive pitting caused by cavitation for a period of eight thousand (3000) operating hours from the date it was placed in service, but not to exceed two (2) years from the date of the corresponding taking-over.

- During the guarantee period the unit shall not be operated for more than 100 hours at outputs greater than outputs within the range of guarantee indicated in the hill chart, and not for more than 100 hours at outputs less than outputs within range of guarantee indicated in the hill chart, during the guarantee period.
- The pumpturbine shall be set with the center line of distributor at elevation indicated in the technical specifications and shown on the sectional drawing submitted herewith.
- The tailwater level during operation shall not be lower than the normal minimum.
- Erosion or damage caused by solid particles in the water and corrosion caused by aggressive chemical substances in the water are not intended to be covered by the cavitation guarantee.

<u>Excessive cavitation</u>

The cavitation Guarantee is the guarantee below or equal to the excessive cavitation which is defined as below:

- Maximum Permissible Cavitation Pitting Depth

$$x = 4 * D^{0,4} * \frac{N}{3000}$$

x is the Cavitation Pitting Depth in mm

D is the outlet diameter of the runner in m

N is the total number of operating hours.

(single wormholes up to a damaged area of 1 cm² and surfaces which have a peak to valley height of less than 0.5 mm should be not considered as excessive cavitation)

- Maximum Permissible Cavitation Pitting Volume

$$y = 20 * D^2 * \frac{N}{3000}$$

y is the Cavitation Pitting Volume in cm³

D is the outlet diameter of the runner in m

N is the total number of operating hours.

The cavitated volume on one single runner blade shall not exceed 0.3 times the guaranteed volume for the entire runner. For all non-rotating parts the value of volume y shall be half the value stated for the runner. The value of depth shall be equal the value stated for the runner.

Measurement of the amount and dimensions of the metal removal shall be as defines in IEC 60609.

The water temperature shall not be higher than 30 degrees Celsius.

2.3.10 Hydraulic axil thrust

The maximum hydraulic axial thrust shall be evaluated under transient conditions and for the higher of steady state runaway or operation within the normal operating range.

The model test shall demonstrate that this value is not exceeded throughout the normal steady state operating range nor during runaway.

The maximum hydraulic axial up thrusts (towards the generator-motor) under any conditions are stated in the data sheets. The model test shall identify the maximum value throughout the normal steady state operating range.

The expected hydraulic axial thrust at the rated point shall be stated in the data sheet.

The verification measurement of the values will be done in the model test.

The maximum expected radial thrusts in turbine and pump operation, under the most unfavourable circumstances shall be stated in the data sheets.

2.3.11 Wicket gate torque

The maximum hydraulic wicket gate torque shall be stated in the data sheets.

The values shall be given for both operation, pump and turbine mode.

2.4 Design requirements for the main components

The below stated design requirements for the main components are described for the pumpturbine but are valid for both runners (initial mode & final mode).

The structural design shall be of the highest possible integrity so as to give the highest possible availability with the lowest possible maintenance and repair cost, and a stated life time of minimum 60 years.

The pumpturbine nameplate shall be displayed in a prominent position to be approved by the Employer.

2.4.1 Runner

The pumpturbine runner shall be manufactured as a single mono block cast stainless steel item or alternatively as a fabricated welded stainless steel design consisting of individually cast crown, band, and blades, welded together.

During the runner design process, 3-D CFD analysis by an approved numerical method shall be performed on the runner to attain optimal flow conditions through the runner blade passages.

The material of the entire runner shall be studied based on the water quality during the life time of the plant. A comprehensive material selection report for all moving parts in the waterway shall be transmitted for Employer approval before the material procurement process started.

The hydraulic profile of the runner shall be homologous with the model on which the performance is proven, within the tolerances specified.

All surfaces exposed to the flow shall be ground to accurate template forms or CNC machined to obtain even and smooth surfaces without depressions, projections or other defects liable to affect the performance or cause premature wear. The Contractor shall supply a complete set of templates to the Supervisor.

The runner shall be designed to operate under cavitation-free conditions under all normal operating conditions with the submergence given above. It shall be guaranteed against excessive pitting and metal loss due to cavitation in accordance with the cavitation guarantee.

The runner shall be designed to operate safely at steady state runaway speed for at least 15 minutes, although it will not be tested. It shall possess a minimum factor of safety at the maximum runaway speed.

The runner blades shall be ground smooth and hand finished where necessary and inlet and outlet edges properly shaped in accordance with the manufacturer’s best practice.

The runner shall be capable of supporting its weight together with the weight of the turbine shaft, when the assembly is uncoupled from the generator and lowered to rest on the discharge or bottom ring.

Sealing surfaces matching the rings on the top cover and bottom ring shall be formed as integral parts of the crown and band of the runner. The renewal of these runner sealing surfaces in the future by means of separate sealing rings shall nevertheless be provided for; the means of attachment of the future rings shall be subject to Employer´s approval.

The completed runner shall be non-destructively tested.

The complete runner shall preferably be dynamically balanced in two planes, or at least as per ISO 1940 Grade 6.3, at the manufacturer's factory before despatch. In the event of any occurrence which causes doubt about the satisfactory balance of the runner, it shall be balanced again at Site at the Contractor's expense. The Contractor shall provide a method statement detailing the balancing approach offered. Runner balancing by the means of non-concentric machining of the band or crown shall not be permitted. Small modifications in balancing shall be achieved by using approved international standards.

For efficient inspection and maintenance purposes of the runner is planned to make the dismantling of the runner possible in two ways:

- Dismantling through the draft tube cone. Therefore the draft tube cone can be removed through the access gallery. After removal of the bottom ring the runner can be lowered and transported to the machine hall by using the central transport opening.
- Dismantling of the runner in connection with the compact part of the pumpturbine. The compact part includes following components:
    - Turbine shaft
    - Guide bearing
    - Head cover + all built-on equipment
    - Wicket gate mechanism
    - Runner

The design of the related parts need to secure an easy and trouble free dismantling of the compact part and further lifting and transportation to the machine hall floor of the cavern. In below picture a lifted compact part for maintenance purposes is shown.

The runner shall be connected to the shaft by a bolted flange connection. The bolt holes in the flanges shall be reamed to their final dimension when the shaft and runner are assembled at the manufacturer's factory and the alignment of the assembly checked on completion of reaming and fitting of the coupling bolts.

If applicable a nose cone, of the same grade stainless steel as the runner, shall be provided as an extension of the central runner crown to guide the water discharging from the runner blades or pump inflow. It shall be bolted to the runner. Where bolts are located in the water passageway covers shall be used that maintain the hydraulic profile. Care shall be taken in the design to minimize the effect of vibration to which the fixing arrangements may be subjected.

The cooling water for the runner seals during blowdown operation shall be drawn from the cooling water system and an additional booster pump shall be foreseen to achieve the required pressure.

2.4.2 Turbine shaft

The turbine shaft shall be of forged carbon steel with minimum mechanical properties. The first critical bending speed of the whole rotating parts shall be at least 25% higher than transient runaway speed. The critical torsional frequencies must be at least 15% away from the multiples of the excitation frequencies (e.g. nominal speed, etc).

It shall be dimensioned to be able to operate at any speed up to the maximum runaway speed without any harmful vibrations or distortions. A forged flange, forming an integral part of the shaft, shall be provided to couple the runner to the turbine shaft.

It shall be of the solid or hollow type whereby the respective choice is left to the Supplier’s discretion. The solid type shaft shall be fabricated of forged open hearth or electric furnace carbon steel, properly heat treated, accurately machined and smoothly finished throughout with integrally forged upper and lower flanges for bolting to the intermediate shaft and the runner respectively.

The shaft shall be perfectly round and free from imperfections having a central bore not less than 150 mm in diameter, extending axially over its entire length. The finish of the bore shall be sufficiently smooth to permit visual inspection of the central material.

If no air admission is installed the shaft’s upper end shall be hermetically sealed with a suitable plug or cover not subject to corrosion and/or sticking.

The shaft shall be suitably machined and finished over its entire length. Particular care shall be taken with bearing surfaces, the target surfaces of vibration monitoring equipment, and surfaces to be used in the checking of alignment. Machining tolerances, and mechanical and electrical runout shall be minimised on all of these locations by the appropriate use of machining, grinding and rolling techniques.

The turbine shaft shall be connected to the intermediate shaft and the runner by a bolted flange connection. The bolt holes in the flanges shall be reamed to their final dimension when the shaft and runner are assembled at the manufacturer's factory and the alignment of the assembly checked on completion of reaming and fitting of the coupling bolts.

All necessary reaming tools, keys, wrenches and other coupling assembly gear as well as the coupling bolts and nuts for attaching the generator shaft to the turbine shaft, the metal guards on both halves of the coupling for covering the coupling bolts and nuts, and all other special equipment for field assembly of the coupling are part of the turbine supply.

Means shall be provided by suitable lines and index markers on the turbine shaft and on the adjacent guide bearing housing to enable the vertical movement of the shaft to be observed when jacking the rotating parts of the set.

Relevant standard for the shaft is IEEE SA-810-2015 “Standard for hydraulic turbine and generator integrally forged shaft couplings & shaft run out tolerances”. All test reports shall be submitted to the engineers for approval.

The balancing quality for the entire shaft of the unit shall comply with ISO 1940, quality grade G 6.3.

2.4.3 Intermediate shaft

The intermediate shaft shall have the same technical characteristics as described above under turbine shaft. The main aim of the intermediate shaft is to allow a dismantling of the upper pumpturbine parts (head cover, wicket gate mechanism, guide bearing, runner) without dismantling the motor-generator.

The length and position of the intermediate shaft is designed accordingly in order to dismantle the shaft and transport it to the machine hall floor through the main bring in opening of the cavern.

2.4.4 Turbine guide bearing

The turbine guide bearing shall be located close to runner yet still permit easy inspection, easy dismantling and easy maintenance of the shaft seal placed below.

The bearing shall be amply designed for normal operation and shall be able to function indefinitely under any speed or output corresponding to normal or emergency conditions which may occur, including runaway speed, running at pump shut-off with the main inlet valve closed and guide vanes open, or on the occurrence of guide vane failure, during which the specified acceptable bearing temperatures shall not be exceeded. Only during emergency condition which may occur, the bearing temperature can increase above the specified temperature for normal operation. It must be guaranteed however, that the bearing in such case will not get damaged and there is no reduction in service life.

The radial forces exerted upon the bearing shall be absorbed by the head cover and transferred safely to the civil foundations. The bearing shall permit axial movement of the shaft for thrust bearing maintenance without dismantling.

The bearing shall have removable metal-lined bearing pads. All guide bearing gaps shall be adjustable and the pads shall be easily replaceable.

The bearing shall be arranged so as to permit vertical movement of the runner of an amount sufficient for clearing the male and female portions of the shaft coupling.

Suitable lifting eyes and shall be provided to facilitate removal and installation of the bearing.

An appropriate oil mist suction device shall be supplied by the Contractor.

The bearing shall be of self-pumping type. If the flow achieved through self-pumping is thought insufficient then it shall be supplemented by the use of external motor-driven oil circulation pumps, or other such system. It is recognized that multiple shoe bearings provide greater mechanical stability, facilitate adjustment of bearing clearances and are easier to handle during dismantling, maintenance and repairs.

Guide bearing shall be equipped with temperature and vibration detectors. Temperature detectors shall be installed in more than one position and symmetrically around the bearing perimeter.

Means shall be available for draining and refilling the bearing oil.

The bearing pot shall have sufficient oil so that the machine oil temperature alarm will not be exceeded when there is no cooling water flow over a 30 minute period.

The same make and grade of oil shall be used in the pumpturbine and motor-generator guide bearings, thrust bearing and pumpturbine governing system. Preferred will be oil according to ISO VG 46. A sufficient oil quantity for the first oil charge shall be included with the initial first fill supply.

The guide bearing shall be designed so as to permit easy access to the shaft seal for maintenance. The bearing housing shall be split vertically into two or more sections to facilitate dismantling, and the bearing housing shall be doweled securely. The guide bearing shall be designed such that the normal working temperature does not exceed 80°C (just underneath the Babitt-metal lining).

An unguided shut down of the unit from full load rejection without mechanical and electrical braking, as well as without the high pressure oil supply must not destroy the bearings.

The turbine bearing shall also be capable without harm for 30 minutes at the speed of 10 rpm.

The bearing shall be provided with the temperature control devices.

The bearing shall have a set of external oil coolers cooled by the unit cooling water system. It shall be possible to manually changeover coolers to facilitate maintenance whilst the unit is in operation without tripping it.

Special measures shall be undertaken by the Contractor to avoid contamination of the station drainage system and reservoirs with oil. All necessary precautions must be undertaken in the bearing design, including provision of oil trays and oil traps to keep it out of the top cover drainage system. The isolating valves on the bearing oil drain pipe shall be provided with padlocks. The bearing shall be equipped with an oil sampling system for periodic analysis.

2.4.5 Shaft seal

The sealing arrangements on the turbine shaft shall be of the axial mechanical type and shall employ renewable elements. A radial design will not be permitted. Special attention shall be paid to durability and minimum wear and it is required that the wearing part shall be able to operate without attention for a minimum of five years.

The design shall nevertheless permit easy inspection and maintenance, without disturbing the guide bearing. A visual wear indicator shall be accessible during routine inspections. The dismantling of the seal for maintenance without dismantling the bearing is not required.

Provision shall be made for drawing off leakage water, containing it local to the shaft seal, and gravity draining it from the top cover region by a closed pipework system. Arrangements shall be made so that the leakage flow can be monitored and seal wear indicated, as an aid to maintenance and as a measure of the shaft seal performance.

The seal shall be continuously supplied with filtered water (supplied from the cooling water system) at a pressure sufficient to prevent any grit, silt or other foreign matter from entering.

The requirement for operation of the unit with the runner spinning in air shall be noted. The shaft seal shall therefore seal well against air under pressure as well as water, in order to economise the consumption of blowdown air.

An inflatable maintenance seal shall be provided to permit examination of the main seal parts and, if necessary, exchange of the wearing elements, without the need for dewatering the pumpturbine.

2.4.6 Spiral case with stay ring

The spiral casing, with the stay rings and stay vanes, shall be made as an integral assembly unit having proper hydraulic dimensions and shape.

The spiral casing shall be designed for both the design pressure and the long term low-frequency fatigue stresses expected for pumpturbine operating duty. It shall be manufactured, together with the stay ring, out of welded carbon steel. All hydraulic passages shall be designed for bi-directional flow.

All the plate elements in the spiral casing assembly shall be precision cut to exact dimension and all edges chamfered as required for butt welding. The spiral casing shall be welded together onto the stay ring in the manufacturer’s factory, before delivery to Site, as far as possible. All components shall be marked to permit easy assembly at Site.

Although the spiral casing is to be embedded in concrete, it shall be designed to withstand the internal pressure due to the maximum head (including maximum water hammer) without any support from the surrounding concrete.

The stay ring shall consist of cast steel or solid welded steel upper and lower rings, in sections, with cast or welded steel vanes jointing the upper and lower ring segments. The vanes shall be designed to guide properly the flow of water, to carry the tensile load due to the water pressure in the spiral casing and the compressive load due to the weight of the concrete and motor-generator.

The spiral casing shall be solidly embedded in the foundation concrete. The necessary provisions shall be arranged for the axial forces and the moments on the spiral casing to be transferred to the concrete foundations by means of collars and anchorages.

The material specification and the thickness of the steel plate at the inlet shall be as stated in the data sheets. The design shall include 2 mm corrosion allowance.

The spiral case shall be transported to site as one piece as shown in the civil cavern drawings.

The spiral casing shall feature a flange at the upstream end of the intake piece in order to mount the dismantling joint assembly located downstream of the main inlet valve.

Entry to the spiral casing shall be provided by a manhole located on the dismantling joint assembly between the main inlet valve and the spiral inlet flange.

The spiral case shall undergo a pressure test in the workshop or on site. The requested pressure shall be 1.5 times the maximum design pressure.

Depending on the general work time-schedule and sequence of installation one or two sets of pressure test equipment shall be provided including bulkhead, dummy distributor and all related test equipment.

The Contractor shall provide all the necessary equipment for the spiral case water pressure test, for example bulkhead and dummy distributor.

Prior to embedment in concrete, the spiral casing shall be pressured to a fixed value and maintained at this pressure whilst the concrete sets. Typically the fixed pressure value will be minimum static head.

During erection the spiral casing will be suitably supported by concrete saddles to the requirements of the Contractor. The Contractor shall provide a suitable number of lugs for the application of jacks and the fitting of anchor bolts. The necessary jacks, anchor bolts, brackets, and stanchions required for the horizontal and vertical setting of the spiral casing during erection and for supporting and maintaining it in position during concreting shall be supplied.

The Contractor shall be responsible for the temporary internal bracing of the spiral casing during concreting and grouting. All strut assemblies and stiffeners required to prevent distortion of the spiral casing elements during fitting and positioning for erection as well as during concreting shall be provided.

The following pipework connections shall be included on the spiral casing:

- one pair of individually valved Winter-Kennedy tappings shall be provided at a suitable location (determined from the model test) on the spiral casing, arranged for turbine index testing.

It may be more convenient to install connections and associated pipework within the exposed dismantling joint assembly (that section of pipeline between the spiral and main inlet valve) rather than embedding them with the spiral casing.

- a bypass line connecting the spiral case to the draft tube to facilitate dewatering,
- a drain at a low point, discharging into the elbow of the draft tube,
- a spiral balance pipe connection at a high point to connect with the draft tube for use during blowdown operation,
- one or more pipe connections to safely exhaust the air during priming,

located at a high point, if required, four tappings equally spaced around the periphery of the spiral casing inlet section, each at an angle of 45 degrees to the vertical plane, each individually valved and connected to a measuring manifold, to measure the head at the pumpturbine, complete with a valved drain line for flushing,

- one or more tappings on the inlet piece to accommodate the temperature measuring probes associated with the thermodynamic testing,
- an additional single tapping on the inlet piece for measurement of pressure fluctuations.
- two or more stay vanes shall be drilled to relieve leakage build up on the top cover, where possible the pipework will consist of straight runs to permit rodding.

All pipes, pipe brackets, connectors and fittings shall be provided.

2.4.7 Head cover

The head cover shall be made from carbon steel and bolted onto the stay ring. It shall support the regulating apparatus and turbine guide bearing. The head cover shall be designed and manufactured as one part. It shall be stiffened to withstand, without excessive deformation, the maximum design pressure.

Machined surfaces shall be provided to accommodate the guide bearing support, the shaft seal mounting, and all accessories. The guide vane bearing housings shall be made readily removable so that the bearing replacement or guide vane removal can be easily undertaken without major dismantling of the unit. A machined flange shall be provided for the connection to the stay ring.

The upper stationary labyrinth (one or more wearing rings for sealing) shall be manufactured from stainless steel and bolted to the head cover. The material hardness shall be sufficiently different from that of the runner in order to reduce the possibility of seizing should the two rub together, i.e. galling failure. There shall be a facility to measure labyrinth clearance during routine maintenance, for example four off removable plugs installed at 90 degrees to each other.

A stainless steel weld overlay layer shall be provided on the top cover adjacent to the guide vanes, covering the space between the periphery of the runner and the outside diameter of the top cover. A separate renewable stainless steel cheek plate shall not be provided. The inside face, that above the runner crown, shall be designed to minimize friction and swirl.

Leaked water shall be easily drained from the top surface of the head cover through opened holes at the ribs.

The deflection of the head cover shall be measured during commissioning. The Contractor shall provide all instrumentation for this purpose

- The head cover shall have possibilities for stabilization air admission.
- The head cover shall be designed to withstand all operational conditions.
- Construction: The head cover shall include the following features:

- Gate trunnion bearings equipped with self-lubricating bearing bushes, having also thrust faces to locate the guide vanes vertically
- Appropriate seals for the gate trunnions
- Optional (additional costs): Conveniently removable and renewable stainless steel stationary facing plates opposite to the guide vanes.
- Conveniently removable and renewable stainless steel stationary labyrinth type sealing rings facing those on the runner.
- Four feeler holes for checking both the upper and lower labyrinth and wearing ring clearances, located at quarter points around the periphery.
- provision for cooling water supply pipes to a chamber in the labyrinth, for use during blowdown operation
- unloading pipe connecting the area above the runner with draft tube, if required
- air exhaust/ supply system to be used during blowdown
- at least one pressure tapping for measurement of pressure fluctuations between the guide vanes and the runner
- two pressure tappings, normally plugged, at different radii on the same radial section, for provision if required to investigate pressure distribution in the region between the runner crown and top cover

All pipes, pipe brackets, connectors and fittings shall be provided.

2.4.8 Bottom ring

The bottom ring shall be made from carbon steel and bolted onto the stay ring. It shall be stiffened to withstand without excessive deformation the maximum design pressure, and deformation forces present during embedment and spiral pressure testing.

The lower stationary labyrinth (one wearing ring for sealing) shall be manufactured from stainless steel and bolted to the bottom ring. The material hardness shall be sufficiently different from that of the runner in order to reduce the possibility of seizing should the two rub together, i.e. galling failure. There shall be a facility to measure labyrinth clearance during routine maintenance, for example four off removable plugs installed at 90 degrees to each other.

- The bottom ring shall contain self-lubricating bearings for the lower trunnions of the wicket gates.
- Appropriate seals for gates trunnions.
- Optional (additional costs): Conveniently removable and renewable stainless steel facing plates.
- Stationary labyrinth and wearing rings facing the rotating ones.

- provision for cooling water supply pipes to a chamber in the labyrinth, for use during blowdown operation,
- the peripheral drain pipe connections (pipes between closed guide vanes and runner), for use during blowdown operation (if required),

The bottom ring will be removable in order to allow a runner dismantling from the draft tube side.

2.4.9 Draft tube steel liner including draft tube cone

The draft tube shall consist of a welded carbon steel plate structure embedded in concrete. The draft tube shall include the draft tube cone, bolted to the bottom ring, elbow and draft tube extension piece. The extension piece shall connect to the draft tube extension tunnel steel liner.

As an integral part of the draft tube the body of the draft tube gate should be integrated into the design. Further details to the draft tube gate are stated in chapter 5.

The lowest point of the draft tube liner will have to be coordinated with the engineer responsible for the detailed design of the cavern.

The draft tube section shall transform smoothly along its length and shall be fully circular in section, at the point where it joins with the draft tube extension tunnel steel liner, of the diameter shown on the related drawings.

During the design process, 3-D CFD analysis will be performed on the draft tube passage to demonstrate optimal outflow conditions across the head range and study the effects of any rope-vortex swirl or other adverse effects during part load generation operation. In addition the effects of smooth pump inlet flow shall be verified.

The draft tube should come in as few pieces as possible to site in order to minimize field works. Make-up elements shall be properly prepared for field welding and shall be provided with sufficient welding clips and fitting up bolts or similar means for holding the plates in correct position until welded.

The draft tube liner shall be reinforced with continuous circumferential and longitudinal stiffeners placed at sufficiently close centres so as to prevent distortion and reduce vibration to a minimum. All such stiffeners shall have sufficient holes adjacent to the plate surfaces to ensure free passage of air and grout when the liner is being concreted in.

The draft tube liner shall be tied into the surrounding concrete by a sufficient number of anchor irons. A water level depression control system, for use during blowdown operation, shall be installed at the suction cone.

The draft tube cone manhole (min. DN 800) shall have a test stopcock adjacent to bottom of door for checking water level. The manhole shall be sized sufficiently generously to allow access for a thermodynamic test downstream measuring frame.

The inside face of the manhole shall be arranged to conform with the general shape of the inside of the draft tube cone so as to present a smooth passage for the water. The manhole shall allow the installation of a platform for inspection and maintenance beneath the Runner.

One inspection and erection platform shall be provided. The erection platform shall be designed and equipped so as to ensure easy and safe inspection and erection work. Its main cross-members shall be supported in suitable pockets provided in the liner. There shall be necessary guide supports on the bottom of the concrete entrance for pushing the platform beams into the draft tube. The platform shall be an all aluminium construction and feature a man door (if the dimensions will allow a man door) on the platform to enable ladder access to the bottom of the draft tube.

During erection the draft tube will be suitably supported by concrete saddles to the requirements of the Contractor. The Contractor shall provide a suitable number of lugs for the application of jacks and the fitting of anchor bolts. The necessary jacks, anchor bolts, brackets, and stanchions required for the horizontal and vertical setting of the draft tube during erection and for supporting and maintaining it in position during concreting shall be supplied.

The Contractor shall be responsible for the temporary internal bracing of the draft tube during concreting and grouting. All strut assemblies and stiffeners required to prevent distortion of the draft tube elements during fitting and positioning for erection, as well as during concreting, shall be provided.

The stiffeners of the draft tube shall be designed for an load of min. 1.5 m concrete layer above the upper horizontal surface of the draft tube liner. All welding shall be absolutely watertight.

To facilitate grouting, the Contractor shall provide a sufficient number of holes and pressure connections. After grouting has been completed the Contractor shall close the holes by means of metal plugs welded in position and ground to a smooth finish to conform with the surface profile.

The interface at the end of the draft tube shall be 11.9 m downstream from the turbine axis at the start of the transition (rectangular to circular) part. The section from the basic design is approx. WxH 4.0x1.8 m and will be finally determined by the turbine supplier

The following connections shall be supplied and installed by the Contractor for the unit:

- Drainage box with a steel grating to be installed at the bottom of the draft tube prepared for connection to an approx. 200 mm diameter drainage pipe. Installation of the drainage box will be done by the Contractor. Supply and installation of the drainage pipes from the drainage connection extending to the dewatering sump pit including all valves in all concrete stages must be in the scope of the Contractor. The pressure tightness and pressure test shall be performed as well as the test report by the Contractor.

- One connection for a compound pressure/vacuum gauge at the draft tube cone, complete with hand operated shut off valve and seamless steel piping up to the instruments.
- the spiral balance pipe connection, located close to the bottom of the suction cone, for use during blowdown operation,
- the peripheral drain pipe connection, for use during blowdown operation (if required),
- one or more entry points through the suction cone wall for blowdown air, if required,
- unit cooling water take-off connection, complete with securely bolted but removable stainless steel grid fitted over the mouth
- provision for thermodynamic test equipment in the draft tube extension piece.
- Necessary number of recesses for erection platform beams
- All necessary air admission piping and holes for decreasing the vortex effect

2.4.10 Test Head and Test Ring

2.4.10.1 Test Head

The Contractor shall provide at least one test head with the turbine for closing the spiral casing inlet for the hydrostatic pressure test and hydrostatic pressure during concreting.

The test head shall be flanged or field-welded to the casing and will be re-moved by the erector after completion of field pressure test and concrete works.

The required number of test heads the Contractor has to supply shall be determined according the contract time schedule. If the test head will be used for more than one unit an extension length of straight pipe of the test head shall be considered.

2.4.10.2 Test Ring

The Contractor shall furnish with the turbine at least one test ring, complete with bolts, nuts and round rubber gasket, for closing the stay ring bore during hydrostatic pressure testing and concrete works. The test ring will be used in the other turbine and shall be shipped with the first turbine. The test ring shall be designed to permit installation and removal with a minimum amount of field work. The test ring shall also be provided with eye bolts or lugs to facilitate handling with the cranes.

The required number of test rings the Contractor has to supply shall be deter-mined according the contract time schedule.

2.4.11 Wicket gate mechanism including servomotors

Guide vanes

The guide vanes shall be manufactured, cast in one piece with their stems, or forged, in the same grade stainless steel as the runner. The guide vane passageway (formed by welded overlay) shall also be stainless steel, but of a softer grade so as to prevent galling.

The hydraulic profile of the guide vanes shall be fully homologous with the model on which the performance is proven.

Due account shall be taken of bi-directional flows and the fluctuating loads which may be experienced.

The number of guide vanes shall be selected, in combination with the number of stay vanes and runner blades, to minimize the likelihood of undesirable pressure fluctuations or vibrations.

All surfaces exposed to the flow shall be ground to accurate template forms or CNC machined to obtain even and smooth surfaces without depressions, projections or other defects liable to affect the performance or cause premature wear.

The guide vanes shall be adequately supported on the top and bottom stems by substantial renewable bearings. Provision shall be made in the guide vane bearings for supporting axial loads. The bearings shall be in removable housings bolted to the top and bottom rings, and the bearing shells shall be easily renewable in the housings. The lower bearings shall be accessible and dismountable from below. The seal of the middle guide vane bush will be replaceable without removing the top cover.

<u>Regulating apparatus and servo motors</u>

The guide vanes will be regulated via an operating ring design with 2 servo motors operating all wicket gates. Additional for 2 wicket gates a separate servo motor shall be foreseen. In case the detailed design reveals, that more than 2 guide vanes need individual control to meet all technical requirements of the plant, it is the Contractor’s obligation to make all necessary changes to his design on no additional cost for the Employer

- Each guide vane will be monitored and provided with a position indicator.
- Two guide vane has the possibility to make movements out of the collective positioning.
- All bearings of the apparatus shall be of the self-lubricating type.
- Mechanical stoppers should be positioned in a way that collisions between the guide vanes and or the runner can be avoided.

The servomotors shall be of seamless fabricated steel body construction designed to withstand the maximum possible oil pressure during the governor operation. The servomotor shall be provided with two oil drainage points, bleed points, bleed couplings for air bleeding, and connections for pressure measurement.

The servomotor pistons shall be arranged so that at either end of their stroke the velocity of the moving parts is decreased to avoid slamming, the cushioning effect being obtained by means of orifices or other devices arranged for adjustment on Site.

When sizing the guide vane servomotors normal operation, runaway and transient conditions shall be considered together with the hydraulic torque data collected during the pumpturbine model tests.

2.4.12 Turbine pit liner

The turbine pit liner shall be manufactured from welded steel sheets which extend from the stay ring to the turbine floor. The turbine pit liner shall be equipped with anchor rods, and be of sufficient thickness to permit mounting of piping.

However the pit liner should not take any structural loads. Lighting and instrumentation shall be recessed. Piping, as far as possible, shall be routed under the walkway. The Contractor shall supply pathways, platforms, stairs and foot plates to allow access into and around the turbine pit.

A rotating radial runway beam together with hoist shall be provided in the pumpturbine pit, supported from the generator-motor lower bracket and of sufficient capacity for lifting the entire compact part of the pump turbine.

2.4.13 Permanent Flow Measuring System

A permanent flow measuring system shall be installed which shall provide a continuous flow indication, for the unit, and also record cumulative flow per unit over the life of the power station.

The system may take the form of ultrasonic probes installed in the unit penstocks, or any offered alternative system provided the uncertainty is in line with best industry practice.

The measuring devices shall be placed in accordance to the general hydraulic protection system.

For the detail positions of the measuring system see Section VII, Part 3 Power Plant Equipment – Control system.

2.5 Model test

A fully homologous model test shall be carried out by the Contractor. The model test shall be carried out in the laboratory of the Contractor. The turbine efficiency and the cavitation limits shall be determined by a series of tests on a scaled turbine model. This pumpturbine; including its associated main water passages shall be made in an approved manner in accordance with IEC Publication No. 60193 and witnessed by the Employer. The model shall be homologous with the prototype, pumpturbine and its water passages and the tests shall be made under homologous conditions corresponding to those for which guarantees have been given by the Contractor. The model test shall cover the operating range at the weighted efficiency points, as well as absorbed operating limit, cavitation, power, runaway speed and hydraulic forces.

Perspex-made inspection windows and banks shall be provided at the model pumpturbine to permit topmost observation and photographs of the cavitation and vortex phenomenon.

The tested model shall be presented to the Employer and all effort and respectively costs are part of the offer. The contractor shall submit dimension drawings of the model turbine, as well as reports and description for the used calculations.

A maximum total test rig tolerance of +/- 0.25 % is accepted.

If guaranteed values of the unit will be based on a homologous base line model and no model test for the Manara unit will be executed, a report must be prepared for the Manara unit derived from the existing model tests and will be subject to approval of the Employer.

2.5.1 Efficiency

The efficiency of the prototype shall be determined from the efficiency of the model by the current IEC 60193 model stepped-up formula.

The correction shall be applied to the point of maximum efficiency of the model. The efficiency (percent) of the pumpturbine, at other points tested, shall be the model efficiency (percent) increased by the same amount (the same number of percentage points) as for the point of maximum efficiency. All parts forming or lying within the pumpturbine water passages shall be homologous to those of the final, accepted model.

2.5.2 Cavitation and Vortex

The cavitation limits of the pumpturbine shall be determined by the model tests under corresponding conditions of headwater and tailwater levels sufficient to cover the entire operating range to be expected in service.

To determine the cavitation limit of the pumpturbine for any desired power output and head, the model shall be tested under homologous conditions by operating it at a constant speed corresponding to such desired head, at a fixed gate opening suitable to produce a power output corresponding to such desired power output, under a constant head on the model, and by varying the test tailwater level. The efficiency, the discharge (flow of water), and the power output of the model shall be determined for the various tailwater levels of the test.

The cavitation limit of the pumpturbine for such desired power output and head shall be the lowest tailwater level of such test below which the efficiency, the discharge and the power output of the test cease to remain constant.

2.5.3 Test Heads and Loads

Complete tests shall be made at model unit speeds corresponding to all guaranteed heads and at gate openings corresponding to the partial loads. All operation points that are stated in the proposal datasheet needs to tested.

2.5.4 Turbine Mode

- The efficiency behaviour, the discharge and the resulting capacity will be tested for the entire guaranteed operation range. The total operation range from no-load to maximum load at different head conditions will be tested.
- The cavitation and vortex behaviour and general flow conditions shall be tested and documented by sketches, photos and movies.
- Wicket gate torques and forces in the bearings have to be measured at 4 wicket gates for the entire operation range, overspeed and runaway speed of the turbine.
- The hydraulic axial thrust will be measured and the runaway speed will be determined.
- The need for a stabilization air in part load will be checked and
- Pressure fluctuations will be measured for the guaranteed operation range, overspeed and runaway speed including a frequency analysis of the fluctuations.

2.5.5 Pump Mode

- The efficiency behaviour, the discharge and the resulting capacity will be tested for the different wicket gate openings from Q_P=0 to Q_P=max.
- The cavitation and flow behaviour shall be tested and documented by sketches, photos and movies. The cavitation limits shall be recorded.
- Cavitation start a suction and pressure side of the wicket gates.
- Start of changing efficiency under cavitation influence
- Wicket gate torques and forces in the bearings have to be measured at 4 wicket gates for the entire operation range
- The hydraulic axial thrust
- Pressure fluctuations measurement as for turbine mode
- Water level of blown down pumpturbine runner

2.5.6 Runaway Speed

Measurements with allowing the determination of the maximum runaway speed shall be done.

2.5.7 Radial forces at the runner

Measurements over the entire operation range, overspeed and maximum runaway speed for pump and turbine mode shall be done.

2.5.8 Four quadrant measurement

The measurement of the full characteristic diagram in all 4 quadrants in relation to speed and wicket gate opening shall be done. The diagram shall be transmitted to the Employer in digital version (Excel format) and three (3) hard copies.

2.5.9 Additional Test and Measurements

Additionally the Contractor shall establish a list of supplementary tests that he will have to perform on his model including but not limited to the following:

- air admission test and determination of necessary air pressure and discharge
- calculation of the transient behavior (water hammer calculation) and based on that calculation of the axial forces at the shaft, torques at the wicket gates etc.

2.5.10 Test Report

After full acceptance of the data, curves and measurements of the components of the tested model, the Contractor shall prepare a model test report.

The test report shall include a full video coverage of the entire test as an digital attachment. In the video the different operation settings must be clearly visible.

In addition the detailed photo documentation of all covered test and operation points shall be attached to the report.

The complete test report shall be submitted to the Employer digital and in five (5) hard copies latest 5 weeks after the acceptance test.

2.6 Inspection and Tests

2.6.1 General

Inspection and tests shall be made in accordance with the EPC Contract, as completed and/or modified by the following specifications:

The Contractor shall furnish the Employer with certified copies of shop tests.

All inspections and tests required by IEC or other local authorities shall be performed by the Contractor.

A detailed inspection plan overview will be part of the Contract.

The Participant shall submit with the Proposal a preliminary Inspection and Test plan (ITP) based on the RWHM (Guidelines for Materials in Hydraulic Machines 2009). The final ITP shall be agreed as specified in Annex 10 (Test on Completion) to the EPC Contract.

2.6.2 Tests at Workshops

2.6.2.1 Tests on Raw Components

- Chemical analysis of the material used for the main components such as runner, shaft, wicket gates, fixed and rotating labyrinth and sealing rings, draft tube liner, stay vanes, spiral casing, head cover, bottom ring, servomotor cylinders, air/oil pressure receiver

- Mechanical resistance tests on materials used for the same components shall include tensile strength, yield point, elongation, bend, impact (Charpy V-notch)
- Ultrasonic inspection of the steel plates over 25mm thickness used for spiral casings, head covers, bottom rings, draft tube liners, pressure vessels.

2.6.2.2 Tests on Welded Components and Assemblies

- 100 % ultrasonic testing of all major stress exposed and full penetrated welds of the spiral casings, turbine head covers and bottom rings, draft tube cone (draft tube elbow shall be subject to dye penetration testing), pressure vessels, servomotor cylinders.
- Radiographic examination, only where ultrasonic examination is doubtful.

2.6.2.3 Tests on Cast Steel Sections

- Magnetic particle inspections are required to cover the whole surface of the steel castings with no linear indications as the acceptance standards.
- All castings shall be subject to inspection by the Employer prior to annealing and after annealing but before machining.
- Defects disclosed in castings shall be chipped to sound clean metal before repairs are made. If the removal of metal to correct the defect reduces the stress-resisting cross section of the casting more than 50 % in excess of the area required for the allowable stress, no repairs shall be permitted without the Employer’s approval in writing and the casting may be rejected. Castings requiring welding repairs after annealing shall be re- annealed after repairs unless waived by the Employer.
- Repair of main cast pieces shall be allowed only after Employer’s approval. In this case, the repair procedure shall be submitted to the Employer for approval in time so as not to interfere with the progress of the work.

2.6.2.4 Test on Pumpturbine Runners

The turbine runners vanes shall be checked for surface roughness, originally specified by Contractor, especially on the water flow side. Liquid penetrant inspection or magnetic particle inspection shall be performed on all surfaces of the vanes.

Furthermore, ultrasonic or radiographic inspection of all doubtful indications found by one of the above methods and of all heavily solicited parts shall be made.

2.6.2.5 Tests on Pumpturbine Shaft and Flanges

- Examination of shaft boring to Contractor’s standards with no segregation or cracks.
- Surface roughness inspection (surface roughness to be originally stated by Contractor).
- Ultrasonic examination.

2.6.2.6 Tests on Wicket Gates

- Liquid penetrant or magnetic particle inspection shall be made.
- Furthermore, ultrasonic or radiographic inspection of all doubtful places indicated by one of the above mentioned methods shall be made.

2.6.2.7 Shop Assembly and Tests

- The pumpturbine (insofar as practicable, shall include subassembly of stay ring and vanes, head cover, labyrinth and wearing ring, shaft seal, guide bearing, turbine regulating mechanism assembled separately as far as possible), governor and as much as possible of the oil pressure piping shall be assembled, aligned, fitted and tested in contractor’s shop and properly match marked to insure correct assembly and alignment in the field.
- All parts of the pumpturbine including the related auxiliaries and piping, which will be subject to high pressure water under operating conditions, shall be tested for a period of 60 minutes under a hydrostatic pressure of not less than 50 % above the design pressure.

2.6.2.8 Defects and Corrections

Any leakage, distortion, or other defects developed during or after the tests shall be corrected to the satisfaction of the Employer. The tests shall be repeated, if in the opinion of the Employer further tests should be necessary.

2.6.3 Field Measurements and Tests During and After Installation

2.6.3.1 General

The procedures for testing of the equipment to ascertain its conformity with the specifications will be in accordance with the „Guide for Commissioning Operation and Maintenance of Hydraulic Turbines“ - document (Central Office) 30 of the IEC.

After the pumpturbine and governor have been installed, and before putting this equipment into service, they shall undergo field tests. Upon completion of satisfactory performance of the tests, the equipment will be put into operation by the operating personnel under the direct supervision and responsibility of the Contractor.

Tests that are expected to be performed during site commissioning and performance testing of the pumpturbine include:

- watering up,
- bearing heat run,
- unit overspeed trip test,
- governor stability,
- trip and load rejection,
- MIV operation,
- power output and power input tests,
- mode changeover tests,
- vibration, pressure and power fluctuations foot print,
- pumpturbine site efficiency,
- permanent flow measuring equipment tests,
- reliability trial.

The Contractor shall provide, install and subsequently remove, any temporary equipment and instruments required to carry out all measurements during the commissioning and site tests. Provision at the manufacturing stage for any tappings, fixing lugs, cable glands, pockets, etc., likely to be required for the tests, shall be made by the Contractor. The cost of such provision shall be included in the prices of the Plant.

The Contractor shall provide all test personnel required to carry out commissioning and testing.

All commissioning activities shall be fully documented. Method statements and test procedures shall be produced prior to each commissioning activity. They shall be amended to record the actual, rather than envisaged, commissioning process and parameters. All drawings of importance for the tests, and all relevant data, documents, specifications, certificates and reports shall be made available to the Employers Engineer during the tests. Copies of all test results shall be handed over to the Employers Engineer as the tests proceed.

Before start commissioning of the pump turbine the reservoirs and power water ways will be filled. The upper reservoir will be filled up to 95% of the active storage volume.

2.6.3.2 Alignment of Combined Generator and Turbine Shaft

Shall be made according to NEMA Standard No. MG 5.2 1972.

2.6.3.3 Field Tests

* Efficiency and power tests should be performed according to IEC Publication 60041, „International Code for the Field Acceptance Test of Hydraulic Turbines“. The thermodynamic method shall be applied. All provisions for the measurements as penstock measuring points, all necessary piping, shut off valves and related equipment shall be part of the pumpturbine supply. For pressure taps and taps for installing the probe hose necessary in the penstock the taps will be supplied by the Contractor. All necessary information about location of installation and kind of pressure taps must be delivered by the pumpturbine Contractor.

  The Contractor shall indicate in the proposal for the Employer’s consideration the total cost for performing the absolute efficiency test. The cost shall include all labour and materials required to perform this test.
* The maximum opening values of the wicket gates shall be checked and operating limits shall be established, considering noise level, or output and/or efficiency decrease.
* Should there exists some range of load in which continuous operation may seem to be undesirable, the limits of this range shall be established and an agreement shall be made on how to eliminate the trouble and/or how to pass through this range.
* The field tests of the governing systems shall be performed according to IEC Publication 308, „International Code for Testing of Speed Governing Systems for Hydraulic Turbines“ or other practicable method to be agreed upon.

* Field tests for overspeed shall be performed only after taking all proper precautions, such as having all emergency devices ready to operate.

3 GOVERNOR

The equipment to be supplied is shortly described in the following pages. The Contractor shall bind himself to supply a complete assembly in perfect operating conditions and equipped with all necessary safety devices.

The performance of the controller must be adapted to the intended operating modes of the pump turbine including all necessary switch over between the operating conditions.

The governor shall safely control the guide vane position during automatic start-up and loading including synchronizing the unit to the grid, and normal and emergency shutdown sequences and all other mode changes, no manual operation shall be carried out at any stage. The governor shall interface with the unit controller. The governor shall be integrally connected to automatically operate and control the speed of the pumpturbine during generating and pumping as necessary.

When the unit is operating as a pump, the governor shall operate the guide vanes during start up and stopping, adjust the guide vane openings automatically to the optimum efficiency position with reference to changing pumping head over the complete pumping mode, and close the guide vanes automatically on shutdown.

Start-up and shut down shall be both locally and remote controlled, respectively from the turbine control board and from the control room.

Testing and emergency situations, as well as start-up and shut down operations shall be carried out from the turbine control board.

The Contractor shall furnish a detailed description of the automated interlocking and control systems proposed within his scope of supply.

3.1 Type

The governor shall be of the PID type. The governor head shall be of the electronic type either with speed signal and power supplied by a pilot alternator or with a speed signal supplied by a speed or frequency detector with independent power supply system.

The Governor shall be able to control power and speed.

3.2 Requirements for Characteristics

The regulation system shall operate in accordance with the needs of the electric power supply system, both for the operation of the power station as a "local dispatching center" regulating the frequency and complying with the load programmes and for the operation with a frequency power type regulation system.

The speed regulation must be stable for the operation on an isolated network. In case of a sudden load fluctuation, the governor shall progressively restore the unit to its normal operating speed, with no harmful oscillations.

The governor furnished under this specification shall sense the speed of pump turbine rotation, determine an error signal and there from develop a hydraulic control signal of sufficient power to regulate the gate servomotors to control the hydraulic turbine in accordance with the operating requirements stipulated in paragraph 2.2.7 „Planned operation pattern“ here above.

The governor shall be realised as a programmable logic controller (PLC) with a touch panel operation. For emergency cases an operation without the touch panel shall be possible. The necessary control and monitoring equipment has to be foreseen.

The control concept has to realize different closed loop control functions in turbine mode, including:

- Rotation speed control for no load operation and island mode
- Opening control of guide vans
- Discharge control
- Power output control; operation at output limitation with power feed back
- Control function for island operation of the unit
- Load frequency control with adjustable dead band in turbine mode.
  The offered primary load frequency control power is given as a set point from the control system to the governor. If the frequency deviation is within the dead band no change of generated power will be done. In case of a frequency deviation of -200 mHz the whole offered primary control power has to be delivered additionally. In case of a frequency deviation of +200 mHz the output power of the unit has to be reduced by the whole offered primary control power. If the frequency deviation is between the dead band and the limits of ±200 mHz the necessary primary control power will be adjusted linearly
- Quick shutdown in case of mechanical failures
- Emergency shutdown in case of electrical failures
- Special function for turbine filling, guide van opening for pump operation mode, calibrating of turbine position sensors, manual control of guide vans in case of revision
- Minimal load limit in turbine mode
- Non jumping operation mode changeover
- Hand / automatic mode, internal start-stop sequence
- Time synchronisation of PLC and touch panel by NTP timeserver
- Detailed signal lists and technology screens on touch panel

The governor shall consist of a main controller and an independent emergency controller.

3.2.1 Capacity

The governing system shall be capable of operating the main servomotors to obtain a minimum opening time of 20 seconds and a total closing time of not less than 10 seconds.

It shall be possible to modify the rate of movement of the main servomotors such that the opening time may be from 10 seconds to 40 seconds. It shall be possible to modify the total closing time from 5 seconds to 20 seconds. This adjustment shall positively restrict the flow of oil so that the operation of any control, safety or auxiliary device cannot cause the gate servomotors to move at a rate which exceeds the maximum for which the adjustment has been set.

A secure and rigid means shall be provided to prevent unauthorized changing of the opening or closing times after commissioning.

3.2.2 Stability and Parameter Settings

Suitable characteristics shall be incorporated in the governing system with adequate adjustment such that acceptable performance can be achieved.

The permanent speed droop regulation shall be adjustable from 0 to 10 percent.

Various parameters are used to describe the adjustments available in different governor types. The following figures are representative of an accelero -tachometric governor with temporary speed droop.

- The damping device time constant Td shall be adjustable from 0.1 to 60 seconds.
- The derivative time constant Tn shall be adjustable from 0.1 to 5 seconds.
- The temporary speed droop bt shall be adjustable from 0.1 to 200 %.

Automatic means may be provided to permit rapid load control when the motor-generator is connected to a large network.

Joint Control shall be possible; the joint controller itself will be part of the plant control system.

Governor of the generating unit required to perform primary and secondary load frequency control shall comply with the requirements of IECo.

The controller has a parameter set that allows fast synchronization to the network. The controller must operate reliably during synchronization and also during no load operation.

If instability occurs, the unit must be switched off automatically, before any danger to the unit or on the plant system arises.

3.2.3 Speed Variation

The maximum momentary speed rise shall not exceed 45 % of the rated speed in the most unfavourable conditions.

3.2.4 Dead Time

The servomotor dead time shall be less than or equal to 0.2 seconds.

3.2.5 Dead Band

The speed dead band shall be adjustable between 0 and 2 % of guaranteed speed.

3.2.6 Feedback Signals

All feedback signals for the governing system shall be provided. In case of a failure in the restoring system of the main controller a backup system with full functionality shall be provided to increase availability of the unit. The control valves will not be redundant, only the controller.

A List of hardware's and serial connected binary and analog interface signals must be given.

3.2.7 Command Signals

The speed and load command signals shall be adjustable. The range of the speed command signal shall be from 0 % of the nominal speed at zero load and zero speed droop/regulation to 200 % of the nominal speed at full load and maximum speed droop/regulation. The command signals shall be equipped to permit remote electric control.

A List of hardware's and serial connected binary and analogue interface signals must be given.

3.2.8 Gate Opening Limits

The gate shall be provided with opening limits. The gate opening limits shall be effective for all modes of governor operation. It shall be possible to remotely control the gate opening limits.

The setting range of the power setpoint value should be between -120% and + 120% of the nominal power of the unit.

3.3 Requirements for Composition and Structure

The governing system shall be complete with the following components:

- Speed Signal Generator
- Command Signal Device for Speed and Load
- Stabilizing Device
- Power Amplifiers
- Power Supply Systems

The governor shall be furnished with the necessary auxiliary devices for manual, local fully automatic and remote fully automatic control of the turbine. Said auxiliary devices shall permit transfer from one method of control to the other without disturbing the operation of the turbine.

All transmitters, contacts etc. for remote operation and remote indication of the necessary governing value shall be included in the supply.

The governor head shall be able to accept the future network regulator signals.

The active power of the motor-generator shall be used as permanent feedback.

The governor shall allow for an easy switching over from automatic control to hand control and vice-versa, at any load. In case of a major fault on the digital governor it shall be possible for the operator to continue energy production. The switching shall be adjusted accordingly.

The governor shall allow for an easy switching over from automatic control to hand control and vice-versa, at any load.

3.4 Pressure System

3.4.1 General

The governor oil pressure system for the governor (installation foreseen on turbine floor) shall consist of the oil pumps, piston accumulators and nitrogen bottles using an max. pressure of 150 bar, sump tank and the necessary oil and air piping.

3.4.2 Oil Pumps

The governor shall be provided with three (3) identical AC oil pumps, one (1) for normal duty and two (2) as stand-by, having each a capacity acc. IEC 61362 standard. The pumps shall be of the positive displacement (piston or screw) type and shall be self- priming under the maximum working oil pressure and capable of running continuously against relief or unloader valves.

The pumps shall work in a rotational mode in order to assure an equal running time of the two pumps.

The motors shall be directly connected to the pumps and shall be of the 3-phase, squirrel-cage, 380 V AC, 50 Hz low- starting current, induction type designed for full voltage starting. The motors shall have moisture and oil-resistant insulation. Automatic controls shall be furnished for supplying oil when the oil pressure in the pressure receiver drops to a present value or when its level falls under the corresponding level.

The following oil pressure switches shall be provided:

- 1 high pressure / alarm only
- 1 main pump on
- 1 low pressure / alarm only / stand by pump on
- 1 low pressure / alarm and shut down

The governor oil pumps shall be interconnected so that they can be operated independently. The necessary valves shall be furnished so as to permit complete isolation of any pump from the oil system, and to permit removal of the pump for repairs without shutting-down the governor.

3.4.3 Piston accumulators and nitrogen bottles

The governor shall be provided with a piston accumulator / nitrogen bottle system located on the turbine floor. The piston accumulator design pressure shall be approx. 120bar.

The pressure system shall be designed that in case of failure of the oil pumps acc. to IEC standards three (3) fully strokes can be done in the sequence close –open-close.

The accumulator/nitrogen bottle system shall be equipped with all necessary safety equipment to ensure the safety of the operational staff. The structural design, construction and inspection of the pressure system shall comply with any relevant legal requirements and the latest standards.

3.4.4 Sump Tank

The sump tank shall have a capacity of not less than 115 % of the active oil in the governor system (active oil is defined as that portion of the total system oil which can be returned to the sump tank by the governor system). The tank shall be provided with a suitable oil level gauge for indicating the amount of oil in the tank, a manhole for access to the interior of the tank and suitable strainers through which all oil returned from the servomotors shall pass. The sump tank shall have a supply connection for filling the tank, a drain connection for draining the tank. Connections for an oil purifier shall also be provided. All strainers shall be readily accessible for inspection and removable for cleaning.

If cooling of the governor oil proves necessary an oil/water cooler is to be in-stalled. The supply of same shall include the necessary feeder and discharge pipes, valves, connections and a flow controller in the discharge piping. The whole hydraulic governor shall be placed in a stainless steel tray which can collect minimum the total oil volume + 5 % safety of the hydraulic system.

For drainage and filling of the sump tank oil an adequate pipe to the below floor or other suitable location including a control valve shall be provided by the Contractor.

The governor shall be placed in a stainless steel tray which can collect minimum the total oil volume of the pressure oil system.

3.4.5 Piping

All interconnecting piping and valves associated with the governing system shall be furnished. All piping shall be of such size that the maximum velocity of the oil does not exceed 5 meters per second to avoid pressure waves.

The entire piping system shall be welded. Welding of branches, headers, bends, etc. shall be done in the shop as far as practicable and consistent with the requirements for shipment and erection. Adequate pipe supports shall be provided to prevent vibration and movement of the oil piping during sudden pressure variations in the lines.

Due to the small pipe diameters (max. pipe diameter 42 mm), an alternative to a welded pipe system, a high pressure pipe fitting system with formed tube soft-sealed systems without cutting rings can be used. The final decision can be done during design and agreement with O&M contractor.

All necessary studs, bolts, nuts, washers, oil resisting gaskets, packing, etc. required in connection with the field assembly of the governor oil piping system shall be furnished by the Contractor.

The structural design, construction and inspection of the piping shall comply with any relevant legal requirements.

3.5 Auxiliary Functions

3.5.1 Speed Switches

Auxiliary speed switches shall be supplied, mechanical or electrical, independently adjustable. All switches shall have electrically separate contacts and be readily changeable from circuit opening to circuit closing, as desired. The switches shall be supplied as follows:

- One (1) electrical overspeed switch: 110%, delay time to be adjusted after load rejection test during commissioning
- One (1) electrical overspeed switch: 130%, delay time to be adjusted after load rejection test during commissioning
- One (1) mechanical overspeed switch: 140%, final setting after over-speed test (for the mechanical overspeed, there is a tolerance of ± 5%)
- One (1) mechanical overspeed switch with adjustable range, to initiate shut-down at max. operating speed (at approx. 140 % rated speed).
- One (1) electrical overspeed switch to initiate unit stopping and shut-down at approx. 110 % - 120 % rated speed.
- Space shall be provided for one additional switch.

Instead of the mechanical overspeed switch a failsafe and redundant electrical overspeed protection can be provided.

3.5.2 Gate Position Auxiliary Switches

The gate position will be calculated by the digital controller. Necessary control relays have to be provided as follows:

- One (1) switch to close at zero gate position for use in the automatic generator brake circuit.
- Two (2) switches; one to close and one to open at zero gate position for supervisory indication.

- One (1) switch to close at and below speed-no-load gate position for use in the generator breaker trip circuit.
- One (1) switch to close slightly above speed-no-load gate position to be used in the governor dashpot by-pass solenoid circuit.
- One (1) switch to close at full gate open position for supervisory indication.

3.5.3 Hydraulic Hand Control

Manual control of the turbine gates shall be provided at the actuator. Manual control shall be continuous over the full range of the gates' opening and gates' closing stroke. The transfer from actuator to manual control and vice versa shall be accomplished by a manual control button accessible from the front of the actuator cabinet. The manual control shall be supplied with an indicator to show the control in service.

Manual control of the wicket gate during maintenance will be possible via touch panel and turbine governor as well as backup governor.

3.6 Indicators

3.6.1 Speed

Dual speed command signal and speed indicator shall be realized at the governor touch panel.

3.6.2 Load and Output

Dual load command signal and output indicator shall be realized at the governor touch panel.

3.6.3 Gate Limit and Position

Dual gate limit and gate position indicator shall be realized at the governor touch panel.

3.6.4 Governor Oil Pressure Gauge

The governor oil pressure shall be transmitted by a corresponding emitter to an oil pressure indicator (calibrated in bar) situated in the turbine control board.

3.6.5 Speed Signal Generator

The supply shall include at least three (3) speed or frequency detectors of the proximity sensor type or equivalent. Speed calculation and creep detection will be realized in the digital governor.

Four speed sensitive relays for the generator shall be provided. Each relay shall have two sets of ungrounded, NO contacts; with settings to amply adjustable. For each of the following speeds, one relay shall be provided for approx. 1% rated speed, 30% rated speed, 95% rated speed and 140% rated speed as required for checking the stand-still of the generator, switching-on the brakes, controlling the synchronising and announcing over-speed respectively.

The speed sensitive relays shall be located either in the station relay room or in the cubicles referred to herein for the generator terminal equipment.

All necessary piping, tubing, fittings, etc. between relays, indicators, gauges, etc. shall be furnished and installed by the Contractor. All wiring shall be connected to terminal blocks in generator terminal cabinets as specified hereafter.

The type, construction and other particulars of the relays, instruments and other control devices shall be subject to the Employer's approval.

3.7 Acceptance Tests

The value, range and/or function of each item specified shall be tested in accordance with the International Electromechanical Commission’s Publication 60308, „International Code for Testing of Speed Governing Systems for Hydraulic Turbines“ or other practicable method to be agreed upon.

Inspection tests are planned for the digital turbine controller and the hydraulic part in the factory.

The main focus will be on the mechanical design of the control cabinet, as well as a functional test with a simulation control section, which can be used to test controller transitions, switchovers, fault and message processing.

Evidence for hardware specifications and system properties must be confirmed by certified test centers (shock, temperature, EMC strengths, overvoltage strengths of inputs / outputs, etc.)

Test certificates (or type test protocols) can also be prepared for the insulation tests of the cabinet and the input and output elements.

The functional and commissioning results on the installation shall be documented by the Contractor in a complete final report.

The necessary knowledge for the proper operation of the system must be ensured with appropriate documentation and system training for the personnel.

Field Tests

Speed Governing System:

- The hydraulic governor and its auxiliary equipment shall be completely assembled in the Contractor’s shops and tested insofar as practicable.
- Servomotor cylinders and governor oil pressure system shall be subjected to a pressure test of 50% above the maximum normal pressure for a period of 30 minutes. After being tested, the equipment and piping shall be thoroughly cleaned of any liquids that may cause corrosive action

- Governor components carrying oil shall be tested for leaks after final assembly in the contractor's shop for 60 minutes at 1,5 times of maximum operating pressure in order to confirm there is no leakage.
- All hydrostatic tests shall be in accordance with the requirements of ASME Boiler and Pressure Vessel Code, or other recognized standard approved by the Employer.
- The following tests shall be carried out before operational tests:
  - Visual tests according to drawings and flow diagram
  - Check of painting
  - Check of function and characteristic of proportional valve
- Operational tests shall be performed on all equipment or device insofar as practicable to demonstrate that they function properly. Adjustable devices shall be checked for range of adjustment and given final adjustment, insofar as possible, in the shop.
- The electrical devices shall be given dielectric tests in accordance with applicable provisions of NEMA, ANSI and IEEE or equivalent standards.
- The governor shall be given shop tests that it meet the requirements specified in respect to dead band, dead time, speed sensing as per (IEC 308, IEEE 125 and ASME PTC 29). The digital governor shall be connected to a pair of main distribution valves and servomotors. For the shop tests the test rig oil pressure system shall be used. The oil pressure system (HPU with accumulator) will be shop tested in the facility of HPU sub-supplier.
- The connection between the actuator and servomotors shall include suitable restoring devices. For the dead band tests, speed sensing element shall be driven from either a suitable constant frequency power source which shall have provision for plus or minus step frequency changes of 0,01% of normal frequency or by the speed sensing device which shall be driven from a suitable constant and adjustable speed source. An oscillograph, high speed strip chart recorder, or other approved means shall be used which will provide a simultaneous and parallel record of speed, relay valve position, servomotor position and timing signal.
- A complete functional test of the pumpturbine digital governor cubicle having opening controller, speed controller, power controller and manual control switches, indicators and transducers located on this control board shall be included in the shop performance test. All input/outputs for status signal, analog signals and controls shall be individually verified during test. The digital communication link from micro processor to the plant computer shall be

simulated and functionally checked to ensure duplicates and discreet I/O signals identified in remote interface requirements.

- Stability studies; using appropriate methods, the interface of power waterway, pumpturbine, motor-generator load and governor shall be simulated to investigate the possibility of limited load, stable operation when adequate adjustment of the governor parameters are set and transient pressures and speed after load rejections are within the specified limits when the turbine wicket gate servomotor closing time are appropriately adjusted.
  If simulation cannot be done at factory then this test shall be carried out at site.

  The results of stability studies indicating the setting range of the governor parameters shall be submitted to the Employer.
- The following checks shall be done on the touch panel of the governor head in addition.

1. Entering ‘PROGRAM MODE’ with password to enable calibration mode and exit this program.

2. Entering ‘SERVICE MODE’ with password to perform:

   Wicket gate actuator adjust

   Analog input adjust

   Speed setting

   Speed droop setting

   Governor parameters

   Power supply check

Password cannot be changed by the Contractor unless written permission is given by the Employer.

4 MAIN INLET VALVE

The Francis-type pumpturbine shall be equipped with one (1) spherical type valve acting as emergency closure inlet valve. The spherical valve shall be designed to open under balanced conditions and close against double of the maximum flow in case of emergency for the 156/220 MW.

4.1 Scope of supply

4.1.1 Main inlet valve

This specification covers the design, calculations, technical drawings, manufacture including corrosion protection, erection at the factory, testing at the factory and site, packing, transportation from factory to site, storage, complete erection, documentation, testing and commissioning, training of operational staff. Additional tests and inspections during the guarantee period including documentation. The Contractor has sole responsibility for his deliverables, performance and services.

In this specification described scope of supply includes following main components for the spherical type inlet valve:

- Valve body,
- Valve rotor,
- Upstream seal assembly (Maintenance seal),
- Downstream seal assembly (Service seal),
- Shafts/trunnions,
- Shaft/trunnion bearings,
- Slinging supports,
- Hydraulic servomotors with operating mechanism,
- MIV oil hydraulic system,
- Pressure accumulator(s),
- Make up pipe,
- Dismantling joint assembly with manhole door,
- Block flanges with blind covers as a possibility for the later installation of a bypass pipe system,
- Mechanical locks for upstream seal,
- Locking pin assembly,
- Valve and hydraulic servomotor foundation embedded parts and sliding supports,
- Local control system,
- Local control and operating panel/cubicle,
- Automatic greasing system. Self-lubricating bearings are accepted too. In case of self-lubricating bearings the possibility to install a grease system shall be provided.
- Oils and greases, first lubricant fill plus 10% extra in barrels
- Set of covers, platforms, stairs, ladders, railings and access pedestals
- Set of special tools and erection devices
- Valve nameplate,
- Interconnecting pipework,

- Drain, scour valves for seals with connecting pipes and fittings,
- Instrumentation and protection devices,
- Limit switches and indicators,
- Seals,
- Plant cabling,
- Corrosion protection of the whole equipment
- Tools for erection installation and maintenance
- Shop and field tests
- Training for the Operational staff
- Operation- and maintenance manuals and full documentation of supplied equipment including as built drawings.
- any other items required for completeness.

The outline of the deliverable and performance is structured in the following way:

4.1.2 Design

- Basic and Detail design
- As-Built design
- Training of O&M staff

4.1.3 Manufacturing

- Procurement of materials
- Workshop manufacturing
- Workshop and field assembly

4.1.4 Inspection and tests

- Material tests
- Factory acceptance tests
- Field acceptance tests

4.1.5 Transportation and Shipment

- All components carriage paid to final erection position
- Packaging
- Loading, transhipping and unloading
- Transport per rail, road, ship or plane
- Transport incurrence
- Transport monitoring

4.1.6 Erection at site

- Erection tools
- Measurement surveys
- Erection personal
- Erection insurances

4.1.7 Commissioning and trial runs

- All related documents
- As built drawings
- Operating instructions and regulations
- Inspection and test protocols

4.2 Technical Guarantees

4.2.1 Head Loss

The Contractor shall guarantee the head loss across the MIV at a nominal turbine discharge of 27.2 m³/s. The pressure drop shall be calculated between the two MIV flanges and shall be stated in the data sheets.

4.2.2 Leakage

The Contractor shall guarantee following seal leakage rate according to EN12266:

Leakage rate B according EN 12266-1 Point A.4.3 is defined for following components:

- Valve body (shaft sealing)
- Maintenance sealing (upstream)
- Service sealing (downstream)

is defined as:

1. Pressure test – 30 Minutes:

DN 1500 0.3*1500 = 450 mm³/s; 450 mm³/s*1800 s = 810,000 mm³ (0,81 l)
Test pressure for leakage test: 93 bar (design pressure)

2. Pressure test – 10 Minutes:

Test pressure: 140 bar

4.2.3 Pressure equalization

The MIV shall be designed to open the valve at a maximum pressure difference of 30% of the design pressure.

4.2.4 Pressure oil system

The pressure system shall be designed that in case of failure of the oil pumps acc. to IEC standards **three (3) fully strokes** can be done in the sequence close –open-close.

4.3 Design Parameters

The MIV shall be suitable for duty as a pumpturbine inlet valve and as a pump discharge valve, both during starting of the pump and under normal operating conditions. The MIV shall act as principle protection and isolation for the pumpturbine during normal operation, emergency operation and during turbine maintenance.

As shown on the specification power house drawings the inlet valve shall be located upstream of the generating unit.

The inlet valve shall be designed and constructed for the following design parameters:

Valve type	Spherical valve
Number of valves	1 (one upstream)
Nominal diameter	1500 mm[1]
Design pressure	93 bar
Test pressure	140 bar
Capable of emergency shut down	yes
Design discharge	76 m^3/s
Closing time (adjustable)	10 - 200 s
Opening time (adjustable)	10 - 200 s
Time to fill the spiral case through by-passes	max. 300 s
Test pressure valve body	1.5 x design head
Test pressure rotor (leakage test)	1.0 x design head

The MIV shall operate primarily in automatic mode. In addition an emergency hand operation shall be implemented to open or close the valve manually.

For the following operation conditions the valve stays either in closed position or closes from an open position:

- The pumpturbine changes to standstill mode.
- The pumpturbine will be stopped due to an error. (trough the electrical or mechanical protection system)
- Automatically closure due to a MIV control error.
- Signal “Emergency closure” is active.
- The MIV will be closed from the control room or manually.

[1] to be adjusted with final spiral case inlet diameter

4.4 Design requirements for the main inlet valve

The closed MIV shall be able to seal against the MIV Design Head, and against any pumping case where the resultant pressure is greater than the maximum shut-off head developed by the pump.

The MIV shall not cause dangerous surges or water hammer under any circumstances while it is being opened or closed, or due to seal movement or any other conditions, nevertheless, automatic means for suppressing resonance shall be provided together with an alarm initiation.

Under all operating conditions the transient pressure following closure of the MIV shall be lower than the maximum guaranteed transient pressure at machine centreline as specified in the Data Sheets. This requirement shall also be met in the case of any loss of control (mechanically and electrically) of the MIV components.

The MIV shall be suitable to meet the changes in dynamic system responses.

When in open position the MIV shall offer no obstruction to water flows.

All MIV, make-up piece, and dismantling joint components shall have a design life of at least **60 operation years**, except electronic components and the trunnion bushes.

Suitable access ladders and platforms shall be provided as necessary for maintenance of MIV.

4.4.1 Valve Body

If the MIV body is a two-piece construction it shall be joined by a flanged bolted connection. The joint shall be vertical orientation and shall not be through the trunnion. The valve body shall be constructed in cast steel or combination of cast and fabricated construction to facilitate assembly and transport.

The MIV body shall be of rigid construction and shall be capable of withstanding all forces arising during valve operation without undue distortion.

The MIV body shall be mounted on soleplates of rigid design which shall be bolted to the foundations in such a manner that valve is free standing without support from the penstock. The design of the feet and foundation bolts shall be made considering the reaction from the servomotors is carried by them and not by the penstock. The valve should be designed to move slightly on the foundation pedestal (self-lubricated) to account for any axial extension of the penstock, i.e. sliding design.

The MIV shall be designed to transmit the hydraulic thrust resulting from the MIV to the upstream penstock and to the rock anchoring system. The Contractor shall calculate the maximum expected thrust in both directions.

The MIV trunnions and bearing shall be amply proportioned and shall have integral bearing bushes and inner and outer seals.

The valve body shall be of welded construction with strong circumferential ribbing to ensure ample rigidity.

A highly erosion resistant stainless steel replaceable sealing seat shall be provided at convenient place in the valve body. Replacement of the seat ring must be possible without disconnecting the valve from the penstock.

Both ends of the body shall have properly faced and drilled flanges for making watertight connections with the upstream and downstream piping.

The trunnion bearing blocks (housing) shall be of high quality cast steel and welded onto the body so as to form an integral part. The bearing of the valve rotor shall be self-lubricating type.

The trunnions shall have a double sealing and must have the possibility to change the air side sealing under pressurized conditions.

Support of the valve shall be sturdy pads welded onto the valve body. The supporting face of the pads shall be machined so to ensure perfect setting and alignment of the valve. The slide bearing between valve support and concrete foundation shall be self-lubrication and must be corrosion resistant.

Suitable thrust rings shall be provided to centralize the rotor within the body and support axial thrust. The MIV body shall have bolted flanges upstream and downstream; the upstream flange shall incorporate double seals so that seal joint can be tested by pressurizing the inter-seal space without filling the tunnel system. All test connections shall be provided.

A scour connection shall be provided at the lowest point of the MIV body and an air bleed of sufficient capacity shall be provided at the highest point. The scour connection shall be equipped with a manually operated taper plug or ball valve suitable for continuously throttling from maximum static penstock to atmospheric pressure. The drain valve shall have a capacity of 10 l/s with the min. water level. The drain and air release connections shall be provided with suitable isolating valves and the drain shall be provided with a grating suitable to prevent blockage by debris.

4.4.2 Valve Rotor

The MIV rotor shall be in cast steel or combination of cast and fabricated construction. The rotor shall have sufficient rigidity to avoid undue distortion and minimize deformation under any normal or emergency operating conditions.

The MIV rotor shall be supported in the MIV body by shafts and trunnions. The shaft shall be rigidly bolted on to the rotor by screws and dowelled. The shaft and trunnion shall be designed to safely transmit the maximum forces and torque to and from the rotor to the operating mechanism under all the operating conditions.

The shaft passing through the MIV body shall be provided with shaft sealing arrangement suitable to adjust for rotor sliding movement if any. The shaft sealing shall be of design which allows the packing to be replaceable without dewatering the penstock.

The rotor shall be fixed with service and maintenance seal seats.

A visual rotor position indicator shall be provided as well as a position transducer.

4.4.3 Sealing Arrangement

4.4.3.1 General

The valve shall be provided with double sealing arrangement, an upstream maintenance seal and a downstream service seal. Both the seals shall be sliding metal-to-metal type. The service seal shall be incorporated in the automatic operating sequence of the valve as necessary.

The seal seats, seal housing, and seal rings shall be made of solid and appropriate stainless steel. (Minimum material requirement stainless steel shall be 13% Cr – 4% Ni)

An adequate differential hardness shall be maintained between the seal seats, seal housing, and seal rings. The Contractor shall guarantee the seal seats, seal housing, and seal rings are within the respective hardness ranges. The Contractor shall guarantee against galling of the mating seal surfaces. The material shall prevent any corrosion or galvanic action that may cause the seal to stick or fail to move.

The rubber seals used for sealing the sliding seals shall not be subjected to ring rolling, have adequate hardness and be suitable for duty. These shall be of proven design.

The design of the sealing arrangement shall be such that there shall be no vibration under any operating conditions.

4.4.3.2 Upstream Seal Assembly (Maintenance Seal)

The upstream seal will be used during maintenance inspection and repair. The maintenance seal shall be operated manually by manual control valves. The seal will preferably be of double acting design i.e. actuation shall be by pressurized oil from the MIV oil pumping set in both the applied and retracted directions. In order to avoid oil to water leakage the seal rings can also be operated by pressurized water from the penstock.

The maintenance seal shall be designed to permit maintenance or replacement of the service seal with full penstock pressure.

In addition, the maintenance seal shall be provided with a mechanical locking device. The mechanical locking device shall be arranged such that once it is applied, the pressure oil closing the seal can be released without causing the seal to leak, so that the spiral casing may be safely entered. The mechanical locking device shall also provide locking for the seal in the retracted position. The position of the locking device shall be monitored to the control system.

A hydraulic interlock system shall be provided to prevent the rotor moving when the maintenance seal is applied by pressurized oil and/or when the mechanical locking device is applied. Likewise, the maintenance seal shall not be applied until the MIV is completely closed. The interlock system shall be all hydraulic, with no reliance on electrical components.

4.4.3.3 Downstream Seal Assembly (Service Seal)

The service seal will be used during normal operation of the pumpturbine and shall be automatically applied and retracted during opening and closing of the MIV by the control system. The seal will preferably be of double acting design i.e. actuation shall be by pressurized oil from the MIV oil pumping set in both the applied and retracted directions.

Where possible, the space between water and oil seals on the service seal actuation should be drained to atmosphere as a tell-tale. A wiper seal shall be installed upstream of every water seal. The housings and metal sealing area of all water seals shall be provided in corrosion resistant materials.

The service seal shall be designed to allow the valve to close against maximum turbine flow without damage to the seal.

The service seal shall be designed such that sliding seal, seal housing and seal seat can be replaced with pre-finished components after the upstream maintenance seal is applied with full penstock pressure, while the other pumpturbine unit is in operation.

A seal indicator with “on” and “off” position switches shall be provided and any seal movement or reduction of applied pressure shall provide an alarm signal to the unit controller.

An interlock system shall be provided to prevent the rotor moving as long as the service seal ring is engaged. Likewise, the service seal shall not be engaged until the MIV is completely closed.

4.4.4 Shaft Trunnions and Bushes

The valve shall preferably be equipped with greased trunnion bushes but with no grease released to the waterways. Self-lubricating greaseless bushes, with supporting information on design, suitability for this application and reliability, may be offered as an option. The trunnion bushes shall be suitable for high edge loading. The bush shall be housed in a replaceable push fit housing of corrosion resistant material and shall be replaceable without dismantling the valve.

The bushes shall be from a reputable manufacturer, and in a material that has been proven in both prototype and accelerated laboratory tests. The design bush surface loadings shall be conservative compared to the bush manufacturer’s recommended maximum. The bush design shall conform in all respects with the bush manufacturer’s guidelines and specifications.

An inner seal shall be provided on the trunnion bushes to prevent foreign matter such as grit or silt from the water entering the bush. The inner seal shall be able to withstand the maximum expected internal water pressure without any leakage. The

Employer’s preference is for double seal type with intermediate drain to the outside of the valve.

An outer seal shall be provided. They shall be of the chevron type. They shall be replaceable with full circle rings, and replaceable with split seal rings if a valve lever would otherwise need to be removed, even if the original seal is installed as a full circle seal.

All seal housings and pressure plates shall be provided in corrosion resistant materials.

The bushes shall be capable of maintenance free operation for at least the trunnion bushes design life stated in the Data Sheets or be capable of being replaced under full penstock pressure. The unit start/stop operations per year for bush life calculations are minimum **6500** open and close cycles per year.

The trunnions shall be provided with suitable corrosion resistant (replaceable or weld overlay) surface at the bush, inner seal and at the outer seal. The corrosion resistant surface shall have suitable hardness to suit the bush pressure and shall be designed to support high loads arising from trunnions, and preclude becoming loose during operation if of replaceable design.

The inner and outer seals shall be replaceable in-situ, without dismantling or removing the MIV.

Where greased bushes are supplied an automatic greasing system shall be supplied for the MIV. This system shall consist of a central grease reservoir, distribution system, and tubes to individual bushes. The distribution system shall provide adjustable, controlled, discrete release of grease to each bush. The distribution system shall indicate if there is a blockage in an individual supply.

4.4.5 Operating Mechanism

4.4.5.1 General

The operating mechanism shall consist of two (2) double acting servomotors, operating lever arms, and necessary connection between these parts. Oil pressure for the servomotors shall be supplied from the MIV Oil Pumping Set. The components shall be designed to ensure smooth operation under all operating conditions of the pumpturbine.

The operating mechanism shall be provided with open and closed stops, to allow fine adjustment of the valve open position, and fine adjustment of the closed position to correctly align the service seal. These stops shall be adjustable during erection and major maintenance by the substitution of stop plates or rings. The stops shall be designed to withstand the maximum force that the operating system can apply to each stop.

The servomotor shall have sufficient capacity to open and close the MIV with the minimum design oil pressure under all the operating conditions without any possibility of flutter.

The servomotor design shall consider the pressure rise expected in the servo cylinder due to hydrodynamic torque during closing with minimum bush friction.

The Contractor shall specify the opening and closing times, which shall be within the specified range of closing times. The closing time shall be such that the transient pressure created during closure of the MIV is lower than the system Design Head and all change over time guarantees are fulfilled.

A selectable fixed orifice shall be fitted in the servomotors to prevent inadvertent adjustment to MIV closing time.

The operating mechanism shall be provided with a manual locking device to lock the MIV in the closed position. The locking device shall be designed to resist the maximum servomotor forces produced by the oil pressure unit. The locking system shall be fitted with “engaged” and “retracted” feedback facilities.

All parts of mechanisms of the servomotor and MIV shall be designed to safely withstand forces generated when maximum oil pressure of the MIV Oil Pumping Set is applied in event of MIV becoming jammed in any position.

4.4.5.2 Hydraulic Servomotor

The servomotor shall be of seamless fabricated steel body construction designed to withstand the maximum possible oil pressure during MIV operation. The servomotor shall be provided with two oil drainage points, bleed points, bleed couplings for air bleeding, and connections for pressure measurement.

Each servomotor shall be designed such that each cylinder is able to close safely the MIV in case of a hydraulic pipe failure at one servomotor.

The Contractor shall provide a piston rod of suitable material to provide good running characteristics, seal life, and corrosion resistance. The piston seals shall be self-lubricated low friction type.

A spherical rod eye shall be provided at connection with operating lever arms and corrosion resistant self-lubricated bearing at the rear end of the servomotor.

The servomotor shall be provided with internal fixed damping to slow down the speed of the MIV rotor towards the end of its travel in both directions.

4.4.6 By-pass and Air Valves

Pressure equilibration shall be achieved by using the seal ring.

Block flanges with blind covers as a possibility for the later installation of a bypass pipe system,

The size of the bypass connection shall be such, that pressure equalization required from normal opening of the main inlet valve can be achieved with worn out wicket gates. The wicket gates are considered worn out when the clearance between the wicket gates and the head cover respectively bottom ring is double compared to new condition’s.

For the filling and dewatering procedure of the spiral case sufficient and automatically operating air valves shall be foreseen.

All external piping shall be of stainless steel.

4.4.7 Pressure test equipment

The Contractor shall provide at least one set of test heads with the MIV for closing the casing inlets for the hydrostatic pressure test.

Each head shall be equipped with drain and air vent connections.

The test head shall be flanged or welded to the casing and will be removed by the erector after completion of pressure test.

4.4.8 Make Up Pipe

The Contractor shall provide a make-up pipe to form the connection between MIV and the penstock, as shown on the drawings. The internal diameter of the make-up pipe shall be the internal diameter of the MIV.

The Contractor shall design the make-up pipe, and the make-up pipe to penstock weld joint. The make-up pipe design pressure shall be the same as the MIV Design Head. The make-up pipe shall be designed to the penstock design standard as or an approved equivalent. The penstock design standard is “CECT Recommendations for the design, manufacture and erection of steel penstock of welded construction”.

The make-up pipe shall be suitable for adjustment of both alignment and length between the MIV and the penstock. The make-up pipe shall have a trimming allowance of 300 mm.

The design of the make-up pipe shall be such that the pipe transmits the maximum thrust forces produced by the MIV, in both the upstream and downstream direction, to the penstock.

All necessary pipe connections shall be included (drainage and dewatering connections, other pipes…)

The make-up pipe shall be supplied as a single section.

The penstock supplier will finish his penstock at the interface location as specified in the Data Sheets with an additional trim allowance of 200 mm. The interface between the penstock and the MIV supply shall be approximately 1000 mm upstream the upstream MIV flange and shall be coordinated in the detail design together with the Employers Engineer.

The final portion of the penstock will be a horizontal pipe section, with the centreline of the pipe at the centreline of the MIV. The diameter of the pipe at the interface point will be the same diameter as the make-up pipe. The Contractor shall supply the final internal diameter of the make-up pipe to the penstock contractor as soon as this is available.

The make-up pipe shall be fabricated from the same material as the protruding penstock section.

The Contractor shall trim both the penstock and the make-up pipe to the correct matching lengths. The Contractor shall perform the weld preparation of both the penstock and the make-up pipe, and then perform the field weld of penstock to make-up pipe.

4.4.9 Dismantling joint assembly

The downstream side of the MIV shall be provided with a telescopic type dismantling joint connecting spiral case to the MIV.

The dismantling joint shall be designed to allow installation, maintenance of MIV and allow longitudinal movement between MIV and pumpturbine. The Contractor shall calculate the value of movement required under normal and emergency conditions, also accounting for the design air and water temperature ranges. The Contractor shall provide 50% additional longitudinal movement in both directions over that calculated as being required.

The dismantling sleeve must be provided with stainless steel material or surfacing for both surfaces of the sliding portion, and for the sliding surfaces and housings of seals for this joint. If surfaced, the minimum finished thickness of stainless steel shall be no less than 1mm.

The dismantling joint pipes shall be of the same material as spiral case. It shall be directly connected via bolted flanges to the spiral case and to the MIV body.

A man access hatch shall be provided in the dismantling joint section. The hatch shall be located at approximately the 4 o'clock position. The hatch shall be circular and have a clear opening diameter of a minimum of 700 mm. The inner surface of the hatch shall be profiled to match the surface of the dismantling joint to minimise hydraulic losses. The hatch shall be hinged at the bottom and be supplied with an eyebolt fitted to the top of the hatch to allow controlled lowering of the hatch via a hoist. The contractor shall supply and install a mounting bracket and manual hoist, for example chain-block, at a suitable location above the hatch to provide controlled lowering and raising.

If necessary all required pipe connections and tappings adjacent to the spiral inlet that may be more conveniently located within the dismantling joint assembly rather than in the spiral case shall be executed.

The following connections shall be provided on each inlet pipe:

- Connection for the by-pass pipe as shown on the drawings. Complete by-pass system is part of main inlet valve supply.
  - All necessary connections for drainage and dewatering system
  - one or more pipe connections with flange, to safely exhaust the air during priming, located at a high point,

- four tappings equally spaced around the periphery of the section, each at an angle of 45 degrees to the vertical plane, to measure the head at the pumpturbine,
- one or more tappings on the inlet piece to accommodate the temperature measuring probes associated with the thermodynamic testing,
- One (1) manhole with inner diameter of 800 mm and inclined by appr. 30 °. The manhole shall, when closed, flush with the inner surface.
- an additional single tapping on the inlet piece for measurement of pressure fluctuations.

The Contractor shall supply blank flanges or plugs, bolts, nuts, and gaskets to allow pressure testing on the dismantling joint assembly. The dismantling joint assembly shall be installed with the blanking plates and plugs installed.

The length of the outlet pipe has to be defined by the supplier. The outlet pipe will be directly connected to the pumpturbine spiral case inlet pipe.

4.4.10 Pressure Oil System

4.4.10.1 General

A fully self-contained oil pressure system shall be provided for the MIV, similar to the pumpturbine governor. This shall comprise as a minimum the sump tank, positive displacement pumps, valves, pressure pipework, sensors, hoses, and pressure accumulator(s).

The governor oil pressure system for the MIV (installation foreseen on MIV floor – level 2) shall consist of the oil pumps, piston accumulators and nitrogen bottles using an max. pressure of 150 bar, sump tank and the necessary oil and air piping.

The make and grade of the MIV pumping set oil shall be identical with those of the pumpturbine unit bearing oil.

For security after closure of the MIV, manually operated isolation valves shall be provided which isolate the servomotors from any source of pressure oil and connects the opening side of the servomotor to drain. These valves shall be lockable.

The Contractor shall provide all necessary filtered oil to fill the entire hydraulic system to normal full level. The Contractor shall provide all filter elements, greases, oils, and other consumables for completeness of the Plant.

4.4.10.2 Oil Pumps

The MIV oil pressure system shall be provided with three (3) identical AC oil pumps, one (1) for normal duty and two (2) as stand-by, having each a capacity acc. IEC 61362 standard. The pumps shall be of the positive displacement (piston or screw) type and shall be self- priming under the maximum working oil pressure and capable of running continuously against relief or unloader valves.

The pumps shall work in a rotational mode in order to assure an equal running time of the two pumps.

The motors shall be directly connected to the pumps and shall be of the 3-phase, squirrel-cage, 380 V AC, 50 Hz low- starting current, induction type designed for full voltage starting. The motors shall have moisture and oil-resistant insulation. Automatic controls shall be furnished for supplying oil when the oil pressure in the pressure receiver drops to a present value or when its level falls under the corresponding level.

Additionally one emergency operation hand pump shall be foreseen.

The following oil pressure switches shall be provided:

- 1 high pressure / alarm only
- 1 main pump on
- 1 low pressure / alarm only / stand by pump on
- 1 low pressure / alarm and shut down

The MIV oil pressure system pumps shall be interconnected so that they can be operated independently. The necessary valves shall be furnished so as to permit complete isolation of any pump from the oil system, and to permit removal of the pump for repairs without shutting-down the governor.

4.4.10.3 Piston accumulators and nitrogen bottles

The MIV oil pressure system shall be provided with a piston accumulator / nitrogen bottle system located on the MIV floor – level 2. The piston accumulator design pressure shall be approx. 120 bar.

The pressure system shall be designed that in case of failure of the oil pumps acc. to IEC standards three (3) fully strokes can be done in the sequence close –open-close.

The capacity of the oil pressure accumulator shall be sufficient to hold the valve in open position for 12 hours without oil pumps running.

The accumulator/nitrogen bottle system shall be equipped with all necessary safety equipment to ensure the safety of the operational staff. The structural design, construction and inspection of the pressure system shall comply with any relevant legal requirements and the latest standards.

4.4.10.4 Sump Tank

The sump tank shall have a capacity of not less than 115 % of the active oil in the MIV oil pressure system (active oil is defined as that portion of the total system oil which can be returned to the sump tank by the MIV oil pressure system). The tank shall be provided with a suitable oil level gauge for indicating the amount of oil in the tank, a manhole for access to the interior of the tank and suitable strainers through which all oil returned from the servomotors shall pass. The sump tank shall have a supply connection for filling the tank, a drain connection for draining the tank.

Connections for an oil purifier shall also be provided. All strainers shall be readily accessible for inspection and removable for cleaning.

If cooling of the MIV oil pressure system oil proves necessary an oil/water cooler is to be in-stalled. The supply of same shall include the necessary feeder and discharge pipes, valves, connections and a flow controller in the discharge piping.

For drainage and filling of the sump tank oil an adequate pipe to a suitable location including a control valve shall be provided by the Contractor.

The whole MIV oil pressure system shall be placed in a stainless steel tray which can collect minimum the total oil volume + 5 % safety of the hydraulic system.

4.4.10.5 Piping

All interconnecting piping and valves associated with the MIV oil pressure system shall be furnished. All piping shall be of such size that the maximum velocity of the oil does not exceed 5 meters per second to avoid pressure waves.

The entire piping system shall be welded. Welding of branches, headers, bends, etc. shall be done in the shop as far as practicable and consistent with the requirements for shipment and erection. Adequate pipe supports shall be provided to prevent vibration and movement of the oil piping during sudden pressure variations in the lines.

All necessary studs, bolts, nuts, washers, oil resisting gaskets, packing, etc. required in connection with the field assembly of the MIV oil pressure system piping system shall be furnished by the Contractor.

The structural design, construction and inspection of the piping shall comply with any relevant legal requirements.

4.4.11 Limit Switches and Transmitters

The following min. status outputs shall be transmitted to the plant control system:

- MIV position (0-100%),
- MIV bypass valve position,
- Pressure differential across the MIV
- MIV maintenance seal position,
- MIV service seal position,
- MIV maintenance seal mechanical lock status.

The inlet valve shall be provided with the following limit and intermediate switches:

- One (1) limit switch for the fully open position of the valve.
- One (1) limit switch for the fully closed position of the valve.
- One (1) intermediate switch initiating when the valve is closing because of minor oil leakage by appr. 6° from its fully open position.
- One (1) intermediate switch initiating alarm when the rotor has departed by appr. 12 ° from its fully open position.

- One (1) intermediate switch provoking shut down of the respective generating set when the rotor has departed by appr. 18 ° from its fully open position.

4.4.12 Instruments

All local instruments and indicators form part of the inlet valve supply. This applies also to all emitters transmitting indications to the instruments located in the control room.

4.4.13 Miscellaneous Items

Working, operating and inspection platforms to allow access to all parts for maintenance and checking, complete with supporting steel works, floor plates, grating, stairs, ladders etc. shall form part of supply of butterfly valves. Corrosion protection for all steel part shall be hot galvanized.

4.5 Inspection and Tests

4.5.1 General

Inspection and tests shall be made in accordance with the EPC Contract, as completed and/or modified by the following specifications:

The Contractor shall furnish the Employer with certified copies of shop tests.

All inspections and tests required by IEC or other local authorities shall be performed by the Contractor.

A detailed inspection plan overview will be part of the Contract.

The Participant shall submit with the Proposal a preliminary Inspection and Test plan (ITP) based on the RWHM (Guidelines for Materials in Hydraulic Machines 2009). The final ITP shall be agreed as specified in Annex 10 (Tests on Completion) to the EPC Contract.

4.5.2 Tests at Workshops

4.5.2.1 Tests on Raw Components

- Chemical analysis of the material used for the main components such as valve body, valve rotor, shaft trunnions, operating mechanism, sealing arrangement, make up pipe, dismantling joint assembly, By-pass and pressure test equipment.
- Mechanical resistance tests on materials used for the same components shall include tensile strength, yield point, elongation, bend, impact (Charpy V-notch)
- Ultrasonic inspection of the steel plates over 25mm thickness

4.5.2.2 Tests on Welded Components and Assemblies

- 100 % ultrasonic testing of all major stress exposed and full penetrated welds of the valve body, valve rotor, any pressure vessels, servomotor cylinders.
- Radiographic examination, only where ultrasonic examination is doubtful.

4.5.2.3 Tests on Cast Steel Sections

- Magnetic particle inspections are required to cover the whole surface of the steel castings with no linear indications as the acceptance standards.
- All castings shall be subject to inspection by the Employer prior to annealing and after annealing but before machining.
- Defects disclosed in castings shall be chipped to sound clean metal before repairs are made. If the removal of metal to correct the defect reduces the stress-resisting cross section of the casting more than 50 % in excess of the area required for the allowable stress, no repairs shall be permitted without the Employer’s approval in writing and the casting may be rejected. Castings requiring welding repairs after annealing shall be re- annealed after repairs unless waived by the Employer.

4.5.2.4 Test on valve rotor

The valve rotor shall be checked for surface roughness, originally specified by Contractor, especially on the water flow side. Liquid penetrant inspection or magnetic particle inspection shall be performed on all water faced surfaces.

Furthermore, ultrasonic or radiographic inspection of all doubtful indications found by one of the above methods and of all heavily solicited parts shall be made.

4.5.2.5 Tests on Shafts and Flanges

- Examination of shaft boring to Contractor’s standards with no segregation or cracks.
- Surface roughness inspection (surface roughness to be originally stated by Contractor).
- Ultrasonic examination.

4.5.2.6 Shop Assembly and Tests

- The MIVs, pressure oil system and as much as possible of the oil pressure piping shall be assembled, aligned, fitted and tested in contractor’s shop and properly match marked to insure correct assembly and alignment in the field.
- Stability test of the valve body according EN 12266-1, Test P10
- Leakage test of the valve body according EN 12266-1, Test P11
- Leakage test of valves according EN 12266-1, Test P12
- Stability of the valve rotor according EN 12266-2, Test P20
- Leakage test of the sealing arrangement according EN 12266-2, Test P21
- Functional test according EN 12266-2, Test F20
- The entire MIV including the related auxiliaries and piping, which will be subject to high pressure water under operating conditions, shall be tested for a period of 60 minutes under a hydrostatic pressure of not less than 50 % above the design pressure.

Pressure oil System:

- The hydraulic pressure oil equipment shall be completely assembled in the Contractor’s shops and tested insofar as practicable.
- Servomotor cylinders and MIV oil pressure system shall be subjected to a pressure test of 50% above the maximum normal pressure for a period of 30 minutes. After being tested, the equipment and piping shall be thoroughly cleaned of any liquids that may cause corrosive action
- Pressure oil components carrying oil shall be tested for leaks after final assembly in the contractor’s shop for 60 minutes at 1,5 times of maximum operating pressure in order to confirm there is no leakage.
- All hydrostatic tests shall be in accordance with the requirements of ASME Boiler and Pressure Vessel Code, or other recognized standard approved by the Employer.
- The following tests shall be carried out before operational tests:

  - Visual tests according to drawings and flow diagram

- Check of painting
- Check of function and characteristic of proportional valve

- Operational tests shall be performed on all equipment or device insofar as practicable to demonstrate that they function properly. Adjustable devices shall be checked for range of adjustment and given final adjustment, insofar as possible, in the shop.
- The electrical devices shall be given dielectric tests in accordance with applicable provisions of NEMA, ANSI and IEEE or equivalent standards.
- The following checks shall be done on the touch panel of the MIV head in addition.

1. Entering 'PROGRAM MODE' with password to enable calibration mode and exit this program.

2. Entering 'SERVICE MODE' with password to perform:

MIV servo motor adjust

Analog input adjust

Opening/Closing speed setting

MIV parameters

Power supply check

Password cannot be changed by the Contractor unless written permission is given by the Employer.

4.5.2.7 Defects and Corrections

Any leakage, distortion, or other defects developed during or after the tests shall be corrected to the satisfaction of the Employer. The tests shall be repeated, if in the opinion of the Employer further tests should be necessary.

4.5.3 Field Measurements and Tests During and After Installation

After the MIV has been installed, and before putting this equipment into service, it shall undergo field tests. Upon completion of satisfactory performance of the tests, the equipment will be put into operation by the operating personnel under the direct supervision and responsibility of the Contractor.

Tests that are expected to be performed during site commissioning and performance testing of the MIV include:

- leakage verification tests on maintenance and service seals,
- positioning of sealing system and seal travel,
- leakage rate shall be as guaranteed,

- MIV operation, opening and closing time under normal shut down conditions,
- emergency MIV trip tests closing time up to maximum flow,
- verification of close–open–close routine without accumulator recharging, to demonstrate that valve shall close safely at end of three strokes,
- testing and setting of all relays, limit switches and electrical controls, inter locks and sequence tests.

Emergency MIV trip tests shall be performed with the unit in generating mode and in conjunction with the unit site tests

The Contractor shall provide, install and subsequently remove, any temporary equipment and instruments required to carry out all measurements during the commissioning and site tests. Provision at the manufacturing stage for any tappings, fixing lugs, cable glands, pockets, etc., likely to be required for the tests, shall be made by the Contractor. The cost of such provision shall be included in the prices of the Plant.

The Contractor shall provide all test personnel required to carry out commissioning and testing.

All commissioning activities shall be fully documented. Method statements and test procedures shall be produced prior to each commissioning activity. They shall be amended to record the actual, rather than envisaged, commissioning process and parameters. All drawings of importance for the tests, and all relevant data, documents, specifications, certificates and reports shall be made available to the Employers Engineer during the tests. Copies of all test results shall be handed over to the Employers Engineer as the tests proceed.

5 DRAFT TUBE GATE

On the downstream side of the pumpturbine an operationally reliable draft tube gate is foreseen in order to hydraulically isolate the pumpturbine from the low pressure waterway tunnel. It shall be either of roller gate type or of the flap gate type. It shall be equipped with a hydraulic cylinder complete with cylinder support and ancillaries to be operated by an oil-hydraulic power unit.

In the following specification a roller gate is described but as an alternative also a flap gate (as shown in the powerhouse drawings) can be offered.

Any additional excavation volume for the cavern related to the draft tube gate need to be stated in the datasheets in item 1.3.

5.1 Scope of Supply

This specification covers the design, calculations, technical drawings, manufacture including corrosion protection, erection at the factory, testing at the factory and site, packing, transportation from factory to site, storage, complete erection, documentation, testing and commissioning, training of operational staff. Additional tests and inspections during the guarantee period including documentation. The Contractor has sole responsibility for his deliverables, performance and services.

In this specification described scope of supply includes following main components for the draft tube gate:

- Roller gate
- Set of embedded and built-in parts for the gate up to deck elevation, including dogging device
- Set of automatic hydraulically actuated interlocking which prohibits the gate closing while the main inlet valve is not closed,
- Set of hydraulic hoisting equipment including hydraulic power unit (HPU)
- Complete bypass pipe arrangement,
- Set of position indicators
- Local control system,
- Local control and operating panel/cubicle,
- Automatic greasing system,
- Oils and greases, first lubricant fill plus 10% extra in barrels
- Set of covers, platforms, stairs, ladders, railings and access pedestals
- Set of special tools and erection devices
- Gate nameplate,
- Interconnecting pipework,
- Instrumentation and protection devices,
- Limit switches and indicators,
- Seals,
- Plant cabling,
- Corrosion protection of the whole equipment
- Tools for erection installation and maintenance
- Shop and field tests

- Training for the Operational staff
- Operation- and maintenance manuals and full documentation of supplied equipment including as built drawings.
- any other items required for completeness.

The outline of the deliverable and performance is structured in the following way:

5.1.1 Design

- Basic and Detail design
- As-Built design
- Training of O&M staff

5.1.2 Manufacturing

- Procurement of materials
- Workshop manufacturing
- Workshop and field assembly

5.1.3 Inspection and tests

- Material tests
- Factory acceptance tests
- Field acceptance tests

5.1.4 Transportation and Shipment

- All components carriage paid to final erection position
- Packaging
- Loading, transhipping and unloading
- Transport per rail, road, ship or plane
- Transport incurrence
- Transport monitoring

5.1.5 Erection at site

- Erection tools
- Measurement surveys
- Erection personal
- Erection insurances

5.1.6 Commissioning and trial runs

- All related documents
- As built drawings
- Operating instructions and regulations
- Inspection and test protocols

The scope shall include, first and second stage anchor plates and embedded parts as well as any other necessary element to the proper operation of the gate.

The location and general arrangement of gate and ancillary equipment are shown in the basic design drawings. The Contractor shall supply the draft tube gate according to the following specification including all auxiliaries necessary for operation and maintenance.

5.2 Technical Guarantees

5.2.1 Head Loss

The Contractor shall guarantee the head loss across the draft tube gate, including losses associated with the gate slots, at a nominal turbine discharge of 38 m³/s. The pressure drop shall be calculated and stated in the data sheets.

5.2.2 Leakage

The maximum roller gate leakage rate at FSL shall be 0,05 l/min per meter of seal, related to the draft tube dimensions. The maximum total leakage of the closed roller gate must not exceed 1,2 l/min.

5.3 Design Data

The gate shall be designed according to DIN 19704 or equivalent and for the following conditions:

Draft tube Gate Data	
Type of gate	Roller gate or Flap gate
Number of gates	One (1) (on downstream)
Clear span	4.0 m (related to draft tube dimensions)
Clear height	1.8 m (related to draft tube dimensions)
Sealing side	Upstream (in pump mode flow direction)
Skin plate side	Upstream (in pump mode flow direction)
Design flow	38 m³/s
Emergency closure function	Yes
Design pressure	10 bar
Test pressure	15 bar
Emergency shutdown discharge	appr. 17 m³/s (manhole DN 800 left open)
Bypass pipe	DN 150 / PN 10
Operating equipment	Hydraulic hoist
Material	EN 10025-2-S355J0
Deflection of main beam	< 1/1000 in relation to the supporting span

For material, design, manufacture and corrosion protection requirements see the corresponding clauses and annexes of the general technical specifications.

Operation conditions:

The draft tube gate will be designed to close under emergency shutdown discharge conditions.

Normally the gate will be hanging in guard position inside the gate shaft and will be operated for maintenance purposes under balanced pressure condition. It shall be operated from the local control board (LCB) and from the remote control as well.

In an emergency situation, if downstream (in pump flow direction) equipment or installations have to be protected, the gate shall be closed by the control system or by emergency push button from the main control room (MCR). Emergency closure of the gate must be possible independent to external power supply, only by the gate dead load. The effective operating force shall be 20% above the value determined when all relevant dead loads, frictions and hydraulic loads are considered.

In closed position the gate must be protected against water pressure from headwater side with relief flaps integrated in the gate body.

While the gate is hanging in its guard position inside the gate shaft measures must to be taken to prevent closing of the gate until the main inlet valve is not closed.

5.4 Design requirements for the draft tube gate

The gate shall be sturdy designed and manufactured for the expected stresses of emergency operation included water hammer. The structure of the gate shall be made of steel to obtain high rigidity and good strength.

The structural design shall be of the highest possible integrity so as to give the highest possible availability with the lowest possible maintenance and repair cost, and a stated life time of minimum 60 years.

Special attention shall be paid to the possible uplift effect of the gate. If necessary the gate shall be properly ballasted to prevent accidents. A detail calculation shall be provided by the contractor to support its design and for determining the gate driving forces.

5.4.1 Gate Leaf

The gate leaf shall be made of steel with upstream (in pump mode flow direction) skin plate, horizontal beams and vertical bracing members, bearing plates, seals, main and side rollers, lifting lugs and all other necessary components. Alternative orientation of the skinplate on downstream side is a matter of Employers approval. The horizontal beams shall carry the horizontal water load to the end vertical girders. From them the forces shall be transferred via the wheel axes, bearings and wheels to the embedded structures. The gate leaf shall be arranged of one part.

Rigid vertical beams shall be arranged on both sides of the gate structure in order to bear the moments introduced by the axes of the wheels. Preferably wheels shall not be assembled of the cantilever type.

All horizontal webs shall be drained through generously sized holes, to minimize the accumulation of debris and silt on the gate, and maximize its clearance during lifting.

In order to distribute the forces on the gate, main cross beams shall be properly distributed as per the water thrust.

The bottom edge of the roller gate shall be shaped for low vibration while lowering the gate in running water or under full load.

All welding seams of the gate shall be continuous to avoid corrosion points and all permanent steel joints shall be sealed by welding. The size of sealing fillet welds shall not be smaller than 3 mm.

The piston rod or of the hydraulic cylinder must be connected to the gate leaf by spherical bearing and stainless steel pin. That pin shall be easy to be removed by the operating personnel when handling the lifting link. Threaded holes for extraction, special devices and tools shall be foreseen for that purpose.

5.4.2 Wheel Assembly

Wheels shall be of forged or cast stainless steel, and they shall be fitted with bearings of the roller type. They shall be efficiently sealed to exclude dirt, moisture and water under all operation conditions.

The axes shall be made of stainless steel. Since more than two wheels will be used per side of each gate, they shall be adjustable. Articulated connection or eccentric shafts may allow adjustments in order to distribute the force equally over the wheels. The roller bearings shall be spherical type to allow gate deflection. Additionally upstream counter guide rails for the wheels as well as side guide rollers shall be provided in the embedded guide beams to prevent wheel misalignment.

The bearings shall be selected considering an axial load of 10% of the maximum radial load on the wheel and following the manufacturer recommendations. The lifetime shall be selected in accordance with 60 year service

The support area of the wheels provided with fixed axes shall ensure that the pressure between the wheel and the rail bearing surface is within the limits stated in DIN 19704. The Hertzian stresses must be checked in this respect and the hardness penetration shall be carefully assured.

5.4.3 Gate Seals

The gate seals shall be bolted to the skin plate with full- or partial-length clamps, nuts, washers, ferrules and bolts all made of stainless steel. Ferrules shall ensure constant clamping of the seal against the clamping bars.

Material and properties of the seals shall be as specified in the general technical specifications.

Seal corners shall be molded pieces, shop vulcanized to provide a single continuous seal. The tensile strength of all shop splices shall not be less than 50% of the tensile strength of the basic material.

Lateral seals are supposed to be of the music note type and the top seal is supposed to be from the stem type, botch shape activated by the upstream water pressure, considering the water head. The bottom seal as well as the connecting seals are supposed to be of the flat bar type if necessary with round edge.

The side and the top seals shall be coated with PTFE or comparable coating in order to reduce friction.

5.4.4 Gate instrumentation

In general the gate shall be equipped with following instruments for monitoring, control, and protection:

- Analog position indicator consisting of a sturdy vertical sliding stainless steel rod with scale for direct reading the gate leaf position
- Limit switches for gate position mounted on the stainless steel rod (closed, opened, filling positon)
- Analog position indicator (4 – 20 mA)
- Pressure switches in the gate hydraulic actuating system
- Pressure measurement equipment in the intake channel (reservoir side and penstock side)
- Differential pressure measurement equipment
- Various limit switches for monitoring and interlocking

The switches shall be used to relay information to the control panel, to control the operation of the hydraulic pump and in conjunction with pressure switches in the hydraulic system, to trigger the alarm signal "gate is stuck".

5.4.5 Differential pressure measurement system

A differential pressure measurement system shall be installed in order to determine if the pressure is equalized for opening the gate.

5.4.6 Watertight housing and cover of the gate shaft

The entire gate shall be placed in a watertight housing as an integral part of the pumpturbine draft tube.

The gate housing should come in as few pieces as possible to site in order to minimize field works. Make-up elements shall be properly prepared for field welding and shall be provided with sufficient welding clips and fitting up bolts or similar means for holding the plates in correct position until welded.

The housing liner shall be reinforced with continuous circumferential and longitudinal stiffeners placed at sufficiently close centers so as to prevent distortion and reduce vibration to a minimum. All such stiffeners shall have sufficient holes adjacent to the plate surfaces to ensure free passage of air and grout when the liner is being concreted in.

An easy removable watertight cover, consisting of multiple-parts shall be foreseen on top of the gate shaft. This cover shall contain sealed bushings for the hydraulic cylinder rod and the position indicator rod. To gain the necessary tightness of the cover it will be necessary to machine the flanges of the cover parts and the shaft lining. In addition to the fastening screws, threaded holes for removing the cover shall be foreseen.

A manhole for getting inside the housing for inspection and maintenance purpose shall also be an integral part of the watertight cover.

The gate shall be driven by a hydraulic cylinder, located in the cylinder chamber above the gate shaft as shown on the basic design drawings. That cylinder shall be mounted on the watertight cover. Therefore it shall also be designed to carry the operation loads of the gate, seismic loads etc.

5.4.7 By-pass pipe arrangement and air valve

An integral part of the watertight housing shall be the by-pass pipe arrangement. The by-pass pipe will be used for controlled filling of the draft tube from lower reservoir. The by-pass pipe shall be made of stainless steel. The valves will be situated in the cylinder chamber. For the normal operation a hydraulically actuated valve shall be foreseen and additionally for maintenance purpose also a manual actuated valve.

Also an integral part of the watertight housing shall be an air valve for controlled aeration and de-aeration while dewatering of filling the draft tube. The air valve shall have one manual shut-off valve for maintenance purpose.

5.4.8 Auxiliary Lifting Equipment

Provisions shall be made and delivered to lift out the gate for maintenance purposes. The design has to guarantee easy and save removal during lifting in and lifting out. Lifting lugs, threaded holes and special devices and tools shall be foreseen and delivered for the gate extraction and reinstallation.

5.4.9 Hydraulic hoist

The hydraulic cylinder and the controls must be designed to properly “open” and “close” the gate as above described. Provisions shall be made to recover the gate position in case it sinks because of malfunctioning or leakages in the hydraulic system.

The actuator and its hydraulic system shall be designed to close the gate fail safe and designed in accordance with the requested standards.

5.4.9.1 Oil Hydraulic Cylinder

The cylinder shall be designed in accordance with DIN 19704 and the general technical specifications. The connection with the gate shall be articulated by a spherical bearing. Cylinder rods shall be made of stainless steel chromium platted. Ceramic-coated cylinder rods are also acceptable.

The required operating forces shall be 20% above the values determined when all relevant dead loads, frictions and hydraulic loads are considered.

All bolts, washers and nuts used in the hydraulic actuator equipment shall be properly corrosion protected as per the ambient conditions.

5.4.9.2 Oil Hydraulic Power Unit

The oil hydraulic unit shall be designed in accordance with DIN 19704 and the general technical specifications. The hydraulic power unit shall be provided as one unit located in the operation building.

The unit shall be equipped with two (2) pumps driven by AC motor, each one capable to operate the gate at a maximum normal operating pressure as given in DIN 19704. One of the AC motor driven pumps shall be back-up to operate the gate if the other operation pump fails. The hydraulic power unit shall be placed in an oil tray which has the minimum capacity to collect the whole oil amount of the oil reservoir.

The hydraulic power unit and the LCB shall be located in the cylinder chamber.

The oil pumps shall be located on the top of the oil reservoir and be arranged for easy maintenance and properly identified.

The unit shall be provided with all required hydraulic and electric devices to guarantee reliable and safe operation. Following equipment shall be included, but not be limited to:

- Relief valves
- Limit switches
- Pressure gauges
- High and low oil pressure alarm switches
- Alarm switches
- Protective relays

The first filling with hydraulic fluid shall be included in this scope.

5.4.9.3 Hydraulic Pressure Piping

The Contractor shall supply all necessary hydraulic piping. Pipe hangers and necessary hardware shall be included as well.

Piping and socket welded fittings of stainless steel shall be used throughout the oil system according to DIN 19704.

5.4.10 Electrical and Control Equipment

The complete local control system required to operate the draft tube gate and auxiliaries has to be furnished under this Contract. Gate control shall be possible from the LCB and the MCR as well.

Remote control shall be supplied and the LCB with all instruments/components needed for that remote control.

The equipment must contain a programmable logic control (PLC), integrated in the LCB and shall be selected in accordance with the general technical specifications, electrical equipment.

5.4.10.1 Equipment

The LCB shall be an outdoor, self-standing type of steel plate construction having hinged front cover with lock, and the main equipment to be mounted inside and on the operating board shall be at least:

- Moulded case circuit breakers
- Miniature circuit breakers
- Contactors and relays
- Protective relays for motors
- Voltmeter and ammeters
- Valve control equipment
- A LOCAL/REMOTE control selector switch. This switch shall be key-operated, with the key only being removable when the switch is in the ’remote’ position.
- Emergency stop lock button for maintenance purposes and manual operation
- Push-buttons and indicating lamps for local control of the gate
- Continuous gate position indicator (0 - 100%)
- Gate position indicator lamps (opened, closed)
- Indicating lamps for the different alarms
- Terminal interface to the gate and the main control room (MCR)
- Signals and alarms shall also be transmitted to the MCR

- All terminal blocks and other equipment necessary to complete the control system

5.4.10.2 Control Operation

Local control shall be available from the LCB located in the cylinder chamber. It shall allow the operator to open or close the gate. This control panel shall be foreseen watertight and properly protected against ambient working conditions and floods.

Each gate control panel shall be provided with an emergency stop push-button, which shall be hard-wired to over-ride all other gate controls.

If the gate is selected for ‘local’ control at its control panel, all gate control shall be by push buttons on the LCB. ‘Local’ control shall be hard-wired and completely independent of the sequence controller such that it remains operable in case of any failure of the PLC. ‘Local’ control will normally be used for maintenance when the intake stop log is set.

If the gate is selected for ‘remote’ it shall be controlled via the main plant control system.

5.4.10.3 Main Control System

The Contractor shall supply all required signal interfaces with the main plant control system. The Contractor shall supply and install the relevant cables and interfaces.

5.4.10.4 Controls, Alarms and Indications

The Contractor shall provide the controls, alarms and indications contained in the following schedule. Some deviation from these requirements may be permitted if this is appropriate for the equipment being provided.

Description	**Type**	**Signal**	**Location**
Draft Tube Gate			
Control mode, remote/local	control	control selector	LCB/MCR
	indication	status	LCB/MCR
Gate open/stop/close	control	pushbuttons/ keyboard	LCB/MCR
Gate opening/stopped/closing	indication	lamps	LCB/MCR
Emergency stop	control	pushbutton	LCB
	indication	status	LCB/ MCR
Gate fully closed	indication	lamp/status	LCB/ MCR
Gate fully opened	indication	lamp/status	LCB/ MCR
Filling valve open/stop/close	control	control selector	LCB/ MCR
Filling valve opening/stopped/closing	indication	lamps	LCB/MCR
Gate position	indication	status	LCB/ MCR

Gate travel time exceeded	alarm	status	MCR
Gate control faulty	alarm	status, grouping of * below	MCR
Gate HPU motor power supply failed *	alarm	lamp/status	LCB
Gate control power supply failed *	alarm	lamp/status	LCB
Gate HPU motor overload operated *	alarm	lamp/status	LCB
Gate control circuit breaker tripped *	alarm	lamp/status	LCB
Gate HPU system fault *	alarm	lamp/status	LCB/ MCR
HPU oil pressure low *	alarm	lamp/status	LCB
HPU oil pressure high *	alarm	lamp/status	LCB
Gate hoist excess pressure *	alarm	lamp/status	LCB
Gate excess travel *	alarm	lamp/status	LCB
Power supplies healthy	indication	lamp	LCB
Gate hoist oil pressure	indication	gauge	LCB
Sump oil level	indication	gauge/status	LCB/ MCR
Oil filter blocked	indication	flag	LCB/ MCR

LCB = Local Control Board   MCR = Main Control Room

5.4.11 Embedded Parts

The Contractor shall provide the complete sealing frames on the upstream side. That frame shall consist of sill and lintel beams, and side frames, all with a stainless steel seal seat. Both lateral sealing frames shall extend from the sill elevation not less than twice the gate height.

The Contractor shall also provide the complete track beams on the downstream side. Both rails shall extend from the sill elevation not less than twice the gate height.

Furthermore lateral guide beams shall be provided from the sill elevation to the deck elevation inside the gate shaft.

The seal seats and sliding surfaces as well as the wheel rolling surfaces shall be made of stainless steel and properly machined according to the tolerances permitted in DIN 19704. An adequate dimensioned carbon steel girder under the wheel rolling surface shall keep the concrete pressure under the allowable values.

All joints between parts shall be equipped with bolts, dowels and anchor plates.

At deck elevation the embedded parts shall also include a dogging device, for the case of maintenance on the hydraulic hoist. This dogging device shall be of sturdy design to bear the whole gate assembly in order to be able to dismantle the hydraulic hoisting equipment.

The threaded bolts will be welded at site to anchor plates, being encased into first stage concrete.

Anchor plates and threaded bolts shall be arranged in such a manner, that all parts to be embedded in second stage concrete are adjustable and can be rigidly fixed. Reinforcement, anchor rods and other supporting mild steel parts must have a sufficient concrete cover. The minimum plate thickness of embedded parts shall be 15 mm.

Threaded bolts must have a minimum diameter of 16 mm. The required thread length shall be sufficient, to assure easy adjustments. The threaded bolts shall be equipped with adjusting nuts.

Supply and erection of all embedded parts as well as all studs, nuts, washers, etc., needed for the proper installation and adjustment of the second stage embedded parts, are in Contractor´s scope of works.

5.4.12 Miscellaneous Metal Work

The Contractor shall provide any access ladders and platforms, handrails, cover plates, curbing, etc., related to the equipment supplied under this Contract.

The ceiling above the roller gate has to be water tight. The gate actuator, also the manhole and all pipe and cable penetrations has to be water tight as well.

All shall be in accordance with requirements of the general technical specifications.

5.5 Inspection and Tests

5.5.1 General

Inspection and tests shall be made in accordance with the EPC Contract, as completed and/or modified by the following specifications:

The Contractor shall furnish the Employer with certified copies of shop tests.

All inspections and tests required by IEC or other local authorities shall be performed by the Contractor.

A detailed inspection plan overview will be part of the contract.

The Participant shall submit with the Proposal a preliminary Inspection and Test plan (ITP) based on his experiences. The final ITP shall be agreed as specified in Annex 10 (Test on Completion) to the EPC Contract.

5.5.2 Shop Assembly and Test

Basis for shop test shall be the inspection and test plan which will be agreed during contract negotiations. The Contractor shall provide suitable facilities for all inspections and tests required in the functional specification, by the quality plan and for statutory purposes. Individual workshop tests for equipment shall be specified within the ITP by the Contractor during the design phase, and shall include test descriptions together with references to relevant standards according Contractors ITP.

The in-works testing of control and instrumentation equipment shall take account of the requirements given in general requirements.

5.5.2.1 Roller Gate and Embedded Parts

The draft tube gate including seals, wheels and bearings shall be assembled in the shop in the approximate position that it shall have after installation at site. While assembling, the gate shall be checked for dimensions, tolerances and accuracy of alignment and balancing. The seals shall be fitted to their supports during the shop assembly.

Built-in parts shall be assembled too. Sealing frames, track frames, side guide frames and sill beams shall be checked by means of straight edge and feeler gauge. All dimensions of the guide frames that correspond to the gate dimensions shall be checked.

Parts shall be clearly match marked before disassembly for transportation and any error or misalignment discovered shall be promptly corrected.

5.5.2.2 Hydraulic Actuator and Hydraulic Power Unit

The hydraulic actuator and the hydraulic oil unit shall be completely assembled in the shop and pressure-tested according to DIN 19704 and the general technical specifications to ensure all parts are sound and that all parts fit and operate properly.

The oil to be used for the test shall be new, clean light hydraulic oil. Special care shall be taken not to introduce harmful foreign matters such as dirt, chips, water, etc., into the hydraulic system before, during or after the test.

The following items, at least, shall be checked during the shop operation test:

- Operation speed
- Voltage and current of electric motor
- Oil pressure in hydraulic unit
- Temperature raise of bearings, motor and oil pump
- Existence of noise and vibration
- Operation of limit switches
- Measurement of oil leakage past the piston rod
- Oil level low
- Accuracy of position indicator

- Manual operation of oil pump equipment
- Condition of control cabinets, including alarm signal, etc.

Any defect or improper operation discovered in the test shall be promptly corrected and the entire test shall be repeated to the satisfaction of the Employer.

5.5.3 Tests on Completion

After completion of the installation work at site, dry-commissioning and wet-commissioning tests shall be performed in accordance with the conditions of this specification and the general technical specifications.

The tests on completion shall consist of dry-commissioning tests and wet-commissioning tests.

5.5.3.1 Dry-Commissioning Tests

Dry commissioning shall include, but not be limited to the following:

- Inspection of the waterway and removal of foreign or loose objects which might cause damage
- 100% of load carrying site welds shall be tested with ultrasonic method and if the result shows discontinuities the test shall be redone with radiographic method
- Inspection of corrosion protection completion and touch ups
- Insulation resistance tests on all site installed wiring and electrical connections
- Calibration of scale for gate opening
- Operation of HPU, automatic and manually-operated starting and stopping devices and signaling devices and motors power consumption
- Oil level and pressure in HPU; condition of oil filters
- Check of accuracy of indication, limit setting and alarm signals from LCB/MCR (oil level, oil temperature, travel, pressure)
- Temperature raise of motors, oil, etc.
- Times for opening and closing of the roller gate
- Check of travel limits
- Bearing clearance for gate wheels
- Inspection of satisfactory sealing seat by feeler gauge measurement of all seals

- Proper fastening of the manhole in the cylinder chamber

5.5.3.2 Wet-Commissioning Tests

After satisfied that all conditions have been met, leakage and structural performance tests can be done. These tests need to be executed in coordination with the first filling procedure of the upper reservoir, described in the owners requirements.

When the first interim level during filling the upper reservoir is reached the following sequence shall be proceeded for wet commissioning static tests of the roller gate:

1. Closing the roller gate via LCB.
2. Controlled filling the low pressure tunnel by crack opening the lower reservoir roller gate.
3. Check of water leakage on downstream side of closed gate, leakage must not exceed rates specified under item 5.2.2.
4. Balancing of water pressure by filling of downstream waterway via filling valve on by-pass pipe. For this step the commissioning of the pump turbine and its up and downstream waterways must be finished.
5. Opening and closing the gate under balanced conditions via LCB and remote controlled from the MCR

After completion of above described static tests at FSL, the emergency closure of the roller gate shall be tested.

A detailed commissioning procedure shall be submitted by the Contractor.

5.6 Transport and Installation

Transport and installation works shall be performed according general technical specification especially see chapter 10 transport and installation.

5.6.1 Guide Frames

The lateral and sill frames shall be assembled in their recesses in accordance with the final approved drawings, brought to line and grade within the tolerances specified and firmly secured in place.

Alignment bolts or other necessary device shall be used to install the built-in parts in accurate position. Connections between the built-in parts, anchor materials and the alignment device shall be adjustable and firmly tightened to hold the frames securely in position while concrete is being placed in the recesses.

Additional bracing shall be provided where necessary to ensure the required alignment. Extreme care shall be taken to ensure that the guide, bearing and sealing surfaces lie in a true plane within the tolerances specified.

Placement of concrete in the recesses shall not proceed until the built-in parts have been completely assembled and secured. During encasing the concrete, alignment tolerances shall be checked and remedial action taken if reading indicates that displacement has occurred.

5.6.2 Roller Gate

The gate complete with rollers, seals and ancillaries shall be assembled and erected in accordance with the details shown on the final approved drawings.

Joints shall be watertight where required. The bottom of the gate when erected shall be in true alignment to ensure a tight and even bearing of the rubber seal on the sealing face at the sill beam. The sides of the gate shall be in true alignment so that the rubber seals, when installed, shall have a tight and even support on the sealing faces. The gate shall be assembled and erected to meet the specified tolerances.

5.6.3 Hydraulic Actuator and Hydraulic Power Unit

The hydraulic actuator and hydraulic power unit shall be assembled and installed in accordance with the final approved drawings.

During installation of the actuator, hydraulic power unit and connection piping, special care shall be taken to prevent the entrance of dirt, chips, piping compound and other foreign matters into the hydraulic systems. Before connecting the actuator to the gate, the installed servomotors with hydraulic unit shall be repeatedly flushed several times in order to remove foreign materials from the oil circuits and to check their correct function and operation.

After confirmation of the correct operation of the hydraulic actuator by the trial operation, the hydraulic actuator shall be connected to the gate and then operation test of the gate shall be performed. The absence of any oil leakage shall be confirmed during the shop test. Any defect or improper operation discovered during the test shall be fixed the entire test shall be repeated to the satisfaction of the Contractor.

6 DOCUMENTATION

The documentation and engineering documents for the above described scope shall be done in accordance to Volume 2, Section VI, General Technical Specifications, especially with chapter 4.

The Contractor shall furnish assembly and detail drawings wiring diagrams and cuts of the work in such number and detail as necessary for installation, operation and maintenance of the equipment and for demonstrating that it complies with the requirements of the specifications.

All drawings and documents delivered to the Employer for approval shall be registered with the Employer project number stated in the project manual.

All drawings shall show the material part numbers, dimensions, finish, fits, clearances, tolerances, bolting and such other information as may be necessary to demonstrate compliance with the requirements of the specifications.

Bill of Materials (BOM) shall be shown on the related drawings or given as a separated list to Employer.

From all parts of the scope of supply a 3D-file (step, sat) shall be delivered to the Employer at the same time 2D drawings are transmitted. The 2D drawings shall be clear for understanding including all dimensions, tolerances, pose numbers and description in order to fulfil all requirements at the erection and maintenance time. Drawings shall be generated using a (3D-) CAD program (current Auto-CAD-Version or a widely used electrical CAD program for wiring drawings, terminal drawings, etc.).

CAD files, inclusive 3D CAD Files have to be submitted, due to the fact that as built documentation will be done by the civil contractor. For updating the civil drawings the as built design of the E&M equipment in 2D and 3D CAD is necessary.

The 3D-CAD Files do not have to contain each detail, meaning the civil contour of the embedded parts and installed equipment shall be delivered in 3D (step, sat format) for implementation into the civil as built design.

Final drawings mean all approved drawings and drawings embodying all design modification as approved by the Employer. Such drawings shall be submitted in 3 hard copies and 1 soft copy (in pdf and acad-dwg format). The final detail drawings must additionally be submitted in a 3D soft copy in one of the following file types: 3D CAD, adsk, .step or .sat format.No later than 2 weeks after the Works Commencement Date the Contractor shall deliver to the Employer an overall and complete document delivery list including expected date of delivery, Employers project number and document description.

Such drawings shall include but not be limited to the following:

6.1 General Drawings

- General Arrangement of equipment, Plan view
- General Arrangement of equipment, Longitudinal section
- General Arrangement of equipment, Transverse section
- Schematic pumpturbine control diagrams to illustrate the functioning of all principal component parts of equipment, including the pumpturbine and governor, MIV, Draft tube gate and auxiliaries.
- All arrangement and layout drawings shall be drawn to scale. The General Arrangement Drawings shall show the physical arrangement of Works and their layout in the Powerhouse and appurtenances.

6.2 Pumpturbine

- General unit assembly drawing,
- Assembly drawings (sections and plans) of the entire pumpturbine,

  The assembly drawings shall show all elements and the main dimensions of individual components in plan view, cross-section, side and top views. The **assembly** drawings shall include erection drawings, piping diagrams and piping arrangement drawings, etc., showing the dimensions, design and data of all constructions, apparatus and Works to be furnished under this Contract.

  These drawings shall show:

  - Assembly of the Works in plan, elevation and detail views with main dimensions
  - Sub-assembly of the principal components of the Works which shall require dismantling, assembly and adjustments at site for maintenance, giving overall dimensions, adjustment, clearances and fitting tolerances
  - Sub-assemblies in which the Contractor proposes to ship the Works
  - Instructions for heat treatment, pressure tests, surface preparation and anti-corrosive protection
  - Full details of parts for which adjustment is provided or which are subject to wear
  - Method and sequence of installation, field joints, erection and lifting devices, jacks, grout plugs, anchoring details, etc., if not shown on foundation drawings.
- Detailed drawings and sub assembly section and plans of the principal component parts including:
  - Runner, shaft and shaft attachment to runner and intermediate/generator shaft respectively

  - Guide bearing
  - Shaft seal (stuffing box)
  - Guide vane operating mechanism, including servomotors
  - Upper and lower wicket gate bearings and seals
  - Stay ring, head cover and bottom ring
- Preliminary and final detail drawings of the spiral casing and draft tube,
- Foundation requirements (Civil works) drawings of all parts set into or coming in contact with concrete, showing the method of supporting and method of anchoring into concrete,
- Detailed drawings of all parts embedded in concrete,
- Detailed drawings of all parts of the work connected to or related with the equipment supplied by other manufacturers or to equipment furnished by the Employer.
- All details pertaining to every part subject to wear, or which is provided with adjustments,
- Locations of detectors, gauges, limit switches, etc.
- Arrangement drawings of the pumpturbine air admission equipment

6.3 Speed Governor

- Assembly sections and plans of the speed governor
- Such sub-assemblies, cuts, illustrations, or drawings as required illustrating the functioning of the various parts of the governor.
- Detail drawings of the actuator cubicle showing the location of the various element and instruments.
- Details of the mounting and dimensions of the individual instruments and apparatuses.
- Principal control and wiring diagrams showing the operation principals and connections of the speed regulator.
- Regulation Scheme.

6.4 MIV

- General MIV assembly drawing,
- Assembly drawings (sections and plans) of the entire MIV,
- detailed drawings and sub assembly section and plans of the principal component parts
- Preliminary and final detail drawings of the MIV

- Foundation requirements (Civil works) drawings of all parts set into or coming in contact with concrete, showing the method of supporting and method of anchoring into concrete,
- Detailed drawings of all parts embedded in concrete,
- Detailed drawings of all parts of the work connected to or related with the equipment supplied by other manufacturers or to equipment furnished by the Employer.
- All details pertaining to every part subject to wear, or which is provided with adjustments,
- Locations of detectors, gauges, limit switches, etc.

6.5 Draft tube gate

- General gate assembly drawing,
- Assembly drawings (sections and plans) of the entire gate,
- detailed drawings and sub assembly section and plans of the principal component parts
- Preliminary and final detail drawings of the gate
- Foundation requirements (Civil works) drawings of all parts set into or coming in contact with concrete, showing the method of supporting and method of anchoring into concrete,
- Detailed drawings of all parts embedded in concrete,
- Detailed drawings of all parts of the work connected to or related with the equipment supplied by other manufacturers or to equipment furnished by the Employer.
- All details pertaining to every part subject to wear, or which is provided with adjustments,
- Locations of detectors, gauges, limit switches, etc.

6.6 Auxiliaries

- General unit assembly drawings for the cooling water system, compressed air system and drainage and dewatering system.
- Assembly drawings (sections and plans) of the entire auxiliaries,
- detailed drawings and sub assembly section and plans of the principal component parts including:
  - Piping layout
  - Block out drawings
  - Support constructions
  - Access platforms

  - Room layout drawings for the auxiliary systems
  - Measurement and instrumentation drawings
- Foundation requirements (Civil works) drawings of all parts set into or coming in contact with concrete, showing the method of supporting and method of anchoring into concrete,
- Detailed drawings of all parts embedded in concrete, and required block outs
- Detailed drawings of all parts of the work connected to or related with the equipment supplied by other manufacturers or to equipment furnished by the Employer.
- All details pertaining to every part subject to wear, or which is provided with adjustments,
- Locations of detectors, gauges, limit switches, etc.

6.7 Piping, Wiring and Accessories

- Outline drawings of the pressure oil supply system, air supply system (if applicable) and water supply systems with schematic diagrams and schematic diagram of automatic control.
- All related P&ID schematics.

  Schematic diagrams of pumpturbine control and auxiliary systems like oil pressure unit, compressed air system, drainage / dewatering system, cooling water system etc. shall be supplied. These drawings shall show all instruments and control devices. Standard abbreviations and component numbers shall be used as per relevant standards.

- Piping and arrangement drawings of all systems with dimensions.
- Detail drawings of the oil pumps, oil sump tank, air/oil pressure receiver, oil collector pans, oil return pumps, hand-operated pumps, strainers, control cabinets and necessary accessories including valves, piping and fittings.
- Detail drawings of the control cabinets showing the location of the various instruments and accessories.
- Wiring diagrams

6.8 Calculations

The Contractor shall furnish the Employer detailed calculations concerning the equipment indicating in particular the safety factors allowed, the normal and exceptional stresses to which the equipment may be subjected. The Contractor shall also state the forces and loading imposes on the equipment, and the loading and forces that the equipment concerned will impose on the structures and foundations.

Such calculations shall include but shall not limited to the following:

- Loads on concrete – calculation report
- Pumpturbine hydraulic characteristics
- Calculation of maximum hydraulic pressure
- Calculation of maximum momentary speed variation
- Calculation of fly-wheel affect required by the pumpturbine
- Calculation of runaway speed
- Calculation of first critical speed of the pumpturbine-motorgenerator shaft
- Calculation of servomotor capacity
- Governor equipment characteristics
- Calculation of pressure oil supply system
- Calculation of oil pump capacity
- Calculation of oil pressure tank capacity
- Calculation of compressed air system
- Calculation of air compressor capacity
- Calculation of air tank capacity
- Calculation of flow, pressure and head losses in the cooling water system
- Calculation of pipe deformation and supports for pipes categories I (according to PED2014/68/EU), for pipes category 0 no detailed calculations needs to be performed.
- Critical speed computation, in cooperation with the generator Contractor
- Pumpturbine structural design, including analysis of the spiral casing, bearing and shaft design
- Wicket gate operating mechanism
- Calculation of switch over times

6.9 Other Documents

- The list of drawings and documents and the list of parts with their individual serial number and references
- The reports of all the shop tests (including material certificates)
- Photographs (digital with HQ) of the equipment finally assembled in the workshop.
- The reports of all the site tests
- The time schedule of shop manufacturing (detail program)
- The operating instructions
- The maintenance handbook
- The program for the shop tests
- The detailed list of spare parts

- The program for erection
- The program for the field tests
- Alarm Lists

These lists shall indicate all alarms and shall contain at least:

- Description and denomination of alarm
- Data of alarm detector (contact) referring to applicable circuit diagram
- Data of alarm annunciator (location and clear text labelling
- Data of alarm-trip set values which shall be applied shall submit before 3 mounths Accaptance.

The complete set of all final drawings and documents necessary for dismantling, erection, maintenance and operation of the supplied equipment brought up-to-date „as-built“ including the field modifications.

7 SPARE PARTS, TOOLS AND CONSUMABLES

The requirements are defined in the General Technical Specifications for all the entire E&M equipment.