

VOLUME-2
PART- I
Section-2
Turbine and
Accessories

Contents

2. Turbine and Accessories	1
2.1 Scope of Work	1
2.2 Scope of Supply	1
2.2.1 Material	1
2.2.2 Services	2
2.3 Specific Parameters and Layout Conditions	2
2.3.1 Layout and General Arrangement	2
2.3.2 Operating Conditions	4
2.3.3 Operating Data	4
2.4 Design Requirements	5
2.5 Problem of Silt & Provisions to mitigate	7
2.6 Rating and Functional Characteristics	7
2.6.1 Turbine Rating	7
2.6.2 Rated Speed	7
2.6.3 Pressure Rise and Speed rise	7
2.6.4 Runaway speed	7
2.7 Performance Guarantee	8
2.7.1 Guaranteed Output	8
2.7.2 Guaranteed Efficiency	8
2.7.3 Cavitation Pitting Guarantee	9
2.7.4 Other Technical Guarantees	9
2.7.5 Liquidated Damages for shortfall in Output and Efficiency	10
2.7.6 Tender Evaluation on Account Of Efficiency Difference	10
2.7.7 Rejection Limit	10
2.7.8 Transposed Model Acceptance Test	10
2.7.9 Field Acceptance Test	11
2.8 Design and Construction	11
2.8.1 Standards	11
2.8.2 Operational requirement	12
2.8.3 Design Stress Limit	12
2.8.4 Material Selection and Standards	12
2.9 Construction Details	13
2.9.1 General Arrangement	13
2.9.2 Runner	14
2.9.3 Spiral Casing, Stay Ring and Generator Side Covers	14
2.9.4 Draft Tubes	14
2.9.5 Wicket -gate mechanism with gate operating mechanism	15
2.9.6 Guide Vanes	15
2.9.7 Gate Operating Ring	15
2.9.8 Servo-motors	15
2.9.9 Shaft Sealing Arrangement	16

2.9.10	Turbine Shaft (if applicable)	16
2.9.11	Flexible Coupling	16
2.9.12	Turbine Drains	17
2.10	Turbine Flow Meter	17
2.10.1	Winter Kennedy Flow meter	17
2.11	Piezometer Taps	17
2.12	Railing, ladder for E&M equipment	17
2.13	Name Plate	17
2.14	Control and Monitoring	17
2.15	Instrumentation and Control	18
2.16	Level Monitoring Devices	18
2.16.1	Tailrace Water Level Meters	18
2.16.2	Reservoir Water Level Monitoring	18
2.17	Over-speed Device	18
2.18	Drawings, Documents and Design Calculations	19
2.18.1	Design Memorandum	19
2.18.2	Drawings and Documents	19
2.18.3	Design Calculations	19
2.18.4	Drawings	19
2.19	Shop Assembly and Tests	20
2.19.1	General	20
2.19.2	Material Tests	20
2.19.3	Defects and Corrections	21
2.19.4	Record of shop Measurements	21
2.20	Field Tests during Erection, Pre-Commissioning and Commissioning	21
2.20.1	General	21
2.20.2	Calibration	21
2.20.3	Testing of Protective Devices	21
2.20.4	Operational Tests	21
2.20.5	Pre -Commissioning Tests	21
2.20.6	Commissioning Tests	22
2.21	Field Acceptance Tests on Turbine	23
2.21.1	General	23
2.22	Specified Spare Parts	23
2.23	Special Tools	25
2.24	Quality Assurance and Testing	25
2.25	Guaranteed and Technical Particulars	25
2.26	Completeness of Equipment	25
2.27	Deviation from Specifications	26
2.28	Schedule of Installation	26

2. Turbine and Accessories

2.1 Scope of Work

Scope of work under this section covers the provision of labour, tools, plants, materials and performance of work necessary for the design, manufacture, quality assurance, quality control, shop assembly, shop testing, delivery at site, site storage and preservation/insurance, installation, commissioning, performance testing, acceptance testing, training of Purchaser's personnel, handing over to Purchaser and guaranteed trouble free operation of horizontal shaft Francis Turbines for Keyi Hydroelectric Project, Arunachal Pradesh, as per the specifications hereunder, each complete with all auxiliaries, accessories, spare parts and warranting a trouble free safe operation of the installation.

The scope of supply shall also include all parts, accessories, spares etc. which are essential for assembly, erection, construction, trial operation, trial run, test run, commissioning, testing and maintenance of the complete prime mover / unit even through these are not individually or specifically stated or enumerated. The corresponding components of all the turbines and associated equipment & spares shall be of the same material, dimensions and finish and shall be interchangeable.

The turbine manufacturer shall co-ordinate with the generator supplier so that the generator coupled to the turbine is matched in respect of speed, runaway speed, moment of inertia, over load capacities, coupling and other relevant requirements.

The scope of work shall be a comprehensive functional system covering all supply and services including but not be limited to following:

2.2 Scope of Supply

2.2.1 Material

1. Two (2) sets of horizontal shaft Francis Turbines complete in all respects comprising of following main components:
 - Fixed/ embedded components including draft tube liner, dewatering arrangement, stay ring, spiral case, embedded piping, and foundation parts etc.
 - Stationary / removable components including draft tube cone, generator & draft tube side head covers, guide apparatus and regulating mechanism, servomotor etc.
 - Rotating components including runner, runner cone and turbine shaft (if applicable) etc.
 - Bearing (if applicable) and main shaft seals.
 - Runner and turbine / generator shaft coupling bolts
2. Two (2) sets of anchors, turnbuckles, fixtures, machine pads, base plates, jacks and foundation bolts etc.
3. Two (2) sets of penstock & spiral case drainage system
4. Two (2) sets of necessary fittings / piping / accessories etc.

5. Two (2) sets of Winter - Kennedy flow measurement system
6. Winter Kennedy instruments.
7. Two (2) set tail race level measuring equipment
8. Two(2) sets of all necessary control, monitoring, safety and metering instruments/ devices/ system including interfacing with plant SCADA
9. Over speed protection device (mechanical and electrical type)
10. Temperature/pressure gauge.
11. Mandatory Spare parts
12. Special Tools and instruments

2.2.2 Services

1. Transportation and delivery to site including transit insurance.
2. Site storage, handling, preservation and transport to work site as per requirements. Suitable open space for storage shall be provided by the Employer.
3. Site erection/installation and commissioning.
4. Field / touch-up painting including all painting materials.
5. Pre-commissioning and Commissioning testing
6. Trial run and handing over
7. Training of Purchaser's personnel including operation and maintenance staff.
8. All the technical documentation & drawing including preparation and submission of O&M manuals.

2.3 Specific Parameters and Layout Conditions

2.3.1 Layout and General Arrangement

2.3.1.1 Layout

A surface powerhouse having installation of two units of 11.5 MW with horizontal shaft Francis Turbine directly coupled to synchronous generator. Two (2) main inlet valves installed in powerhouse shall be of butterfly type.

Layout of powerhouse and general arrangement of generating units and other equipment, details of water conductor system have been outlined in the layout drawings as enclosed with the tender documents.

The drawings are not to be considered as defining the design of the plant but are intended to show the general layout and space requirements. Changes can be made in the plant layout to suit the design of the TG sets if the Purchaser finds such modifications are appropriate and acceptable.

2.3.1.2 Hydraulic System

The details of the hydraulic system of the generating units and basic data for design of turbines are given in Table below:

Hydraulic System and Data for Turbine Design-

Sl. No	Parameters	Units	Value
1)	Powerhouse installed capacity	MW	23
2)	Number of units	Nos	2
3)	Rated capacity of each generating unit	MW	11.5
4)	Type of turbine		Horizontal Francis turbine
5)	Head water levels		
	Full supply level, FSL (EL.)	m	902.60
	Minimum Drawdown level, MDDL (EL.)	m	902.10
6)	Tail water levels		
	Maximum tail water level during flood (EL.)	m	780.60
	Normal tail water level (all units running at rated capacity) (EL.)	m	772.65
	Minimum tail water level (one unit running at part load) (EL.)	m	771.75
7)	Static heads for turbine		
	Maximum gross head at FSL and minimum tail water level	m	130.85
	Minimum gross head at MDDL and normal tail water level	m	129.95
8)	Head losses		
	Head loss at rated discharge	m	4.33
	Head loss during one machine running at part load	m	0.35
9)	Net heads		
	Maximum net head at FSL during one machine running at part load	m	130.50

	Normal maximum net head at FSL at all machines running	m	125.65
	Minimum net head at all machines running at MDDL	m	125.12
	Rated net head	m	125.45
	Design head (considered)	m	125.45
10)	Discharge through each turbine	m ³ /s	10.25
	Total design discharge	m ³ /s	20.50
	Total discharge with 10% continuous overload	m ³ /s	22.55
11)	Efficiency (considered)		
	Minimum Turbine efficiency at rated net head	%	93.5
12)	Powerhouse crane		
	Number	No.	1
	Capacity of main hoist (tentative)	Tones	40T/10T

2.3.2 Operating Conditions

The plant is purely a run of the river scheme. The power station shall be operated with the outputs from the two generating units optimised within 110 to 40% of rated capacity.

2.3.3 Operating Data

The turbines shall be horizontal shaft Francis type coupled directly to the Generator of matching rating. The basic data for design of turbines is given in Table below.

Turbine Basic Data-

Sl. No.	Parameters	Units	Value
1	Rated capacity of turbine at rated net head to generate rated power at generator terminal	MW	11.5
2	Continuous overloading	%	10
3	Type of turbine		Horizontal Francis turbine
4	Various Heads		
	Maximum gross head at FSL and minimum tail water level	m	130.85
	Maximum Net Head at FSL with one machine running at part load	m	130.50

	Normal Maximum Net Head at FSL with all machines running	m	125.65
	Minimum Net Head at all machines running at MDDL	m	125.12
	Rated net head	m	125.45
	Design head (considered)	m	125.45
5	Discharge through Turbine		
	Design Discharge	m ³ /s	20.50
	Flow through each unit at rated condition at rated net head	m ³ /s	10.25
	Flow through each unit at overloading	m ³ /s	11.275
6	Minimum Efficiency (considered) at rated head and rated discharge	%	93.5
7	Inlet diameter Spiral casing	mm	1400
8	Elevation of center line of Runner	m	EL.769.52
9	Speed		
	Rotational Speed	rpm	600
	Runaway speed (Maximum)	rpm	1080
10	Cavitation Standard		IEC-60609
11	Pressure Rise	%	Within 25% at maximum discharge
12	Speed Rise	%	Within 50% at maximum discharge
13	Moment of Inertia (GD ²) of the generating unit	T-m ²	55 Tm ²

2.4 Design Requirements

The turbines shall be designed to give satisfactory, quiet and smooth operation, free from excessive noise, vibrations, pressure pulsations, power swings, hunting etc. in the required range of operation of heads and outputs.

The weight of the turbine rotating parts and any unbalanced vertical hydraulic thrust shall be supported by the generator thrust-bearing. The turbine/generator shaft and bearing shall be designed to operate under any guide vane opening.

Turbine shall be capable to operate 40% of rated capacity continuously with cavitation and vibration/ noise and pressure pulsation within limit as per relevant IEC

The turbine and/or generating unit shall be designed to withstand the additional stresses resulting from operation of unit with two or more adjacent guide vane passages in blocked condition.

The required flywheel effect (GD2) of generating units to limit the speed rise and pressure rise within specified limits shall be provided.

The bidders shall compute the maximum momentary pressure rise, and speed rise using the parameters of the plant, and the operating conditions and furnish the design computations of pressure rise and speed rise worked out in their bids.

The bidder shall indicate the maximum momentary pressure rise at turbine inlet, considering the effect of water hammer due to water mass inertia, under worst conditions of load acceptances and rejection and governor closing and opening times.

The turbine shall be so designed and constructed as to enable assembly of components at works and at the same time to permit easy transportation. The weights and sizes of the components/packages shall be within the permissible transport limits.

At least the information listed hereunder shall be given by the Tenderer. The Tenderer may support advantages in his design or of special technical features of his offer by additional documents / descriptions.

1. Compute pressure rise at turbine inlet under the most unfavourable conditions (load acceptance and rejection). Conditions considered as well as governor acting times to be clearly indicated in the computations.
2. Compute turbine speed rise under conditions as above and for following load rejection parameters.

○	From	maximum output at maximum head to zero		
○	from	100	%	rated output to zero
○	from	80	%	rated output to zero
○	from	40	%	rated output to zero

3. Expected flow characteristics during closing and opening of wicket gates as function of time.
4. Expected performance curves for the rated net head. The curves shall also show the overload output, if provided, at maximum possible wicket gates opening extending beyond the guarantee points.
5. Curves showing the critical and plant sigma values.
6. Provide dimensional drawing (cross section) of turbine and associated equipment showing main dimensions.
7. Provide information on model or field performance tests performed on a turbine, which is geometrically similar to the proposed turbine. Indicate at least the following:
 - name of the projects & its year of commissioning
 - place of model or field tests
 - year of model or field tests
 - designed rated turbine output

- rated net head
- rated speed

2.5 Problem of Silt & Provisions to mitigate

The suppliers shall note that there is a de-silting arrangement provided to eliminate silt particles of 0.2 mm diameter and higher size. Even then, the water going to the turbines may contain considerable quantity of harmful, hard and coarse silt particles particularly during peak flow in the river. The details of typical petrographic (size and hardness wise distribution) analysis of silt in various months and chemical analysis of water shall be given to the successful bidder to enable him to offer the underwater parts with hard coating, if required.

The supplier shall critically examine the silt data and the chemical analysis of water and suggest remedial measures to reduce the harmful effects of silt etc. to the underwater turbine parts, butterfly valves and other auxiliary equipment. If HVOF coating is required, the same shall be supplied at extra cost. However, the price of HVOF may be quoted separately in the bid for consideration of the purchaser.

2.6 Rating and Functional Characteristics

2.6.1 Turbine Rating

Each turbine shall have a rated output of not less than 11.855 MW (corresponding to generator rating of 11.5 MW) at shaft coupling and at rated speed of 600 RPM when operating at a rated net head of 125.45 m. Each turbine shall have 10% continuous overloading capability at rated net head.

2.6.2 Rated Speed

The speed of the units shall be 600 rpm in clockwise direction when viewed from NDE.

2.6.3 Pressure Rise and Speed rise

The maximum pressure rise at turbine inlet, considering the effect of water hammer under worst conditions of load acceptance/rejection and governor closing/opening times shall be indicated by the Contractor. However, the pressure rise shall not be more than 25% of static head acting on the spiral case with full reservoir level and speed rise shall not be more than 50% of the synchronous speed i.e. 600 rpm under any worst condition.

2.6.4 Runaway speed

The generating unit shall be designed to withstand the forces and stresses without any damage in the following operating conditions:

1. 15 minutes at normal speed without Cooling water.
2. 5 minutes at runaway speed with Cooling water supply.

3. 2 minutes at runaway speed without Cooling water supply.

The runaway speed shall be ≤ 1.8 times of rated speed.

2.7 Performance Guarantee

The generating units along with all auxiliaries and accessories shall be capable of performing intended duties under specified conditions. The Contractor shall guarantee the reliability and performance of the individual equipment as well as of the complete system.

Field tests shall form the final basis to establish fulfilment of guarantee of the turbine and for purposes of liquidated damages and rejection of the plant.

The peak efficiency of the turbine at rated head & output shall not be less than 93.5%.

2.7.1 Guaranteed Output

The Contractor shall guarantee the following turbine outputs at shaft coupling at rated speed of 600 rpm:

Rated turbine output of not less than 11.855 MW at a rated net head of 125.45 m and within 90% guide vane opening,

The guaranteed turbine output shall be demonstrated by model test report or model chosen by the manufacturer for this project.

Should the Contractor fail to achieve the output guarantee, then the Contractor shall correct the design to achieve the guaranteed output within reasonable period in order to fulfil the guarantee. The Contractor shall be responsible for all costs associated with any necessary modifications and testing of the machine. If the guaranteed output cannot be achieved by means of a modification or if by mutual agreement such modifications are omitted, the Contractor shall pay to the purchaser penalties as specified in the contract. No bonus will be given for the performance exceeding the guaranteed values.

The rated turbine output of proto type shall be verified by field tests according to IEC 60041. Should the Contractor fail to achieve the rated turbine output guarantee, then the Contractor shall pay to the Purchaser penalties as specified in the contract. Penalties shall be paid only once based on model measurements or on the field measurements depending on which one is the higher value. No bonus will be given for the performance exceeding the guaranteed value."

2.7.2 Guaranteed Efficiency

The guaranteed weighted average efficiency at the rated net head shall be calculated as follows:

$$n_{aw} = 0.7 \times n_{100} + 0.15 \times n_{80} + 0.1 \times n_{60} + 0.05 \times n_{50}$$

where

n_{aw} = Weighted average efficiency of turbine

n_{100} = Turbine Efficiency at 100 percent of rated output when operating at rated net head

n80 = Turbine Efficiency at 80 percent of rated output when operating at rated net head

n60 = Turbine Efficiency at 60 percent of rated output when operating at rated net head

n50 = Turbine Efficiency at 50 percent of rated output when operating at rated net head

Liquidated damages shall be imposed as per Clause 2.7.5, "Liquidated damages for shortfall in output and efficiency" in case of shortfall in weighted average efficiency and output vis-à-vis the corresponding guaranteed values.

The liquidated damages because of shortfall in output and weighted average efficiency shall be computed separately for each turbine and the total amount of liquidated damages shall be the sum of all the turbines. However, tolerance in computation of efficiency shall be in accordance with the IEC 60041 for field acceptance test for hydraulic turbines.

2.7.3 Cavitation Pitting Guarantee

The Contractor shall guarantee that pitting due to cavitation during a period of 24 (twenty four) months or 8000 operating hours, whichever is earlier, from the date the unit is placed into commercial operation, will not impair the strength of the runner or be measurably detrimental to the efficiency or power output of the turbine.

The material loss of runner during this period shall not exceed as per IEC 60609.

If any of the runner passages or individual turbine components taken together as listed above fail to meet the above guarantee, the Contractor shall, at his own expense, repair the pitted area by welding and also repair in a satisfactory manner all other areas, at the same location, of other water passages or identical turbine components where similar damage due to the same cause may have occurred although to a lesser extent.

Cavitation inspection will be carried out after first year or after 4000 hours of operation at which time the Contractor can assess the amount of damage and effect minor corrections.

2.7.4 Other Technical Guarantees

2.7.4.1 Wicket Gate Torque

The maximum wicket gate torque (caused by hydro-dynamic forces) shall be indicated in closing and opening sense preferably for two opposite gates, under the most unfavourable transient conditions. The wicket gate torque shall have the closing tendency for all openings down to an opening, which keeps the turbine at no-load speed below the synchronous speed.

Compliance with the guarantee shall be proved by model test / model test report.

2.7.4.2 Mechanical Behaviour

The guarantee concerning mechanical behaviour shall cover a period of 2 years from the date of taking over.

During this period, all main steel parts especially those in contact with the water flow or in the turbine pit will be inspected at the end of trial operation, and then every 2000 hours of operation until expiry of above-mentioned defect liability period.

The inspection shall be performed in compliance with the inspection of the machined runner for the defect on surfaces. If the inspections carried out during the Defect liability period as mentioned above should reveal the appearance of cracks in any portion of the turbine, the Purchaser reserves the right to apply one of the following procedures:

If the cracks or other defects do not demonstrate any systematic character, the Contractor shall eliminate or repair said defects at his own cost according to an approved and recognised method.

If the cracks or other defects demonstrate any systematic character all over the runner, the Contractor shall propose a general repair procedure followed by a heat treatment.

All repairs are subject to the Engineer's prior review and acceptance of the repair procedure. The repairs shall be made at no cost to the Purchaser and will be considered successful, if they allow operation for a minimum of 8000 hours without the appearance of new cracks or other defects.

During the defect liability period, all necessary repairs on the runners shall be made by the Contractor at his own cost.

2.7.5 Liquidated Damages for shortfall in Output and Efficiency

Liquidated damages for any shortfall in the tested values of rated output and the weighted average efficiency of turbine and generator vis-à-vis the corresponding guaranteed values respectively, shall be computed as per Volume 1, Section 9- Appendix 9 (point 3).

2.7.6 Tender Evaluation on Account Of Efficiency Difference

The difference in efficiencies of turbine in various bids shall be taken into account in evaluation of bids. Loading for equalization for this purpose shall be done on the same basis as adopted for penalty as specified above for shortfall in weighted average efficiency.

2.7.7 Rejection Limit

The Purchaser reserves the right to reject the turbine if the tested values of either weighted average efficiency or the output at rated net head of 125.48 m falls short by two (2) percent or more of the corresponding guaranteed values during field acceptance tests.

2.7.8 Transposed Model Acceptance Test

Conductance of model test is not in the scope. However, calculations to prove guaranteed Within 30 (thirty) days following the receipt of the transposed model test report, the Owner shall communicate his approval of the model to the Bidder. The Bidder shall commence the manufacture of the prototype only after the approval of the model has been accorded by the Owner.

If the model fail to meet the guarantees and requirements, it shall be optional for the Owner to conditionally accept the model and direct the Bidder to modify the model until it complies with the

requirements. All expenses involved for the modification and subsequent model tests shall be borne by the Bidder.

The Bidder shall make good and meet the guarantee again within shortest possible time from the date of witnessing the original model tests. No delay, however, shall be allowed in the original delivery schedule due to this reason

In case of failure to obtain satisfactory results to ensure guaranteed performance, the Owner reserves the right to cancel the contract or to accept the same subject to levy of penalty as per Bidding Document, Volume 1, Instruction to Bidder and Condition of Contract.

2.7.9 Field Acceptance Test

Capacity and efficiency tests shall be carried out on one turbine, chosen by Engineer at a later date, to verify that the power output and efficiency guarantees have been fulfilled.

The power output and efficiency tests on the turbine shall be made at net effective head as near as practicable to the rated net head.

The turbine efficiency and capacity tests shall be conducted in accordance with the provisions of IEC Publication 60041, International Code for Field Acceptance Tests of Hydraulic Turbines, under the direction of a qualified independent expert to be decided by the engineer and in presence of EM Contractor. The Field acceptance test shall be conducted by Third party appointed by Employer.

In addition to the field acceptance test, an Index test for flow measurement by winter Kennedy apparatus shall also be performed after calibration of the winter Kennedy apparatus in accordance of IEC by the Contractor. The purpose of index test shall be:

- To determine the performance characteristics as expressed by the relative values of power, discharge and efficiency
- To conduct Index test to check the deterioration in performance of the machine with time.

2.8 Design and Construction

2.8.1 Standards

The system and equipment shall be designed, built, tested and installed to the latest revisions of the following applicable standards. In the event of other standards being applicable they will be compared for specific requirement and specifically approved during detailed engineering for the purpose:

Standards	Description
IEC 60193	Hydraulic turbines, storage pumps and pump-turbines - Model acceptance tests.
IEC 60609	Cavitation pitting evaluation in hydraulic turbines, storage pumps and pump turbines.
IEC 60041	Field acceptance tests to determine the hydraulic performance of hydraulic turbines, storage pumps and pump- turbines.

IEC 60545	Guide for commissioning, operation and maintenance of hydraulic turbines.
IEC 60995	Determination of the prototype performance from model acceptance tests of hydraulic machines with the consideration of scale effects.
ISO 7919 part-5	Mechanical vibrations of non-reciprocating machines - Measurements on rotating shafts and evaluation criteria of machines set in hydraulic power generating and pumping plants.
IEC 61366-2	Technical Specification for Francis Turbines
ASME	ASME's "Boiler and Pressure Vessel Code"

2.8.2 Operational requirement

2.8.2.1 Smooth, Stable & Quiet Operation and Noise Limit

Turbine design shall be such as would ensure smooth and quiet operation with low vibrations, pressure pulsations, power fluctuations and noise etc. The vibration amplitude at the shaft shall not exceed the recommended values specified in ISO-7919 (part 5) and ISO-3945.

The vibrations and pulsations of prototype turbine shall be measured at site as per the IEC No.60994 "Guide for field measurement of vibrations and pulsation in the hydraulic machines". The Contractor shall guarantee that the detrimental pulsations (both for pressure and power) do not occur at any load from 40% of full load to permissible maximum load at any net head from minimum to maximum.

The peak-to-peak pressure pulsations shall not exceed 3% of the rated net head.

The peak-to-peak power pulsations shall not exceed 32% of the rated power ignoring any isolated sharp peaks.

If air injection equipment is required for reducing the vibrations, pressure and power pulsations and to have smooth running of the machines, it shall be the responsibility of the Contractor to provide the same.

The maximum noise level at any and including transient conditions (start, load rejection or surge) at any place 1.0 m distance from turbine shaft shall not exceed 90 db and the same shall be guaranteed and proved at site by actual measurement. Design provision made for achieving these guarantees, shall be elaborated during design stage.

2.8.3 Design Stress Limit

The design stress limit is as per relevant ASME standards for both normal operation and abnormal conditions.

2.8.4 Material Selection and Standards

1. RUNNER- X3CrNiMo13-4(1.4313)+QT/Equivalent, EN 10028-7
2. WICKET GATES/ GUIDE VANES- S355J2+N /P355N(1.0562)/Equivalent

3. LABYRINTHS 60BHN)- Cast Fabricated (Welded), GX4CrNiMo 13-4(1.4317) + QT1/Equivalent, EN 10028
4. FACING PLATES- GX4CrNiMo13-4(1.4317)+QT1/Equivalent, EN 10283
5. SPIRAL CASING- GX4CrNiMo13-4(1.4317)+QT2/Equivalent, EN 10283(hardness diff with runner 50- EN 10025
6. STAY RING- S355J2+N+Z25 /P355N(1.0562)+Z2/ EN 10025/Equivalent, Testing in Z direction as per EN 10164
7. STAY VANES- S355J2+N /P355N(1.0562)/ Equivalent, EN 10025
8. HEAD COVER- S355J2+N /P355N(1.0562)/ Equivalent, EN 10025
9. BOTTOM COVER- S355J2+N /P355N(1.0562)/ Equivalent, EN 10025
10. WICKET GATES LINK AND LEVER- S355J2+N /P355N(1.0562)/ Equivalent, EN 10025
11. WICKET GATES OPERATING RING- S355J2+N /P355N(1.0562)/ Equivalent, EN 10025
12. DRAFT TUBE BEND- S355J2+N/S235J2+N EN 10025/Equivalent
13. DRAFT TUBE CONE- S235J0+N EN 10025/Equivalent
14. HEAD COVER THRUST RELIEVING PIPES- SS -304/SS- 316/ Equivalent
15. WICKET GATES BEARINGS BUSHES- DEVA /DU GGB Glacier
16. WICKET GATES BEARING HOUSINGS- ASTM A240 TYPE- 304/ASTM 240 A316/ Bronze (Centrifugally Cast) EN 1982
17. WICKET GATES SEALS- Trelleborg/ Simirit/Hunger(Pressure operated Lip Seals). O-Ring Seals Not acceptable.
18. RUNNER CENTRE BOLT- 30CrNiMo8 (1.6580).

2.9 Construction Details

2.9.1 General Arrangement

The turbine shall be of the spiral casing type so constructed as to allow all the removable parts to be dismantled conveniently. The design shall also permit horizontal movement of runner shaft by an amount sufficient for adjustment of bearings and for clearing the joint at the coupling between the turbine and the generator.

All equipment shall be neatly arranged and shall be readily and easily accessible for operation and maintenance. Necessary walkways, ladders, handrails, chequered plates, platforms, etc., to be provided by the contractor, wherever required. Each turbine shall consist of following major parts.

2.9.2 Runner

The runner shall be cast fabricated/welded in 13% Chromium, 4% Nickle stainless steel (ASTM A-743 Gr. CA-6NM) and shall be designed to provide the best hydraulic profile so that it gives maximum efficiency with minimum of cavitation. The runner cone shall be stainless steel casting/weld plate stainless steel fabrication. The runner shall ultimately be one-piece construction. It shall have suitable flange to mount generator shaft. Relief pipes shall be provided for thrust relief of the Runner. The runner will have adequate number of blades which shall be polished and ground smooth. The runner shall be free from hollows, roughness, cracks and projections. The water passage on the blades, crown & skirt shall be finished to correct profiles for the prototype based on homology with successful turbine model. The finished and ground runner shall be statically balanced in the works before despatch.

2.9.3 Spiral Casing, Stay Ring and Generator Side Covers

The spiral casing shall be complete with stay ring and sufficient number of stay vanes.

The spiral casing shall consist of several steel plate sections, adapted to the side plates of the stay ring and welded in place. The stay ring besides guiding the flow into guide vanes shall provide structural rigidity to the spiral casing against hydraulic forces.

On the upstream side, a welded flange with a spacer piece shall be provided to facilitate a connection between the spiral inlet to the turbine inlet valve.

The generator side (front side) and draft side (rear side) covers of welded plate shall be flanged to spiral casing. Required number of bushes for support of guide vane pivots will be provided on the front side and rear side covers. The guide vane stems on the rear cover side (draft tube side) are assembled to the operating mechanism.

The turbine spiral casing shall be mounted on the turbine floor by supporting feet and foundation plates. The required anchoring material etc. shall be a part of the scope.

The site welds in the spiral casing shall be inspected by dye-penetration test/ultrasonic test.

The spiral /speed ring will be designed to withstand maximum water pressure including water hammer as specified.

Suitable tapping/connections for drainage, bypass, instrumentation, discharge measurement by Winter Kennedy method, field efficiency test, air release etc. shall be provided.

The assembly will be pressure tested in the works/site at 150% of maximum pressure including water hammer pressure for 60 minutes before its shipment to site.

The embedding at site of spiral casing in concrete shall be carried out with the casing under suitable pressure. For the purpose of pressure test at site, stay ring openings shall be closed by separate pressure test rings.

2.9.4 Draft Tubes

Draft Tubes shall be complete with steel liner comprising of

- (i) Cones
- (ii) Elbow Section
- (iii) Conical Liner
- (iv) Anchoring Material

Each turbine shall be provided with a Draft tube liner/ suction bend of welded construction of structural steel. The draft tube cone shall have machined flange for bolting with the runner chamber. The design of the draft tube shall be such as to ensure the best overall efficiency for the turbine and stable & pulsation free operation of the machine.

The draft tube shall be totally works assembled, with no requirement of any welding at site. The interior of the liner shall be flush and smooth with no abrupt change in direction of flow.

2.9.5 Wicket -gate mechanism with gate operating mechanism

The generator side head cover (front cover) & draft tube side cone (rear cover) shall be of suitable construction of steel, to accommodate guide bearings, casings, labyrinth rings, shaft sealing, guide vane bearings etc. The head covers to be suitably designed to resist the superimposed hydraulic load such that any consequential deflections / slopes of the head cover would not hamper the functioning of the wicket-gate operating mechanism.

2.9.6 Guide Vanes

Each guide vane and its stem shall be an integral casting in 13-4 stainless steel. The contacting surface of gates and the gate stems shall be smooth and machined finish. All guide vane bearings (Axial / radial) shall be maintenance free, with appropriate sealing against water flow channel by 'O' rings.

The angular movement of the gates shall be so limited and the mechanism so designed that the bedding faces of the guide vanes close, with no gap, with the servo-motor at its closed position.

The guide vane links/ levers shall be clamped to the guide vane stem and locked in position during assembly. A suitably designed frictional clutch mechanism to prevent possible damage to the wicket gates in case of trapped foreign bodies between the gates shall be provided.

2.9.7 Gate Operating Ring

A suitably designed gate operating ring, operated by a servo-motor shall be supplied. The operating ring shall be provided with maintenance free bushes.

2.9.8 Servo-motors

Double Acting servo-motors operated by governor oil pressure shall be mounted on the generator side head-cover. The servo-motor shall be supplied with a feedback transmitter. Servo-motors shall be of sufficient capacity to operate the wicket gates, when supplied with oil at minimum pressure.

Opening /closing timings will be adjusted during works tests. The servo-motors will be pressure tested at 1.5 times the design pressure.

2.9.9 Shaft Sealing Arrangement

The Bidder shall provide two (2) shaft seals, one as main working seal and another as maintenance seal of infallible seal type.

The working seal shall be of non-contact type seal. This seal ensures that spinning parts are sealed from pressurized water circulating around the runner.

Maintenance seal, of inflatable type, shall be applied, when turbine is stopped. This enables work to be carried during maintenance operation in the pit and prevents flooding of the turbine pit or even the power station.

The main working seal shall be installed on the rotating sump attached to turbine-shaft. Filtered water shall be injected, under pressure higher than the water pressure on top of the runner crown, headcover, into the two concentric rings of shaft-seal. During operation there shall be rubbing between fixed shaft seal ring and spinning wearing plate. The wearing ring of shaft seal shall be screwed to movable ring. The movable ring shall be mobile in translation. This translation motion shall be important for small movement of the seal during operation but also to compensate the wear or to be able to lift the rotor during dismantling, erection or maintenance.

The Bidder shall provide necessary piping and valves, including pressure reducing valves, filters, piping and fittings within the turbine pit, terminated by unions and flanges, at a point outside the turbine pit.

A water flow meter of suitable make with adjustable alarm contacts shall be provided in the water supply piping to the seal. These contacts shall be wired to terminal blocks in the turbine terminal box. One additional contact shall be provided to operate an indication light in the gauge panel to indicate that shaft seal water is "ON". A duplex pressure gauge shall be provided to indicate the pressure beneath the seal and in the supply line.

All bolts, nuts screws and hard ware used in connection with the shaft water seal shall be of stainless steel.

2.9.10 Turbine Shaft (if applicable)

The turbine shaft will be 1.5% Mn. steel forging conforming to Indian standard or equivalent International Standard. The shaft shall be polished where it passes through the guide bearing.

Method to avoid damage due to axial forces of the horizontal machine shall be elaborated in the bid document.

2.9.11 Flexible Coupling

The generator shaft and turbine shaft shall be coupled via a flexible coupling, designed for the maximum output and operating condition. In case runner is directly mounted on generator shaft, Flexible coupling is not required.

2.9.12 Turbine Drains

Adequate provision shall be made for collection of any leakage water around the turbine and its delivery to a lowest point of the station drain. A drain connector at lowest point of scroll case for draining into the draft tube/drainage sump shall be provided.

2.10 Turbine Flow Meter

2.10.1 Winter Kennedy Flow meter

Each turbine shall be provided with a winter Kennedy type flow measurement system in the penstock or spiral case extension, for continuous on-line monitoring of flow through the turbine.

The flow meter shall be designed to operate utilizing the pressure differential obtained from Winter Kennedy tapping to be provided in the shroud of the stay ring and the spiral case or at any convenient locations. The flow-meter shall indicate the instantaneous flow (in cubic meters per second) through the turbine on a uniformly graduated direct reading indicator and shall record the flow on a recording device. The equipment shall be capable of measuring over the entire range of turbine operation from 10% to 120% of maximum turbine discharge.

2.11 Piezometer Taps

Four piezometer taps equally spaced around the turbine inlet pipe and four piezometer taps at the draft tube exit section shall be provided for field-testing in accordance with IEC Field test code.

Connections shall be terminated in a manifold adjacent to the turbine inlet pipe. Vacuum/pressure gauge shall be connected to the manifold and mounted conveniently.

2.12 Railing, ladder for E&M equipment

Railing or ladder, if required, for safety of E&M equipment within the powerhouse is to be supplied. The requirement of railing, if applicable, shall be discussed with employer during execution stage.

Railings for staircase will be arranged by employer.

2.13 Name Plate

A rating nameplate of stainless steel shall be attached to each major and auxiliary item of equipment supplied. This plate shall be permanently engraved with the designed full load ratings, serial number, type number, date of manufacture and other identification deemed necessary. Hydraulic and electric control system diagram plates shall also be supplied. The identifying inscription shall be approved by the Engineer.

2.14 Control and Monitoring

The turbine and associated accessories/equipment shall be controlled and monitored at two levels:

- Automatically from respective Unit Control Boards (during individual automatic operation of the unit),
- By Computerized control and monitoring (SCADA) system through Operator's work station (during centralized automatic control).

The details of control and monitoring requirement are defined in "Computerized Control and Monitoring System" and "Protection System" sections.

The Contractor shall make provision of contacts and/or ports in control cubicles for interfacing with SCADA system for control and monitoring.

2.15 Instrumentation and Control

The Contractor shall include suitable Control & instruments, safety devices, gauges, switches, contacts for achieving desired control and monitoring as defined in the sections for Turbine, Computerized Control and Monitoring System" and "Protection System".

2.16 Level Monitoring Devices

2.16.1 Tailrace Water Level Meters

One set of transducer or digital transmitter shall be provided for measurement of tailrace level. The transducer shall be mounted in such a way that any oscillations in water level are damped out. It should be possible to take out the transducer for calibration and checking. Accuracy shall be better than $\pm 0.5\%$. Output shall be fed as an input to Data SCADA. Local level indicator, in addition, shall also be provided. This is being covered in Automation chapter.

2.16.2 Reservoir Water Level Monitoring

For monitoring water level upstream of intake gates, 2 sets of suitable digital transmitter operated from float or capacitive type level transducers shall be provided, complete with attachments for mounting the same in gauge well, which will be constructed upstream of barrage. The output of transducer 4-20 mA (or as approved by Purchaser) shall be used as input to Remote Terminal at barrage site for signal transmission. This signal will be transmitted through telecommunication network to powerhouse and/or remote control centre, decoded and displayed in control room on a digital output meter calibrated in metres and used in hydraulic mimic of SCADA.

Turbine output shall be regulated automatically by the governor based on reservoir water levels.

2.17 Over-speed Device

Electronic overspeed device and speed detection will be provided through the digital governor. Overspeed of 20% will shut down the turbine along with the main inlet valve.

2.18 Drawings, Documents and Design Calculations

2.18.1 Design Memorandum

The Contractor shall submit to Purchaser a design memorandum prepared in accordance to clause 1.2 of "Section 1-General Technical Specifications of the proposed equipment /system fulfilling the contract specification/requirement for approval prior to submission of drawings and documents. The design memorandum shall include the design philosophy, methodology, system description, input parameters for design, standards and codes, design & selection criteria, equipment data, material specification, major technical features, basic arrangement / layout etc.

2.18.2 Drawings and Documents

The Contractor shall submit all the drawings and documents in accordance with requirements stipulated in "Section 1-Technical Documents" of "General Technical Specification (GTS)"

2.18.3 Design Calculations

The Contractor shall submit the design calculation in accordance to "General Technical Specification (GTS)" covering at least the following, for review / acceptance.

- Structural and stress analysis of stay ring, spiral case, side covers, and discharge ring, bearing, servomotors, draft tube etc.
- Structural and stress analysis of runner,
- Structural and stress analysis of turbine shaft and coupling bolts,
- Critical speed and bearing arrangement
- GD2 calculation,
- Hydraulic transient analysis including speed and pressure rise,
- Draft tube surge frequency,
- Natural frequency of the unit,
- Calculation of Foundation loads including unbalanced forces, their point of application under various normal and most abnormal operating conditions

2.18.4 Drawings

The following drawings shall be enclosed with the bid:

- Cross section of the Powerhouse with sectional view of turbine including scroll case, runner, draft tube, and inlet pipe etc.
- Plan view of the powerhouse showing plan of turbine including scroll case, runner, draft tube, inlet pipe, shaft coupling arrangement with generator, bearing details etc.
- Foundation arrangement of scroll case, inlet pipe, draft tube
- Detailed cross-sectional view of turbine

- Assembly and dis-assembly procedure of turbine
- Details of Labyrinth and shaft seal
- Details of guide apparatus, regulating ring and servo-motor linkage
- Wicket gate arrangement in open and closed position
- Shear pin linkage details
- Any other drawing necessary to elaborate essential feature of the offered turbine

2.19 Shop Assembly and Tests

2.19.1 General

The major shop tests are detailed below:

Assembly-

Each individual assembly viz. complete draft tube, the spiral casing and the stay rings, end covers, wicket gates and operating rings, and shaft seals shall be trial erected in the factory and dimensional inspection performed to ensure correct reassembly and alignment in the field.

Servomotor Cylinders and Oil Pressure Systems-

The servomotor cylinders and oil pressure system shall be subject to a pressure test of 50 % above maximum normal pressure, for a period of 30 minutes. After being tested, the equipment and piping shall be thoroughly cleaned and protected. Leakage test shall also be performed.

Static balancing of runner shall be performed in the shop.

Acceptance test-

All acceptance tests as per relevant standards for runner, draft tube, guide vane, regulating system/distributor, shaft seal, spiral casing, stay ring etc. shall be carried out in presence of Employer representatives.

2.19.2 Material Tests

Material tests for important components such as runners, guide vanes, shaft, discharge ring and other important components shall be done.

Tests on Sub-Assemblies-

A record shall be made of shop measurements of all critical dimensions, diameters, eccentricities, run-outs, clearances, etc. of the turbine moving and stationary parts, which may affect the field erection and alignment or normal operation of the turbine.

2.19.3 Defects and Corrections

Any leakage, distortion, or other defects developed during or after the tests shall be corrected and retested. The tests shall be repeated after repairs, if in the opinion of Purchaser further tests are necessary.

2.19.4 Record of shop Measurements

Tests on sub-assemblies to verify fits or alignment, proper functioning, radiograph, magnetic particle, dye penetrant, or ultrasonic inspections shall be performed as required by good standard practice. A list of sub-assemblies and tests proposed for quality checks shall be submitted.

2.20 Field Tests during Erection, Pre-Commissioning and Commissioning

2.20.1 General

All field tests including operational, pre-commissioning and commissioning tests shall be conducted by Contractor. The Contractor shall furnish a detailed procedure for commissioning of the turbines and other associated equipment and shall submit the same to the Purchaser not later than 12 (twelve) months prior to the scheduled date of commissioning of the first unit.

2.20.2 Calibration

Calibration of guide vane openings including their relationship and measurement of clearances

2.20.3 Testing of Protective Devices

Testing of protective devices i.e. oil level, temperature, pressure, over speed, alarms, tripping, non-operation of gate servomotor, spiral leakage, shaft seal breakdown, generator mechanical brake failure etc. including adjustments, if any.

2.20.4 Operational Tests

Control logic field tests to prove control logic scheme for operation and interlocks of auxiliaries, including annunciation and shutdown scheme shall be done in so far as practical.

2.20.5 Pre -Commissioning Tests

- Tests to check all weld joints done at site
- Clearances of labyrinth assembly
- Shaft rotational checks for alignment
- Tests to determine opening and closing time of guide vane servomotors. Also tests to determine servomotor stroke characteristics and to ensure that these characteristics are identical and in conformity with design; Suitable transducers shall be used to record the characteristics.
- All the pre-start tests as detailed in Cl. 6.1 and 6.2 of IEC: 545.

- Load rejection tests at 25, 50, 75, 100 and 110 percent of rated output to verify speed rise and pressure rise.
- Unit starting, stopping, braking, no load no excitation run test, part load, full load and overload operational tests to ensure performance as per specifications.
- Leakage from shaft seal
- Measurement of vibrations during various operating conditions
- Braking time from 150 /100 percent speed to 20 percent speed during the shutdown

Any other checks/tests to ensure that requirements of the specifications are being met. No extra charges for such tests shall be payable.

2.20.6 Commissioning Tests

2.20.6.1 General

All applicable tests listed in IEC Guide for Commissioning, Operation and Maintenance of Hydraulic Turbines (IEC Publication 545) shall be carried out in accordance with specified procedures. These shall include but not be limited to the following:

- Deformation of covers and bearing supports
- Noise/ vibration in turbine and/or generator
- Turbine safety and signal devices
- Operating condition of all pumps
- Oil levels, temperature, pressure, cooling water temperature etc.
- Shaft run-out at turbine and generator bearings
- Load run and load rejection tests

2.20.6.2 Index test

Index test shall be performed on each unit to calibrate the flow meter within 0.5 per cent accuracy to assess change in efficiency during operation, and to optimize power output.

2.20.6.3 Performing Testing

If nothing unusual has been observed in load run and load rejection tests, the test service period of 72 hours shall follow. During this test service period, the unit must operate continuously at rated condition without any interruption, except of those beyond the control of the Bidder. However, such interrupted period shall not be counted for in the test service period.

The Bidder shall be responsible for the equipment during test service and also for the way it is operated. However, owner's personnel shall operate the equipment under the Bidder's presence during the test service period.

2.21 Field Acceptance Tests on Turbine

2.21.1 General

Tests for general acceptance and efficiency/output will be done by Third party appointed by Employer as soon as possible after the equipment has been placed in operation. In the event it is necessary to place the equipment in regular service for a considerable period of time, before the acceptance tests are made, the equipment will be inspected carefully and so far as possible restored to its original condition by Purchaser before tests are conducted.

2.21.1.1 Test Instruments

The Third party shall provide all necessary calibrated instruments and equipment required to determine the turbine efficiency at site by Acoustic or any other suitable method. These instruments will remain the property of the Third party.

2.21.1.2 Test Codes

Unless otherwise mutually agreed to in writing, acceptance tests will be conducted in accordance with the latest edition of the "International Code for the Field Acceptance Tests of Hydraulic Turbines" (IEC-60041).

2.21.1.3 Test Supervisor

Purchaser may contract for the service of an independent test supervisor, experienced and skilled in the art of conducting turbine efficiency tests.

2.21.1.4 Provision

The Contractor shall make all necessary provisions (such as pick-ups, embedded connections, etc.) on all the turbines, for the efficiency test to enable to select any of the turbines for efficiency test.

2.21.1.5 Procedures

Procedure to be adopted for conducting the commissioning and field tests shall be submitted well in advance, and shall be subject to approval of the Purchaser.

2.22 Specified Spare Parts

Following specified spare parts are included in the present scope of supply:

S. No.	Description	Quantity

1.	Runner complete with moving labyrinth seals, runner cone and fixing bolts.	1 no.
2.	Coupling bolts turbine shaft to generator shaft	1 set
3.	Labyrinth seals Upper including fasteners	
	• Fixed labyrinth seals	1 set
	• Moving labyrinth seals	1 set
4.	Labyrinth seals Lower including fasteners	
	• Fixed labyrinth seals	1 set
	• Moving labyrinth seals	1 set
5.	Liner/facing plates for top cover including fasteners	1 set
6.	Complete set of guide vanes	1 set
7.	Set of Shaft seal sleeve	1 no
8.	Turbine guide bearing segments/ pads complete set	1 set
9.	Guide apparatus	
i	Bushes for top, middle and bottom stems of guide vanes	1 set of each used type
ii	Guide vane servomotors	1 no
iii.	Shear pins	1 set
iv.	Bushes for regulating mechanism	1 set
10	Pressure gauge of each type	1 no.
11	Pressure switch / pressure transmitter of each type	1 no.

12	Valves including penstock drain valve	1no.of each type
----	---------------------------------------	------------------

2.23 Special Tools

The Contractor shall propose the list of recommended special tools including their make and detailed specification as recommended by manufacturer(s) and to be accepted by the Purchaser. The special tools shall include the followings:

- a) Tools for runner handlings, assembly and dismantling.
- b) One (1) set of hydraulic torque tensioners with one identical tensioners for runner/turbine shaft flange coupling bolts, as applicable.
- c) One (1) set of hydraulic wrenches for opening each type of bolt size viz. head cover, bottom ring, runner coupling bolts, labyrinths, draft tube cone bolts etc. used in the plant.
- d) One (1) set of torque wrenches of adequate torque capacity for Labyrinth, top cover, bottom ring, draft tube cone bolts etc.
- e) One (1) set of runner blades templates.
- f) One (1) set of guide vanes templates.
- g) Four (4) nos. of eyebolts of each size (M12 or above) used in the turbine components.

2.24 Quality Assurance and Testing

The bidder shall submit the quality assurance plan along with bid for approval of the purchaser. The Contractor shall follow the quality assurance and testing requirements as per quality assurance plan approved by the purchaser.

2.25 Guaranteed and Technical Particulars

Guaranteed and Technical Particulars as called for in Vol. VI shall be furnished along with the bid. Bids lacking in this may be considered unresponsive. Particulars subject to guarantee shall be clearly marked

2.26 Completeness of Equipment

All fittings and accessories of the turbine and associated auxiliary & ancillary equipment which may not have been specifically mentioned in these specifications, but are usually necessary for completion of the above equipment, shall be deemed to be covered by the specification; and shall be indicated and furnished by the supplier without any charges to the purchaser.

2.27 Deviation from Specifications

While the purchaser does not bind himself to accept any deviation, due consideration will be given to any special devices or equipment put forward by the supplier with a view to increase the efficiency of the equipment and minimize the maintenance cost of the equipment as a whole.

Should the supplier wish to depart from these specifications, he shall submit a complete and itemized list of such deviations, together with full particulars of the reasons for the deviations in a separate schedule with special reference to clause and paragraph nos. of this specification (as per Proforma given at Schedule-B). Unless this is done and also the purchaser's concurrence in respect of such deviations is obtained in writing, the equipment offered shall be deemed to comply in every respect with these specifications.

2.28 Schedule of Installation

The bidder shall furnish a list of similar equipment supplied and duly erected by him as per proforma enclosed with the bid.