TECHNICAL REPORT

IEC 61366-6

First edition
1998-03

Hydraulic turbines, storage pumps and pump-turbines –
Tendering Documents –
Part 6: Guidelines for technical specifications for pump-turbines

Turbines hydrauliques, pompes d'accumulation et pompes-turbines –

Documents d'appel d'offres –

Partie 6:
Guide des spécifications techniques pour les pompes-turbines

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IEC publications prepared by the same technical committee

The attention of readers is drawn to the end pages of this publication which list the IEC publications issued by the technical committee which has prepared the present publication.

* See web site address on title page.

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

HYDRAULIC TURBINES, STORAGE PUMPS AND PUMP-TURBINES – TENDERING DOCUMENTS –

Part 6: Guidelines for technical specifications for pump-turbines

FOREWORD

1) The IEC (International Electrotechnical Commission) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of the IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, the IEC publishes International Standards. Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. The IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
2) The formal decisions or agreements of the IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested National Committees.
3) The documents produced have the form of recommendations for international use and are published in the form of standards, technical reports or guides and they are accepted by the National Committees in that sense.
4) In order to promote international unification, IEC National Committees undertake to apply IEC International Standards transparently to the maximum extent possible in their national and regional standards. Any divergence between the IEC Standard and the corresponding national or regional standard shall be clearly indicated in the latter.
5) The IEC provides no marking procedure to indicate its approval and cannot be rendered responsible for any equipment declared to be in conformity with one of its standards.
6) Attention is drawn to the possibility that some of the elements of this International Standard may be the subject of patent rights. The IEC shall not be held responsible for identifying any or all such patent rights.

The main task of IEC technical committees is to prepare International Standards. In exceptional circumstances, a technical committee may propose the publication of a technical report of one of the following types:

- type 1, when the required support cannot be obtained for the publication of an International Standard, despite repeated efforts;
- type 2, when the subject is still under technical development or where for any other reason there is the future but no immediate possibility of an agreement on an International Standard;
- type 3, when a technical committee has collected data of a different kind from that which is normally published as an International Standard, for example "state of the art".

Technical reports of types 1 and 2 are subject to review within three years of publication to decide whether they can be transformed into International Standards. Technical reports of type 3 do not necessarily have to be reviewed until the data they provide are considered to be no longer valid or useful.

IEC 61366-6, which is a technical report of type 3, has been prepared by IEC technical committee 4: Hydraulic turbines.

The text of this technical report is based on the following documents:

Committee draft	Report on voting
4/110/CDV	4/122/RVC

Full information on the voting for the approval of this technical report can be found in the report on voting indicated in the above table.

Technical Report IEC 61366-6 is one of a series which deals with Tendering Documents for hydraulic turbines, storage pumps and pump-turbines. The series consists of seven parts:

IEC 61366-1: General and annexes (IEC 61366-1)

Part 2: Guidelines for technical specification for Francis turbines (IEC 61366-2)

Part 3: Guidelines for technical specification for Pelton turbines (IEC 61366-3)

Part 4: Guidelines for technical specification for Kaplan and propeller turbines (IEC 61366-4)

Part 5: Guidelines for technical specification for tubular turbines (IEC 61366-5)

Part 6: Guidelines for technical specification for pump-turbines (IEC 61366-6)

Part 7: Guidelines for technical specification for storage pumps (IEC 61366-7)

Parts 2 to 7 are "stand-alone" publications which when used with IEC 61366-1 contain guidelines for a specific machine type (i.e. Parts 1 and 4 represent the combined guide for Kaplan and propeller turbines). A summary of the proposed contents for a typical set of Tendering Documents is given in the following table 1 and annex A. Table 1 summarizes the arrangement of each part of this guide and serves as a reference for the various chapters and sections of the Tendering Documents (see 3.2 of this part).

A bilingual edition of this technical report may be issued at a later date.

Table 1 – Summary of guide for the preparation of Tendering Documents for hydraulic turbines, storage pumps and pump-turbines

CONTENTS OF GUIDE IEC 61366-1 TO IEC 61366-7

Part	**Clause**	**Title**
1		General and annexes
1	–	
1	1	Object and scope of this guide
1	2	Reference documents and definitions
1	3	Arrangement of Tendering Documents
1	4	Guidelines for tendering requirements
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1	6	Guidelines for general conditions, special conditions and general requirements
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3		Pelton turbines
4		Kaplan and propeller turbines
5		Tubular turbines
6		Pump-turbines
7		Storage pumps

SAMPLE TABLE OF CONTENTS OF TENDERING DOCUMENTS (TD)
(Example for the Francis turbines; see 61366-1, annex A)

Chapter	**Title**
1	Tendering requirements
2	Project information
3	General conditions
4	Special conditions
5	General requirements
6	Technical specifications
6.1	Technical requirements
6.1.1	Scope of work
6.1.2	Limits of the contract
6.1.3	Supply by Employer
6.1.4	Design conditions
6.1.5	Performance and other guarantees
6.1.6	Mechanical design criteria
6.1.7	Design documentation
6.1.8	Materials and construction
6.1.9	Shop inspection and testing
6.2	Technical specifications for fixed/embedded components
6.3	Technical specifications for stationary/removable components
6.4	Technical specifications for guide vane regulating apparatus
6.5	Technical specifications for rotating parts, bearings and seals
6.6	Technical specifications for thrust bearings
6.7	Technical specifications for miscellaneous components
6.8	Technical specifications for auxiliary systems
6.9	Technical specifications for instrumentation
6.10	Spare parts
6.11	Model tests
6.12	Installation and commissioning
6.13	Field acceptance tests

HYDRAULIC TURBINES, STORAGE PUMPS AND PUMP-TURBINES – TENDERING DOCUMENTS –

Part 6: Guidelines for technical specifications for pump-turbines

0 Introduction to technical specifications

The main purpose of the technical specifications is to describe the specific technical requirements for the hydraulic machine for which the Tendering Documents (TD) are being issued. To achieve clarity and to avoid confusion in contract administration, the Employer should not specify anything in the technical specifications which is of importance only to the preparation of the tender. Such information and instructions should be given only in the instructions to Tenderers (ITT). Accordingly, the ITT may refer to other chapters and sections of the Tendering Documents but not vice versa. *As a general rule the word "Tenderer" should be confined in use only to TD chapter 1 "Tendering requirements"; elsewhere the term "Contractor" should be used.*

Special attention should be given to items of a project specific nature such as materials, protective coating systems, mechanical piping systems, electrical systems and instrumentation. It is common for the Employer to use technical standards for such items which would apply to all contracts for a particular project or projects. In this event, detailed technical standards should be specified in TD chapter 5 "General requirements".

Technical specifications for the various types of hydraulic machines included in this guide are provided in the following parts:

– Francis turbines (Part 2);
– Pelton turbines (Part 3);
– Kaplan and propeller turbines (Part 4);
– Tubular turbines (Part 5);
– Pump-turbines (Part 6);
– Storage pumps (Part 7).

The guidelines for preparation of pump-turbine specifications include technical specifications for the following:

– Design conditions: Project arrangement, hydraulic conditions, specified conditions, modes of operation conditions, generator characteristics, motor characteristics, synchronous condenser characteristics, speed-up procedure for pump mode, transient behaviour data, change-over times and characteristics, stability of the system, noise, vibration, pressure fluctuations and safety requirements.
– Technical performance and other guarantees:
    - power
    - discharge
    - specific hydraulic energy (head)
    - efficiency
    - maximum momentary pressure
    - minimum momentary pressure
    - maximum momentary overspeed
    - maximum steady-state runaway speed
    - cavitation pitting
    - hydraulic thrust

  - change-over times
  - maximum weights and dimensions for transportation, erection and maintenance
- Mechanical design criteria: design standards, stresses and deflections and special design considerations (earthquake acceleration, etc.).
- Design documentation: Contractor’s input needed for the Employer's design, Contractor's drawings and data, Contractor's review of the Employer's design and technical reports by the Contractor.
- Materials and construction: material selection and standards, quality assurance procedures, shop methods, corrosion protection and painting.
- Shop inspection and testing*:* general requirements and reports, material tests and certificates, dimensional checks, shop assembly and tests.
- Fixed/embedded components: spiral case with compressible wrapping (if any), stay ring, foundation ring, discharge ring, draft tube, draft tube liner, pit liner, and foundation plates and anchorages.
- Stationary/removable components: headcover, bottom ring, facing plates, stationary wearing ring, guide vanes.
- Regulating apparatus for guide vanes: servomotor, connecting rods, regulating ring (if any), guide vane linkage system, guide vane overload protection and locking devices and mechanical synchronizing device (if any).
- Rotating parts, bearings and seals: runner (impeller), main shaft, intermediate shaft (if any), guide bearing with oil supply, oil/water cooler, main shaft seal, standstill (maintenance) seal.
- Thrust bearing (if part of the hydraulic machine supply): bearing support, thrust block, rotating ring, thrust bearing pads and pivots, oil sump with oil supply (common with guide bearing, if any), oil/water coolers, instrumentation.
- Miscellaneous components: walkways, lifting fixtures, special tools, standard tools, turbine pit hoist, nameplate, draft tube maintenance platform.
- Auxiliary systems: runner pressure balancing and pressure relief lines, turbine pit drainage and other drainage systems; lubrication, draft tube air admission, tailwater depression, cooling water supply for runner seal for blow-down operation.
- Instrumentation: controls, indication and protection.
- Spare parts: basic spare parts.
- Model acceptance tests: test requirements.
- Site installation and commissioning tests: installation procedures and commissioning tests.
- Field acceptance tests: scope of field tests, reports and inspection of cavitation pitting.

An example of the proposed table of contents for Tendering Documents for a Francis turbine is given in annex A of IEC 61366-1. The example does not include technical specifications of the control system, shut-off valves, gates motor-generator, pony motor, frequency converter for starting into pump-mode, excitation system which may, at the Employer's option, be included in the Tendering Documents for the pump-turbine or may be specified in separate documents.

Chapter 6 (technical specifications) of the Tendering Documents should be arranged as follows:

6.1 Technical requirements;

6.2 Technical specifications for fixed/embedded components;

6.3 Technical specifications for stationary/removable components;

6.4 Technical specifications for guide vane regulating apparatus;

6.5 Technical specifications for rotating parts, guide bearings and seals;

6.6 Technical specifications for thrust bearing;

6.7 Technical specifications for miscellaneous components;

1 Scope

This technical report, referred to herein as the Guide, is intended to assist in the preparation of Tendering Documents and tendering proposals and in the evaluation of tenders for hydraulic machines. This part of IEC 61366 provides guidelines for pump-turbines.

2 Reference documents

IEC 60041:1992, *Field acceptance tests to determine the hydraulic performance of hydraulic turbines, storage pumps and pump-turbines*

IEC 60193:1965, *International code for model acceptance tests of hydraulic turbines*

IEC 60308:1970, *International code for testing of speed governing systems for hydraulic turbines*

IEC 60609:1978, *Cavitation pitting evaluation in hydraulic turbines, storage pumps and pump-turbines*

IEC 60805:1985, *Guide for commissioning operation and maintenance of storage pumps and of pump-turbines operating as pumps*

IEC 60994:1991, *Guide for field measurement of vibrations and pulsations in hydraulic machines (turbines, storage pumps and pump turbines)*

IEC 61362,— *Guide to specification of hydro-turbine control systems* [1)]

ISO 3740:1980, *Acoustics – Determination of sound power levels of noise sources – Guidelines for the use of basic standards and for the preparation of noise test codes*

3 Technical requirements

3.1 Scope of work

This subclause should describe the scope of work and the responsibilities which are to be conferred upon the Contractor. The general statement of scope of work presented in TD [2)] section 2.1 (5.1 of IEC 61366-1) shall be consistent with what is presented here. In a similar manner, pay items in the tender form, TD section 1.2 (4.2 of IEC 61366-1) should be defined in TD subsection 6.1.1.

The scope of work should begin with a general statement which outlines the various elements of the work including (where applicable) the design, model testing, supply of materials and labour, fabrication, machining, quality assurance, quality control, shop assembly, shop testing, spare parts, transportation to site, site installation, commissioning, acceptance testing, warranty and other services specified or required for the items of work.

[1)] To be published.

[2)] All references to Tendering Documents (TD) apply to annex A of IEC 61366-1.

The layout of a pump-turbine may lead to a single or multistage machine. The latter can be of a regulated or non-regulated type. Economical operation and operational flexibility of a pump-turbine set may require additional equipment such as starting turbine, pony motor, and frequency converter for starting in the pump-mode. It is also possible to consider the use of a motor-generator with different rotational speeds for pump and turbine mode.

Multistage pump-turbines are not presented in this volume. For the description of additional components refer to Part 7 (storage pumps).

The general statement should be followed by a specific and detailed list of the major items which the Employer wishes to have as separate payment items in the tender form, for example:

Item Description

1 Four (4) vertical shaft, single stage, regulated Francis type pump-turbines, each with a specified power of not less than 255 MW under a specified specific hydraulic energy of 4 719 J/kg (head of 481 m), pump discharge of 42,5 m^3/s with design tolerance of –5% to +5 % at a specific hydraulic energy of 4 758 J/kg (pump head of 485 m);

2 Pump-turbine model testing;

3 Tools, slings and handling devices required for maintenance of the pump-turbines;

4 Transportation and delivery to site;

5 Site installation, commissioning and acceptance testing of the pump-turbines;

6 Preparation and submission of operation and maintenance manual and training of Employer's operating and maintenance staff in the optimum use of these manuals; and

7 Spare parts required for operation and maintenance.

3.2 Limits of the contract

This subclause, making reference to the Employer's drawings and data, should give in detail the limits of the contract considering the following:

- details of the design and supply limits of the high-pressure reference section;
- details of the design, location and responsibility for field connection of spiral case to penstock or valve on high-pressure side;
- details and location of the low-pressure reference section;
- details and location of the downstream termination of the draft tube liner;
- details and location of pump-turbine valve and gate on high and low-pressure side;
- elevation of the upper pump-turbine shaft flange and/or distance to the pump-turbine distributor centreline;
- responsibility for supply and installation of flange coupling bolts, nuts and guards at motor-generator/pump-turbine coupling, including drilling jig;
- responsibility for supply and installation of bolts, nuts, gaskets at piping termination;
- termination of governor piping;
- termination of spiral case and draft tube dewatering piping;
- termination of spiral case air exhaust piping (if any);
- termination of pit drainage piping;
- termination of bearing lubricating oil piping;
- termination of piping (if required) to carry upper runner/impeller seal leakage to the draft tube;
- termination of shaft seal piping (if any);
- terminations of piping external to that provided to enhance operating stability when the unit is required to function outside the optimum operating conditions;

- termination of cooling water piping for bearings, shaft seals and runner seals;
- pump-turbine head cover mounted thrust bearing (if specified);
- termination points and junction boxes for wiring for power, control, indication, protection, and lighting;
- compressed air for blow-down, service and other functions.

NOTE – Contract limits will change if other major items of equipment (such as control system, valves and gates, motor-generators, excitation systems, control metering and relaying systems, switchgear, power transformer and thrust bearing) are included with the pump-turbine equipment in a common set of Tendering Documents.

3.3 Supply by Employer

This subclause should be complementary to 5.6 of IEC 61366-1 (TD subsection 2.6) and should list the items and services which will be the responsibility of the Employer or others. The following should be considered:

- services during erection;
- temporary enclosures for site storage of pump-turbine parts or for erection;
- installation in primary concrete of small items provided by the Contractor such as anchors, sole plates and piping;
- concrete for embedment of pump-turbine components - supply, placement and control;
- grout injection if required either within or around pump-turbine components;
- powerhouse crane and operator;
- connections to powerhouse air, oil and water piping systems;
- supply of filtered water for pump-turbine shaft seals;
- supply of cooling water for runner seals;
- electrical wiring and hardware external to specified termination points;
- electric motor starters and controls;
- control, annunciation and protection systems external to specified termination points;
- external lubricating oil storage, distribution, and purification systems;
- lubricants, bearing and governor oil to the Contractor's specifications.

It should be stated that any materials or services required for installation and commissioning of the units, and not specifically mentioned in the above list of the Employer supplied items and services, are to be provided by the Contractor under contract.

3.4 Design conditions

3.4.1 Project arrangement

The detailed project arrangement should contain the Employer's description and general arrangement drawings of the powerhouse and waterways at the low and high-pressure sides including channels, galleries, penstocks, surge tanks, gates and valves. The description should be an extension of the applicable data provided in TD chapter 2 "Project information". The data shall be sufficiently clear so that the Contractor is aware of physical conditions which may influence the application of its detailed design.

In any event, the Employer should retain responsibility for specifying values of all parameters on which guarantees are based, as part of the overall design of the plant. This applies particularly to the correct inlet and outlet conditions and in the coordination of the interaction between the hydraulic machine and the waterways.

3.4.2 Hydraulic conditions

This subclause should present the hydraulic conditions under which the Employer proposes to operate the completed facility such as:

- range of specific hydraulic energy (head) of the plant;
- specific hydraulic energy losses between headwater level and high-pressure reference section of the machine ($E_{L\ 3\text{-}1}$), turbine and pump mode;
- specific hydraulic energy losses between low-pressure reference section of the machine and tailwater level ($E_{L\ 2\text{-}4}$), turbine and pump mode;
- specific hydraulic energy (head) of the machine (see 2.5 of IEC 61366-1);
- headwater levels, maximum, minimum and normal and when no water is flowing;
- tailwater levels, maximum, minimum and normal and when no water is flowing;
- minimum tailwater level as a function of discharge for the cavitation guarantee;
- power values in the range of specific hydraulic energy (head);
- maximum specific hydraulic energy (head) for runaway speed guarantee;
- range of water temperatures;
- water quality analysis (chemical, corrosive nature, biological, and suspended solids);
- range of ambient temperatures and humidity (tropical environment or extreme cold needs to be clearly defined).

3.4.3 Specified conditions

a) Modes of operation: As an extension to TD section 2.5, the Employer should provide sufficient data to enable the Contractor to understand the Employer's intended mode(s) of operation, e.g. base load or peaking, synchronous condenser, parallel with the network and isolated operation in turbine mode, in addition operation in pump mode, etc. Data should include, wherever possible, the anticipated number of start-stops per year, the capacity factor of the plant and the number of fast change-over cycles from pump to turbine mode. Special operating uses should also be clearly identified such as synchronous condenser, spinning reserve, isolated and black start operations, penstock draining through turbine, penstock filling through pump.

b) Starting procedures and changeover sequences: The Employer should specify the method of starting procedure for pump operation, e.g.:

   - pump-turbine runner (impeller) rotating in water;
   - accelerated directly by the motor-generator;
   - accelerated by a pony-motor;
   - pump-turbine runner (impeller) rotating in air;
   - accelerated by the motor-generator;
   - accelerated by a starting turbine.

   The Employer should indicate data (if any) for changeover sequences, e.g.:

   - standstill to pump mode;
   - pump mode to standstill;
   - fast changeover from pump mode to turbine mode.

c) Specific hydraulic energy (E) [head (H)], discharge (Q) and power (P): The specified specific hydraulic energy (head) and discharges (turbine mode, pump mode) are determined from an analysis of available discharge, reservoir volumes, specific hydraulic energy (head) of the plant and hydraulic losses external to the machine with respect to statistical duration in turbine mode, pump mode and reservoir management. The relevant pump power has to be determined according to the motor characteristics and to the required pump discharge.

If the range of specific hydraulic energy is wide, more than one specified value for *E*, *Q* and *P* may need to be selected to define the operational range of the machine.

In the case of an unregulated pump-turbine and if there are any limitations on maximum discharge at any specific hydraulic energy (head) or limitations on power, the Employer shall provide adequate data in the technical specifications to enable the Contractor to optimise pump-turbine design while respecting these limitations.

d) Speed: The choice of speed of the unit has an impact on pump-turbine and motor-generator costs, on the setting of the pump-turbine with respect to tailwater levels and on powerhouse costs. The choice of speed may also be influenced by strength considerations; e.g. in the case of an underground powerhouse where, because of favourable cavitation conditions mainly in pump operation, a higher speed could be selected but the higher speed may be limited by strength considerations and others.

   If permitted by the project schedule, the approximate cost per meter of powerhouse setting (see annex B, clause B3 of IEC 61366-1), and the approximate cost per kVA for various possible speed options for the motor-generator should be specified by Employer in the ITT, (TD subsection 1.1.15) so that Tenderers may quote the pump-turbine which best suits site conditions and its available design.

   In most cases, the project schedule dictates an early decision with respect to speed(s). Under such conditions, discussions should be held with potential suppliers of pump-turbines and motor-generators to fix a (the) preferred speed(s); alternative proposals may be invited in the ITT.

e) Direction of rotation: The direction of rotation of the pump-turbine is dictated by the optimum orientation of the spiral case with respect to intake, penstock and power house costs. The direction in turbine operation should be specified clockwise or counter-clockwise looking from the motor-generator toward the pump-turbine.

3.4.4 Motor-generator characteristics

The specifications should state the principal characteristics of the motor-generators to which the pump-turbines will be coupled, for example:

– capacity (kVA) as motor and as generator;
– power factor as motor and generator;
– frequency (normal and exceptional range);
– inertia or flywheel effect of motor-generator;
– preferred speed as motor and as generator (if established);
– preferred bearing arrangement (if established);
– approximate rotor diameter (if available);
– inner diameter of stator for passage of pump-turbine components (if available).

3.4.5 Transient behaviour data

The Employer should, during preliminary design phase of the project and prior to pump-turbine selection, determine and establish the various factors relating to power acceptance and power rejection by the pump-turbine. Transient operating conditions cause pressure and speed variations dependent on the type of machine and on the movement of the shut-off valve. The factors to be considered in the calculation of transient phenomena (water hammer calculation) are:

– acceptable variation in electrical system frequency;
– inertia of the rotating parts or mechanical starting time;
– details of high-pressure and low-pressure conduits for the pump-turbine, including surge tanks;
– velocity of pressure waves (sound velocity in water);

– water starting time;
– pump-turbine guide vane opening and closing times (turbine operation);
– high and low-pressure side valve(s) opening and closing time;
– transient characteristics (operating characteristics, four quadrant characteristics) of the pump-turbine;
– modes of operation;
– emergency conditions, e.g.:
  - full or partial power failing
  - the shut-off valve is closing if the guide vanes remain open (pump mode)
  - the shut-off valve does not close
  - when there are several units at the same waterway, one shut-off valve is closing only or all valves are closing.

The results of the water hammer calculation should confirm such items as:

– transient pressure variation along the water conduits (maximum/minimum momentary pressure);
– transient pressure variation in the spiral case (pressure rise) and draft tube (pressure drop);
– pressure fluctuations at high and low-pressure side of pump-turbine;
– speed variations of the unit (maximum/minimum momentary speed and runaway speed).

Transient behaviour data established by the Employer should be provided and those data which require verification by the Contractor should be specified. Other data not specified by the Employer may have to be established by the Contractor. (Refer to guarantees in 3.5.5 and 3.5.6.)

3.4.6 Stability of the system

The hydro-turbine control system should be specified in accordance with IEC 61362. The performance of the hydro-turbine control system should be specified according to IEC 60308. The Employer should furnish the information necessary in order to predict possible resonances in the water passages of the power plant and in the unit. Admissible limits may be specified for fluctuation of shaft torque and of pressure in the draft tube.

3.4.7 Noise

Noise level limits may be legislated by national or local statutes. Noise abatement measures may be the combined responsibility of the Employer and the Contractor. Reference should be made by the Employer to ISO 3740 together with other standards, statutes or guides to establish noise measurement and acceptance criteria. The limits and the means by which they can be achieved should be specified in TD subsection 6.1.5.11.

NOTE – The Employer should recognize that additional protection to reduce noise level may have a significant effect on the cost of the machine.

3.4.8 Vibration

The specifications should require that the machine operates through its full range of specified conditions without vibration which would be detrimental to its service life. Reference should be made by the Employer to IEC 60994 together with other suitable standards and guides to establish deflection measurements and acceptance criteria. Limits of vibration may be established for steady-state conditions and for normal transient regimes as criteria for final acceptance.

3.4.9 Sand erosion considerations

Risk of sand erosion may influence the design and operation of the hydraulic machine. In this event, the technical specifications should indicate the content of suspended solids, their type, hardness, size and shape. See IEC 61366-1, annex H.

3.4.10 Safety requirements

The Employer should state specific safety requirements which shall be met in the design of the pump-turbine. These requirements are in addition to the general safety related items outlined in 5.6 of IEC 61366-1.

3.5 Technical performance and other guarantees

3.5.1 General

Hydraulic performance guarantees for hydraulic machines are discussed in clause 3 of IEC 60041. The main guarantees outlined in IEC 61366-1, annex E and should be read in conjunction with IEC 60041.

The main steady state hydraulic performance guarantees (i.e., power, discharge, efficiency and runaway speed) may be verified by model tests or field acceptance tests. Guarantees may be referred directly to the hydraulic performance of the model (without scale effect) or alternatively to the hydraulic performance of the prototype computed from model tests with allowance for scale effects. (Refer to IEC 60193.)

The Employer should establish and specify the parameters on which the performance guarantees are to be based. These parameters include plant specific hydraulic energy (plant head) and energy losses external to the high-pressure and low-pressure reference sections of the machine (in both modes of operation). The Employer should retain responsibility for specifying acceptable inlet and outlet conditions of the machine and for co-ordination of the study of the interaction between the machine and the external waterways transient and steady-state oscillating conditions.

In those cases where it is not possible to perform field acceptance tests under specified conditions, refer to IEC 60041. The Employer should specify measurement methods and measurement uncertainties which are contractually applied if different than those established by relevant IEC publications. In addition to specifying the guaranteed performance provisions in the technical specification, it is important that the Employer summarise these provisions in TD subsection 1.1.13 of the "ITT". Also, it is desirable that the manner in which Tenderers shall present and state their performance guarantees be clearly specified.

The Employer should select the appropriate level and type of performance guarantees for the machine taking into consideration the intended mode of operation and the importance of the machine in the system.

When it is necessary to include other aspects of the machine under performance guarantees (such as stability, noise and vibration), the Employer should include these provisions at the end of this section taking into consideration that data available may not be sufficient based on extended experience. In any event, conditions under which guarantees are evaluated shall be specified.

3.5.2 Guaranteed power

In specifying the guarantee power, in the turbine and pump modes, refer to TD subsection 6.1.4.3 of the specified conditions, and state clearly the basis of the guarantee.

Pump power is normally guaranteed for one or more specified values of specific hydraulic energy (pump head) and for normal and higher frequency (e.g. 52 Hz). The Contractor should be required to state the maximum pump power which shall not be exceeded.

Turbine power is normally guaranteed for one or more specified values of specific hydraulic energy (turbine head).

In the pump mode, it should be noted that specific hydraulic energy E is the specific hydraulic energy of the plant E_g (plant head H_g) plus the specific hydraulic energy losses E_L (head losses H_L) in the water conduits on the low and high-pressure side. In the turbine mode, the specific hydraulic energy E is E_g minus E_L. (Refer to 2.5 of IEC 61366-1).

It is necessary in this subclause, to establish the contractual obligations of the Contractor if the guaranteed values of power are not met. The method(s) of measurements, method of comparison with guarantees and application of IEC 60041 shall be defined.

3.5.3 Guaranteed discharge

Although it may not be usual for a pump-turbine, under certain circumstances, it may be necessary to have a guarantee for low, continuous and stable discharge in turbine mode. This is true for projects with low discharge requirements as a mode of operation. Since this operation may be outside the normal operating range, it is not covered by guarantees applied to the normal operating range. The Employer should indicate the expected duration of this operation.

The guaranteed pump discharge at specified specific energy (pump head) has to be specified including design tolerances (e.g. –6 % to +4 %). It is necessary to establish in this subclause the contractual obligations of the Contractor if the guaranteed pump discharge is not met.

3.5.4 Guaranteed efficiency

The Employer shall establish and specify:

a) basis of guarantee; model or prototype;

b) method(s) proposed to measure guaranteed efficiency

   – by model acceptance tests in the Contractor's laboratory or in another laboratory acceptable to both parties using test results without scale effect or using test results with a mutually agreed step-up formula (see IEC 60193), or

   – by field acceptance tests of one or more prototype pump-turbines (see IEC 60041);

c) efficiency weighting formula to allow the Tenderer to optimise the guaranteed efficiency in the normal operating range of the pump-turbine (turbine and pump mode) with respect to both power and specific hydraulic energy (head) at turbine mode and to specific hydraulic energy (pump head) at pump mode respectively while taking into consideration the value specified by the Employer for gain or loss in efficiency;

d) applicable codes (see 2.1 of this guide);

e) measurement methods and preliminary estimated measurement uncertainties to be contractually applied if different than those established by relevant IEC publications;

f) contractual consequences, if any, of the Contractor's failure to fulfil the guaranteed efficiencies or of the Contractor exceeding its guaranteed efficiencies (penalty or bonus).

The technical data sheets of the tender forms should provide space for the Tenderer to record its guaranteed weighted efficiencies.

In large projects which justify the expense, the Employer may choose to preselect two or more competing Tenderers for the performance of pump-turbine model tests at the Employer's expense. In this event, the results of the model tests can be used in the final award of the contract to the successful Tenderer.

3.5.5 Guaranteed maximum zero-discharge (shut-off) specific hydraulic energy

The Contractor guarantees the maximum specific hydraulic energy generated by the pump-turbine in pump mode when operating at specified speed against closed shut-off valve (guide vane position to give maximum pressure) and in addition against closed regulator apparatus. The Employer should specify any higher speed in the event a higher network frequency needs to be considered.

3.5.6 Guaranteed zero-discharge power

The Contractor guarantees the zero-discharge power for the same conditions as indicated in 3.5.5.

Depending on the starting procedure [see 3.4.3 b)], the relevant power may be guaranteed for when the runner/impeller(s) is/are rotating in water or air.

3.5.7 Guaranteed maximum/minimum momentary pressure

It is usual for the Contractor to guarantee momentary pressure rise even when there is no responsibility for the complete of the plant (refer to E.2.6 of IEC 61366-1). The Contractor should be required to calculate and guarantee the maximum and minimum momentary pressure at the high-pressure reference section (spiral case inlet) and at the low-pressure reference section (draft tube) under load rejection from specified conditions (specified power and specified specific hydraulic energy) in turbine and pump mode and under most unfavourable transient conditions established by the Employer.

However, the Employer shall specify all relevant information because of the involvement and influence of the electrical motor-generator, speed regulator and waterway system in the transient phenomenon.

3.5.8 Guaranteed maximum momentary overspeed

The maximum momentary overspeed is the overspeed attained under the most unfavourable transient conditions. Under certain conditions, it may exceed maximum steady state runaway speed. The maximum momentary overspeed should be guaranteed by the Contractor.

However, the Employer shall specify all relevant data because of the involvement and influence of the electrical generator, speed regulator, and waterway system in the transient phenomenon (see 3.4.5).

3.5.9 Guaranteed maximum steady-state runaway speed

The specifications should require that the Contractor guarantees the maximum steady-state runaway speed under the worst combination of conditions, for example, maximum specific hydraulic energy (head) and physical maximum guide vane opening conditions on the pump-turbine considering variations in the plant cavitation factor. Taking into consideration powerhouse arrangement, number and type of independent shut-off devices, local or remote control and type of control and protection systems, the specifications should state the duration for which the unit shall be capable of functioning at maximum steady-state runaway speed. The duration may vary from a few minutes to several hours at this speed, but the design of the plant should keep this duration to a minimum. The guarantee should be stated in the technical data sheets submitted by the Tenderers.

NOTE – It is recommended not to specify or to conduct steady-state runaway speed tests at site. If it is mutually agreed to conduct such tests, they should be performed at reduced specific hydraulic energy (head); refer to IEC 60041. The purpose of this precaution is to reduce physical stresses on the civil structures and the generating unit (particularly the electrical machinery). The value of maximum steady-state runaway speed should be verified by model tests.

3.5.10 Cavitation pitting guarantees

Severe cavitation pitting creates three major problems for hydraulic machines: high cost of pitting repairs; loss of revenue caused by outages; and the potential decrease in efficiency. With careful planning the possibility of severe pitting can be greatly reduced.

In the design of turbines and their application to a specific site, it is necessary to balance the increased cost for a lower turbine setting, larger runner diameter and slower operating speed and increased powerhouse excavation with the potential loss of revenue caused by any outage.

IEC 60609 outlines factors which need to be considered when specifying cavitation guarantees. Refer to annex F of IEC 61366-1 which provides an example of an interpretation of IEC 60609.

Factors which can influence the amount of cavitation pitting damage and the limits of the cavitation guarantee include plant operating range and conditions, low tailwater level, water quality, material selection, shop inspection, quality control and field inspection after commissioning.

3.5.11 Guaranteed hydraulic thrust

This subclause should outline the conditions of operation which can be used by the Contractor to determine the maximum and minimum hydraulic thrust. This information will be needed for the design of the thrust bearing.

3.5.12 Guaranteed maximum weights and dimensions

In some cases, the Employer may need to establish and fix without subsequent change, certain features of the pump-turbine to be incorporated in the design of the project. These features should be specified in this subclause and may include, for example, such items as inlet valve size, pump-turbine runner and shaft weights and maximum component dimensions and or weights (for transportation and project handling restrictions), intake gate and draft tube gate size, etc.

3.5.13 Other technical guarantees

This subclause may cover other technical guarantees such as vibrations, noise, fluctuations of pressure and power and behaviour of protective coatings.

If guaranteed limits for vibration are specified by the Employer or agreed upon by the parties to the contract, reference should be made to IEC 60994 which gives guidelines for measurement procedures. If the Employer specifies a guarantee for the guide vane hydraulic torque tendency, these guarantees may be confirmed by model tests. The Employer may specify a guarantee to cover an emergency shut-down of the machine without cooling and/or lubrication of the bearings.

3.6 Mechanical design criteria

3.6.1 Design standards

This subclause should list the appropriate international standards and codes which the Employer proposes to apply directly to the pump-turbine equipment.

3.6.2 Stresses and deflections

The Contractor should be required to adopt design methods and practices in regard to allowable stresses and deflections to ensure an extended service life from the pump-turbine with reasonable care and maintenance. The correlation of allowable stresses to the following load conditions shall be specified for:

– normal load conditions;
– extraordinary load conditions; and
– load case for emergency condition (including earthquake acceleration).

The Employer should indicate the anticipated service life. Whenever the Contractor proposes to deviate from its conventional successful practice, he should be obligated to justify such deviation in advance to the Employer.

3.6.3 Special design considerations

The technical specifications should describe clearly the particular criteria and requirements relating to operation, reliability and maintainability (for erection, dismantling and maintenance of the main components). Any general statement in this subclause should be expanded as necessary under the headings of the particular components concerned.

The pump-turbine and motor-generator equipment Contractors should, as a part of their respective contracts, be required to carry out design of the dynamic behaviour of the combined motor-generator and pump-turbine with respect to critical speed calculations and shaft system alignment criteria. The two Contractors should be obliged to participate in the analysis and mutual agreement for resolution of any problems which may arise in this regard.

3.7 Design documentation

3.7.1 General

The Tendering Documents should provide a general statement on the manner in which Contractor's design documentation will be submitted for review. It shall be recognized that design responsibilities which are assigned to the Contractor by the Employer shall remain under the Contractor's direct control. The provisions of TD subsection 6.1.7 shall be consistent with those given in TD section 5.2 "Technical documents".

3.7.2 Data for Employer's design

The Employer should outline data to be submitted by Contractor relating to design and layout of the pump-turbine. Data should include such items as embedded component weights and dimensions, loads to be transferred to the structure, water passage dimensions (i.e. spiral case, stay ring, foundation ring and draft tube), size and location of anchor bolts, dimensions of first stage concrete voids for subsequent installation of embedded components, weights and dimensions of heaviest and largest components to determine crane capacity and lift height requirements when not specified by the Employer (see 3.5.12), details of lifting devices handled by crane, electrical interconnections, governor system connections, motor-generator coupling data, etc.

3.7.3 Requirements for Contractor's drawings, technical calculations and data

Requirements for Contractor's drawings, technical calculations and data should be described so that the Contractor is fully aware of information to be submitted. Associated with this is the need for the Employer to specify a predetermined number of design meetings with the Contractor to expedite necessary action items. The extent of review intended by the Employer should be defined. The Contractor is normally responsible for design of the pump-turbine and the Employer's review should only be to the extent that the product conforms to the requirements of the technical specifications in particular, and the contract documents in general.

3.7.4 Contractor's review of Employer's design

A number of items in the design of the pump-turbine impact on the design of the powerhouse. The Employer should outline the requirements for review by the Contractor of the Employer's design. This could include a review of substructure construction drawings showing pump-turbine anchor bolt and installation details, draft tube water passages and other details which influence pump-turbine layout.

3.7.5 Technical reports by Contractor

The Employer should specify submittal requirements for the Contractor's technical reports. These reports could include model tests, dynamic behaviour of pump-turbine/motor-generator, installation procedures, commissioning and acceptance test procedures and similar items.

3.8 Materials and construction

3.8.1 Scope

– Care should be taken that specifications for materials and construction in TD subsection 6.1.8 are consistent and do not conflict with the general requirements specified in TD section 5.4 "Materials and Workmanship". A number of items included in TD subsection 6.1.8 could be specified in TD section 5.4 but this is left to the Employer's preference.

– It should be stated that it is not the intent of the Employer, in its specifications, to dictate how the pump-turbine should be constructed but rather to provide sufficient data for the Contractor to establish the class of equipment for which the Employer is willing to pay. The Contractor should be permitted to offer alternatives to the minimum specified requirements thereby offering the maximum benefit of the Contractor’s experience. The basis of such alternatives shall be justified and documented.

3.8.2 Material selection and standards

– All materials shall be new and suited to the intended purpose as demonstrated by Contractor's prior experience or demonstrated by tests whose results are divulged to Employer for acceptance.

– Specification should be limited where possible to generic types of materials to leave the Contractor the flexibility of procurement from its usual sources.

– Where national material standards are specified, demonstrated equivalents should be accepted.

– Any change of material during the contract period shall be subjected to approval by the Employer.

3.8.3 Quality assurance procedures

– Minimum quality requirements should be specified preferably with reference to international or national standards and should not conflict with general requirements in TD section 5.5.

– Required documentation attesting to quality checks should be established.

– Material test certificates including certificates for material of doubtful quality or origin.

– Procedures for repair of defects should be established.

– Need for the Employer's witness and notice in advance of same.

3.8.4 Shop methods and personnel

– Shop methods and routing information should be divulged to the Employer's representative(s) to the extent necessary to permit evaluation of same and to schedule attendance at import and verification points in the manufacturing sequence.

– The Contractor should be required to demonstrate upon request, that the qualifications of his staff and workers for specific tasks, such as welding, are adequate for the class of work being done.

3.8.5 Corrosion protection and painting

– Minimum general grade or corrosion protection should be specified and it should be consistent with the environment to which the pump-turbine components will be subjected, both atmospheric and hydraulic.

– International or national standards may be used to define minimum surface preparation and painting requirements.

– If a particular paint system is specified, its generic type and number of primer and finish coats should be given to facilitate the preparation of estimates during the tender period.

– Minimum and maximum dry film thickness for each coat in the specified paint systems should also be given.

– Minimum corrosion protection requirements for machined surfaces, prior to shipment should be given along with packaging, transportation and site storage requirements in TD sections 5.8 and 5.9.

– If standard coating systems are specified by the Employer in TD section 5.4 of the general requirements, only the system code number and colour schedules need to be specified in these technical specifications with cross-reference to TD section 5.7.

3.9 Shop inspection and testing

As with 3.8, some of the requirements set forth in 3.9 could be specified in TD section 5.6. This is left to the discretion of the author of the documents.

3.9.1 General requirements and reports

– This subclause should make reference to and be consistent with TD Section 5.6 giving in general terms the shop test, inspection and report requirements to be met.

– Reference should be made to TD section 5.5 so that reporting standards and record-keeping are consistent with the specified level of quality assurance.

– Method for handling non-conformance cases should be stated.

3.9.2 Material tests and certificates

– Specifications should require that material used in the fabrication of major components of the pump-turbine should be identifiable in the Contractor's records for the project in terms of type, grade and source. Copies of such records for major components should be supplied to the Employer's representative upon request.

– Tests for physical or chemical properties or other characteristics shall be specified for major components and the results reported to the Employer in writing. The Employer's representative shall be given the opportunity to witness such tests.

– The Employer may specify the supply of sample material.

– Where materials are purchased outside of the Contractor's organization, it shall require, as a minimum, that certificates be provided for major components at the time of material shipment, attesting to the type and grade of material being supplied.

– Where no specific tests are specified for major component requirements, it shall be assumed that the tests required by the international or national standard shall apply. This is true for:

- plate and structural steel;
- castings;
- forgings;
- weldments.

3.9.3 Dimensional checks

- Specifications should require that critical dimensions be checked prior to shipment of the component to the job site. The nature of the records to be kept from such checks will be determined by the specified level of quality assurance to be maintained and by Contractor's experience regarding the effect of such checks on its ability to assemble erect, test and guarantee the pump-turbine.
- If model acceptance tests are performed, geometric similarity with the model pump-turbine shall be checked in accordance with IEC 60193.

3.9.4 Shop assembly and tests

Detailed specifications of each major component should establish minimum requirements for shop assembly and tests. The following factors should be considered:

- remoteness of project site;
- possibility of shipment of part or all of the pump-turbine fully assembled;
- thoroughness of dimensional checks;
- need for hydrostatic pressure test (e.g. guide vane servomotors);
- importance of a possible error in dimensional checks; and
- match marking to reassemble at site.

Designated auxiliary components and systems should be tested in the shop for proper functioning.

4 Technical specifications for fixed/embedded components

General note

Clauses 4 to 11 inclusive, outline technical specifications for major components of the machine. These specifications shall present concisely the Employer's specific technical requirements and preferences for these components. It is suggested that the technical specifications for major components be arranged using the following headings wherever possible:

- general description;
- design data;
- general data.

Although the guide may appear somewhat repetitive in the clauses which follow, it should be understood that the purpose of the guide is to illustrate preferred and consistent methods for specifying pump-turbine components without presenting detailed specifications. Such details are the responsibility of the Employer.

As noted in 3.3.1.1 of IEC 61366-1 and to avoid confusion, requests for information from Tenderers shall be provided in the Instructions to Tenderers and not in the technical specifications.

Consistent with the foregoing notes, TD section 6.2 should begin with a general description of the major embedded components, for example:

The embedded components for the pump-turbine to be provided may include:

– spiral case;
– stay ring;
– foundation ring;
– draft tube and draft tube liner;
– pit liner.

4.1 Spiral case

A general description of the spiral case should be given here.

4.1.1 Design data

The Employer's design data should be carefully outlined including such items as:

– design pressure;
– maximum permissible stresses onto surrounding concrete, limitable by compressible wrapping;
– test pressure and location of test (shop or site);
– internal pressure during embedment;
– concrete embedment pour rates and other details;
– material by generic type or recognized international or national standards (indicate if alternatives will be accepted).

4.1.2 General data, connections and auxiliaries

The Employer should provide general data which applies to the spiral case such as:

– location, size and type of pump-turbine inlet connection (specify tolerances);
– location, size, and type of all other connections for peripheral or auxiliary systems (cooling water, potable water, service water, pressure relief devices, irrigation devices, etc.);
– location, size and details of access for maintenance;
– details of all indication and test connections and devices;
– temporary and permanent transportation and erection support and handling devices.

4.2 Stay ring

As with the spiral case, the Employer should provide similar subsections beginning with a short description of the stay ring.

4.2.1 Design data

– See 4.1.1.
– Weight of concrete, motor-generator and other vertical loads supported by stay ring.

4.2.2 General data, connections and auxiliaries

– Tolerances on location in plan and elevation.
– Provisions for concrete placement and grouting.
– Location, size, type and other details of connections (e.g. pump-turbine pit drains, test connections, etc.).
– Transportation and erection support and handling devices.

4.3 Foundation ring

Brief description of foundation ring.

4.3.1 Design data

- Special loading conditions, if any.
- Material.
- Transportation and site handling limitations.

4.3.2 General data, connections and auxiliaries

- Tolerances on location in plan and elevation.
- Provisions for concrete placement and grouting.
- Location, size, type and other details of connections (pump-turbine pit drains, draft tube aeration, etc.).
- Temporary and permanent transportation and erection support and handling devices.

4.4 Draft tube and draft tube liner

Brief description of draft tube.

4.4.1 Design data

- Minimum external design pressure for liner.
- Minimum thickness if pertinent.
- Minimum external rib arrangement for limiting infiltration to powerhouse.
- Type of material.
- Transportation and site handling limitations (dimensional).
- Concrete embedment rates and details.
- Dimensional tolerances, concrete and liner.

4.4.2 General data, connections and auxiliaries

- Location and details of downstream limit of draft tube liner.
- Location, size and details of access for maintenance.
- Location, size, type and details of runner maintenance platform and devices.
- Location, size and details of all connections (e.g. spiral case, draft tube drains, aeration piping or devices, cooling water, service water, draft tube water level controls, indication and test devices, etc.).
- Temporary and permanent transportation and erection support and handling devices (anchors, tie rods, supports, etc.).

4.5 Pit liner

Brief description of pit liner.

4.5.1 Design data

- External pressure.
- Minimum thickness if pertinent.
- Minimum external rib arrangement.

- Type of material.
- Servomotor support criteria.
- Openings for motor-generator air recirculation.
- Support for pump-turbine pit hoist, if any.

4.5.2 General data, connections and auxiliaries

- Approximate lifting diameter required (e.g. for stator clearance).
- Elevation of top of pit liner with respect to the pump-turbine distributor centreline.
- Location, size and details of pump-turbine pit access.
- Preferred location of guide vane servomotor support flanges.
- Location, size and details of piping connections (generator pit drainage, pump-turbine pit drainage, bearing cooling water, bearing lubricating oil, servomotor, service air, central grease lubrication system, etc.).
- Transportation and erection support and handling devices.
- Permanent pump-turbine pit hoist, if required.

5 Technical specifications for stationary/removable components

The Employer should give a general description of distributor assembly.

5.1 Headcover and bottom ring

The Employer should give a short description of headcover and bottom ring.

5.1.1 Design data

- Comments on preferred arrangement (e.g. both headcover and bottom ring to be removable for maintenance; guide vane bushings to be replaceable without dismantling headcover and bottom ring, etc.).
- Requested type of material.
- Preferred pump-turbine pit drainage arrangement.
- Preferred thrust bearing location.

5.1.2 Facing plates

- Comments on preferred arrangement.
- Requested material by generic type.
- Minimum thickness.

5.1.3 Runner seal stationary wearing rings

- Comments on preferred arrangement.
- Requested type of material (resistant to corrosion, erosion and cavitation).

5.1.4 Guide bearing support

- Comments on preferred arrangement.
- Access for maintenance of bearing pads.

5.1.5 Guide vane bearing housing and bushings

- Preferred material.
- Special features (dirt seals).

5.1.6 Guide vane seals

- Comments on preferred arrangement.
- Preferred material, if any.

5.2 Guide vanes

The Employer should provide a brief description of the guide vanes.

5.2.1 Design data

- Rates for opening and closing when governor system is not included in pump-turbine supply.
- Requested type of material (corrosion resistant, erosion resistant).
- Preferred hydraulic torque characteristics (in case of a pump-turbine the consequences have to be discussed).

5.2.2 Guide vane stems

- Requested material by generic type.
- Guide vane stem seals.
- Other requirements.

6 Technical specifications for guide vane regulating apparatus

Description of apparatus either with a regulating ring or individual servomotors for each guide vane.

6.1 Servomotors

- Material type.
- Pressure testing requirements.
- Preferred location in pump-turbine pit considering motor-generator foundations.
- Maximum and minimum allowable operating pressure if governor supplied separately.
- Guide vane restoring device for governor.
- Responsibility for alignment at assembly.
- Other requirements regarding operation and maintenance.
- Cross-reference TD subsection 6.3.2.1 for opening and closing times.

6.2 Connecting rods

- Preferred arrangement.
- Minimum bushing requirements.
- Type of material.

6.3 Regulating ring

- Preferred arrangement.
- Minimum support requirements on headcover.
- Type of material.

6.4 Guide vane linkage

- Preferred arrangement.
- Types of material.
- Individual adjustability on each guide vane in closed position.

6.5 Guide vane overload protection

- Preferred arrangement.
- Basic criteria.
- Criteria for readjustment (on-line, off-line spiral case drained).
- Overload indication.
- Overload annunciation.

6.6 Locking devices

- Preferred arrangement.
- Automatic or manual.
- "Closed" or "open" positions.
- Are they required to be adjustable for limiting power?
- Lock position detection.
- Lock position annunciation.

6.7 Synchronizing device (optional)

- Preferably mechanical synchronizing device in case of individual servomotors with overload protection characteristics (refer to 6.5).

7 Technical specifications for rotating parts, bearings and seals

Description of rotating parts and method of erection and dismantling.

7.1 Runner

Description of runner.

7.1.1 Design data

- Minimum material requirements by generic type (weldable, corrosion resistant, erosion resistant and cavitation resistant).
- Support of runner and shaft during erection and subsequent maintenance.
- Static balancing requirements.

7.1.2 Runner water passage shape and surface

Proper control of runner water passage shape and surface conditions is an important step in limiting potential cavitation damage. Proper quality control shall be provided during all phases of fabrication and manufacture to ensure that the final product is homologous to the model runner, in the case of model tests or to the hydraulic design. Reference should be made to IEC 60193.

7.1.3 Rotating seal rings

– Material type.
– Compatibility with materials used on stationary wearing rings.
– Preferred design; i.e. removable, one piece with runner/impeller.

7.2 Main shaft

Brief description of shafts.

7.2.1 Design data

– Lowest critical speed (greater than maximum steady-state runaway speed).
– Coupling standard, if any.
– Material type.
– Elevation of main or intermediate shaft coupling flange(s), whichever is connected to the generator motor shaft, with respect to centreline distributor.
– Shaft seal sleeve.
– Concentric hole through the entire length of shaft (for purpose of runner dismantling).
– Coupling bolt holes, interchangeability requirement.
– Define co-ordination with motor-generator supplier for combined alignment, dimensional interface, critical speed and run-out check.

7.2.2 Coupling bolts, nuts and nut guards

– Material type.
– Responsibility for supply and installation, including drilling template.
– Pump-turbine end.
– Motor-generator end.
– Interchangeability.
– Locking devices.
– Responsibility for coupling.
– Nut guards for turbine and generator ends.

7.3 Pump-turbine guide bearing

General description for type and design of guide bearing.

– Access for maintenance.
– Material types.
– Lubrication.
– Cooling of bearing oil.
– Oil fill and drain piping.

- Oil circulation (common with thrust bearing, if any).
- Oil level detection for control and annunciation.
- Oil level indication.
- Contamination of oil (test connections).
- Bearing temperature.
- Bearing oil temperature.

7.4 Main shaft seal

- General description.
- Material for housing and wear elements.
- Design for longevity and ease of maintenance.
- Clean lubricating water and cooling water.
- Quality and quantity of cooling water.
- Shaft seal temperature detection and indication.
- Shaft seal cooling water flow detection and indication.
- Wear indicator.
- Shaft seal sleeve/sliding ring material type and special maintenance requirements.

7.5 Standstill (maintenance) seal

- General description.
- Material for housing and active seal ring.
- Actuation (e.g. by compressed air).

8 Technical specifications for thrust bearing (when specified as part of pump-turbine supply)

Description of bearing assembly and location.

8.1 Design data

- Weights and loads on bearing external from pump-turbine.
- Limitation for operation under runaway speed conditions.
- Cooling water temperature range.
- Deflection limitations.

8.2 Bearing support

- Location.
- Materials.
- Accessibility.

8.3 Bearing assembly

- General description and design considerations.
- Access for maintenance.
- Material types.

- Lubrication.
- Cooling of bearing oil.
- Oil fill and drain piping.
- Oil circulation (common with guide bearing, if any).
- Oil level detection for control and annunciation.
- Oil level indication.
- Contamination of oil (test connections).
- Bearing temperature.
- Bearing oil temperature.

8.4 Oil injection pressure lift system

- Number and types of pumps (a.c. or d.c.).
- Filters.
- Flow regulators.
- Pressure detectors.

9 Technical specifications for miscellaneous components

Description of miscellaneous components.

9.1 Walkways, access platforms and stairs

- Pit access.
- Runner/impeller inspection platform.
- Description of minimum requirements.
- Removal and handling weight limitations.
- Minimum design loading criteria.
- Reference to applicable safety codes.

9.2 Lifting fixtures

- Runner and shafts.
- Headcover with guide vanes and regulating mechanism.
- Servomotors.
- Guide vane operating mechanism in pit.
- Guide vanes.
- Bottom ring.
- Coupling bolts.
- Pump-turbine guide bearing.
- Thrust bearing and single bearing pads.

9.3 Special tools

- Coupling bolt loosening and tightening device.
- Replacing overload protection and guide vane levers.
- Special wrenches.

- Special jacks.
- Shaft lifting device.
- Slings.

9.4 Standard tools

- Complete set for maintenance requirements (not for erection).

9.5 Pump-turbine pit hoist

- If required by pump-turbine size to facilitate maintenance of main guide bearing, thrust bearing pads, guide vane operating mechanism, etc.

9.6 Nameplate

- Minimum data.
- Size.
- Mounting location.

10 Technical specifications for auxiliary systems

Description of systems included.

10.1 Bearing lubrication system

When an external oil cooling system is preferred, specify:

- number and type of pumps, filters and coolers;
- dimension criteria for external tank (e.g. with capacity to contain complete system volume);
- detectors for level, flow, humidity, etc.

10.2 Runner pressure balancing and pressure relief lines

Define responsibility for external piping, if any.

10.3 Pump-turbine pit drainage

- Describe preferred system.
- Define responsibility for all pumps, controls and piping where required.

10.4 Lubrication of guide vane regulating system

- Self-lubricating bushings are recommended.
- Describe preferred arrangement if grease lubrication is adopted.
- Controls, indication, malfunction annunciation.

10.5 Draft tube air admission system

- Define limits of responsibility.
- Automatic isolation of air admission system in load ranges where not required.
- Preferred type of design.

10.6 Tailwater depression system (if applicable)

– Quantity of air required for initial depression? (see technical data sheets).
– Quantity of air required to sustain depression (see technical data sheets).
– Maximum time necessary to fill accumulator.
– Limits of supply items.
– General description of system and its controls, if included.
– Runner seal water lubrication requirements.

11 Technical specifications for instrumentation

Description of instrumentation.

11.1 Controls

List controls included in the contract. Detailed cross-references should be given to the subsection dealing with the item involved; e.g. unit start interlocks, low flow to guide bearing cooling, low flow to shaft seal lubrication, etc.

11.2 Indication

Define devices for indication such as:

– bearing oil level;
– shaft seal wear;
– bearing temperature, etc.

11.3 Protection

Define protection requirements for example:

– bearing high temperature;
– shaft seal high temperature;
– excessive shaft displacement (run-out) etc.

12 Spare parts

Requirements for basic spare parts for pump-turbine should be established by the Employer.

Extent of spare parts will depend on operating criteria, location of project, availability of replacement components. The basic spare parts list required by the Employer may be augmented by experience of the Contractor. Spare parts should be manufactured with the main contract and delivered with pump-turbine components.

Provide a list of minimum requirements, e.g.:

– bearing shell or pads;
– set of guide vane bushings;
– shaft seal wear elements;
– complete set of seals and/or gaskets for dismantling;
– spare studs, nuts, bolts, etc.

In the ITT, request Tenderers to submit a list of their recommended spare parts with their tender form.

13 Model acceptance tests

It is recommended that model tests be performed. The results may be used to determine the guaranteed or anticipated performance of the pump-turbine. The Employer may elect to use the Contractor's applicable existing model data available from previous homologous model tests. The Employer may also consider use of results from previous field tests of homologous pump-turbines in lieu of new model tests. For some small units and for special cases where near homologous model data are available, it may be cost-effective to accept a model design which can be readily adapted to the site of the work. In this event, the Contractor should be required to explain the basis of numerically adapted performances.

Under certain circumstances the Employer may wish to receive tenders, evaluate them and select two or three Tenderers to construct pump-turbine models, at the Employer's expense, for competitive testing at an independent laboratory. A contract may then be awarded on the basis of best performance and price. Nevertheless model tests should be carried out in accordance with IEC 60193. Only supplementary requirements need to be specified in detail.

The end use of the model test results should be stated:

- model acceptance tests - verification of guarantees on the model;
- comparison of model test results with guarantees on prototype with due consideration of scale effects in accordance with IEC 60193;
- evaluation of model performance with regard to cavitation behaviour (setting of the machine);
- evaluation of specific operating characteristics, such as runaway speed, quadrant tests hydraulic thrust, etc., in accordance with IEC 60193;
- evaluation of competing designs or from different Tenderers;
- comparative/competitive model tests performed according to the rules of the model acceptance tests;
- development model tests as the basis for the prototype design; in this case, model tests will provide information on performance and machine behaviour at an early stage of the project.

The schedule of conducting model tests, including witnessing by the Employer and for submitting the final report should be specified, taking into account that design, manufacturing and tests of a model may require a 12 months to 18 months programme. A check list for model test specifications is given in IEC 61366-1, annex G. See also IEC 60193, subclause 6.3.1 and annex E, thereof, where all items which need agreement between the parties are listed.

14 Site installation and commissioning tests

14.1 General

- Refer to IEC 60805.
- Elaborate on what is stated in TD section 5.9 and in TD subsections 6.1.1, 6.1.2 and 6.1.3.
- Outline clearly the limits of the Contractor's responsibilities.
- State the method the Employer proposes to use to control, monitor and verify the Contractor's embedded parts and anchor bolts are not disturbed during concrete placement and grouting operations by others. This should include such items as pour rate and pressure limitations imposed by the Employer on construction of civil works. The Contractor should be permitted to comment on and agree to these provisions for control.

14.2 Installation procedures

– The specifications should stipulate that an erection procedure shall be prepared by the Contractor and submitted to the Employer before the start of erection and installation at site. This will allow the Employer to resolve any conflicts which may exist with other Contractors on the site. The procedures should contain cross-referencing to turbine drawings and to location of measurement points and should become a part of the operating and maintenance manual TD section 2.5.

– Erection tolerances if specified should follow National or industry standards or guidelines.

– The procedures should incorporate the controls, monitoring and verification proposed by the Employer to limit distortion and/or movement of embedded parts and anchors during concreting and grouting by others.

– The procedures take into account the requirements of the connected generator.

– Requirements should be specified for measurement records to be made during alignment and installation, for example, clearances, relative location and rotational test results.

14.3 Tests during installation

– Functional tests on components and systems.

– Specify non-destructive testing such as radiographic, ultrasonic, dye penetrant, etc., proposed for structural field welds on major components.

– State pressure test requirements (if any) on spiral case; include specifications for test bulkheads.

– Specify other site tests, such as tightness of guide vanes which may be required during installation.

14.4 Commissioning tests

List all tests to be done upon completion of erection, for example:

– rotational checks;

– guide vane operating times in the dry (if conducted);

– operation of unit without load and at speeds specified for checking runout of rotating parts and for verifying guide and thrust bearing behaviour and for setting overspeed trip devices;

– operation of unit under load to full guide vane opening at the available specific hydraulic energy (head) to set servomotor stops (if provided) to check bearing behaviour and to check run-out of rotating parts under load, thereby permitting the setting of shaft runout monitors (if provided) to check for vibration, pulsation and noise;

– mode changes;

– load rejection tests for turbine and pump operation (adjust guide vane operating times if necessary);

– blow-down and refilling tests for synchronous condenser operation (if specified);

– operation of other pump-turbine components.

15 Field acceptance tests

15.1 Scope and reports

Field acceptance tests should be done in accordance with IEC 60041 in particular with reference to clause 4 "Organization of tests". The methods of measurements should be fixed in the technical specifications.

Field acceptance tests for confirming that hydraulic performance guarantees have been met may comprise:

– efficiency tests, i.e. determination of absolute efficiency of the machine (if model acceptance tests were not performed);
– power tests as a function of hydraulic parameters (*E*, *Q*).

If model acceptance tests have been performed, informative field tests may be conducted for:

– power-guide vane relationship tests;
– index tests for relative efficiency; see IEC 60041, clause 15.

15.2 Inspection of cavitation pitting

– Refer to 3.5.8.
– Define participation of contracting parties (see IEC 61366-1, annex F).
– Ensure that operating records are maintained during the guarantee period to verify that the machine has been operated within specified ranges of net positive suction specific hydraulic energy together with power, discharge, and specific hydraulic energy (head).

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- ☐ to write specifications
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- ☐ for a lawsuit
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- ☐ other (published by...................)
- ☐ other (published by...................)

6.

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- ☐ fairly well
- ☐ exactly

7.

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- ☐ clearly written
- ☐ logically arranged
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- ☐ illustrations
- ☐ technical information

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- ☐ floppy disk
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- ☐ CD-ROM
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10A.

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- ☐ raster image
- ☐ full text

11.

My organization is in the following sector (e.g. engineering, manufacturing)

....

12.

Does your organization have a standards library:

- ☐ yes
- ☐ no

13.

If you said yes to 12 then how many volumes:

....

14.

Which standards organizations published the standards in your library (e.g. ISO, DIN, ANSI, BSI, etc.):

....

15.

My organization supports the standards-making process (check as many as apply):

- ☐ buying standards
- ☐ using standards
- ☐ membership in standards organization
- ☐ serving on standards development committee
- ☐ other................................

16.

My organization uses (check one)

- ☐ French text only
- ☐ English text only
- ☐ Both English/French text

17.

Other comments:

....

....

....

....

....

....

18.

Please give us information about you and your company

name: ....

job title:...

company: ....

address:..

....

....

....

No. employees at your location:.........

turnover/sales:.................................

Publications de la CEI préparées par le Comité d'Etudes nº 4

60041 (1991) Essais de réception sur place des turbines hydrauliques, pompes d'accumulation et pompes-turbines, en vue de la détermination de leurs performances hydrauliques.

60193 (1965) Code international concernant les essais de réception sur modèle des turbines hydrauliques.
Modification n° 1 (1977).

60193A (1972) Premier complément.

60198 (1966) Code international concernant les essais de réception sur place des pompes d'accumulation.
Modification n°1 (1971).

60308 (1970) Code international d'essai des régulateurs de vitesse pour turbines hydrauliques.

60497 (1976) Code international concernant les essais de réception sur modèle réduit des pompes d'accumulation.

60545 (1976) Guide pour la réception, l'exploitation et l'entretien des turbines hydrauliques.

60607 (1978) Méthode thermodynamique de mesure du rendement des turbines, pompes d'accumulation et pompes-turbines hydrauliques.

60609 (1978) Evaluation de l'érosion de cavitation dans les tur-bines, les pompes d'accumulation et les pompes-turbines hydrauliques.

60609-2 (1997) Part 2: Evaluation dans les turbines Pelton.

60805 (1985) Guide pour la réception, l'exploitation et l'entretien des pompes d'accumulation et des pompes-turbines fonctionnant en pompe.

60994 (1991) Guide pour la mesure in situ des vibrations et fluctuations sur machines hydrauliques (turbines, pompes d'accumulation et pompes-turbines).

60995 (1991) Détermination des performances industrielles des machines hydrauliques à partir des essais sur modèle en considérant les effets d'échelle.

61116 (1992) Guide pour l'équipement électromécanique des petits aménagements hydro-électriques.

61362 (1998) Guide pour la spécification des régulateurs des turbines hydrauliques.

61366.— (Publiée en langue anglaise seulement).

61366-1 (1998) (Publiée en langue anglaise seulement).

61366-2 (1998) (Publiée en langue anglaise seulement).

61366-3 (1998) (Publiée en langue anglaise seulement).

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61366-6 (1998) (Publiée en langue anglaise seulement).

61366-7 (1998) (Publiée en langue anglaise seulement).

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60041 (1991) Field acceptance tests to determine the hydraulic performance of hydraulic turbines, storage pumps and pump-turbines.

60193 (1965) International code for model acceptance tests of hydraulic turbines.
Amendment No. 1 (1977).

60193A (1972) First supplement.

60198 (1966) International code for the field acceptance tests of storage pumps.
Amendment No. 1 (1971).

60308 (1970) International code for testing of speed governing systems for hydraulic turbines.

60497 (1976) International code for model acceptance tests of storage pumps.

60545 (1976) Guide for the commissioning, operation and maintenance of hydraulic turbines.

60607 (1978) Thermodynamic method for measuring the efficiency of hydraulic turbines, storage pumps and pump-turbines.

60609 (1978) Cavitation pitting evaluation in hydraulic turbines, storage pumps and pump-turbines.

60609-2 (1997) Part 2: Evaluation in Pelton turbines.

60805 (1985) Guide for commissioning, operation and maintenance of storage pumps and of pump-turbines operating as pumps.

60994 (1991) Guide for field measurement of vibrations and pulsations in hydraulic machines (turbines, storage pumps and pump-turbines).

60995 (1991) Determination of the prototype performance from model acceptance tests of hydraulic machines with consideration of scale effects.

61116 (1992) Electromechanical equipment guide for small hydro-electric installations.

61362 (1998) Guide to specification of hydraulic turbine control systems.

61366.— Hydraulic turbines, storage pumps and pump-turbines – Tendering Documents.

61366-1 (1998) Part 1: General and annexes.

61366-2 (1998) Part 2: Guidelines for technical specifications for Francis turbines.

61366-3 (1998) Part 3: Guidelines for technical specifications for Pelton turbines.

61366-4 (1998) Part 4: Guidelines for technical specifications for Kaplan and propeller turbines

61366-5 (1998) Part 5: Guidelines for technical specifications for tubular turbines

61366-6 (1998) Part 6: Guidelines for technical specifications for pump-turbines

61366-7 (1998) Part 7: Guidelines for technical specifications for storage pumps.

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