# INTERNATIONAL STANDARD

# IEC 60193

Second edition
1999-11

## Hydraulic turbines, storage pumps and pump-turbines – Model acceptance tests



*This **English-language** version is derived from the original **bilingual** publication by leaving out all French-language pages. Missing page numbers correspond to the French-language pages.*

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

# HYDRAULIC TURBINES, STORAGE PUMPS AND PUMP-TURBINES – MODEL ACCEPTANCE TESTS

## 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.

International Standard IEC 60193 has been prepared by IEC technical committee 4: Hydraulic turbines.



This second edition of IEC 60193 cancels and replaces the first edition of IEC 60193 published in 1965, its amendment 1 (1977), IEC 60193A (1972), as well as IEC 60497 (1976) and IEC 60995 (1991).

Clauses 1 to 3 of this standard cover the scopes dealt with in the above-mentioned publications. Additional information is given in clause 4.

The text of this standard is based on the following documents:

| FDIS | Report on voting |
|---|---|
| 4/157/FDIS | 4/162/RVD |

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

Annexes B, F, G, K, L and M form an integral part of this standard.

Annexes A, C, D, E, H, J, N and P are for information only.

The committee has decided that this publication remains valid until 2004. At this date, in accordance with the committee's decision, the publication will be

- reconfirmed;
- withdrawn;
- replaced by a revised edition, or
- amended.

# HYDRAULIC TURBINES, STORAGE PUMPS AND PUMP-TURBINES – MODEL ACCEPTANCE TESTS

## 1 General rules

### 1.1 Scope and object

#### 1.1.1 Scope

This International Standard applies to laboratory models of any type of impulse or reaction hydraulic turbine, storage pump or pump-turbine.

This standard applies to models of prototype machines either with unit power greater than 5 MW or with reference diameter greater than 3 m. Full application of the procedures herein prescribed is not generally justified for machines with smaller power and size. Nevertheless, this standard may be used for such machines by agreement between purchaser and supplier.

In this standard, the term "turbine" includes a pump-turbine operating as a turbine and the term "pump" includes a pump-turbine operating as a pump.

This standard excludes all matters of purely commercial interest, except those inextricably bound up with the conduct of the tests.

This standard is concerned with neither the structural details of the machines nor the mechanical properties of their components, so long as these do not affect model performance or the relationship between model and prototype performances.

#### 1.1.2 Object

This International Standard covers the arrangements for model acceptance tests to be performed on hydraulic turbines, storage pumps and pump-turbines to determine if the main hydraulic performance contract guarantees (see 1.4.2) have been satisfied.

It contains the rules governing test conduct and prescribes measures to be taken if any phase of the tests is disputed.

The main objectives of this standard are:

– to define the terms and quantities used;
– to specify methods of testing and of measuring the quantities involved, in order to ascertain the hydraulic performance of the model;
– to specify the methods of computation of results and of comparison with guarantees;
– to determine if the contract guarantees, which fall within the scope of this standard, have been fulfilled;
– to define the extent, content and structure of the final report.

The guarantees can be given in one of the following ways:

– guarantees for prototype hydraulic performance, computed from model test results considering scale effects;
– guarantees for model hydraulic performance.

Moreover additional performance data (see 1.4.4) can be needed for the design or the operation of the prototype of the hydraulic machine. Contrary to the requirements of clauses 1 to 3 related to main hydraulic performance the information of these additional data given in clause 4 is considered only as recommendation or guidance to the user (see 4.1).

It is particularly recommended that model acceptance tests be performed if the expected field conditions for acceptance tests (see IEC 60041) would not allow the verification of guarantees given for the prototype machine.

This standard may also be applied to model tests for other purposes, i.e. comparative tests and research and development work.

If model acceptance tests have been performed, field tests can be limited to index tests (see IEC 60041, clause 15).

If a contradiction is found between this standard and any other standard, this standard shall prevail.

### 1.2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication, the editions indicated were valid. All normative documents are subject to revision, and parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

IEC 60041:1991, *Field acceptance test to determine the hydraulic performance of hydraulic turbines, storage pumps and pump-turbines*

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

IEC 60609-2:1997, *Cavitation pitting evaluation in hydraulic turbines, storage pumps and pump-turbines – Part 2: Evaluation in Pelton turbines*

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

IEC 61364:1999, *Nomenclature of hydraulic machinery*

IEC 61366 (all parts), *Hydraulic turbines storage pumps and pump-turbines – Tendering documents*

ISO 31-3:1992, *Quantities and units – Part 3: Mechanics*

ISO 31-12:1992, *Quantities and units – Part 12: Characteristic numbers*

ISO 468:1982, *Surface roughness – Parameters, their values and general rules for specifying requirements*

ISO 1438-1:1980, *Water flow measurement in open channels using weirs and Venturi flumes – Part 1: Thin-plate weirs*

ISO 2186:1973, *Fluid flow in closed conduits – Connections for pressure signal transmissions between primary and secondary elements*

ISO 2533:1975, *Standard atmosphere*
Addendum 1: 1985

ISO 4006:1991, *Measurement of fluid flow in closed conduits – Vocabulary and symbols*

ISO 4185:1980, *Measurement of liquid flow in closed conduits – Weighing method*

ISO 4373:1995, *Measurement of liquid flow in open channels – Water level measuring devices*

ISO 5167-1:1991, *Measurement of fluid flow by means of pressure differential devices – Part 1: Orifice plates, nozzles and Venturi tubes inserted in circular cross-section conduits running full*

ISO 5168:1978, *Measurement of fluid flow – Estimation of uncertainty of a flow-rate measurement*

ISO 6817:1992, *Measurement of conductive liquid flow in closed conduits – Method using electromagnetic flowmeters*

ISO 7066-1:1997, *Assessment of uncertainty in the calibration and use of flow measurement devices – Part 1: Linear calibration relationship*

ISO 7066-2:1988, *Assessment of uncertainty in the calibration and use of flow measurement devices – Part 2: Non-linear calibration relationships*

ISO 8316: 1987, *Measurement of liquid flow in closed conduits – Method by collection of the liquid in a volumetric tank*

ISO 9104:1991, *Measurement of fluid flow in closed conduits – Methods of evaluating the performance of electromagnetic flow-meters for liquids*

VIM:1993, *International vocabulary of basic and general terms in metrology (BIPM-IEC-ISO-OIML)*



## 1.3 Terms, definitions, symbols and units

### 1.3.1 General

For the purpose of this International Standard the following common terms, definitions, symbols and units apply. Specialized terms are explained where they appear.

Clarification of any term, definition or unit of measure in question shall be agreed to in writing by the contracting parties in advance of the test.

#### 1.3.1.1 point

A *point* is established by one or more consecutive sets of readings and/or recordings at unchanged operating condition and settings, sufficient to calculate the performance of the machine at this operating condition and these settings

#### 1.3.1.2 test

a *test* comprises a collection of points and results adequate to establish the performance of the machine over a specified range of operating conditions

#### 1.3.1.3 hydraulic performance
all performance parameters attributable to the machine due to hydrodynamic effects

#### 1.3.1.4 main hydraulic performance data
a subset of the hydraulic performance parameters, i.e. power, discharge and/or specific hydraulic energy, efficiency, steady-state runaway speed and/or discharge. The influence of cavitation must be considered.

#### 1.3.1.5 additional data
a subset of hydraulic performance data which can be determined for information on the model (see 1.4.4). However, the prediction of the corresponding prototype data is less accurate than that achievable for the main hydraulic performance data, due to application of approximate similarity rules.

#### 1.3.1.6 guarantees
specified performance data contractually agreed to

### 1.3.2 Units

The international System of Units (SI, see ISO 31-3) has been used throughout this standard.

All terms are given in SI base units or derived coherent units[1]). The basic equations are valid using these units. This has to be taken into account if other than coherent SI units are used for certain data (e.g. kilowatt instead of watt for power, kilopascal or bar instead of pascal for pressure, $min^{-1}$ instead of $s^{-1}$ for rotational speed, etc.). Temperatures may be given in degrees Celsius since absolute temperatures (in kelvins) are rarely required.

Any other system of units may be used but only if agreed in writing by the contracting parties.



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[1]) N = kg·m·$s^{-2}$ Pa = kg·$m^{-1}$·$s^{-2}$ J = kg·$m^2$·$s^{-2}$ W = kg·$m^2$·$s^{-3}$

### 1.3.3 List of terms, definitions, symbols and units

#### 1.3.3.1 Subscripts and symbols

| Subclause | Term | Definition | Subscript or symbol |
|---|---|---|---|
| 1.3.3.1.1 | High pressure [1] reference section | The high pressure section of the machine to which the performance guarantees refer (see figure 1) | 1 |
| 1.3.3.1.2 | Low pressure [1] reference section | The low pressure section of the machine to which the performance guarantees refer (see figure 1) | 2 |
| 1.3.3.1.3 | High pressure measuring sections | Whenever possible, these sections should coincide with section 1; otherwise the measured values must be adjusted to section 1 (see 3.5.2.1.3) | 1',1'' .. |
| 1.3.3.1.4 | Low pressure measuring sections | Whenever possible, these sections should coincide with section 2; otherwise, the measured values must be adjusted to section 2 (see 3.5.2.1.3) | 2', 2'' .. |
| 1.3.3.1.5 | Specified | Subscript denoting values of quantities such as rotational speed, discharge etc. for which other quantities are guaranteed | sp |
| 1.3.3.1.6 | Maximum/minimum | Subscript denoting maximum or<br>minimum values of any term | max<br>min |
| 1.3.3.1.7 | Limits | Contractually defined values:<br>– not to be exceeded<br>– to be reached | <br>////<br>□ or //// |
| 1.3.3.1.8 | Prototype | Subscript denoting values related to the full size machine | P |
| 1.3.3.1.9 | Model | Subscript denoting values related to the model | M |
| 1.3.3.1.10 | Model at constant Reynolds number | Subscript denoting values related to a model and referred to a constant value of Reynolds number | M* |
| 1.3.3.1.11 | Reference | Subscript denoting values related to a specified reference condition | ref |
| 1.3.3.1.12 | Optimum | Subscript denoting the best efficiency point | opt |
| 1.3.3.1.13 | Ambient | Subscript referring to surrounding atmospheric conditions | amb |
| 1.3.3.1.14 | Plant | Subscript denoting values related to the operating conditions of the prototype in the plant | pl |
| 1.3.3.1.15 | Runaway | Subscript referring to runaway conditions | R |

[1] The terms "high pressure" and "low pressure" define the two sides of the machine irrespective of the flow direction and therefore are independent of the mode of operation of the machine.

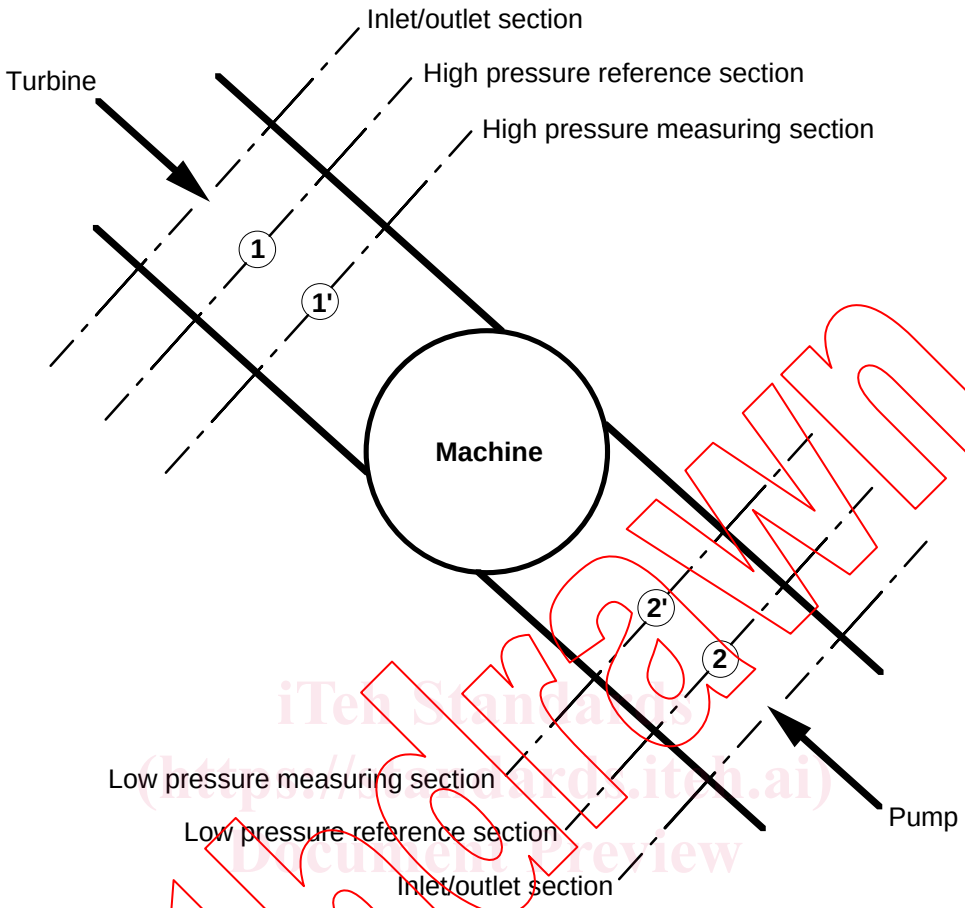
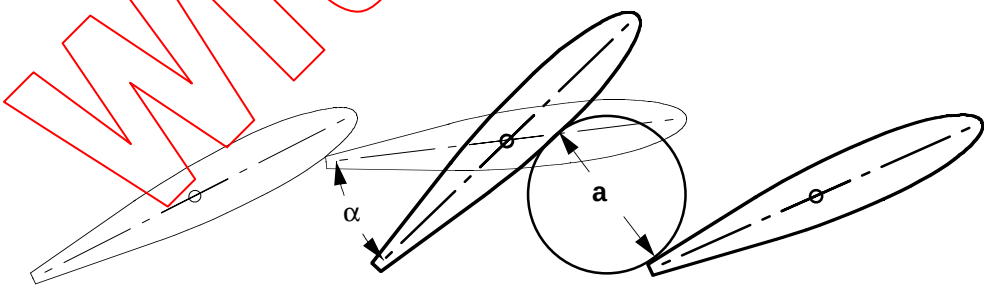



**Figure 1– Schematic representation of a hydraulic machine**






Closed position: $\alpha = 0^{\circ}$ or a = 0 mm

**Figure 2 – Guide vane opening and angle**