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International code for model acceptance test of hydraulic turbines

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

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International code for model acceptance tests of hydraulic turbines

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CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

INTERNATIONAL CODE FOR MODEL ACCEPTANCE TESTS OF HYDRAULIC TURBINES

FOREWORD

1) The formal decisions or agreements of the I E C on technical matters, prepared by Technical Committees on which all the National Committees having a special interest therein are represented, express, as nearly as possible, an international consensus of opinion on the subjects dealt with.

2) They have the form of recommendations for international use and they are accepted by the National Committees in that sense.

3) In order to promote this international unification, the I E C expresses the wish that all National Committees having as yet no national rules, when preparing such rules, should use the I E C recommendations as the fundamental basis for these rules in so far as national conditions will permit.

4) The desirability is recognized of extending international agreement on these matters through an endeavour to harmonize national standardization rules with these recommendations in so far as national conditions will permit. The National Committees pledge their influence towards that end.

PREFACE

This Recommendation has been prepared by I E C Technical Committee No. 4, Hydraulic Turbines.

The outline of the Code and the various chapters were decided upon at the meeting held in Zurich in 1957, when a number of Working Groups were set up to prepare the drafts of the different chapters.

Following the meeting held in Madrid in 1959, a draft was submitted to the National Committees for approval under the Six Months' Rule in February 1962.

The following countries voted explicitly in favour of publication:

Austria	Japan
Australia	Netherlands
Belgium	Norway
Canada	Romania
Czechoslovakia	Sweden
France	Switzerland
Germany	United Kingdom
India	United States of America

As with all Codes, revisions will be found desirable and, after the Model Test Code for Hydraulic Turbines has been in use for several years, it will undoubtedly be desirable to issue a revised edition based on the experience gained in its use.

INTERNATIONAL CODE FOR MODEL ACCEPTANCE TESTS OF HYDRAULIC TURBINES

Part 1 — General Recommendations

INTRODUCTION

In place of, or complementing tests in the field, model tests can be used as a basis for the acceptance of hydraulic turbines. It might happen that test conditions at site cannot conveniently or in full extent be obtained, in accordance with guarantee assumptions, or generally that the requirements of the International Field Test Code for Hydraulic Turbines (in the following referrred to as F.T.C.) cannot be satisfied. For these or other reasons, it might be agreed between the purchaser and the supplier to substitute for the field test of a prototype turbine a model test of a homologous model to determine the performance of the prototype.

Decisions as to the choice of either field test or model tests for each guaranteed quantity should be taken as early as possible and preferably a clear statement should be included in the inquiry specification.

Even when provisions have been made for field tests, model tests may be defined by supplementary agreement, should field tests become impossible or unsuitable.

CHAPTER I — OBJECT AND SCOPE

The purpose of this code is to establish arrangements for the preparation and execution of laboratory model tests, as well as to evaluate the results obtained so that the hydraulic performance of a model turbine and of the corresponding prototype turbine can be ascertained.

1. Types of turbines

In general the code applies to any type of hydraulic reaction or impulse turbine tested under laboratory conditions.

2. Excluded topics

2.1 This code excludes all matters of purely commercial interest except those inextricably bound up with the conduct of the acceptance tests.

2.2 This code is not concerned with the structural details of the turbines nor with the mechanical properties of their components, so long as these do not affect model performance.

2.3 Model tests for research performance are not specially dealt with in this code. It is recommended, however, that equipment and methods described in the code be applied in the current testing work in the laboratory, to keep it prepared for acceptance tests.

CHAPTER II — TERMS, DEFINITIONS, SYMBOLS AND UNITS

1. Measuring systems

The metric system of units is adopted throughout the code but other systems shall be allowed if preferred.

The terms, definitions, symbols and units adopted in this code are listed below:

2. List of terms

	Term	Definition	Symbol	Units
2.1	*Rate of flow or discharge*	Volume of water per second passing a specified section.	Q	m³/s (ft³/s)
2.1.1	Turbine discharge	Volume of water used by the turbine per second, including leakage water in stuffing boxes and turbine thrust relief pipes but excluding water required for operation of the dynamometer auxiliary machinery and for cooling of bearings.	Q	m³/s (ft³/s)
2.1.2	Guaranteed discharge	Turbine discharge at guaranteed head, output and speed.	Q_r	m³/s (ft³/s)
2.1.3	No-load discharge	Turbine discharge at no-load and normal speed and guaranteed head.	Q_o	m³ (ft³/s)
2.2	*Area* (see Figures 1 to 4)	Cross-sectional area normal to the general direction of flow.	A	m² (ft²)
2.2.1	Area at turbine inlet	*a)* In plants with open flume, the area of the agreed section downstream of turbine inlet screen. *b)* In plants with closed conduit, the area of section through the agreed measuring point near the turbine casing downstream of inlet valve.	A_1	m² (ft²)
2.2.2	Area at turbine outlet	In reaction turbines, the area of draft tube cross-section normal to the flow at the outlet end of the draft tube must be mutually agreed. In plants not having a typical draft tube, the location of the outlet section must be mutually agreed upon. In impulse turbines, the area of cross-section at outlet cannot be defined and is assumed infinitely large.	A_2	m² (ft²)
2.3	*Mean velocity*	Rate of flow divided by area of cross-section: $v = Q/A$	v	m/s (ft/s)
2.4	*Pressure*	The pressure at any point in the system expressed as force per unit area.	p	kp/cm² (lbf/in²)

Term		Definition	Symbol	Units
2.4.1	Gauge pressure	The reading given by a gauge of the pressure at any point in the system.	p_g	kp/cm² (lbf/in²)
2.4.2	Pressure at inlet to turbine	The gauge pressure at the inlet measuring point corrected for the elevation of gauge.	p_1	kp/cm² (lbf/in²)
2.4.3	Pressure at outlet from turbine	The gauge pressure at the outlet measuring point corrected for elevation of gauge.	p_2	kp/cm² (lbf/in²)
2.5	*Specific weight of water* [1]	The weight in air of unit volume of water used by turbine.	γ	kp/dm³ (lbf/ft³)
2.6	*Head*			
2.6.1	Pressure head	The head of water equivalent to the pressure at any point in the system.	h_p	m (ft)
2.6.2	Velocity head	The head equivalent to the square of the mean velocity divided by twice the acceleration of gravity: $h_v = \frac{v^2}{2g}$ [2]	h_v	m (ft)
2.6.3	Potential head (Geodetic head)	Elevation of a measuring point above mean sea level or other reference datum.	z	m (ft)
2.6.4	Total head	The sum of potential head, pressure head and velocity head, in a given section: $h_t = z + h_p + h_v$	h_t	m (ft)
2.6.5	Net head	The head available for doing work on the turbine; it is the difference between total head at inlet and outlet. (See illustrative examples shown in Figures 1 to 4.)	H_n	m (ft)

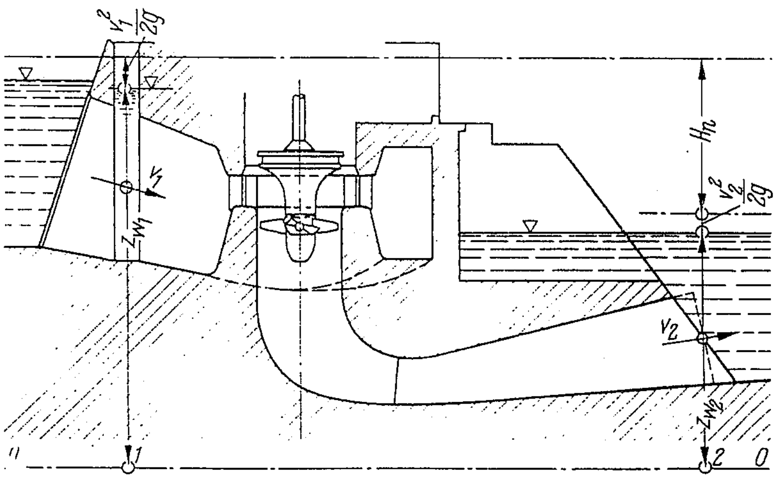

FIG. 1. — Reaction turbine (Francis, Propeller, Kaplan). Rectangular spiral casing in concrete; draft tube bend.

$$H_n = (z_{w_1} - z_{w_2}) + \frac{(v_1^2 - v_2^2)}{2g}$$

[1] See tabulated values of γ at end of this chapter, Table I.

[2] See tabulated values of g at end of this chapter, Table II.

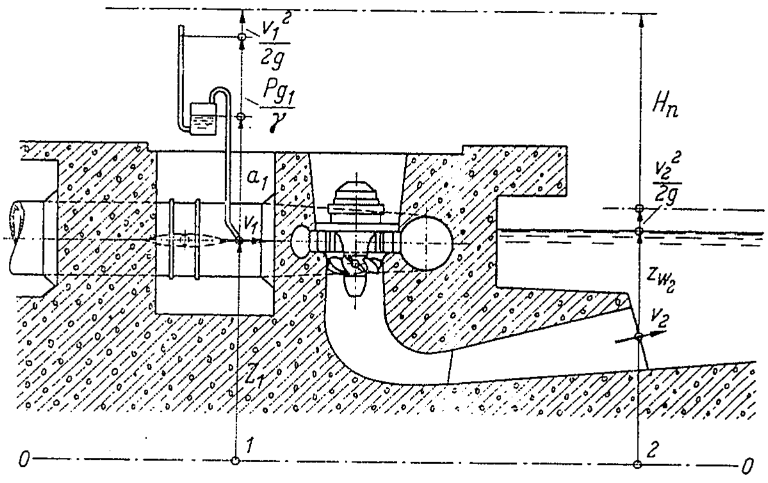

FIG. 2. — Reaction turbine. Spiral casing with circular section.

$$H_n = (z_1 + a_1 - z_{w_2}) + 10 \cdot \frac{p_{g_1}}{\gamma} + \frac{(v_1^2 - v_2^2)}{2g}$$

(metric)

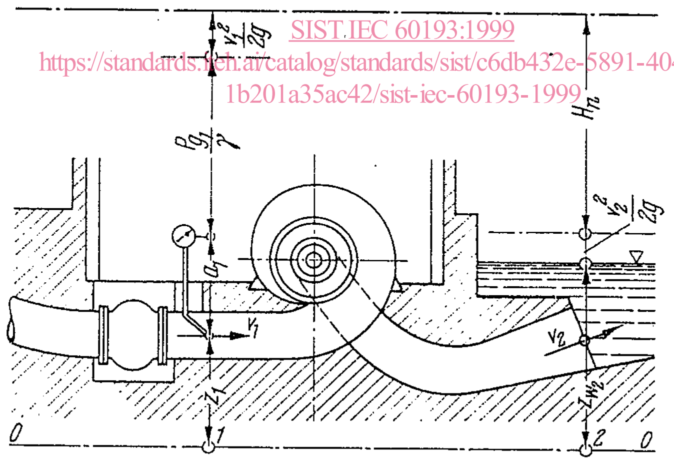

FIG. 3. — Reaction turbine. Horizontal shaft.

$$H_n = (z_1 + a_1 - z_{w_2}) + 10 \cdot \frac{p_{g_1}}{\gamma} + \frac{(v_1^2 - v_2^2)}{2g}$$

(metric)

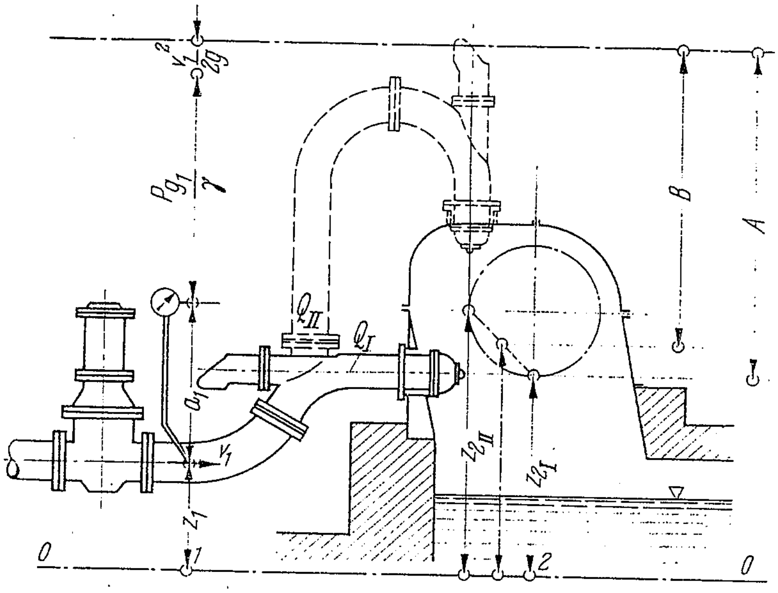

FIG. 4. — Impulse turbine.

A: Single nozzle

$$H_n = (z_1 + a_1 - z_2) + 10 \cdot \frac{p_{g1}}{\gamma} + \frac{v_1^2}{2g}$$

B: Twin nozzle

$$H_n = \frac{Q_I}{Q_I + Q_{II}} (z_1 + a_1 - z_{2I}) + \frac{Q_{II}}{Q_I + Q_{II}} (z_1 + a_1 - z_{2II}) + 10 \cdot \frac{p_{g1}}{\gamma} + \frac{v_1^2}{2g}$$

(metric)

	Term	Definition	Symbol	Units
2.6.6	Guaranteed head	The net head for which the turbine is ordered.	H_r	m (ft)
2.6.7	Loss of head	Loss of total head between any two sections.	H_l	m (ft)
2.6.8	Height of measuring instrument	The difference in elevation between the datum for which the measuring instrument is calibrated and the location of the measured point.	a	m (ft)
2.6.9	Barometer height	The height of the water barometer corresponding to the atmospheric pressure at the corresponding temperature.	h_b	m (ft)
2.6.10	Vapour pressure	The height of the column of water corresponding to the vapour pressure at the temperature of the test water.	h_{va}	m (ft)
2.6.11	Geodetic suction head	Height of turbine or runner above tailwater level (see Figure 5).	h_s	m (ft)

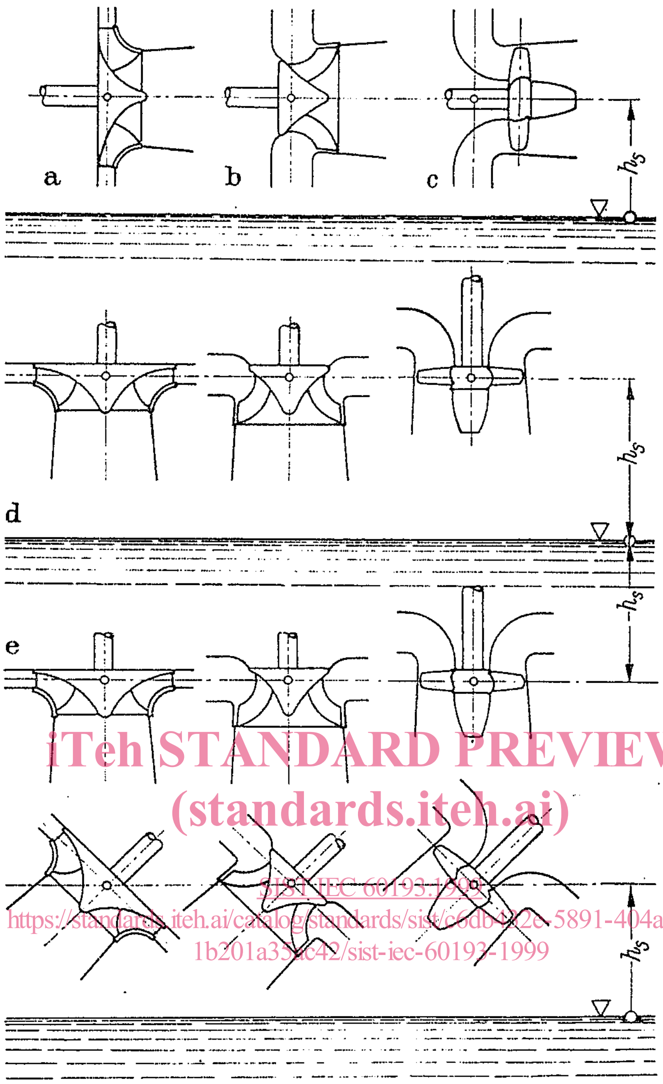

FIG. 5. — Definition of geodetic suction head h_s.

a) Francis low specific speed
b) Francis high specific speed
c) Kaplan, Propeller
d) positive suction head
e) negative suction head

▽ Tailwater level

Term		Definition	Symbol	Units
2.7	*Input and output*			
2.7.1	Turbine input	The hydraulic power equivalent of the turbine discharge Q at net head H_n: $P_d = k \cdot \gamma \cdot Q \cdot H_n$ $\left(k = \frac{1\,000}{102}\right)$ (or $k = \frac{1\,356}{1\,000}$ foot pound system)	P_d	kW
2.7.2	Turbine output	The mechanical power delivered by the turbine shaft.	P_t	kW
2.7.3	Guaranteed output	The turbine output at guaranteed net head H_r and guaranteed speed n_r for which the turbine is ordered.	P_r	kW
2.8	*Efficiency*			
2.8.1	Turbine efficiency	Ratio of turbine output to turbine input.	η_t	%
2.8.2	Turbine weighted average efficiency	The weighted average efficiency computed arithmetically from the single values: $\eta_1, \eta_2, \eta_3, ...$ at the guaranteed output or discharge values and at their respective weights: $w_1, w_2, w_3, ...$ agreed for these outputs or discharges by: $\eta_{t_w} = \frac{w_1 \cdot \eta_1 + w_2 \cdot \eta_2 + w_3 \cdot \eta_3 + ...}{w_1 + w_2 + w_3 + ...}$	η_{t_w}	%
2.8.3	Turbine arithmetical average efficiency	Weighted average efficiency as defined in 2.8.2 with $w_1 = w_2 = w_3 = ... = 1$	η_{t_a}	%
2.8.4	Turbine planimetric average efficiency	The mean height of the efficiency curve within the guaranteed range.	$\eta_{t_{pl}}$	%
2.9	*Speed*	Number of revolutions per unit time.	n	rev/min
2.9.1	Guaranteed speed	The speed for which the turbine is ordered.	n_r	rev/min
2.9.2.	Runaway speed	The maximum speed attained when all load is removed, that is at zero torque on the runner, and when the supply of water is unchecked in such a position of guide vanes (and runner blades of Kaplan turbines) which gives maximum runaway speed.	n_R	rev/min
2.10.	*Cavitation*	In model testing cavitation (the formation of vapour bubbles due to low local pressure) may be directly viewed through suitable observation ports.		–