INTERNATIONAL STANDARD

ISO 21630

First edition
2007-08-15

Pumps — Testing — Submersible mixers for wastewater and similar applications

Pompes — Essais — Mélangeurs immergés pour eaux usées et applications similaires

Reference number
ISO 21630:2007(E)

ISO copyright office
Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.org
Web www.iso.org

Published in Switzerland

Contents

Page

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 21630 was prepared by Technical Committee ISO/TC 115, *Pumps*, Subcommittee SC 2, *Methods of measurement and testing*.

Introduction

This International Standard prescribes acceptance test methods for submersible mixers for wastewater and other applications. It is intended for performance measurements relevant to submersible mixers bearing in mind the similarities to, and crucial differences from, submersible pumps. Hence head (pressure) and flow rate measurements are not included. The basic output performance parameter is the thrust. As continuous operation is commonplace, electric power consumption is important for the Life Cycle Cost, and is put forward as an important parameter. It is acknowledged that the present International Standard draws heavily on ISO 9906:1999 in the generalities.

The major objectives of this International Standard are to

— increase uniformity/compatibility in equipment performance characterization, enabling a comparison of mixers,

— simplify communication between customer and supplier and protect customers,

— reduce the need for documentation,

— increase quality and efficiency in both machinery and process.

Pumps — Testing — Submersible mixers for wastewater and similar applications

1 Scope

This International Standard prescribes acceptance test methods for submersible mixers (hereafter “SM” or “mixer”) used for mixing in wastewater and other applications where at least one system component is a liquid.

“Submersible mixer” is taken to mean a fully submersible aggregate consisting of a drive unit and an axial flow type impeller, and optional parts, such as shrouds, supporting the basic functions.

“Liquid” is taken to mean a body without capacity to accommodate shear stresses when at rest. This includes suspensions and dispersions (liquid/solid, gas/liquid and gas/liquid/solid), and non-Newtonian liquids, provided that a possible small yield stress does not prevent the liquid from flowing when agitated.

2 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

2.1
thrust-to-power ratio
ratio of mixer thrust force to mixer power consumption

$$R_{FP} = F / P_1$$

NOTE 1 The ratio of minimum required mixing system power dissipation to mixer power consumption is an (end-user oriented) system efficiency. To understand the importance of the thrust-to-power ratio, consider the case of an SM generating a longitudinal flow velocity u in a recirculation channel such as a wastewater oxidation ditch. This is in fact a common application of the SM, and the following argument is in principle possible to generalize to other applications.

The momentum loss of the flow over one circulation equals the rate of momentum provided by the SM at quasi-steady state. This is given by the mixer thrust F. The power dissipated as a result of this momentum loss is $P = F\,u$, and this is the minimum required mixing system power to maintain the velocity u. Hence, the system efficiency is $P / P_1 = F\,u / P_1$.

It is possible to isolate the mixer properties from the system requirement in this expression, and this leads to the thrust-to-power ratio, R_{FP}, as the most relevant efficiency-related parameter of the SM. It should be noted that it is dimensional, and hence it depends on the impeller diameter and speed, not only on the impeller geometry. Other considerations than energetic efficiency of generation of longitudinal flow provide for the multitude of impeller diameters and speeds available in practice.

NOTE 2 An impeller efficiency, defined as the ratio of power of axial motion of the impeller discharge to the electric power uptake of the mixer, can be defined. The definition draws on the assumption that the approaching velocity, u, is small enough to have negligible influence on the mixer impeller characteristics. The hydraulic discharge power $P_h = p\,Q$ can be expressed in thrust using the relations

$$p = F / A \text{ and } F = 2\,\rho\,Q^2 / A$$

which are approximately valid for the mixer test established herein. The conventional area of the *vena contracta* $A / 2$ is used, as this discharge section best fulfils the flat velocity profile requirement. With $A = \pi\,D^2 / 4$, one obtains

$$P_h = (F / A)\,(A\,F / 2\,\rho)^{1/2} = F^{3/2} / [D\,(\pi\,\rho / 2)^{1/2}]$$

Hence the impeller efficiency can be written

$$\eta = F^{3/2} / [(\pi \rho / 2)^{1/2} D P_1]$$

It can be noted that, often correct to within 1 %, the efficiency is conventionally given as (assuming SI units $[F]$ = Newton, $[P_1]$ = Watt, $[D]$ = meter, and clean cold water as defined in 5.4.5.2)

$$\eta = F^{3/2} / (40 D P_1)$$

Although the derivation given here is not based on completely correct assumptions, the approximate expression for the efficiency may be derived in more rigorous ways.

The value of the impeller efficiency alone is not deemed to be of primary interest because of the dependency of mixer-system efficiency on the impeller diameter and speed.

2.2
advance ratio
ratio of propeller traversing speed or mean liquid ambient speed to (essentially) tip speed

$$J = u / nD$$

2.3
impeller Reynolds number
ratio between inertial and viscous forces prevailing at impeller

$$Re = (F / \rho)^{1/2} / \nu$$

NOTE F is the thrust for the same mixer running at the same speed in clean cold water as defined in 5.4.5.2. Also note that this is not the same as the blade Reynolds number, nor is it identical, but akin to the impeller Reynolds number used for dry-installed agitators in the process industries.

3 Symbols and abbreviated terms

Table 1 summarizes the symbols in alphabetical order and SI units used.

Table 1 — Alphabetical list of letters used as symbols

Symbol	Quantity	Unit
A	Area swept by impeller	m^{2}
D	Diameter of impeller	m
e	Uncertainty, relative	(pure number), %
f	Frequency	s^{-1}, Hz
F	Thrust	N
J	Propeller advance ratio	(pure number)
L	Length of lever	m
n	Speed of rotation	s^{-1}, Hz
p	Pressure	Pa
P	Power	W
Q	Flow rate	m^{3}/s
R_{FP}	Thrust-to-power ratio	N/W
Re	Impeller Reynolds number	(pure number)
t	Tolerance	(pure number), %
T	Time	s
u	Mean velocity in the axial or longitudinal direction	m/s
U	Voltage	V
x	Generic measured entity	
$<x>$	Time average of x	
η	Efficiency	(pure number), %
ν	Kinematic viscosity	m^{2}/s
ρ	Density	kg/m^{3}
σ	Standard deviation	

Table 2 summarizes the subscripts used for the symbols.

Table 2 — Alphabetical list of letters and figures other than above used as subscript

Subscript	Meaning
1	electric (power)
G	guaranteed
L/L	length ratio
h	hydraulic (power)
LC	load cell related
m	measured
M	mixer related
FP	see R_{FP}
sp	specified
Tr	translated
TS	time series

4 Guarantees

4.1 Subjects of guarantees

4.1.1 General

Terms used herein such as “guarantee” or “acceptance” should be understood in a technical but not in a legal sense. The term “guarantee” therefore specifies values for checking purposes determined in the contract, but does not say anything about the rights or duties arising if these values are not reached or fulfilled. The term “acceptance” does not have any legal meaning here, either. Therefore, an acceptance test carried out successfully alone does not represent an “acceptance” in the legal sense.

A procedure for verifying the guarantees is given in 6.4.

4.1.2 Thrust guarantee

One guarantee point shall be defined by a guarantee thrust F_G.

The manufacturer/supplier guarantees that under the standard test conditions established in this document, the measured thrust will fall in a specified interval surrounding F_G. Unless otherwise stated, the interval is given by the tolerances stated in Table 6.

4.1.3 Electric power uptake guarantee

One guarantee point shall be defined by a guarantee electric power uptake P_{1G}.

The manufacturer/supplier guarantees that under the standard test conditions established in this document, the measured electric power uptake will fall in a specified interval surrounding P_{1G}. Unless otherwise stated, the interval is given by the tolerances stated in Table 6.

4.1.4 Thrust-to-power ratio guarantee

One guarantee point shall be defined by a guarantee thrust-to-power ratio $R_{FP,\mathrm{G}}$. This shall be given by $R_{FP,\mathrm{G}} = F_\mathrm{G} / P_{1\mathrm{G}}$.

The manufacturer/supplier guarantees that under the standard test conditions established in this document, the measured and calculated thrust-to-power ratio will fall in a specified interval surrounding $R_{FP,\mathrm{G}}$. Unless otherwise stated, the interval is given by the tolerances stated in Table 6.

4.2 Conditions of guarantees

Unless otherwise agreed, the following conditions shall apply to the guaranteed value.

a) The guarantee point shall apply to clean cold water (see 5.4.5.2).

b) The relationship between the guarantee values under clean cold water conditions and the likely performance under other liquid conditions shall be agreed in the contract.

c) Guarantees shall apply only to the mixer as tested by the methods and in the test arrangements specified herein.

d) The relationship between the guarantee values under the conditions of the methods and test arrangements specified herein and the likely performance under other operating conditions shall be agreed in the contract.

5 Execution of tests

5.1 Subjects of tests

5.1.1 General

If not otherwise agreed between the manufacturer/supplier and the purchaser, the following shall apply:

— accuracy according to 6.2; and

— tests shall be carried out on the test stand of the manufacturer's works, or on a test stand engaged by the manufacturer/supplier.

Any deviations from this shall be agreed between the purchaser and manufacturer/supplier. This should be done as soon as possible, and should preferably form part of the contract.

Among others, such deviations may be

a) accuracy other than that given in 6.2,

b) tolerance factors other than those given in 6.3,

c) tests in a neutral laboratory.

Annex A shows a checklist of items where agreement between the purchaser and manufacturer/supplier is recommended.

5.1.2 Contractual tests — Fulfilment of the guarantee

The tests are intended to ascertain the performance of the mixer and to compare this with the manufacturer's/supplier's guarantee. The nominated guarantee for any quantity shall be deemed to have been met if, when tested according to this International Standard, the measured performance falls within the tolerance specified for the particular quantity.

When a number of identical mixers are to be purchased, the number of mixers to be tested shall be agreed upon between the purchaser and the manufacturer/supplier.

5.2 Organization of tests

5.2.1 General

Both purchaser and manufacturer/supplier shall be entitled to witness these tests. The test supervisor may delegate his/her responsibilities under 5.2.4 to the test operator, provided the test operator is sufficiently trained to handle these responsibilities.

5.2.2 Location of tests

Performance tests should preferably be carried out at the manufacturer's works, or at another test stand engaged by the manufacturer/supplier, or at a place to be mutually agreed between the manufacturer/supplier and the purchaser.

5.2.3 Date of testing

The date of testing shall be mutually agreed by the manufacturer/supplier and the purchaser if the purchaser by contract requires to witness the test.

5.2.4 Staff

Accurate measurements depend not only on the quality of the measuring instrument used but also on the ability and skill of the persons operating and reading the measurement devices during the tests. The staff entrusted with effecting the measurements shall be selected just as carefully as the instruments to be used in the test.

Specialists with adequate experience in measuring operations in general shall be charged with operating and reading complicated measuring apparatus. Reading simple measuring devices may be entrusted to such helpers who (upon prior instructions) can be assumed to effect the readings with proper care and the accuracy required.

A test supervisor possessing adequate experience in measuring operations shall be mutually appointed. Normally, when the test is carried at the manufacturer's works, the test supervisor is a staff member of the mixer manufacturer.

During the tests all persons charged with effecting the measurements are subordinated to the chief of tests, who conducts and supervises the measurements, reports on test conditions and the results of the tests and then drafts the test report. All questions arising in connection with the measurements and their execution are subject to his/her decision. The parties concerned shall provide all assistance that the chief of tests considers necessary.

5.2.5 State of mixer

When tests are not carried out in the manufacturer's works, or at another test stand engaged by the manufacturer/supplier, both the manufacturer and the installer shall be allowed the opportunity to make preliminary adjustments.

5.2.6 Test program

The program and procedure to be followed in the test shall be prepared by the test supervisor and submitted to both manufacturer/supplier and purchaser in ample time for consideration and agreement.

Only the guaranteed operational data (see 4.1) shall form the basis of the test; other data determined by measurement during the tests shall have merely an indicative (informative) function and it shall be so stated if they are included in the program.

5.2.7 Testing equipment

When deciding on the measuring procedure, the measuring, recording and data handling apparatus shall be specified at the same time. The test supervisor shall be responsible for checking the correct installation of the apparatus and its proper functioning.

All of the measuring apparatus shall be covered by reports showing, by calibration or by comparison with other ISO or IEC standards, that it complies with the requirement of 6.2.3. These reports shall be presented if required. Guidance for a suitable period between calibrations of test instruments is given in Annex E of ISO 9906:1999. For test instruments other than those given there, e.g. force measurement instruments, a period of at most one year between calibrations is recommended.

5.2.8 Records

All test records and record charts shall be initialled by the test supervisor and by the representatives of both the manufacturer/supplier and purchaser, if present, each of whom shall be provided with a copy of all records and charts.

The evaluation of the test results shall be made as far as possible while the tests are in progress and, in any case, before the installation and instrumentation are dismantled in order that suspect measurements can be repeated without delay.

5.2.9 Test report

If the purchaser has requested a test report, then, after scrutiny, the test results shall be summarized in a report which is signed by the test supervisor or test operator alone, or together, by him/her and representatives of the manufacturer/supplier and of the purchaser. All parties specified in the contract shall receive a copy of the report.

The test report should contain the following information:

a) place and date of acceptance test;

b) manufacturer’s name, type of mixer, and serial number;

c) impeller/propeller diameter, blade angle or other hydraulic end identifications;

d) guaranteed characteristics, operational conditions during the acceptance test;

e) specification of the mixer’s driver;

f) sketch of test arrangement, description of the test procedure and the measuring apparatus including calibration data;

g) readings;

h) evaluation and analysis of test results;

i) conclusions:

- comparison of the test results and the guaranteed quantities;
- determination of action taken in connection with any special agreements that were made;
- recommendation on whether the mixer can be accepted or should be rejected and under what conditions (if the guarantees are not fully satisfied the final decision whether the mixer can be accepted or not is up to the purchaser);
- statements arising out of action taken in connection with any special agreements that were made.

5.3 Test arrangements

5.3.1 General

The conditions necessary to ensure satisfactory measurement of the characteristics of operation are defined in this subclause, taking into account the accuracy required (see 6.2).

NOTE 1 The performance of a mixer in a given test arrangement, however accurately measured, cannot be assumed to be a correspondingly accurate indication of its performance in another arrangement.

NOTE 2 Recommendations and general guidance about flow boundary arrangements to ensure satisfactory measurements are given in Clause 7.

5.3.2 Standard test arrangements

The most suitable measuring conditions are obtained when the ambient flow surrounding the mixer is minimized or completely eliminated. In particular,

a) large scale flow structures including vortices or swirl shall be eliminated/reduced,

b) if ambient flow cannot be eliminated, it shall be symmetric and parallel with the mixer impeller axis.

5.4 Test conditions

5.4.1 Test procedure

The duration of the test shall be sufficient to obtain consistent results regarding the degree of accuracy to be achieved.

All measurements shall be made under steady conditions of operation, or under unsteady conditions within the limits given in 5.4.2. A decision to make measurements when such conditions cannot be obtained shall be a matter of agreement between the parties concerned.

Verification of the guarantee point shall be obtained by recording at least 30 readings closely and evenly grouped in time, as specified in 5.2.2. Note that a larger number of readings may be required.

If the driving power available during a test on a test stand is insufficient, and if the test has to be carried out at a reduced speed of rotation, the test results shall be translated to the specified speed of rotation in accordance with 6.1.2. The speed of rotation shall be controlled in accordance with 5.4.4.

If the driving current available during a test on a test stand is insufficient because the SM is Δ-connected, a Y-connection may be applied at a current reduced by a factor $3^{-1/2}$, and a voltage increased by a factor $3^{1/2}$, assuming 3-phase. Note that steady operation must be achieved before measurement readings are taken. The difference in performance between the two connection types shall be accounted for in the test protocol.

5.4.2 Stability of operation

5.4.2.1 General remarks

For the purposes of this International Standard, the following shall be considered.

a) Fluctuations: short period changes in the measured value of a physical quantity about its mean value during the time that a single reading is being made.

b) Variations: those changes in value which take place between one reading and next.

5.4.2.2 Permissible fluctuations in readings

If the signals delivered by the measuring systems are automatically recorded or integrated by the measuring device, this International Standard does not specify a limit on the fluctuations. No such limitation is deemed necessary if

a) the measuring system used includes an integrating device carrying out automatically, with the required accuracy, the integration necessary to calculate the mean value over an integration period much longer than the response time of the corresponding system;

b) the integration necessary to calculate the mean value may be carried out later on, from the continuous or sampled record of the analog signal. (The sampling conditions should be specified in the test report.)

If none of these conditions is fulfilled, a limitation on fluctuations may be agreed on between manufacturer/supplier and purchaser.

5.4.2.3 Number of sets of observations

5.4.2.3.1 General

A set of readings consists of a reading of each of the individual variables. In this International Standard, this consists of a thrust reading and a power reading. Note that the thrust-to-power ratio is based on the final test values of thrust and power.

5.4.2.3.2 Steady conditions

Test conditions are called steady if the mean value of all quantities involved (mixer thrust and power uptake) are independent of time. In practice, test conditions may be regarded as steady if the maximum value observed at the test operating point during at least 30 s of observation does not exceed the minimum observed value during the same observation by more than 5 % of this minimum value. If this condition is met, only one set of readings of individual quantities need be recorded.

5.4.2.3.3 Unsteady conditions

In such cases where the unsteadiness of test conditions give rise to doubts concerning the accuracy of the tests, the following procedure shall be followed. The minimum number of readings of individual quantities is given by the considerations in 6.2.2.

The measured variable is measured at instants separated by a constant period, or it is integrated and averaged during a constant period. The period must be no shorter than half the auto-correlation period of the measurement variable time series. If it is shorter by some factor, the number of readings of the individual variable must be increased by the inverse of this factor.

The autocorrelation period, or auto-correlation time, of a measured variable x, with values $\langle x \rangle + x_i$ measured at times $T_{\text{initial}} + i\,\Delta T$, may be approximated as

$$T_0 = \left[\Delta T / \sigma^2 (N+1)\right] \sum_{N=0}^{M} \sum_{i=1}^{N} x_i x_{i+N} \tag{1}$$

where

$N = M + 1$ would produce the first negative contribution to the sum over N, and

$\Delta T < T_0 / 6$, $N > 5\, T_0 / \Delta T$.

The value of the standard deviation of the set of measurement values is σ.

5.4.3 Voltage and driving frequency during test

The applied voltage shall be within 5 % of the voltage specified for the mixer. The applied driving frequency shall be within 1 % of the frequency specified for the mixer. If agreed between the manufacturer/supplier and purchaser, the frequency may be set to a different value, as specified in 5.4.4.

NOTE These conditions ensure that the rotational speed is the same as under the specified operating conditions for the mixer. Symbolically, this speed is denoted n_{sp}, although it need not be known.

5.4.4 Speed of rotation during test

If agreed between the manufacturer/supplier and purchaser, tests may be carried out at other speeds than that corresponding to the specified frequency and voltage (symbolically called n_{sp}). This shall be accomplished by setting the driving frequency to a defined value, which shall be included in the test report. The frequency may vary from 50 % to 120 % of the specified frequency. It shall be written in the test report whether the speed of rotation varies directly proportionally to the frequency or not. If the speed varies in direct proportion to frequency, the speed can be expressed as

$$n = n_{sp} \left(f / f_{sp} \right) \tag{2}$$

If this simple relation between rotational speed and driving frequency is not present, use of the translation relations given in 6.1.2 may only be made if the manufacturer/supplier and purchaser agree on, and perform a method of determining the value of (n / n_{sp}).

The measured values at these speeds will refer to operation at these speeds only. An approximate way of calculating thrust at yet other speeds of operation is given in 6.1.2. Estimates of power uptake of the mixer and thrust-to-power ratio of the mixer at other speeds require more data, including, for example, the motor data for the SM.

The effect of reduced or increased frequency on the performance of the SM depends not only on the SM itself, but also on the device used for driver frequency variation. If the specified frequency of the SM is not used in the test, a note shall be made in the test protocol that product performance depends on the frequency variation device.

5.4.5 Test on mixer for liquids other than clean cold water

5.4.5.1 General

The performance of a mixer varies substantially with the nature of the liquid being mixed. It is desirable for the parties to agree on the empirical rules to predict the performance of the mixer in another liquid than clean cold water.

5.4.5.2 Characteristics of "clean cold water"

The characteristics of the water corresponding to what is called "clean cold water" herein shall be within the limits indicated in Table 3. The measured values of thrust and power uptake are normalised with regard to water density to correspond to the density $\rho_{sp} = 998{,}2\ kg/m^3$ (which occurs at the temperature 20 °C of clean water at atmospheric pressure). The normalization data and equations are given in 6.1.2.

Table 3 — Specification of "clean cold water"

Characteristics	Unit	min.	max.
Temperature	°C	0	40
Kinematic viscosity	m^2/s	—	$1{,}75 \times 10^{-6}$
Density	kg/m^3	995	1 050
Non-absorbent free solid content	kg/m^3	—	2,5
Dissolved solid content	kg/m^3	—	50

5.4.5.3 Characteristics of liquids for which clean cold water tests are acceptable

Mixers for liquids other than clean cold water may be tested for thrust and power uptake with clean cold water if the liquid is Newtonian and within the specifications in Table 4. It is noted that the Reynolds number depends on the actual outcome of the measurement, and compliance with these limits can with certainty only be established *a posteriori*. The predicted thrust and power uptake for operation in the other liquid shall be calculated according to a procedure agreed between the manufacturer/supplier and the purchaser.

Table 4 — Characteristics of liquids

Characteristics	Unit	min.	max.
Reynolds number	(pure number)	$3{,}0 \times 10^4$	—
Density	kg/m^3	450	2 000
Non-absorbent free solid content	kg/m^3	—	2,5

6 Analysis of test results

6.1 Translation of the test results to the guarantee conditions

6.1.1 General

The quantities required to verify the characteristics guaranteed by the manufacturer/supplier and given in 4.1 are generally measured under conditions more or less different from those on which the guarantee is based.

In order to determine whether the guarantee would have been fulfilled if the tests had been conducted under the guarantee conditions, it is necessary to translate the quantities measured under different conditions to those measured under guarantee conditions.

6.1.2 Translation of the test results into data based on the specified liquid density and speed of rotation

Clean unpressurized water has a dependence of density on temperature as given in Table 5. The data are taken from ISO 5198:1998, Annex C.

Table 5 — Clean unpressurized water density dependence on temperature

Temperature (°C)	0	5	10	15	20	25	30	35	40
Density (kg/m^3)	999,8	999,9	999,7	999,1	998,2	997,0	995,6	994,0	992,2

If the test liquid characteristics, e.g. density ρ, fall within the specified limits given in Table 3, and/or if the test speed of rotation n differs from the specified speed n_{sp} by use of frequency variation as stated in 5.4.4, the measured data on the thrust F can be converted to a test value F_{Tr} by means of Equation (3):

$$F_{Tr} = F\,(\rho_{sp} / \rho)\,(n_{sp} / n)^2 \qquad (3)$$

The value of the speed n shall be controlled as described in 5.4.4. The same equation may be solved for the operational thrust F in a liquid whose characteristics, e.g. density ρ, fall within the limits given in Table 4, when F_{Tr} has been obtained .

Equation (3) may similarly be used for an *estimate* of thrust given driving frequencies outside the limits stated in 5.4.4 and liquid densities outside the limits of Table 4. An *estimate* of the power uptake could be made using Equation (4) (with similar notation):

$$P_{Tr} = P\,(\rho_{sp} / \rho)\,(n_{sp} / n)^3 \qquad (4)$$

This expression approximates the behaviour of the hydraulic power, and it must be recognised that, for example, motor performance will strongly influence the electric power. In addition, the influence of the no-load power is not represented by this expression.

Since the power uptake scaling cannot with certainty be claimed to be cubic with speed, a simple scaling rule for thrust-to-power ratio cannot be given. As a lowest order approximation, the application of the above two equations may be used for an *estimate*:

$$R_{FP,Tr} = R_{FP}\,(n / n_{sp}) \qquad (5)$$

6.2 Measurement uncertainties

6.2.1 General

Every measurement is inevitably subject to uncertainty, even if the measuring procedure and the instruments used, as well as the methods of analysis, fully comply with existing rules.

6.2.2 Determination of random uncertainty

For the purposes of this International Standard, the random uncertainty on the measurement of a variable is taken as $2 \times \sigma$, where σ is the standard deviation of the variable, and at least 30 independent readings of the variable under the same conditions are recorded and used. However, the random uncertainty shall not be greater than 0,75 times the absolute value of the tolerances given in Table 6.

If the maximum allowed random uncertainty e is smaller than the relative random uncertainty $2\sigma / \langle x \rangle$, where $\langle x \rangle$ is the mean value of the measured variable, the number of independent readings shall be increased to $29 \times (2\sigma / e \langle x \rangle)^2$.

When partial errors (the combination of which gives the uncertainty) are independent of each other, are small and numerous and have a Gaussian distribution, there is a 95 % probability that the true value does not fall outside the uncertainty interval from the measured value.

6.2.3 Maximum permissible systematic uncertainty

The uncertainty of a measurement depends partly on the residual uncertainty in the instrument or in the method of measurement used. After all known errors have been removed by calibration, careful measurement of dimensions, proper installation, etc. There remains an error which never disappears and cannot be reduced by repeating the measurements if the same instrument and the same method of measurement are used. This component of the error is called “systematic uncertainty”.

Clauses 7 and 8 describe or enumerate methods of measurement and devices to be used to determine the mixer thrust and electric power uptake. Devices or methods which are known by calibration or references to other standards to result in a measurement with a known systematic uncertainty shall be used. These instruments or methods shall be accepted by the parties concerned. The limitation on the systematic uncertainty shall be for the measured quantities, respectively

a) for thrust ± 2 %, and

b) for electric power ± 2 %.

6.2.4 Overall measurement uncertainty

The random uncertainty due either to the characteristics of the measuring system or to variations of the measured quantity, or both, appears directly as a scatter of the measurements. Unlike the systematic uncertainty, the standard deviation of the mean of a variable can be reduced by increasing the number of measurements of the same quantity under the same conditions.

The overall measurement uncertainty is to be calculated by the square root of the sum of squares of the systematic and random uncertainties [see Equation (8)] in 7.3. The overall measurement uncertainties shall, as far as possible, be determined after the test taking into account the measurement and operation conditions pertaining to the test.

6.2.5 Determination of measurement uncertainty in the thrust-to-power ratio

The overall uncertainty in the trust-to-power ratio is to be calculated as the mean error in the expression F / P_1. In general, the mean error is given by

$$|\Delta R_{FP} / R_{FP}|^2 = |(1/ R_{FP}) (\mathrm{d} R_{FP} /\mathrm{d}F) \Delta F|^2 + |(1/ R_{FP}) (\mathrm{d} R_{FP} /\mathrm{d}P_1) \Delta P_1|^2 + \ldots \qquad (6)$$

whence

$$e_R = (e_F^2 + e_P^2)^{1/2} \qquad (7)$$

6.3 Values of tolerance factors

Because of manufacturing uncertainties, deviations from drawings and exact specifications are present with every mixer.

When comparing the test results with guaranteed values, tolerances shall be allowed, including the possible deviations in operating dates between the tested mixer and a mixer without any manufacturing uncertainties.

It should be pointed out that these tolerances in the operating behaviour of the mixer are relative to the real mixer and not to the test conditions and the measuring uncertainties. To simplify the verification of guaranteed values, the introduction of tolerance factors is recommended. These tolerance factors, t_F, t_P and t_R, shall be applied to the measurement condition specified herein.

Tolerances may be agreed on in the contract. In the absence of a specific agreement on the values to be used, the values given in Table 6 shall be used.

Table 6 — Values of tolerance factors

Quantity	Symbol	Negative %	Positive %
Thrust guaranteed nominal < 300 N	t_F	12	—
Thrust guaranteed nominal ⩾ 300 N	t_F	8	—
Electric power Rated < 5 000 W	t_P	—	10
Electric power Rated ⩾ 5 000 W	t_P	—	5
Thrust-to-power ratio	t_R	$= t_F$	—

6.4 Verification of guarantees

6.4.1 General

The verification of each guarantee shall be accomplished by comparing the results obtained from the tests with the values guaranteed in the contract (including their associated tolerances).

6.4.2 Verification of guaranteed thrust, power uptake and efficiency

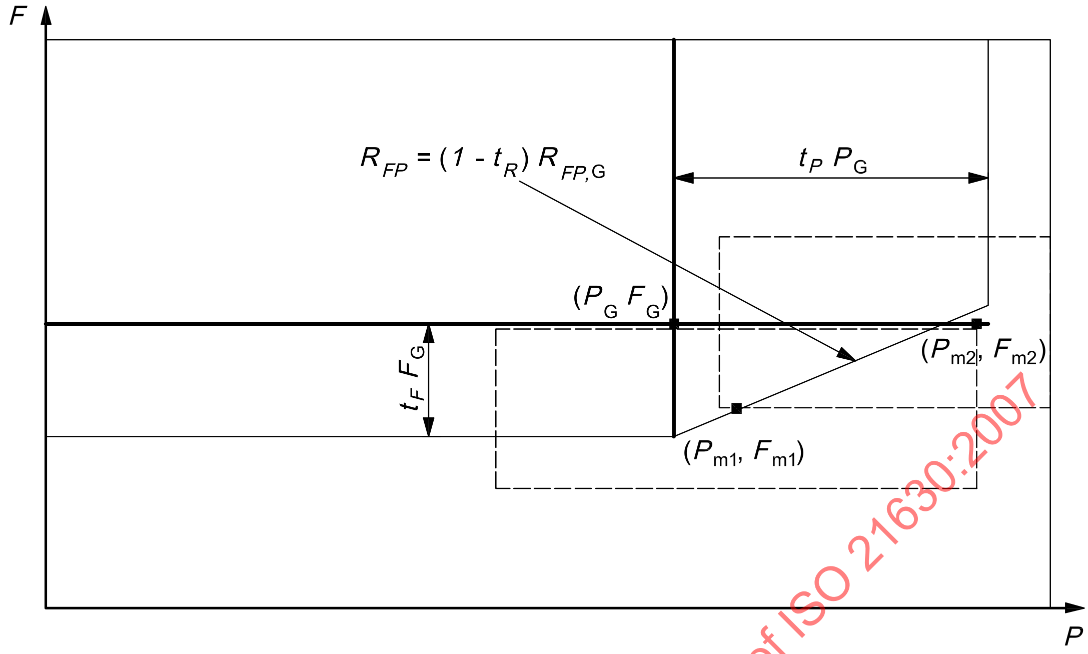
The results of measurements shall be translated to the specified speed and liquid density according to 6.1.2. The verification can be shown graphically as in Figure 1 below. The measurement point (P_m, F_m) must touch or fall within the region above and to the left of the tolerance lines.

The verification may also be explained in the following way. The measured values of thrust and power, F_m and P_m, must be such that they fulfil all of the three conditions:

a) $F_m \geqslant (1 - t_F)\, F_G$;

b) $P_m \leqslant (1 + t_P)\, P_G$;

c) $R_{FP,m} \geqslant (1 - t_R)\, R_{FP,G}$.



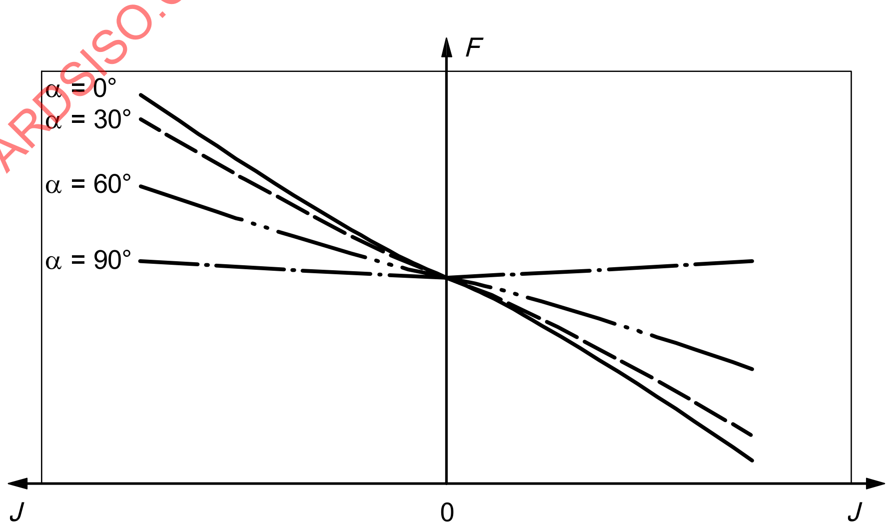
In this case, product number 1 fulfils the guarantee, whereas product number 2 falls outside the guaranteed performance range. The dashed rectangles indicate the measurement uncertainty span.

Figure 1 — Guarantee verification

7 Measurement of thrust

7.1 Flow conditions of mixer thrust measurement

The thrust of a mixer running under conditions specified in 5.4 depends on the boundary conditions. As a simplified example, consider the thrust of a mixer in a homogeneous steady flow whose velocity is u and whose direction is at an angle α to the mixer axis. A thrust performance field may in principle look as in Figure 2.



Negative values of the advance ratio $J = u / nD$ correspond to counter-flow.

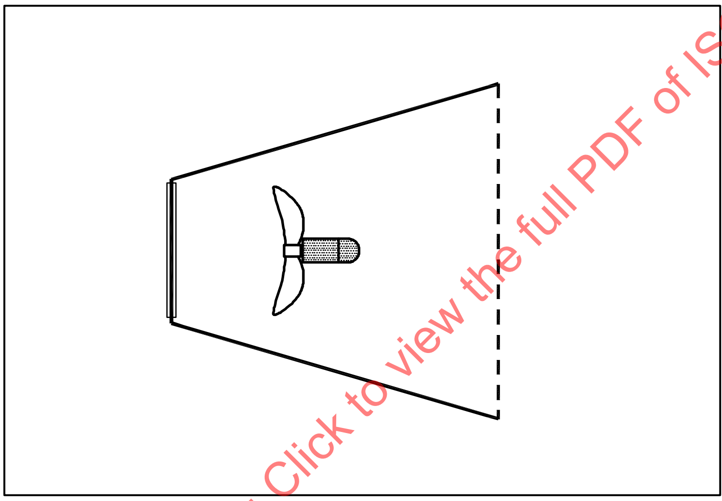
Figure 2 — Principle sketch of mixer thrust in various homogeneous flow conditions

The flow conditions are generally more complex under typical operating conditions. The flow need not be steady or homogeneous. In the present International Standard, measurement of the mixer thrust at $J = 0$, i.e. with no surrounding flow, is selected as the standard measurement.

Apparently, there is no single duty point with a higher representativity than this point in Figure 2. The conditions of operation, referred to as *open sea conditions*, can be obtained either by a *virtual open sea* arrangement or by *true open sea.* A test stand arrangement principle providing open sea conditions is shown in Figure 3 a). Two different approaches are shown in Figures 3 b) and 3 c).

In practice, complete absence of ambient flow, or $J = 0$, may be impossible to achieve. An acceptable tolerance value for J is much smaller than 1 ($\ll$ 1) and should be selected in view of the tolerances given in Table 6.

The effect of tank boundaries and the free liquid surface on the mixer duty point shall also be considered. A standard null case, with minimized boundary effects, is selected for the standard measurement. To remove the effects of boundaries and the free liquid surface, minimum distances from the mixer to the boundaries and the free liquid surface shall be observed.



The front baffle has a hole to let the jet through. Recirculation is smoothed by the contraction generated by the oblique baffles; both on the return way and on the approach to the mixer. A perforated plate at the approaching flow entry reduces the large scale turbulence.

a) Top view of a baffle arrangement securing standard flow conditions in a mixer measurement tank

Figure 3 — Test stand arrangements *(continued)*

