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Hydraulic fluid power — Measurement techniques —

Part 1: General measurement principles

Transmissions hydrauliques — Techniques de mesurage —

Partie 1: Principes généraux de mesurage

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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.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 131, *Fluid power systems,* Subcommittee SC 8, *Product testing*.

This second edition cancels and replaces the first edition (ISO 9110-1:1990), which has been technically revised.

The main changes compared to the previous edition are:

— new normative and informative references have been added;

— new definitions have been added;

— classes of accuracy to measurement have been renamed;

— assessment of uncertainties has been revised and expanded and general measurement considerations and requirements have been renamed;

— guidance on gravity correction has been added;

— readability uncertainty evaluation has been added;

— determination of uncertainty limits and classification of uncertainties has been combined and uncertainty limit specifications have been renamed;

— frequency of calibration has been revised and assurance control techniques have been renamed;

— total measurement uncertainty clause has been added;

— original Annex A has been deleted;

— new Annex A - Measurement System Acceptance Designated Information Sheet, has been added;

— new Annex B - Uncertainty Propagation, has been added;

— new Annex C - Best Practices Tutorial, has been added.

A list of all parts in the ISO 9110 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

Universal measurement standards are required if meaningful comparisons are to be made and valid conclusions deduced. A fundamental aspect of fluid power technology is the need to quantify the performance characteristics of hydraulic components and systems to provide a basis for action or decision-making. The method of measurement used is capable of reliably determining such performance characteristics.

This document provides guidance for identifying uncertainty sources and magnitudes in the calibration of instruments and their use in measurement situations encountered in hydraulic fluid power testing. Methods are described for assessing the uncertainty in measurements and derived results.

It is widely recognized that no measurement, irrespective of the amount of care exercised, can ever be absolutely accurate and free of error. Different circumstances each have unique uncertainty requirements. The value of a measurement is dictated by the use that will be made of it, as well as the particular circumstance. Therefore, the maximum value of a reported measure can only be realized if it can be applied under many different circumstances, requiring that the uncertainty associated with a measure be assessed and reported.

This document is intended to be used in conjunction with others that address the measurement of specific physical parameters: flow, pressure, torque, speed and temperature.

This document (ISO 9110-1) relates to general principles for the measurement of static or steady-state conditions. ISO 9110-2 deals with the measurement of average steady-state static pressure in a closed conduit.

Hydraulic fluid power — Measurement techniques —

Part 1:
General measurement principles

1 Scope

This document establishes general principles for the measurement of performance parameters under static or steady-state conditions.

This document provides guidance on the sources and magnitudes of uncertainty to be expected in the calibration of and measurements using hydraulic fluid power components. It describes practical requirements for assessing the capability of the measuring system, and hence the level of uncertainty of the measurement system, or for assisting in developing a system which will meet a prescribed level of uncertainty.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 5598, *Fluid power systems and components — Vocabulary*

ISO 7870-1, *Control charts — Part 1: General guidelines*

ISO 7870-2, *Control charts — Part 2: Shewhart control charts*

ISO/IEC Guide 98-3, *Uncertainty of measurement — Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 5598 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1
data reduction errors
errors that stem from any processing of test data to the final result, as from digital computer resolution, numerical rounding of results, and uncertainty in model curve fitting and interpolation

3.2
indicated value
magnitude of the measure and the parameter subject to measurement

3.3
parallax
phenomenon responsible for reading errors when the observer's eye is not perpendicular to the meter face, and is not directly in line with a pointer whose tip is not in the same plane as the instrument scale

3.4
readability
ability of a human observer to discern a numeric value to the quantity displayed on the readout device

3.5
uncertainty model
chart, graph or equation that relates the *indicated value* (3.2) to the value of the measure and the parameter being measured

4 Uncertainty of limit specifications

4.1 General aspects

4.1.1 Each performance test standard that incorporates this document as a normative reference shall have its own uncertainty defined for each of the three classes of measurement accuracy described herein, and instrumentation selection criteria stated.

4.1.2 The maximum uncertainty which may be allowed in a fluid power test measurement can only be established by considering the component or system under test, the expected use of the test results, and the economics of the test program.

4.1.3 Each test procedure complying with this document shall include a table of permissible uncertainty that provides the limits for each of the three classes of measurement accuracy relevant to this test procedure: A, B, and C (see 4.2.1, 4.2.2, and 4.2.3). The limits should be based upon the maximum uncertainty allowable for each measurement.

4.2 Classes of measurement accuracy

4.2.1 Class A is the most restrictive and is intended for those measurement situations that are scientific in nature and directed at investigating phenomena. Equipment capabilities and technical expertise required to perform class A measurements would generally be used only in the most stringent applications.

4.2.2 Class B is intended to encompass performance measurements required for selection and application of components and for quality audits. The requirements for class B measurements should be within the capabilities of most fluid power testing laboratories.

4.2.3 Class C would apply to diagnostic situations where the objective is to determine if hardware is functioning properly or has failed, and to monitor the operational status of equipment. Users with limited expertise in fluid power measurements using standard commercial instrumentation would possess the required capabilities.

5 General measurement considerations and requirements

5.1 Calibration

The uncertainty inherent in a measurement system may be associated with individual elements of that system or the system as a whole. In general, calibrating and evaluating the uncertainty of the system as a whole results in smaller errors and reduced uncertainty.

All reference standards and measuring instruments shall be calibrated utilizing traceable standards of known uncertainty and environmental influences. The reference standard shall be traceable to a nationally or internationally certified calibration agency or have been derived from accepted values of natural physical constants or have been derived by the ratio type of calibration technique. Reference standards or physical constants are those recognized by the International Committee for Weights and Measure (CIPM), the International Bureau of Weights and Measures (BIPM), or the National Standard Institute of the respective country. The reference standard used for calibration shall be recorded.

It is recommended that measurement and calibration laboratories establish a measurement assurance program. Analyzing calibration data using control chart methods may be used to characterize the short- and long-term behaviour of instruments. This time dependent behaviour may be used to establish and validate calibration intervals.

The reference standard uncertainty included in the total measurement system uncertainty summation in Clause 10 is obtained either from the manufacturer or certifying agency that provided certification traceable to the reference standards laboratory.

5.1.1 The calibration interval of reference standards is determined by:

a) consideration of usage and environmental factors;

b) manufacturer's recommendations;

c) governing contract, government regulation, or specific industry specifications/customer requirements;

d) inherent stability of the standard.

5.1.2 The complete calibration interval of measuring instruments shall be determined by using the results of intermediate calibrations as per Clause 9. Calibration intervals may also be based on a time interval considering the following factors:

— equipment stability and drift using historical trend analysis or control charts;

— industry and government-related organizations' recommendations;

— quality standards, customer/contract requirements, and industry regulations;

— experience with instrument usage and frequency;

— environmental operating conditions in the application;

— criticality and complexity of the calibration process;

— risks associated with using un-calibrated instruments;

— risk for damage.

For Class A measurements, intermediate calibration should be conducted immediately prior to instrument use. If this is not practical in the test situation, e.g. calibration carried out by an external agency, an intermediate calibration at the end of testing is recommended.

For Class B and C measurements, intermediate calibrations are normally based on a time interval.

NOTE All test results acquired in the preceding calibration interval are suspect if at the next calibration the results fall outside the required allowable measurement uncertainty or control chart limits.

The risk of acquiring suspect data can be assessed considering the following factors:

a) instrument manufacturer's recommendations and specifications;

b) instrument past operating experience and calibration control chart history;

c) calibration data history of similar existing instruments.

5.1.3 New instruments and those without a prior calibration history shall be calibrated at no less than ten calibration points and five repeated trials at each point. Calibration can be conducted internally, or by the instrument manufacturer or an outside calibration agency.

See OIML D10, NCSL International RP-1, ANSI Z540.3, and ISO 10012.

5.1.4 Calibration increments for instruments with linear characteristics shall be spaced in a linear manner. For non-linear instruments, such as turbine flow meters, logarithmically spaced increments are recommended to provide better definition in the non-linear range. The calibration increments selected shall include the end points encountered in the measurement situation.

For instruments with prior calibration history, an intermediate calibration performed at 25 %, 50 %, and 100 % of full scale with three repeated trials is sufficient.

5.1.5 Eliminate systematic standard uncertainty observed during calibration by instrument adjustment or by correcting all data obtained. If systematic standard uncertainty correction is not implemented, include the maximum value of the systematic standard uncertainty in the computation of the total measurement system uncertainty in Clause 10. For example, if the calibration of an instrument reveals a 3 % deviation at mid-range and 1 % at the end points, and the data obtained using the instrument is to be used without correction, the 3 % deviation shall be used in the uncertainty computation.

5.1.6 Correct standard uncertainties which are the result of a physical relationship with another independent variable by using a known mathematical function. This class of uncertainties is normally due to environmental factors. If the standard uncertainty is neglected and no correction is made for its effect, the maximum value of the uncertainty shall be included in the computation of total measurement system uncertainty in Clause 10. The effect of temperature on a transducer strain gage bridge is an example of such an effect.

Gravity varies depending upon the location on earth. Therefore, the need for gravity correction arises because gravity at the location of a reference standard or instrument varies from the internationally accepted standard value.

The value for local gravity may be calculated using Formula (1), the International Gravity Formula (IGF) and the current World Geodetic System model WGS84, which accounts for the rotation of the earth, height above sea level, and the spheroidal shape of the globe.

$$g_l = 9{,}7803267714 \left\{ \frac{1+0{,}0019385138639[\sin(\theta)]^2}{\sqrt{1-0{,}00669437999013 9[\sin(\theta)]^2}} \right\} \left(\frac{R}{R+e} \right)^2 \qquad (1)$$

where

g_l local gravity value (m/s^2);

θ is the geographic latitude;

e is the elevation above sea level (m);

R is the nominal radius of the earth (6 378 137,0 m).

See References [6], [7], [8] and [10].

Gravity correction is accomplished using a ratiometric method in Formulae (2a) and (2b). For example, in torque or pressure measure calibration, which relies upon reference dead weight, the following relationship for correction applies:

$$m_C = \frac{m \cdot g_l}{g_s} \qquad (2a)$$

$$p_C = \frac{p \cdot g_l}{g_s} \quad (2b)$$

where

m_C and p_C	are the corrected values for mass and pressure;
m	is the mass under standard conditions (kg);
p	is the pressure (MPa);
g_I	is the local gravity value (m/s^2);
g_s	is the international standard gravity value (9,808665 m/s^2).

Gravity correction applies to fluid elevation head instruments such as manometers. Gravity correction is accomplished using the relationship in Formula (3):

$$h_{C,t} = \frac{h_t \cdot g_l}{g_s} \quad (3)$$

where

$h_{C,t}$	is the corrected value for the height of the indicating fluid (cm, or m);
h_t	is the height of the indicating fluid (cm, or m);
g_l	is the local gravity value (m/s^2);
g_s	is the international default value for gravity (9,806 65 m/s^2).

5.1.7 If a testing agency is not equipped to perform either an intermediate or a complete calibration, the instrument manufacturer or other agency may be contracted to perform these services. The testing agency and its independent contractor are not exempted from any of the requirements set forth herein.

6 Complete calibration procedure

6.1 Selection of reference standard

Select a reference standard which:

a) is free of physical damage, or the damage was previously noted in the calibration records and is not considered to affect its function;

b) is certified and traceable as per the requirement of 5.1;

c) has its total uncertainty evaluated and documented.

6.2 Procedure

6.2.1 Mount the reference standard in an attitude indicated in its calibration record or as recommended by its manufacturer.

6.2.2 Select the measuring instrument to be calibrated.

6.2.3 Mount the measuring instrument in an attitude recommended by the manufacturer or in an attitude expected in the measurement situation.

