

Transmitters for use in industrial-process control systems —

Part 3: Methods for performance evaluation of intelligent transmitters

The European Standard EN 60770-3:2006 has the status of a
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National foreword

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The UK participation in its preparation was entrusted by Technical Committee GEL/65, Measurement and control, to Subcommittee GEL/65/2, Devices, which has the responsibility to:

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**Transmitters for use in industrial-process control systems
Part 3: Methods for performance evaluation
of intelligent transmitters
(IEC 60770-3:2006)**

Transmetteurs utilisés dans les systèmes
de conduite des processus industriels
Partie 3: Méthodes pour l'évaluation des
performances des transmetteurs
intelligents
(CEI 60770-3:2006)

Messumformer für industrielle
Prozessleittechnik
Teil 3: Verfahren zur Bewertung der
Leistungsfähigkeit von intelligenten
Messumformern
(IEC 60770-3:2006)

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Foreword

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INTRODUCTION

New transmitters for use in industrial process control systems are now equipped with micro-processors which utilise digital data processing and communication methods, auxiliary sensors and artificial intelligence. This makes them more complex than conventional analogue transmitters and gives them considerable added value.

An intelligent transmitter is an instrument that uses digital data processing and communication methods for performing its functions and for safeguarding and communicating data and information on its operation. It may be equipped with additional sensors and functionality which support the main function of the intelligent transmitter. The variety of added functionality can for instance enhance accuracy and rangeability, self-test capabilities, and alarm and condition monitoring. Therefore accuracy-related performance testing, although still a major tool for evaluation, is no longer sufficient to show the flexibility, capability and other features with respect to engineering, installation, maintainability, reliability and operability.

Because of the complexity of intelligent transmitters, a close collaboration should be maintained between the evaluating body and the manufacturer during the evaluation. Note should be taken of the manufacturer's specifications for the instrument, when the test programme is being decided, and the manufacturer should be invited to comment on both the test programme and the results. His comments on the results should be included in any report produced by the testing organisation.

This part of IEC 60770 addresses, in its main body, structured and mandatory methods for a design review and performance testing of intelligent transmitters. Intelligent transmitters will, in many cases, also have the capacity to be integrated into digital communication (bus) systems, where they have to co-operate with a variety of devices. In this case, dependability, (inter)operability and real-time behaviour are important issues. The testing of these aspects depends largely on the internal structure and organisation of the intelligent transmitter and the architecture and size of the bus system. The Annexes A, B and C give a non-mandatory methodology and framework for designing specific evaluation procedures for dependability and throughput testing and function block testing in a specific case.

When a full evaluation, in accordance with this part of IEC 60770, is not required or possible, those tests which are required, should be performed and the results reported in accordance with the relevant parts of this standard. In such cases, the test report should state that it does not cover the full number of tests specified herein. Furthermore, the items omitted should be mentioned, in order to give the reader of the report a clear overview.

The structure of this part of IEC 60770 largely follows the framework of IEC 62098. For performance testing, the IEC 61298 series should also be consulted. A number of tests described there are still valid for intelligent transmitters. Further reading of the IEC 61069 series is recommended, as some notions in this part of IEC 60770 are based on concepts brought forward therein.

TRANSMITTERS FOR USE IN INDUSTRIAL-PROCESS CONTROL SYSTEMS –

Part 3: Methods for performance evaluation of intelligent transmitters

1 Scope and object

This part of IEC 60770 specifies the following methods.

- Methods for
 - reviewing the functionality and the degree of intelligence in intelligent transmitters;
 - testing the operational behaviour, as well as the static and dynamic performance of an intelligent transmitter.
- Methodologies for
 - determining the reliability and diagnostic features used to detect malfunctions;
 - determining the communication capabilities of the intelligent transmitters in a communication network.

The methods and methodologies are applicable to intelligent transmitters, which convert one or more physical, chemical or electrical quantities into digital signals for use in a communication network or into analogue electrical signals (as specified in the IEC 60381 series).

The methods and methodologies listed in this part of IEC 60770 are intended for use by:

- manufacturers to determine the performance of their products and
- users or independent testing laboratories to verify equipment performance specifications.

Manufacturers of intelligent transmitters are urged to apply this part of IEC 60770 at an early stage of development.

This standard is intended to provide guidance for designing evaluations of intelligent transmitters by providing:

- a checklist for reviewing the hardware and software design in a structured way;
- test methods for measuring and qualifying the performance, dependability and operability under various environmental and operational conditions;
- methods for reporting the data obtained.

2 Normative references

The following referenced documents are indispensable for the application 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.

IEC 60050-300, *International Electrotechnical Vocabulary (IEV) – Electrical and electronic measurements and measuring instruments – Part 311: General terms relating to measurements – Part 312: General terms relating to electrical measurements – Part 313: Types of electrical measuring instruments – Part 314: Specific terms according to the type of instrument*

IEC 60068-2-1, *Environmental testing – Part 2: Tests. Tests A: Cold*

IEC 60068-2-2, *Environmental testing – Part 2: Tests B: Dry heat*

IEC 60068-2-6, *Environmental testing – Part 2: Tests – Test Fc: Vibration (sinusoidal)*

IEC 60068-2-31, *Environmental testing. Part 2: Tests. Test Ec: Drop and topple, primarily for equipment-type specimens*

IEC 60068-2-78, *Environmental testing – Part 2-78: Tests – Test Cab: Damp heat, steady state*

IEC 60079 (all parts), *Electrical apparatus for explosive gas atmospheres*

IEC 60381(all parts), *Analogue signals for process control systems*

IEC 60529:1989, *Degree of protection provided by enclosures (IP Code)*
Amendment 1 (1999)

IEC 60654 (all parts), *Operating conditions for industrial-process measurement and control equipment*

IEC 60721-3 (all parts), *Classification of environmental conditions – Part 3: Classification of groups of environmental parameters and their severities*

IEC 60770-1:1999, *Transmitters for use in industrial-process control systems – Part 1: Methods for performance evaluation*

IEC 61010-1:2001, *Safety requirements for electrical equipment for measurement, control, and laboratory use – Part 1: General requirements*

IEC 61032:1997, *Protection of persons and equipment by enclosures – Probes for verification*

IEC 61158 (all parts), *Digital data communications for measurement and control – Fieldbus for use in industrial control systems*

IEC 61298 (all parts), *Process measurement and control devices – General methods and procedures for evaluating performance*

IEC 61326:2002, *Electrical equipment for measurement, control and laboratory use – EMC requirements*

IEC 61499 (all parts), *Function blocks*

IEC 61804 (all parts), *Function blocks (FB) for process control*

CISPR 11, *Industrial, scientific and medical (ISM) radio-frequency equipment – Electromagnetic disturbance characteristics – Limits and methods of measurement*

3 Terms and definitions

For the purposes of this part of IEC 60770, the definitions given in IEC 60770-1 and IEC 60050-300 as well as the following, apply.

3.1

intelligent transmitter

transmitter provided with means for bi-directional communication with external systems and human operators for sending measurement and status information and receiving and processing external commands

3.2**intelligent single variable transmitter**

transmitter that measures one single physical quantity

3.3**intelligent multi variable transmitter**

transmitter that measures two or more identical or different physical quantities

3.4**adjustment**

set of operations carried out on a measuring instrument in order that it provides given indications corresponding to given values of the measurand

NOTE 1 When the instrument is made to give a null indication corresponding to a null value of the measurand, the set of operation is called zero adjustment.

NOTE 2 Many manufacturers use the term calibration for adjustment of zero, span and linearity or conformity.

3.5**user adjustment**

adjustment, employing only the means at the disposal of the user, specified by the manufacturer

3.6**calibration**

set of operations which establishes by reference to standards the relationship which exists, under specified conditions, between an indication and a result of a measurement

NOTE The relationship between the indications and the results of measurement can be expressed, in principle, by a calibration diagram.

3.7**tuning**

process of adjusting the various instrument parameters, required for obtaining a stable and optimal measurement. This can range from "trial and error" to an automatic proprietary procedure provided by the manufacturer

3.8**base load**

minimum amount of software necessary to execute the essential function(s)

3.9**signal generator**

installation or device that provides the physical quantity to be measured by a transmitter. The output of the signal generator shall be accurate and traceable to international standards both under reference conditions and controlled operational conditions in the required range

3.10**configuring**

process of implementing the functionality required for a certain application

3.11**configurability**

extent to which an intelligent transmitter can be provided with functions to control various applications

3.12**set-up**

process of configuring, calibrating and tuning a transmitter for optimal measurement

3.13

dead band

finite range of values within which reversal of the input variable does not produce any noticeable change in the output variable

NOTE The dead band may be entirely defined by the resolution of the digital processing in the data processing subsystem and the electrical output system.

3.14

operating mode

selected method of operation of a transmitter

3.15

accuracy

closeness of agreement between the result of a measurement and the (conventional) true value of the quantity being measured

3.16

error

algebraic difference between the measured value and the true value of a measured quantity

3.17

conformity error

absolute value of maximum deviation between the calibration curve and the specified characteristic curve

3.18

linearity error

absolute value of maximum deviation between the calibration curve and the specified straight line

4 Design review

4.1 General

The design review is meant to identify and make explicit, in a structured way, the functionality and capabilities of the intelligent transmitter under consideration. As stated in the introduction, intelligent transmitters appear in a great variety of designs. A design review is the necessary tool for showing the details of:

- The physical structure.
- The functional structure.

Subclause 4.2 guides the evaluator through the process of describing the physical structure of intelligent transmitters by identifying the hardware modules and the inputs and outputs to the operational and environmental domains. Thereafter, the functional structure can be described, using the checklist of 4.3. The checklist gives a framework of the relevant issues, which need to be addressed by the evaluator, mainly through adequate qualitative and quantitative experiments.

4.2 Transmitter analysis

4.2.1 General

Two different types of transmitters can be identified:

- **Single-variable transmitter.** The measured value (output) represents one single physical quantity measured by one type of sensor.

- **Multi-variable transmitter.** This type of transmitters appears in two versions:
 - An instrument providing a variety of measured values (outputs), each of which is related to a measurement of one distinct input quantity with a specific sensor.
 - An instrument providing composite measured variables resulting from the measurement of more than one quantity through more than one type of sensor and processed through a distinct algorithm (e.g. flow computer, mechanical power meter). In many cases, the individual measured variables are also available to the user.

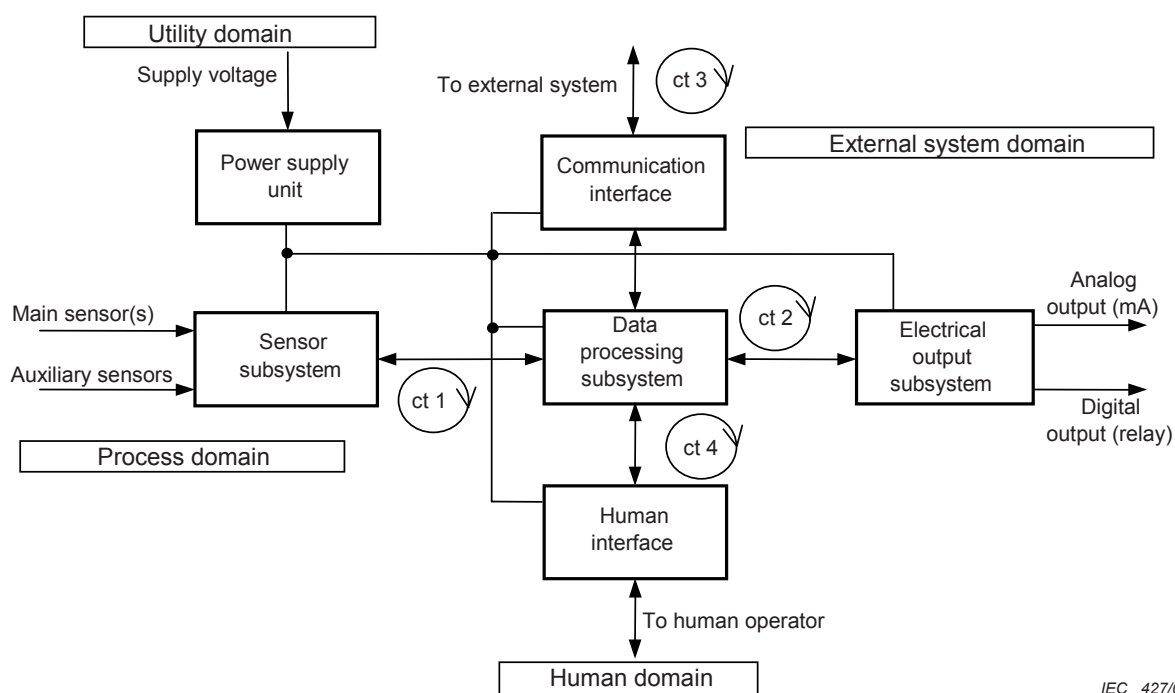
Each type of intelligent transmitter may be equipped with independent auxiliary sensors and auxiliary (mainly digital) outputs, which are not involved in the primary measurement process.

The generic transmitter model of Figure 1 gives a maximum configuration and is a tool for setting up a blockscheme and concise description of the transmitter to be evaluated. It is also important for defining the functions to be considered in the performance tests (see Clause 5).

Functionally, a transmitter is an information transformer. Data enters and then exits the instrument through the various (external) domains given in Figure 1, following distinct data flow paths. The following paths can be defined, but are not always resident in a specific transmitter under consideration:

- Sensors (process domain) to external systems (remote data processing systems).
- Sensors (process domain) to operator displays (human domain).
- Sensors (process domain) to external systems (electrical outputs).
- Operator commands through local keyboard (human domain) to data processing subsystem, consequently affecting the above-mentioned data flows to external systems (remote data processing systems and electrical outputs).
- Remote commands (from external remote data processing systems) to the instrument's data processing subsystem, consequently affecting the above-mentioned data flows to external systems (electrical outputs) and local operator displays (human domain).

A blockscheme and description shall be included in the evaluation report and may be enhanced with photographs or drawings of important details.



IEC 427/06

Figure 1 – Intelligent transmitter model

For an intelligent transmitter, the main physical modules and provisions for connection to external systems and human operators are defined in 4.2.2 to 4.2.9.

4.2.2 Data processing subsystem

The data processing subsystem is the heart of an intelligent transmitter. Its main function is to provide and process the measured quantity(ies) for further real-time use by the human and communication interfaces and/or at the electrical output subsystem. Many transmitters measure one quantity by means of one (main) sensor, but composite measured variables such as heat- or mass-flow and mechanical power require more sensors.

Besides the main measurement function, a transmitter may be equipped with a number of additional functions that can vary considerably from make to make. Amongst the additional functions that may be resident in a transmitter are:

- configuration;
- adjustment, and tuning;
- self-testing, diagnostics, condition monitoring;
- external process control function;
- trending and data storage.

Part of the functionality may be located in external devices that are temporarily or continuously connected to the communication interface (e.g. configuring, trending).

4.2.3 Sensor subsystem

The sensor subsystem converts the physical or chemical quantity(ies) to be measured into electrical signals that are conditioned and digitised for use by the data processing unit. The subsystem may also be equipped with electrical circuits for sensing binary signals (e.g. change measurement range on an external command), or auxiliary sensors of a different type (e.g. auxiliary for compensation or internal diagnostics and condition monitoring purposes).

The sensor and sensor subsystem may be integrated with the other modules in one enclosure. The sensor can also be located remotely (e.g. densitometer, thermocouple transmitter). Certain transmitters (e.g. thermocouple and Resistance Thermometer Detector (RTD)) utilise standardised (third party) sensors that provide an electric signal. In such a case, it may be agreed to perform the evaluation with an acceptable simulator instead of the application of the actual quantity.

Depending on the measurement principle used, the sensor may not require auxiliary (external) power (e.g. thermocouples) or it may require auxiliary power (e.g. strain gauges) or a specifically characterised power source (e.g. electromagnetic and Coriolis flowmeters).

Sensors are, in general, incorporated in the process installations and in many cases, they may also be in direct contact with the process medium. As such, medium properties, medium conditions and installation conditions may adversely influence them. As a remote unit, the sensor may also be subjected to more severe environmental conditions than the other subsystems. Moreover, it shall also be considered whether it is necessary to apply combined environmental and process conditions during an evaluation.

As part of the design review, a list of the types of sensors that are provided and their measuring ranges shall be compiled.

4.2.4 Human interface

The human interface is an important tool for direct interaction and communication with the human operator. It consists of integral means at the instrument for reading out data (local display) and provisions for entering and requesting data (local pushbuttons). Instruments may be provided that are not equipped with a human interface. Access to the database is then provided via the communication interface and the external system or a handheld terminal.

A list of the measurement data that can be shown on the display and the refresh rates, as well as the status data that can either automatically or on request be made available to the operator shall be tabulated. In addition, a summary of the functions and facilities for access and data presentation shall be made.

4.2.5 Communication interface

Transmitter intelligence is supported by the communication interface, which connects the instrument to external systems. Through the interface and the fieldbus (digital communication link), measurement and control data are transferred and access is also provided to the instrument's configuration data. There are also still hybrid instruments, where the digital data is superimposed on an analogue data signal line. There may be instruments which do not have a communication interface. Then configuration and read-out of data may take place via the human interface.

A list of the measurement data that can be transferred to a host and the refresh rates should be compiled. A summary of the status data that can either automatically or on request be transferred to the host shall also be listed. The functions and facilities for access and data presentation shall also be indicated.

4.2.6 Electrical output subsystem

Instruments suitable for connection to a fieldbus need not necessarily be provided with an electrical output subsystem.

The electrical output subsystem primarily converts digital information provided by the data processing subsystem into one or more analogue electrical signals. It may also be equipped with one or more binary (digital) electrical outputs. For these purposes, the instrument may require an additional power supply source.

A listing of the measured variables that can be provided at the electrical output terminals shall be tabulated. The signal types and ranges (e.g. (4 to 20) mA or (1 to 5) V d.c., etc.) shall also be included. A summary of the status data that can be made available at the binary (digital) output terminals shall be compiled.

4.2.7 Power supply unit

Many instruments still require a separate connection to an a.c. or d.c. mains supply. However more instruments are nowadays, "loop powered" which means that they receive power through the signal transmission line or electrical signal output line.

4.2.8 External functionality

Through the data communication interface and the fieldbus, the instrument communicates with host equipment (Personal Computer (PC) or link server, etc.). Through these facilities, parts of the transmitter functionality may be allocated in the host equipment. The following functions may be suitable for remote allocation:

- (Remote) configuration tool.
- Data storage (configuration, trend, transmitter condition).
- Parts of the adjustment and tuning procedure.

The external functionality (if present) shall be treated as an integral part of the transmitter.

4.2.9 Cycle times (ct)

The quality of a transmitter's real-time operation largely depends on:

- The time required to perform and transmit measurements and data to the external world.
- The cycle times for on-line diagnostic tests (ct_d).

The abbreviations ct1-ct4 indicate the cycle times (refresh times) for internal data transfer between the various modules and to the external world. These cycle times do not have to be equal and they may be all or partly user-adjustable.

4.3 Aspects to be reviewed

4.3.1 General

The instrument shall be verified for correct operation prior to any check that may be required to determine the aspects of functionality and capabilities mentioned in the Tables 1 to 7. The instrument shall be error and fault free. This may be indicated on a local display or a remote device (handheld terminal or PC or host computer) connected via a bus system.

The Tables 1 to 7 form the checklist for determination of the implemented functions and properties of a transmitter under consideration. The evaluator shall take into account the aspects mentioned in the last column. Subclause 4.3.9 gives an example of the reporting format.

4.3.2 Functionality

Table 1 – Checklist for mapping functionality

Function/capability	Aspects to be considered during evaluation
Main function(s)	Give a concise description of the measurement principle(s). Describe instrument status information and measurement information (separate and composite quantities) available at the human and communication interfaces and electrical output subsystem. Describe the firmware structure (function blocks and how they can be organised) and rules for application software.
Auxiliary function(s)	Give a concise description of auxiliary analogue and digital input and output functions.
Matching	New releases of a transmitter should be compatible with old versions both in hardware and software.
Function blocks	List the available standardised function blocks (according to either IEC 61499 series or IEC 61804 series) or in case of proprietary function blocks, describe and categorise them in terms of: • time dependent function blocks (totalizers, controllers, timers, lead/lag); • time-independent function blocks, to be divided into: • calculation blocks (e.g. sensor linearization, square root, exponential); • logic blocks (and, or, etc.). For each function block give: • Name. • Adjustment range if user-adjustable. • Default values if applicable. • Check recognition and rejection of invalid values. For details on checking function block features, see Annex C.

Function/capability	Aspects to be considered during evaluation
Signal cut-off	- Check the availability of signal cut-off. Signal cut-off is usually possible at the lower end of the characteristic to avoid invalid or noisy signals, but also signal cut-off at the upper end can be present. Indicate which option is available and whether cut-off values are user-configurable. - Check whether a dead band is present between activation and release and whether it is user adjustable.
Filters	If filters are provided: - Are they analogue (hardware) or digital (software)? - What type (1st, 2nd order) and is the time constant adjustable?

4.3.3 Configurability

Table 2 – Checklist for mapping configurability

Function/capability	Aspects to be considered during evaluation
Fieldbus compatibility	Check whether the instrument under test is suited for either: - Connection to a fieldbus in accordance with IEC 61158 series. - Or stand-alone application in combination with a temporary connection to a proprietary fieldbus. - Or stand-alone application. Give a listing of fieldbus compatible instrument versions.
Configuration tools	Check if the instrument can be configured from: - Local controls (human interface) on instrument. - Remotely from a PC or a host computer. - Via a temporarily connected handheld communication unit. Notice obvious difficulties that appeared when configuring the instrument with these tools. Difficulties could be: - Incorrect entries due to too small distance between keys. - Some parameter entries may give an unnoticed change to other previously set parameters relevant to correct operation.. - Inconsistencies in handling parameters such as no warning message when trying to change a protected parameter.
On-line (re)configuration	Check whether functions and parameters can be changed in control mode. If so, whether the output is unacceptably affected. Check whether there is a security mechanism that prohibits on-line access to all or some parameters and functions.
Off-line configuration	Check whether it is possible to set up and store configurations for a number of transmitters on a separate (off-line) PC. Measure the time required for off-line configuration.
Up/download to/from PC	Check if configuration upload is possible. Check if download of off-line prepared configurations is possible. Measure the time required to perform these actions: - When commissioning a fieldbus system. - In an operative (active) fieldbus system. (The time required for these actions may depend on the number of fieldbus participants in the system).
Configurable restart conditions	When a transmitter is provided with a process control function it may also be equipped with configurable restart conditions for after a power down. Conditions provided can be: - Return to last value. - Go to a user-defined value. - Return to manual mode.
Configurable fail-safe conditions	List the actions that can be configured in the transmitter in the event of detecting an internal failure or sensor failure.

4.3.4 Hardware configuration

Table 3 – Checklist for mapping hardware-configuration

Function/capability		Aspects to be considered during evaluation
Mechanical construction	Hinges/covers	Comment, for these items, on the complexity and soundness of construction and protection against damage. Refer, if applicable, to mechanical problems that have appeared during preparation of the evaluation and during the performance of any test.
	Internal modules	
	Support	
	Protruding parts	Comment, for internal modules, on the location/position and addressing of the hardware by DIP switches or software.
	Local controls	
	Sensor connections	
	Electrical connections	
	Mechanical connections	
Ease of mounting		The mounting procedure may influence the calibration. Check whether it draws adequate attention to alignment, fixation to installation, thermal insulation, etc. Notice any obvious difficulties that may have appeared when dismounting and mounting the instrument. Also, determine the time needed for correct mounting.

4.3.5 Adjustment and tuning

Note 1: Many manufacturers use the term calibration for the procedure of adjusting zero, span and in some cases linearity. This conflicts with the definitions for adjustment and calibration as given in IEC 60050-300

Note 2: Not all types of transmitters may be provided with user-accessible adjustment and tuning tools

Table 4 – Checklist for mapping adjustment and tuning procedures

Function/capability	Aspects to be considered during evaluation
Adjustment procedure	Aspects to be considered are: • How many adjustment procedures exist and what are the differences (which one is advised etc., on-line and off-line adjustment and tuning or configuration) • What external equipment is needed for calibration, adjustment and tuning? • How many times does the user have to interact and when? • Is any part of the procedure automatically performed? • Are adjustment, calibration and tuning data (name of operator, date, parameters, etc.) stored in non-volatile memory? • What are the range limits? • What is the resolution of zero/span adjustments both at upper and lower range limits? • Is linearization part of the procedure? • Measure the time required for adjustment, calibration and tuning. Record any obvious or potential difficulties that may have appeared when performing the procedure.
Tuning procedure	Certain instruments require adaptation and tuning to process conditions and properties, installation conditions and environmental conditions. Briefly describe the procedure. The following shall be considered: • In certain cases, tuning/adaptation may require the setting of fixed process related parameters particularly when configuring the instrument. Often, this method has limited validity, in particular where the actual process parameters may vary over a wide range. • It may also be an automatic procedure to be performed under live conditions. If so, how many times does the user need to interact? Are resulting parameters automatically activated or the can the user ignore/change them and fill in different values? Record the instrument's output during the procedure. The record may show the limitations of the procedure. • Can adjustment, and tuning be integrated inseparably into one procedure? • Measure the time required for tuning.

4.3.6 Operability

Table 5 – Checklist for mapping operability

Function/capability	Aspects to be considered during evaluation
Local controls (tools) for access	Give a concise description of: • The keys (pushbuttons) available. • Accessibility and protection against ingress of gas, water, dust. • Ergonomic layout and use of the keys. • Protection/suitability of keys for use in hazardous locations.
Local displays	Give a concise description of the data that can be shown on the local displays such as: • Number of lines and characters per line. • Control parameters given. • Error messages. • Readability of display without removing the electronics covers.
Human interface(s) at external system	Describe, for PC-based software, the organisation and hierarchy of the various user access groups and related displays and the possible availability of dedicated keyboards. Give, for a handheld communicator, a picture with layout of display and keyboard.
Provisions and tools for engineering and maintenance personnel	Give, for PC-based provisions, a concise description of the organisation and hierarchy of the engineering and maintenance related software and display templates. If available, list other hardware tools (such as switches, potentiometers, etc.) that can be used for configuration, installation, adjustments and calibration.
Process diagnostic aspects	Check whether the instrument – in addition to the main measuring function – has provisions for diagnosing defects and faults in the process and process installations such as: • Cavitation. • Product contamination. • Product inconsistencies (e.g. gas entrapped in liquid). • Blockage of product flow. • Excess vibration of installation. • Loop integrity and performance using information coming from the instruments and function blocks used in the loop. • Fracture, wear, fatigue or corrosion of piping or vessels, etc. Describe relevant tests and alarms implemented such as: • Analysis in time or frequency domain of main sensor signal. • Fingerprinting. • Availability of additional sensors. • Additional software tools for the accumulation of operational time, time at certain load, number of cycles. Check whether these tools are embedded in the transmitter or in the host. • Are tests on-line automatic or operator-initiated? • Are test parameters user-adaptable? • Actions of transmitter on appearance of diagnostic alarms.