

Data quality metrics for industrial measurement and control systems — Specification

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Foreword

This British Standard was prepared by Technical Committee AMT/7. It supersedes BS 7986:2001.

This revised edition of BS 7986 incorporates the recommendations submitted by members of IEC in response to the circulation as a new work item proposal of BS 7986:2001.

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Summary of pages

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Introduction

Digital communication technology is now widely used for data transfer in industrial measurement and control systems. It enables intelligent devices to communicate not only their current values but also related data quality parameters that greatly increase the value and usefulness of the data.

Intelligent devices typically support internal functions for performance compensation and self-checking to improve the reported data quality. The results of these checks need to be communicated using generic parameters that enhance the value of reported device measurement inputs and control outputs. These additional parameters and attributes are known as “data quality metrics”.

1 Scope

This standard specifies functional requirements, intended applications and data quality metrics to be used in industrial measurement and control systems.

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.

PD 6461-3:1995, *General metrology — Guide to the Expression of Uncertainty in Measurement (GUM)*.

NOTE 1 This document is also known as *ISO/IEC Guide to the Expression of Uncertainty in Measurement (GUM)*, 1995.

NOTE 2 The relationship between PD 6431-3 and BS 7986 is explained in Annex A.

3 Terms and definitions

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

NOTE This edition omits the terms “offline”, “unvalidated” and “replaced” because they are deemed to be control modes rather than status states.

3.1

agent

consumer of measurement data and/or the originator of command data that is transferred through a channel

3.2

backcalc

parameter representing data in an actuator or control function block which is made available for access by a preceding control function block for management or initialisation

NOTE The backcalc value is usually the working setpoint or output.

3.3

BAD

VVstatus during which the associated VV is not useful and accompanying sub-status values support diagnosis and control management

3.4

BLIND

VUstatus during which the associated VV is based on historical data

NOTE 1 BLIND indicates that, based on available diagnostic data, the device or function block logic concludes that the input value is not representative of the process variable and sufficient evidence exists to assert that the problem is permanent.

NOTE 2 The VV is projected from past history and uncertainty increases at a rate consistent with past history and any limits configured into the device.

3.5

BLURRED

VUstatus during which the associated VV reports real measurement-derived data but a known problem exists for which compensation has been applied, so the reported value is the best estimate of the current value and the uncertainty has been increased accordingly

3.6

channel

complete sequence of related entities involved in the transfer and manipulation of data moving between a sensor or actuator and an agent

NOTE Practical examples of channels include:

- a) a flow measurement channel comprising an orifice plate, DP cell, totalizer, communication network or fieldbus and function blocks linked to maintenance agents;
- b) a flow output channel including control agents linked to split-range function blocks, communication network, valve positioner and valve.

3.7

CLEAR

VUstatus during which the associated VV is valid, on-line and within nominal data sheet specification values

3.8

CLEAR CASCADE

VUstatus during which the associated VV can be used for control and the accompanying sub-status values support control management

3.9

COMMON MODE FAULT

fault that occurs throughout a set of measurement channels where they share common elements

NOTE An example of this could be where a shared process connection breaks or becomes blocked and affects all measurements using the connection.

3.10

CRIS

Common Relational Information Schema

MIMOSA specification including measurements to support asset management

3.11

CRITICAL MAINTENANCE

VDstatus during which the designer believes, based on available data and diagnostics, that a critical condition exists which could damage the plant or the environment

NOTE An example of this could be the leakage of process fluids from a perforated diaphragm.

3.12

data quality metrics

defined set of quality attributes added to function block data to assist their interpretation by interested agents

3.13

DAZZLED

transient VUstatus during which the associated VV is based on historical data whilst the fault condition is assessed

NOTE 1 DAZZLED indicates that based on available diagnostic data, the device or function block logic concludes that the input value is not representative of the process variable, but needs more data to determine if the problem is permanent.

NOTE 2 The VV is projected from past history and the uncertainty increases at a rate consistent with past history and any limits configured into the device.

NOTE 3 This status could be reported during a test procedure of limited duration which prevents measurement function (intrusive test).

3.14

DEVICE-ON-TEST

VDstatus during which the associated device or group of devices is undergoing an intrusive test or re-calibration action during which normal functions might be disturbed or inhibited

NOTE This status can be self-initiated or externally requested.

3.15**fieldbus**

digital communication system designed for use between sensors, controllers and actuators in automation applications

3.16**Foundation Fieldbus**

industry consortium with interests in fieldbus communications, function block applications and device description languages

3.17**function block**

software functional unit comprising an individual, named copy of a data structure and associated operations specified by a corresponding function block type

3.18**GOOD (CASCADE)**

VVstatus during which the associated VV can be used for control and the accompanying sub-status values support control management

3.19**GOOD (NON-CASCADE)**

VVstatus during which the associated VV is derived from valid process measurement and monitoring data and the accompanying sub-status values support alarm management

3.20**HART****HART Communication Foundation**

industry consortium with interests in fieldbus communications, function block applications and device description languages

3.21**HIGH PRIORITY MAINTENANCE**

VDstatus where the designer believes, based on local diagnostics, that a major fault or incipient problem has been detected in the associated device or group of devices

NOTE Examples of this are where the main measurement is BLIND or the device is expected to become faulty within X_2 hours, where X_2 is configurable.

3.22**intelligent actuation and measurement****IAM**

combined use of instrument functions and communication services to support the control, maintenance and the technical management of industrial automation

3.23**intelligent instrument**

device where embedded computing capability is included as part of a measurement, control or actuation device

3.24**intrusive testing**

test procedure that causes measurement disturbances which are not related to process values

3.25**limit-status**

VVstatus component indicating limit conditions affecting the accompanying VV

3.26**loss-of-variable condition**

condition when the measured value is believed to be unrepresentative of the actual process value

3.27

LOW PRIORITY MAINTENANCE

VDstatus during which the designer believes, based on local diagnostics, that a minor fault or incipient problem has been detected in the associated device or group of devices

NOTE Examples of this are:

- a) where the re-calibration time has passed and the main measurement is BLURRED;
- b) in a multi-measurement device where the main measurement is CLEAR and one or more of the secondary measurements is BLURRED or BLIND;
- c) where the device is expected to become faulty within X_1 hours, where X_1 is configurable.

3.28

Machinery Information Management Open Systems Alliance MIMOSA

industry consortium with interests in asset management, fault diagnosis and maintenance

3.29

NOMINAL

VDstatus during which the designer believes maintenance is not needed by the associated device or group of devices

3.30

non-intrusive testing

test that does not disturb the measurement value

3.31

outputSP

output parameter from an analogue control function block for use as a setpoint input by another control block or an actuation function block

3.32

outputSPD

output parameter from a discrete control function block for use as a setpoint input by another control block or an actuation function block

3.33

PROFIBUS-PA

specification issued by Profibus User Group, an industry consortium with interests in fieldbus communications, function block applications and device description languages

3.34

SECURE (COMMON)

VUstatus during which the associated VV is derived from multiple estimates of the same measurement, at least two of which are CLEAR but which are susceptible to common mode faults

3.35

SECURE (DIVERSE)

VUstatus during which the associated VV is derived from multiple estimates of the same measurement, at least two of which are CLEAR and are not susceptible to common mode faults

NOTE SECURE (DIVERSE) is most appropriate for the output of a function block which combines data from independent instruments using different measurement technologies. It is not anticipated that single measurement instruments will provide this status as common elements exist, such as power supply and processing units, even where multiple transducers and process connections are present.

3.36

SECURE (CASCADE)

VUstatus during which the associated VV can be used for control and the accompanying sub-status values support control management

3.37**setpoint****SP**

control objective provided to an analogue control or actuation function block

3.38**setpointD**

control objective provided to a discrete control or actuation function block

3.39**UNCERTAIN**

VVstatus during which the associated VV is of lower quality than normal, but might still be useful and accompanying sub-status values might provide reasons for the reduction in quality

3.40**uncertainty (of data)**

parameter, associated with the result of a measurement or data calculation, that characterizes the dispersion of the values that could reasonably be attributed to the output value
(from PD 6461-3:1995, **2.2.3**)

NOTE 1 The parameter might be, for example, a standard deviation (or a given multiple of it), or the half-width of an interval having a stated level of confidence.

NOTE 2 Uncertainty of measurement comprises, in general, many components. Some of these components can be evaluated from the statistical distribution of the results of series of measurements and can be characterized by experimental standard deviations. The other components, which also can be characterized by standard deviations, are evaluated from assumed probability distributions based on experience or other information.

NOTE 3 It is understood that the result of the measurement calculation is the best estimate of the value and that all components of uncertainty, including those arising from systematic effects, such as components associated with corrections and reference standards, contribute to the dispersion.

3.41**UNCHECKED**

VDstatus where maintenance support is not in operation

3.42**validated actuator analogue capability****VAAcapability**

parameter available from an analogue actuation or control function block indicating the best internal assessment of current performance capability of the associated actuation channel

3.43**validated actuator analogue status****VAAstatus**

accompanying parameter for VAAcapability to classify it using a set of defined states

NOTE The main states (TRACKING/IMPAIRED/INCAPABLE) and the sub-states (*steady/transient/cycling*, *offset/slow/cycling*, *unsteady/limited*) are specified in **8.6.2.3**.

3.44**validated actuator discrete capability****VADcapability**

parameter available from an analogue actuation or control function block indicating the best internal assessment of current performance capability of the associated actuation channel

3.45**validated actuator discrete status****VADstatus**

accompanying parameter for VADcapability to classify it using a set of defined states

NOTE The main states (TRACKING/IMPAIRED/INCAPABLE) and sub-states (*steady/transient*, *liftoff-alarms* and *transition-alarms*) are specified in **9.6.2.3**.

3.46

validated device status

VDstatus

parameter issued by a function block indicating the block designer's best estimate of urgency for maintenance support for the device or group of devices and related equipment that contributes to the function block output

3.47

validated status discrete

VVDstatus

data value produced by a discrete measurement or monitoring or control function block and accompanied by VVDstatus and optionally accompanied by VU and VUstatus

3.48

validated uncertainty

VU

error band of the associated VV data value at 95 % level of confidence, represented in the same units and with the same precision as the VV

3.49

validated uncertainty status

VUstatus

parameter indicating how the associated VV data has been generated

NOTE The specified values of VVstatus assume the VV and associated VU are the data channel best estimate of the true values, including compensation, as available, for any detected problems.

3.50

validated value

VV

data value produced by an analogue measurement or monitoring or control function block and accompanied by VVstatus and optionally accompanied by VU and VUstatus

NOTE VV is normally measurement or control data transferred within a system.

3.51

validated value discrete

VVD

data value produced by a discrete measurement or monitoring or control function block and accompanied by VVstatus and optionally accompanied by VU and VUstatus

NOTE VV is normally measurement or control data transferred within a system.

3.52

VVstatus

parameter indicating how the associated VV data has been generated

NOTE The specified values of VVstatus assume the VV and any associated VU are the data channel best estimate of the true values, including compensation, as available, for any detected local problems.

4 Functional requirements and intended applications for data quality metrics

4.1 General requirements

This clause specifies functional requirements for industrial uses of data quality metrics. It also describes some intended applications within industrial measurement and control systems that shall be supported by data quality metrics.

4.2 Functional requirements for data quality metrics

4.2.1 General

Data quality metrics shall be suitable for use by devices and instrumented data channels when reporting measurement input values and/or actuation output actions.

NOTE 1 For information on some technologies that specify data quality attributes, see Annex B.

The metrics shall be generic, allowing all normal states to be expressed in a common format for use by higher level control and monitoring agents.

The metrics shall be device and technology independent, allowing freedom for evolution of the implementing devices and communications services.

The metrics shall be suitable for function blocks and for monitoring and control applications.

Complete and precise definitions of each status category shall be provided for convenient and consistent use by data consumers, instrument and device designers.

The metrics shall provide a stable and consistent way for designers to express their device performance and to allow higher-level application packages to take advantage of additional data beyond the bare measurement.

Graceful degradation shall be supported for operational continuity and appropriate device performance when problems are believed to exist.

NOTE 2 In general, data publishing devices do not know what tasks are consuming their output data, nor do they know how their published data is being used. So each device should always publish its best estimate of “truth” with open quality indications that enable subscribers and consumers to process the data as appropriate for their own local needs.

4.2.2 Measurement

The metrics for use with measurement and monitoring data values shall include:

- estimates of data uncertainty or accuracy;
- status indicators showing how the related data value has been generated;
- status indicators showing the suitability for control.

4.2.3 Actuation

The metrics for use with actuation values shall include:

- estimates of data value, uncertainty and status for read-back of delivered actuation;
- status indicators of how the actuation function is believed to be performing;
- status indicators and back-calculation values to support control applications.

4.2.4 Maintenance

The metrics for use with device maintenance status shall include:

- status indicators of the designer’s estimated urgency for maintenance or service attention.

4.2.5 Transitions and behaviour during faults

Recommendations shall be provided for reporting values and quality metrics during periods when fault modes are detected or believed to exist.

Generic criteria shall be used to trigger status transitions, for example:

- is the device or channel performing correctly within its data sheet specification range?
- does available device information indicate a fault exists or is likely to occur?
- has the device or channel a good working interface to the process?
- does available information indicate a device or channel certification category is not currently valid? (e.g. EMR class, Ex i, SIL 2, Weights and Measures certification).

NOTE These are examples of checks and criteria that can be internally assessed by intelligent devices and used to decide the most appropriate status to report. Reported values are always the best estimates from the viewpoint of the device or instrument data channel. They are subject to review and modification by higher-level functions with access to additional knowledge.

4.2.6 Scalability

The metrics shall be scalable, for use when data from multiple devices are combined, for example:

- mass flow estimates based on combining volume flow and density measurements;
- energy balance estimates calculated from other input measures;
- unit efficiency based on multiple measures around a unit.

Recommendations shall be provided for combining data and quality values from multiple devices and instrument sources.

NOTE Most applications of data quality reporting will be devices delivering output values such as a temperature or flow measurement. However, the same data quality value metrics can be used to support calculated data representing combinations of device values. For example, a heat exchanger performance can be represented by a data value with quality parameters derived from the quality values of multiple contributing measurements.

4.2.7 Compatibility with other standards

Data quality items shall be compatible with PD 6461-3:1995.

NOTE Data quality items should also be compatible with BS EN 61804-2.

4.2.8 Use with device descriptions

The quality metrics shall be open for specification by device description languages and similar services.

NOTE Default coding may be provided for some groups of metrics.

4.2.9 Support for industrial consortia

Existing examples of quality metrics used by related fieldbus and industry consortia shall be included, to provide compatibility and support for current automation applications.

4.2.10 Profiles

NOTE Profiles may be used to select sub-sets of the specified metrics as appropriate, for support of required applications.

4.3 Intended applications for data quality metrics

4.3.1 Improving control performance

Uncertainty and data status shall be suitable for use by higher-level entities seeking to continuously adopt the “best” control settings and modes.

NOTE 1 This facility ought to allow a greater range of control responses to be automated, resulting in better control and improved plant economics. For example:

- A control function can link data status value to a loop auto/manual mode so that at loss-of-variable or on reaching a limit, the control loop switches immediately to manual.
- An optimization function can monitor the uncertainty and drive the process as close as possible to a plant constraint or limit. When uncertainty increases, the operating state is automatically moved away from the limit to provide an increased margin of safety.
- Loop gain may be decreased when uncertainty indicates a less accurate measurement, so unnecessary cycling can be reduced.
- When uncertainty decreases, loop setpoints may be moved closer to operating constraints and loop gain may be increased to provide for faster responses.
- Measurement reporting functions and control decision functions may be distributed into different parts of a fieldbus network and implemented by different suppliers.

These and similar examples of control responses using data quality metrics are shown in Figure 1.

NOTE 2 These actions can be taken automatically by control agents seeking to maintain best control performance in response to changing device performance capability.

4.3.2 Improving maintenance performance

4.3.2.1 General

Device status in conjunction with other data quality metrics shall be suitable for first level planning of maintenance actions and plant shutdown events.

The availability of maintenance status values from self checking devices shall be device independent, enabling the development of re-useable maintenance packages and procedures for all instrumented units within a site or an organization to gain related operational benefits.

NOTE 1 These functions are intended to support just-in-time maintenance scheduling using real-time quality estimates from devices.

Several levels of maintenance priority shall be supported.

NOTE 2 Intelligent devices are often multi-measurement with failure modes that invalidate some measurements but not others, so a traditional “good/bad” maintenance indication for the complete device is not appropriate.

4.3.2.2 Application mapping

NOTE 1 It should be recognized that service priorities issued by a device or its instrument channel are a device designer’s best estimate of urgency for service needs. These device estimates need to be modified by an appropriate user maintenance function to produce values that reflect the importance of the device within the user application.

For example, a low priority alarm issued by a key measurement device in a safety application should have more significance than a low priority alarm issued by a device executing a secondary process task.

The four primary states specified in Table 1 shall be distinguished for use with any device, based on internal data and local diagnosis.

These statuses shall be chosen to support two basic operational questions.

- How urgent is the maintenance need?
- When is it essential that plant operation is modified or stopped?

These status values shall be suitable for use by operators and maintenance engineers to prioritize and schedule service activity with minimum process disturbance and maximum operating benefit.

Figure 2 shows a mapping function located in a maintenance terminal that converts generic device status values into application specific alerts for operations and maintenance agents.

NOTE 2 Details about a specific fault diagnosis and exact repair needs for a device are always important, but these items are device specific and secondary to the operational issues of when it is essential that maintenance is scheduled or production stopped.

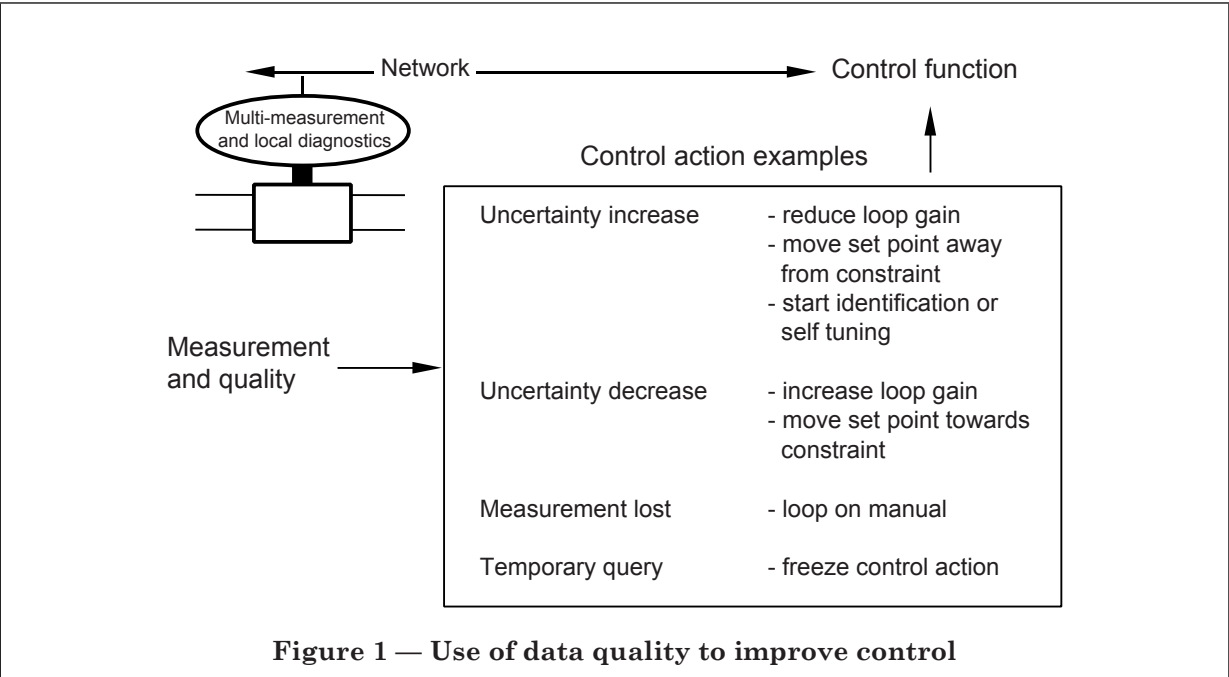
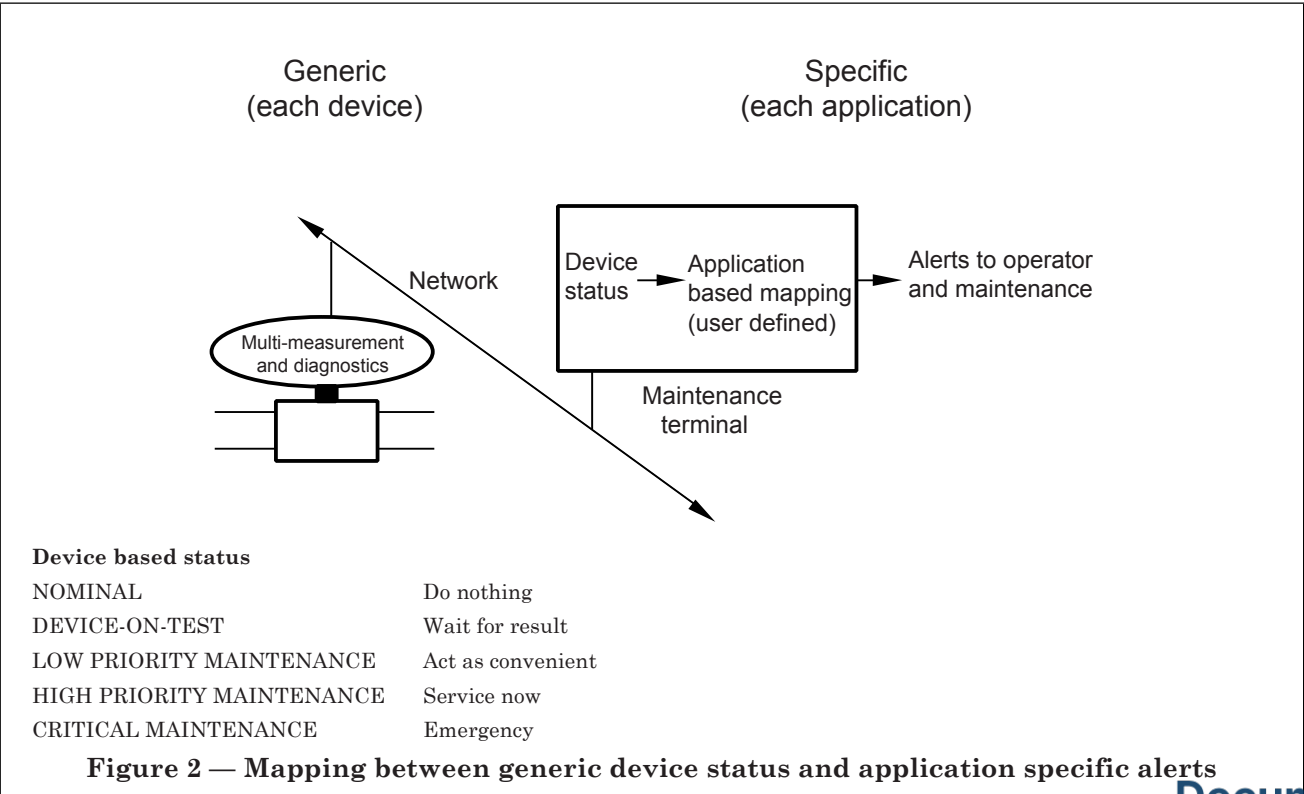


Table 1 — Primary states

State	Status
NOMINAL	The device maker believes maintenance is not needed
LOW	The device maker believes that a minor fault or incipient problem exists
HIGH	The device maker believes that a major fault or incipient problem exists
CRITICAL	The device maker believes that a critical condition exists which might damage the plant or the environment



4.3.3 Improving confidence in instrument data

Internal checking functions shall be supported to reduce the incidence of undetected failures and improve confidence in decision making based on data quality applications.

NOTE Production of data quality values implies periodic self-checking and state analysis by device internal functions, so reported values are expected to be more reliable and trustworthy than outputs without quality checks. An increased level of trust in reported data is expected to reduce the need for additional checking and consequent delay before corrective actions are taken.

4.3.4 Improving manufacturer added value

Data quality metrics shall provide a stable and consistent way for device designers to express their current estimate of device performance. They shall also provide higher-level application packages with additional data beyond a bare measurement.

Makers of devices shall be enabled to promote real “added value” based on the use of internal knowledge of performance and fault modes for their devices.

The results of internal checks and performance evaluation shall be expressed in a standard and general-purpose format suitable for general-purpose maintenance packages.

NOTE 1 This is a major improvement on device specific or maker specific messages such as “error code 45”.

Designers shall be supported by common guidelines for reporting device values during real or suspected fault situations.

NOTE 2 This is a big improvement from some present fault responses which include actions such as “alarm with no output”, “move reported value to zero” or “reported values known to be wrong”.

5 Data quality and function blocks

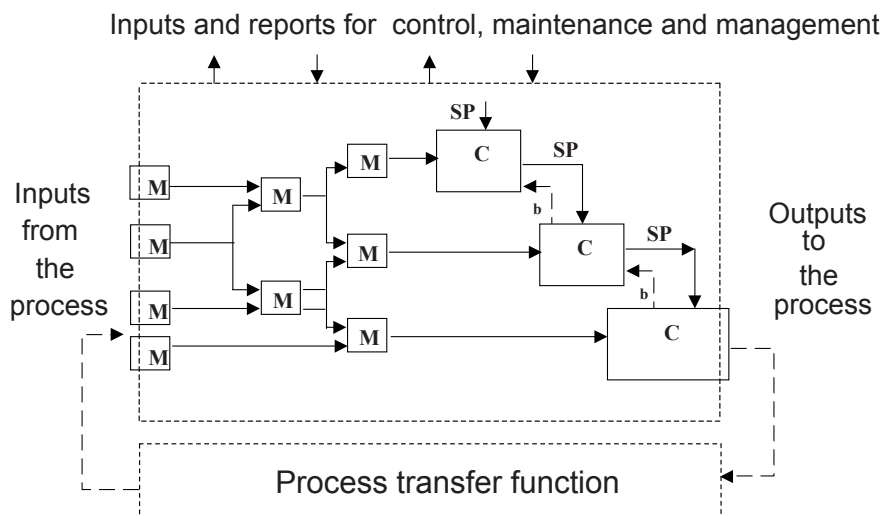
5.1 General

Monitoring and control applications in industrial distributed control systems shall be supported by function blocks and communication services. Function blocks shall be encapsulations of variables and their processing algorithms using variables and communication services to provide timely transfer of data between the function blocks.

NOTE 1 A process control application using function blocks is illustrated in Figure 3.

NOTE 2 These function blocks may be classed as monitoring function blocks or control function blocks according to their part in the application process. The two types of function blocks provide the following main services:

- a) Monitoring function blocks operate on data inputs from the process and use them to generate data and reports required by operations management and other function blocks.
- b) Control function blocks have targets or setpoints and also receive data from monitoring function blocks. Using these input values the control blocks generate outputs to other control blocks or outputs to directly manipulate the process.
- c) The combination of monitoring function blocks, control function blocks and the process transfer function forms a feedback loop with the objective of maintaining required target conditions within the process.
- d) Process alarms and reports of process and control loop conditions are application specific and may be implemented in specific function blocks or added as extra functions in monitoring and control function blocks.



Key

- M Function block used in monitoring the process
- C Function block providing control actions for the process
- SP Set point or target value for a control function block
- b Backwards transfer of data to support control functions

Figure 3 — Process related data flow in a function block application

5.2 Quality attributes to support monitoring data

Monitoring function blocks shall use data from the process and other monitoring function blocks to generate output measurement data such as volume, pressure, or temperature; or derived measurement data values such as unit efficiency, component flow, or mass balance error. These data transfer paths are shown in Figure 4.

Generic data and status items from a monitoring function block to another monitoring block shall include the following:

- a current best estimate of the value of the monitored variable in appropriate units;
- a current accuracy or uncertainty for the monitored variable; and
- status indications reporting how the value and uncertainty have been derived.

NOTE 1 These items enable other function blocks to make best use of the monitoring function block data by reference to its attributes of accuracy and status.

An additional quality item shall support data from a monitoring block to a control function block, i.e. a status indication reporting limit conditions in the function block and its contributing inputs.

NOTE 2 The limit condition status may be used to manage integral action in control blocks using the monitoring data.