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TECHNICAL REPORT

Process analysis technology systems as part of safety instrumented systems

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FOREWORD

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IEC TR 63176, which is a Technical Report, has been prepared by subcommittee 65B: Measurement and control devices, of IEC technical committee 65: Industrial-process measurement, control and automation.

The text of this technical report is based on the following documents:

Enquiry draft	Report on voting
65B/1111/DTR	65B/1131/RVDTR

Full information on the voting for the approval of this technical report can be found in the report on voting indicated in the above table.

This document has been drafted in accordance with the ISO/IEC Directives, Part 2.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under "http://webstore.iec.ch" in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

A bilingual version of this publication may be issued at a later date.

INTRODUCTION

This Technical Report is designed as a recommendation to aid users of process analyzer technology that measures installations as part of safety instrumented systems and should be treated exclusively as a recommendation. Formulations of a binding character encountered in the recommendation are due to the safety-related content. However, the advisory character of this document is maintained as a whole. Process analyzer technology measuring equipment is used, for example, in the process industry as sensor components of safety instrumented systems. In many cases, they represent the only or most efficient method for monitoring a process variable, which, for its part, enables a reliable evaluation of designated use of the system to be protected. Owing to the direct material interaction with the process medium, process analyzer technology measuring equipment is in general more susceptible to failure and requires more maintenance than the sensors widely used for pressure, temperature, filling level and flow measurement. A consequence of this interaction is the inability to avoid systematic failure completely. This problem is usually countered by checking the measuring equipment at short, regular intervals.

The variety of process analytical measurement variables and methods and, consequently, the comparatively limited number of process analyzer technology measuring devices used in each case for a single, precisely limited, application makes a quantitative evaluation of functional safety in accordance with IEC 61511 difficult in most cases. Beside the often-inadequate specifications of manufacturers for evaluating components as safety instrumented systems, there are an insufficient number of comparable applications. However, several hundred safety instrumented systems have been successfully realized in the last 30 years among the process analyser community using process analyzer technology measuring equipment.

Measures are proposed in areas where normative requirements cannot be fulfilled, or only inadequately. These measures lead to an equivalent level of safety when applied carefully.

Requirements concerning functional safety of electrical and electronic systems are described in IEC 61508, specified for “Safety instrumented systems for the process industry sector” in the sector standard IEC 61511. The aim of this document is to describe a procedure for the use of process analyzer technology measuring devices as part of safety instrumented systems in a guideline.

PROCESS ANALYSIS TECHNOLOGY SYSTEMS AS PART OF SAFETY INSTRUMENTED SYSTEMS

1 Scope

This document encompasses recommendations for planning, installation and operation (incl. maintenance) of process analyzer technology measuring equipment in process industry safety instrumented systems. It covers all necessary steps for the qualification of safety equipment and supplements the safety management of safety instrumented system equipment through the addition of special requirements for process analyzer technology equipment. This document does not encompass the entire safety management of safety instrumented system equipment.

The term “qualification” used in this recommendation refers exclusively to the testing of the suitability of the process analyzer technology system for use in a safety instrumented system device. It is different from the term "qualification" used in the pharmaceutical environment.

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.

IEC 61508 (all parts), *Functional safety of electrical/electronic/programmable electronic safety-related systems*

IEC 61508-6:2010, *Functional safety of electrical/electronic/programmable electronic safety-related systems – Part 6: Guidelines on the application of IEC 61508-2 and IEC 61508-3*

IEC 61511 (all parts), *Functional safety – Safety instrumented systems for the process industry sector*

IEC 61511-1:2016, *Functional safety – Safety instrumented systems for the process industry sector – Part 1: Framework, definitions, system, hardware and application programming requirements*

IEC 61326-3-1:2017*, Electrical equipment for measurement, control and laboratory use – EMC requirements – Part 3-1: Immunity requirements for safety-related systems and for equipment intended to perform safety-related functions (functional safety) – General industrial applications*

IEC 61326-3-2:2017, *Electrical equipment for measurement, control and laboratory use – EMC requirements – Part 3-2: Immunity requirements for safety-related systems and for equipment intended to perform safety-related functions (functional safety) – Industrial applications with specified electromagnetic environment*

3 Terms, definitions and abbreviated terms

3.1 Terms and definitions

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

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

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

3.1.1
PAT measuring equipment
process analysis technology systems as entirety of all equipment and media necessary for realization of the substance-related measurement function

Note 1 to entry: An exemplary, but not necessarily complete list includes sampling equipment, sample conveying equipment, sample conditioning equipment, sample recirculation equipment, the analyser, PAT control units and infrastructural equipment such as supply, reference and calibration media and the necessary power supply. From case to case, a required cabinet or the location in an analyser house or room should be included.

3.1.2
basic testing
possible preselection of suitable analytical equipment for safety instrumented systems without any reference to a specific measuring task

Note 1 to entry: This applies exclusively to the testing of analytical equipment according to the criteria mentioned in Annex A.

3.1.3
application testing
test that ensures that the measuring task can be successfully realized with the PAT system

Note 1 to entry: This includes checking the configuration and, occasionally, programming of analytical equipment to correspond to the measuring task, taking the influence of sample processing into consideration, especially its accuracy, determining the influences of the matrix and state variables (pressure, temperature, flow), both of the medium and the analytical equipment environment, and knowledge of the stability over time.

3.1.4
operational experience
knowledge available prior to using an analyser, including the required accessories for comparable measuring tasks

Note 1 to entry: It therefore involves exclusively experience gained through actual use of comparable analytical equipment for comparable measuring tasks.

3.1.5
in-service testing
monitored operation of the PAT system as part of a safety instrumented system during production operation

Note 1 to entry: An explicit differentiation is made here between the procedure in the case of proven operational performance of PAT systems and the corresponding procedure for safety instrumented system equipment.

Note 2 to entry: The test work to be realised, the timetable, specifications for the evaluation of results, additional measures for the fulfilment of the safety function required from case to case during in-service testing and the responsible personnel in this phase should be documented.

3.1.6
proven performance
entirety of knowledge that is part of the final decision in favour of or against the suitability of a proposed process analyser installation as part of a safety instrumented system

Note 1 to entry: Proven performance will be achieved by sufficient operation experience including approvement of suitability of the measuring task. If not practicable, proven performance can be achieved through in-service testing.

Note 2 to entry: Proven performance of PAT is finally determined by a team of experts and differs in the manner of its determination from the method usually used for field devices and PLCs.

3.1.7
calibration
inspection task, its purpose being to confirm the target condition

Note 1 to entry: "Calibration" means determining and documenting the deviation of displayed value of a measurement from the correct value of the measurement.

Note 2 to entry: When calibrating a process analyser, the relationship between input and output is determined and documented under specified conditions. Input value is the physical quantity to be measured. Output value is the electrical output signal of the measuring device.

3.1.8
adjustment
setting or modification of an instrument in order to eliminate systematic errors as far as it is necessary for the intended application

Note 1 to entry: Adjustment is the process by which a meter is set or adjusted so that the measurement errors are as small as possible from the nominal value and are within the device specifications. This adjustment is a process that changes the instrument permanently.

3.1.9
test interval
PAT systems as part of safety systems are subject to different test intervals for proof testing with differing degrees of testing

Note 1 to entry: Examples being the following:

- Test interval for an internal PAT system diagnostic sensor (e.g. the flow meter)
- Test interval for an internal PAT system channel (e.g. automatic calibration)
- Test interval for an internal PAT system channel (e.g. inspection and servicing incl. manual adjustment)
- Test interval for the entire system (manual, PAT + rest of safety instrumented systems)

3.1.10
proof test
test for discovering errors in a technical safety system so that the system, if necessary, can be returned to the condition in which it fulfils its intended function

3.1.11
proof test coverage
coverage of test for discovering errors in a technical safety system

Note 1 to entry: This term originally referred to the proof test. However, any test (see test interval) can, in principle, achieve a coverage <= 1. For sensors, this means that the DU failure rate of the channel increases due to non-function, while the DD rate decreases. Automatic calibration can usually only check a certain DU rate at adequately brief time intervals. It can also not be ruled out that channel failures will remain undetected during inspection and maintenance. Careful planning of test processes should ensure that there is only a low probability of this occurring.

3.2 Abbreviated terms

DC	diagnostic coverage
DD	dangerous detected
DU	dangerous undetected
FAT	factory acceptance test
FMEA	failure mode and effects analysis
FMEDA	failure mode, effects and diagnostic analysis
HazOp	hazard and operability study
HFT	hardware fault tolerance
PAT	process analyser technology
PFD	probability of failure on demand

PID	piping and instrumentation diagram
SAT	site acceptance test
SIF	safety instrumented function
SIL	safety integrity level
SIS	safety instrumented system
SFF	safe failure fraction
PTC	proof test coverage
λ_i	failure rate of i component
μ_i	repair rate of i component
$U_{DD,\ i}$	unavailability through DD failure of i component
$U_{DU,\ i}$	unavailability through DU failure of i component
U_{ch1}	unavailability of channel 1
U_{MooN}	unavailability of entire system in the moon configuration
β	proportion of common cause failures
T_{max}	maximum test interval
PFD_{beta}	proportion of pfd value due to common cause
PFD_{MooN}	pfd value of entire system without taking common cause into consideration
PFD_{PAT}	pfd value of the entire pat system

4 Qualification process

4.1 Overview

PAT measuring devices are generally complex SIS sensors individually tailored to suit the specific requirements of the process engineering process and which describe the condition of the process through measurement of the concentration of one or more substances.

The individuality of these sensors often makes it impossible to transfer operational experience with a sufficient number from existing SIS to new PAT measuring equipment which is to be planned. In-service testing of completed functional measuring equipment should be conducted in these cases. The individuality of these measuring devices requires a high degree of technical competence on the part of those involved in the process at all levels of the qualification process described (see Figure 1). This includes (installation) constructors and operators of the PAT system (see 4.2 and 4.3). Each qualification step will be documented

The qualification process will be performed by PAT-experts under participation of safety engineers for process control and process engineering. All relevant process data for the PAT-System performance will be confirmed by the responsible safety engineer.

Where several measuring methods are technically practical, these methods should be examined and assessed. Further aspects to reduce/minimize the overall failure probability of the PAT system should be considered right from the beginning of planning, including:

- the degree of redundancy/fault tolerance;
- homogeneous or diverse redundancy;
- operational experience/proven performance from other measuring equipment;
- risk associated with the metrological application (e.g. cross-sensitivities, ageing processes, common cause failure).