PURPOSE AND USE OF PROCESS INDUSTRY PRACTICES

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Process Analyzer System Design Criteria

Table of Contents

1. Scope ........................................... 2

2. References .................................. 2
   2.1 Process Industry Practices .............. 2
   2.2 Industry Codes and Standards ........ 2

3. Definitions ................................... 2

4. Requirements .............................. 3
   4.1 General ..................................... 3
   4.2 Safety ....................................... 4
   4.3 Process Interface .......................... 4
   4.4 Sample Transport ........................... 6
   4.5 Sample Conditioning ........................ 7
   4.6 Calibration .................................... 8
   4.7 Analyzer Shelters ......................... 8
   4.8 Status and Validation Signals .......... 9
   4.9 Documentation .............................. 9
1. **Scope**

This Practice describes the engineering, design, and fabrication requirements for use by an analyzer systems engineer for the design and installation of process analyzer systems used for monitoring and control for the following measurements:

a. Process  
b. Effluent  
c. Ambient atmospheric

2. **References**

Applicable parts of the following Practices, industry codes and standards, and references shall be considered an integral part of this Practice. The edition in effect on the date of the contract award shall be used, except as otherwise noted. Short titles are used herein where appropriate.

2.1 **Process Industry Practices (PIP)**

- PIP PCSPA001 - *Instructions for Process Analyzer Project Documentation Requirements Sheets*
- PIP PCSPA002 - *Instructions for Process Analyzer System Data Sheets*

2.2 **Industry Codes and Standards**

- IEC TR61831 - *On-Line Analyser Systems – Guide to Design and Installation*
- NFPA 496 - *Standard for Purged and Pressurized Enclosures for Electrical Equipment*

3. **Definitions**

*process analyzer system*: A system that consists of sample tap, sample probe, sample preconditioning system, transport tubing, sample-conditioning system, analyzer, possibly one or more readout devices, and communication interface to other systems. The system is designed and assembled to automatically take a representative portion of a process stream and to identify and measure specific component concentrations or physical properties of the sample.

*fast loop*: A part of the sample transport system that is designed to transport the process sample close to but not through the analyzer. The purpose is to reduce the time lag in getting sample from the process sample tap to the analyzer and it should be returned to process whenever possible. The term “speed loop or bypass sample line” is sometimes used to define the same part of the system.

*sample*: A portion of the process stream that is delivered to the analyzer for specific component analysis or for physical property determination.

*calibration and auto-calibration*: The procedure for introduction of a known standard to the analyzer. The measured results are compared with the standard, and the response factors of the analyzer are adjusted so that the measured results match the standard. Auto-calibration is the same activity with no human intervention and is normally on a fixed time cycle.
validation and auto-validation: The procedure for introduction of a standard to the analyzer where the measured results are compared with historical data and reported, and the response factor is not changed. Auto-validation is the same activity with no human intervention and is normally on a fixed time cycle. Other terms commonly used are “bench mark” and “check peak.” When the historical data trend of a validation sample clearly exceeds the acceptable limit, the instrument should be calibrated.

Original Equipment Manufacturer (OEM) Tests: The acceptance tests that are performed at the Analyzer Manufacturer’s facility. These tests must have defined and measurable parameters with repeatability factors or tolerance factors that are stated in the data sheets or in engineering notes. Examples of these tests are baseline drift, repeatability, resolution, signal ranges, etc.

Factory Acceptance Tests (FAT): The tests that are performed at an Analyzer System Vendor’s (ASV) facility after complete fabrication and assembly of the analyzer system(s).

Site Acceptance Test (SAT): The initial SAT includes the shipment of an analyzer system, power-up, testing, calibration, and communication. The final SAT includes a defined period of process sampling, on-line operation within acceptable performance parameters. These tests, including the documentation requirements and standards compliance, must be fully defined at the bidding stage of an analyzer project.

4. Requirements

4.1 General

The process analyzer system design shall consider and integrate the following design aspects:

a. Physical and chemical properties data for each monitored sample stream
b. Analytical technologies available
c. Safety (e.g., relief vents, analyzer vents, safety monitors, safety equipment)
d. Process interface (e.g., sample probes, in-line sensing elements)
e. Sample transport
f. Sample conditioning
g. Calibration
h. Analyzer shelter
i. Status and validation signals
j. Signal conversions and control system interfaces
k. Materials of construction
l. Utilities support
m. Maintenance
n. Reliability
o. Operability
p. Environmental (analyzer sample vents)
4.2 Safety

4.2.1 Safety shall be the foremost design parameter during all stages of the analyzer selection and system design.

4.2.2 The system design shall be in accordance with all applicable codes and standards, and all electrical equipment and instrumentation shall meet the electrical (hazardous) area classification where installed.

4.2.3 For highly toxic process samples, the following shall be considered:
   a. Distance (minimize) of the analyzer to the process sample source point
   b. Quantity (minimize) of sample needed for a reliable, safe, and speedy analysis
   c. Distance of the analyzer to the sample disposal or return point for proper disposal of spent samples
   d. Availability of safety support equipment, such as breathing air stations, safety showers, etc.
   e. Emergency escape routes from the analyzer location
   f. Location of toxic gas monitors and alarm devices
   g. Physical protection of sample tubing and probe

4.2.4 For highly flammable process samples, the following shall be considered:
   a. The lower explosive limit of sample stream constituents
   b. The lower explosive limit of chemical reagent components
   c. Surface temperature of sample system hardware components (T-Rating)
   d. Need and location of combustible area monitoring detectors and the calibration of the monitors for the sample stream
   e. Sources of static electricity such as air conditioner blowers, etc.
   f. Safety issues with any of the other process analysis requirements
   g. Physical protection of sample tubing and probe

4.2.5 Transport, conditioning, and disposal of the sample shall not create a hazard to personnel, the environment, the process, or the facility that is being monitored.

4.2.6 All hazardous materials, that are part of the analyzer system, or are required reagents for the system, shall be properly identified, labeled, or tagged.

4.3 Process Interface

4.3.1 Sample Probes

4.3.1.1 A sample probe shall be installed in lines 3 inches (80 mm) or greater in diameter.

4.3.1.2 The sample point shall be selected to provide a representative sample, fast response time and maintainability.

4.3.1.3 The sample probe shall be positioned at 12 o’clock or 3 o’clock on a horizontal line or at any position on a vertical line. There shall be
sufficient clearance for insertion and removal of the probe. The probe shall be located in the permanently gas-filled portion of the pipe for gas sampling and in the permanently liquid-filled portion of the pipe for liquid sampling (flow direction upward in vertical line).

4.3.1.4 Sample points that can be multi-phase shall be avoided.

4.3.1.5 Accessibility must be considered for the removal of the sample probe.

4.3.1.6 Fixed-flange probes are recommended for any operating pressures. These probes shall have the following features:
   a. An arrow stamped on the flange indicating the direction of flow in the process line
   b. Capable of being rodded out or blown back to process
   c. Welded shutoff valve in accordance with line specifications
   d. Sized for approximately 30% immersion beyond the inside pipe wall up to a maximum immersion of 3 inches (75 mm)

   *Comment:* A typical fixed-flange sample probe is shown in Annex A of IEC TR61831. Approximate calculations are shown in subsequent annexes.

4.3.1.7 For high-maintenance service, retractable sample probes shall be permitted if equipped with the following additional safety features and characteristics:
   a. Arrow stamped for flow orientation
   b. Marked for insertion depth

   *Comment:* scoring tubing reduces mechanical strength
   c. Marked for retraction depth to clear the process root valve
   d. Expanded section on end of probe to prevent blowout through packing gland
   e. Safety chain for blowout prevention where retraction mechanism is not provided

4.3.1.8 Special-purpose, high-pressure, retractable probe devices are commercially available and may be used for pipeline or similar demanding service.

4.3.1.9 Fixed or retractable sample probes shall be in accordance with the process pipe specification and shall have the mechanical strength to avoid failure in high-velocity flow conditions.

4.3.1.10 Perform wake frequency calculations on probes installed in process piping to predict safe operation of the sample probe.

4.3.1.11 The sample probe shall be subjected to and marked in accordance with the Positive Material Identification (PMI) requirements.
4.3.2 **In-Line Sensing Elements**

4.3.2.1 In-line sensing elements shall be designed to be removed for replacement or maintenance while the process is in operation where safety considerations permit.

4.3.2.2 Sensing elements and analyzers that are mounted in process slip streams shall be designed to be blocked in, depressurized, and flushed while the process is in operation.

4.3.2.3 All “wet electrolyte” sensing elements, where sensitive to drying out, must be installed so that the sensing element is constantly wetted to ensure that the sensor does not dry out.

4.3.2.4 In-line sensing elements shall be installed so that the sensing element does not become fouled with debris.

4.4 **Sample Transport**

4.4.1 The primary objective of fast loop design shall be to minimize the sample transport time and the mass of sample transported.

4.4.2 One or more of the following techniques may be used to minimize sample transport time or sample mass:

a. Distance reduction

b. Phase change

c. Minimum-bore tubing and components

d. Eductors

e. Pumps

f. Heating

4.4.3 The sample return point selected directly influences fast loop design. The sample return point shall be selected to optimize the sample return flow to process.

4.4.4 **Sample Phase**

4.4.4.1 Phase shall not be changed if the sample phase matches the phase required by the analyzer.

4.4.4.2 Phase shall be changed if required for analyzer system operation.

4.4.4.3 To avoid erratic analysis results, if a phase change is designed into the sample transport system, the phase change shall be maintained once it has occurred.

4.4.5 Sample transport system components shall be stainless steel unless the process sample or environment is not compatible with stainless steel.

4.4.6 Sample transport systems shall be designed and fabricated without low spots, vertical loops, or pockets.
4.5 Sample Conditioning

4.5.1 The sample-conditioning system shall not alter the composition of the measured stream.

4.5.2 Response time of the sample-conditioning system shall be consistent with the requirements of process control or monitoring.

4.5.3 The system shall be maintainable and provide sufficient information to aid in trouble shooting the analyzer system.

4.5.4 All materials used in the sample-conditioning system, including elastomers, metals, and composites, shall be verified for compatibility with the process sample.

4.5.5 Isolation valves shall be provided at the sample probe and sample return points.

4.5.6 Isolation valves and bypass valve shall be provided at the sample-conditioning system to run the fast loop with the sample-conditioning system isolated.

4.5.7 Dead-volume components contributing to increased lag time shall be minimized.

4.5.8 Double block and bleed, or equivalent, shall be used to prevent an incorrect analysis caused by cross contamination from valve leaks in multi-stream sample systems and for the calibration streams.

4.5.9 Pressure or temperature sensitive components or devices used in the sample-conditioning system shall be protected from exposure to excessive pressure or temperature.

4.5.10 Heated sample lines shall enter the sample-conditioning enclosure via heat shrink entry seals to ensure that the sample temperature is uniformly maintained and that no cold spots are created.

4.5.11 The sample-conditioning system enclosure shall have windows suitable for viewing indicating devices (e.g., pressure, flow, etc.) if the enclosure cannot be opened because of safety requirements or operating conditions.

4.5.12 If high temperatures are maintained within the enclosure, all adjustments for the sample conditioning system shall be externally accessible.

4.5.13 Sample-conditioning enclosures shall close and seal sufficiently using, at a minimum, a single-handle, three-point latch mechanism.

4.5.14 All sample-conditioning systems, whether enclosed or plate-mounted, shall be provided with a means for decontamination before maintenance.

4.5.15 For samples containing toxic or flammable materials, the location of sample-conditioning systems shall be determined by the following:

a. For an analyzer located inside an analyzer building, the sample-conditioning system shall be installed on an exterior wall and shall include flow-limiting devices to the analyzer.

b. For field-mounted analyzer enclosures, the sample-conditioning system shall be installed adjacent to the analyzer enclosure.

c. The sample-conditioning system shall be installed where most convenient for maintenance.
4.5.16 Components of all sample-conditioning systems, whether enclosed or plate-mounted, shall be installed in such a way that each can readily be removed for maintenance without removing any others.

4.5.17 All components and controls of sample-conditioning systems, whether enclosed or plate-mounted, shall be clearly tagged and labeled for ease of identification and maintenance. Normal settings such as flow and pressure shall be indicated.

4.6 Calibration

4.6.1 All process analyzer systems shall be provided with a means for calibration.

*Comment:* The design of a process analyzer system influences its overall precision. The calibration standard used on the system determines only the relative accuracy. PIP PCSPA002 defines and specifies these terms.

4.6.2 Calibration samples shall be introduced to the analyzer in the same phase as the conditioned process sample.

4.7 Analyzer Shelters

4.7.1 The selection of a shelter for a Process Analyzer System shall be based upon the following:

a. Analyzer manufacturer’s published specifications for operating conditions
b. Ambient site conditions
c. Criticality of analysis
d. Owner’s requirements
e. Electrical (Hazardous) area classification

4.7.2 The following four basic types of analyzer shelters may be used:

a. Type I – Field mounted - An analyzer in an integral enclosure mounted on a free-standing support
b. Type II – Freely ventilated - Typically a three-sided shelter
c. Type III – Climate controlled - Enclosure interior is temperature controlled for proper operation of the analyzer system(s). Pressurization prevents intrusion of atmospheric contaminants from entering building if required.
d. Type IV – Controlled for area classification reduction - Enclosure interior is pressurized and purged to allow operation of analyzer system(s) that are not rated for the exterior area classification in accordance with NFPA 496.

4.7.3 For shelter Types III and IV, doors shall open outward and shall be equipped with panic hardware, automatic door closers, and windows.

4.7.4 Closed shelters shall be equipped with appropriate sensors for combustible gas, toxic gas, oxygen deficiency, and loss of pressurization.

4.7.5 Alarm conditions shall be shown outside each entry door and transmitted to a continuously monitored location. A corresponding flashing alarm light or alarm horn shall be provided on the interior to warn occupants.
4.8 Status and Validation Signals

4.8.1 Validation signals shall be conveyed to the owner’s Control System.

4.8.2 If a process analyzer system is on closed loop control and has a fault/status signal available, this signal shall be transmitted along with the measured parameter to the owner’s Control System and/or his monitoring computer.

*Comment:* As the complexity of a process analyzer system increases, other signals may be required (e.g., calibration, purge fail, no sample flow, etc.).

4.9 Documentation

4.9.1 Once a process analyzer system is shipped to its final destination, the following minimum documentation shall be provided:

a. Original Equipment Manufacturer’s documentation for all parts of the system
b. Analyzer System vendor’s drawings and documentation
c. Original specifications with all agreed-upon changes documented by the Analyzer System vendor
d. Start-up and shut-down procedures
e. Calibration procedures
f. Installation, Operations, and Maintenance procedures
g. All software documented to facilitate changes by the owner
h. Control Narrative
i. Recommended spare parts list
j. Consumables list including carrier and fuel gases

4.9.2 Documentation shall be provided in accordance with *PIP PCSPA001.*