AMP 217 SENSORS AND TRANSMITTERS NOT SUBJECT TO ENVIRONMENTAL QUALIFICATION REQUIREMENTS (VERSION 2020

Programme Description

The main objective of this AMP is to provide the basis to establish a programme for early detection and appropriate monitoring of ageing effects on I&C sensors and transmitters whose correct operation is necessary to achieve safety functions but are not included in the Environmental Qualification (EQ) programme, in order to ensure adequate performance over the entire service life.

This AMP is a condition monitoring programme based on visual inspection, calibration and response time analysis.

This AMP concerns sensors and transmitters for various parameters such as temperature, pressure, flow, level and valve position.

The documents [1-3] provide additional information about ageing of sensors and transmitters.

Since a transmitter includes electronics, the ageing mechanisms and effects are quite complex. Additional, information about ageing of I&C could be found in [4-5].

This AMP includes polymeric (e.g. O-rings or gaskets) and metal materials that are part of the sensor or transmitter. As operating experience has shown, sensor/transmitter polymeric materials are subject to degradation due to temperature and radiation. Therefore, the ageing management of these materials utilizing visual inspection or periodic replacement of consumables are included in this AMP.

A sensor and its corresponding transmitter can be placed in a common housing at a common location in the plant (e.g. this is a common setup for pressure measurement). Another option is to locate the transmitter separately from the sensor, usually in a less adverse environment (e.g. this is a common setup for temperature measurements).

Fouling is an ageing effect to the performance of the measurement result of feedwater venturi while it is not an ageing effect to the equipment itself. According to document [10] fouling of feedwater venturis during plant operation by deposition of corrosion products leads to increased pressure drop across the venturis. Feedwater venturi fouling is an electrochemical phenomenon which results in deposition of corrosion products in the feedwater onto the venturi flow nozzle throat and tap locations. Deposition occurs preferentially where the flow velocity is high and the local pH is nearly neutral.

The list below provides ageing factors/ageing mechanisms/ageing effects generally associated with sensors and transmitters:

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| **Material** | **Degradation mechanism** | **Ageing effect** |
| Polymer | Radiation-induced oxidation | Loss of sealing function |
| Polymer | Thermal degradation of organic materials | Loss of sealing function |
| Metal | Thermal fatigue/ wear/ corrosion/ erosion-corrosion/ vibrational fatigue/ hydraulic shock  Fouling | Characteristic change |
| Electronic components | Thermal and mechanical loading/ radiation damage/ moisture intrusion | Degradation |
| Electronic components | Material depletion/changing material properties | Characteristic change |
| Various insulation materials | Moisture intrusion | Reduced insulation resistance |
| Various materials | Material depletion/ changing material properties/ vibration | Characteristic change |

Evaluation and Technical Basis

1. Scope of the ageing management programme based on understanding ageing:

This AMP applies to I&C sensors and transmitters whose correct operation is necessary to achieve safety functions, but are not included in the Environmental Qualification (EQ) programme. Such sensors and transmitters concern various parameters including resistance temperature detector, thermal couple, pressure transmitter, venturi and/or orifice plate, level transmitter, valve positioner, etc. Environmental conditions and ageing affect instrumentation performance including accuracy and response time. This AMP provides methods for performance verification and early detection of age degradation.

As there are specific AMPs for instrumentation and control cables, they are excluded from the scope of this AMP.

1. Preventive actions to minimize and control ageing degradation:

This is a condition monitoring programme and no actions are taken (except for periodic replacement of consumable materials (seals, gaskets, O-Rings) as specified for specific sensors/transmitters) as part of this programme to prevent or mitigate ageing degradation. Preventing I&C equipment failure is achieved through different strategies:

* Programmed and periodic replacements, whether the component has failed or not. However, this replacement is done judiciously because it does not always guarantee the correct operation of the instrument. On the contrary, after the first stage of the life of the sensor (in which failure rate is high) monitoring is recommended rather than replacement [1]. Once the lifetime of the instrument design is reached, the failure rate increases again, making sensor replacement necessary at this point.
* This is a typical behavior and responds to the Bathtub Curve Model for failure rates of electronic components [1].
* During the first phase of service life, early failure occurs, which may be due, for example, to manufacturing imperfections or installation errors. Then failure rate decreases, and it is in this second phase when the component is properly installed and in service. In this phase, it is recommended to perform condition monitoring or surveillance (through periodical tests) with an adequate frequency [6]. In the last phase (end of life), the failure rate increases again due to the effects of wear and ageing. At this point it is recommended to replace the component by a new one.
* Periodic inspection and/or replacement of consumable parts. This task can be done during calibration or periodic inspections of the system involved. It is a common practice to perform replacements of consumable parts when the component is disarmed for maintenance, repair or inspection. Also, it is necessary to perform periodic and programmed replacements of consumable parts, with a frequency determined by recommendation of the manufacturer, or by operating experience. The frequency of replacement is determined by recommendation of the manufacturer, design certification or by operating experience.
* Monitoring of temperature, radiation, humidity, and other conditions to which I&C components can be exposed, is a useful tool for monitoring and control equipment lifetime. The lifetime of the component is usually given by the manufacturer, however if it is found that the component operates under less severe conditions than design, its replacement period can be extended.
* The most effective form of fouling measurement has been to use independent flow measurement systems for feedwater flow measurement, which are not susceptible to fouling biases.
* Response time testing: Response time analysis allows to identify if sensors are properly installed in plant, organize and schedule predictive maintenance, and diagnose anomalies in the sensor or process.

1. Detection of ageing effects:

Detection of ageing effects is mainly based on its periodic calibration and adequate control of component installation. Sensors and transmitters are tested periodically in order to verify correct operation. In practice, the test frequency can vary widely between components according to specification of each manufacturer, particular design requirements, regulatory requirements or operating experience. Initially the test period is set according to specification and then it may be adjusted according to operating experience.

* Adequate control of component installation in field. It is verified that the sensor is properly installed, in correct position, and without visible damage. In this procedure it is also recommendable to control the anchorage if this exists, further information is given in AMP 306. It is also recommendable to clean the electronic parts that have been stored for a long period of time, in order to remove dust that may have accumulated on the surface.
* Component installation in field. It is verified that the sensor is properly maintained, in correct position, and without visible damage. Electronic parts are free of contamination, electrolytic capacitors and the growth of whiskers. Detailed information can be found in AMP 213 and further information about electronics can be found in AMP 218.
* Visual inspection: it is performed as part of periodical walkdowns of each system, or during routine maintenance tasks of equipment associated to the instrument. Records are maintained with the description of any observation for monitoring and trending.
* Calibration: calibration frequency of each sensor is initially determined by the manufacturer's recommendation or regulatory requirements. As specific operating experience is obtained, frequency can be changed according to failure rates or anomalies found. It is performed as a preventive maintenance to all instruments and includes operational tests for different values within the measuring range. During calibration or cleaning of this type of sensors, inspection of connection points with the system is performed in order to detect leakage or corrosion.
* Observations of venturi fouling are typically made inferentially, by trending independent plant parameters.

These types of tests are given as general examples and are chosen and carried out judiciously, following internal guides or recommendations specially prepared by each type of sensor. Wrong application of these tests can lead to damage of the instrument.

1. Monitoring and trending of ageing effects:

Periodic review of operation and maintenance records of the component is useful to detect recurrent failures of specific instruments and refine the periods for calibration or replacement. This task includes trend analysis in search of significant failure rate increase or deviations from normal operation (e.g. Continuous drift, as left and as found data).

1. Mitigating ageing effects:

This programme is a condition monitoring programme. This programme has no specific mitigation aspects.

1. Acceptance criteria:

The acceptance criteria for each test are defined by the specific type of test performed and the specific type of component tested.

Sensors and transmitters respond correctly to the process parameters. It is verified that the transmitted signal is adequate during the calibration process, and the sensor is recalibrated if this is not met. The response time should correspond to specification.

Significant drift initiates further investigation since this could be an effect of degradation.

1. Corrective actions:

An engineering evaluation is performed and corrective action is taken if acceptance criteria are not met. The corrective action programme is used to perform an evaluation that considers the extent of the condition, the indications of ageing effect, and changes to the one-time testing programme or alternative inspection programme. Corrective actions may include, but are not limited to, sample expansion, increased inspection frequency, and replacement or repair of the affected components.

Corrective actions performed in case of sensor failures are repair, calibration or replacement.

Use of an independent flow measurement system enables the plant to correct the flow indication on-line and recover the generation lost due to fouling. This correction is performed either by substituting the new feedwater flow indication into the power calculation, or by multiplying the flow nozzle indication by a correction factor based on the independent measurement.

1. Operating experience feedback and feedback of research and development results:

This AMP addresses the industry-wide generic experience. Relevant plant-specific operating experience is considered in the development of the plant AMP to ensure the AMP is adequate for the plant. The plant implements a feedback process to periodically evaluate plant and industry-wide operating experience and research and development (R&D) results, and, as necessary, either modifies the plant AMP or takes additional actions (e.g. develop a new plant-specific AMP) to ensure the continued effectiveness of the ageing management.

Operating experience has shown that elevated temperature, radiation, moisture, electrical transients, vibration, pressure cycling and over-pressurization conditions may increase age-related effects on the differential transmitter. Industry experience has verified that the drift calibration and the time response degradation are important characteristics to be assessed that can indicate the consequences of ageing effects.

Reference [7] describes the failure of an adhesive connection between a coil and its holder in an inductive pick-up of a level measuring sensor.

The programme considers testing techniques to allow the detection of ageing effects. There are known tests as sensor response-time, noise analysis, power interruption, periodic drift monitoring. In addition, other methods can be applied as channel comparisons and collections of dates about calibrations.

Several problems have been detected with temperature sensors in service in NPPs: failure in response time, loose or bad connections, filtering substances through connections to the sheath. A typical problem on thermocouples is failure of the seal that isolates the thermocouple from moisture. Water or corrosive agents can result in wrong instrument readings or signal noise.

There have been situations where thermocouple sheaths broke due to vibration or bad installation and finished circulating through the process systems. The sheaths can also be responsible for the increase in the response time of temperature sensors. Operating under certain conditions, the system may vibrate, generating air spaces between the sheath and the sensor, resulting in a response time increase. This can also happen by wear of the tip of the sensor.

In the case of pressure transmitters, they are connected to the system through piping of small diameter prone to clogging, particularly in systems operating with untreated water. The clogging or the entry of air or gases to these lines affects the response time of the instrument and introduces noise to the signal. All connection points are susceptible to leakage that can lead to false readings of the instruments [3].

NUREG/CR-5383 [8] describes the effect of ageing on response time of pressure sensors and provides a study of consequences of normal ageing on the dynamic performance of pressure transmitters.

NP-7121 [9] includes the study regarding detection of oil-loss failure as a type of cause of degradation of pressure transmitters.

TR-100514 [10] describes the effects of fouling of feedwater venturis and measures to detect deposits.

1. Quality management:

Site quality assurance procedures, review and approval processes, and administrative controls are implemented in accordance with the different national regulatory requirements, (e.g., 10 CFR 50, Appendix B [11]).

References

1. INTERNATIONAL ATOMIC ENERGY AGENCY, TECDOC-1147 “Management of ageing of I&C equipment in nuclear power plants”, IAEA, Vienna, 2000
2. INTERNATIONAL ATOMIC ENERGY AGENCY, TECDOC-1402 “Management of life cycle and ageing at nuclear power plants: Improved I&C maintenance”, IAEA, Vienna, 2004
3. Electric Power Research Institute, TR-1021429, “Nuclear Maintenance Applications Center: Guidelines for the Maintenance Management of Plant Sensors”, EPRI, Palo Alto, CA: 2010
4. ELECTRIC POWER RESEARCH INSTITUTE, Guidelines for the Monitoring of Aging of I&C Electronic Components, EPRI 1008166, EPRI, Palo Alto, CA, 2004
5. ELECTRIC POWER RESEARCH INSTITUTE, Collected Field Data on Electronic Part Failures and Aging in Nuclear Power Plant Instrumentation and Control (I&C) Systems, EPRI 1003568, EPRI, Palo Alto, CA, 2002.
6. Safety Standards of the Nuclear Safety Standards Commission (KTA), KTA 3502 (2012-11) Accident Measuring Systems
7. GRS Weiterleitungsnachricht 2012/05: „Befunde an Messwerken der Füllstandssonden des Typs AVL200" im Kernkraftwerk Grohnde, Gesellschaft für Anlagen- und Reaktorsicherheit (GRS), 2012.
8. UNITED STATES NUCLEAR REGULATORY COMMISSION, NUREG/CR-5383, The Effect of Aging on Response Time of Nuclear Plant Pressure Sensors, USNRC, June 1989.
9. ELECTRIC POWER RESEARCH INSTITUTE, Technical Guidance for Detection of Oil-Loss Failure of Rosemount Pressure Transmitters, EPRI NP-7121, 1990
10. ELECTRIC POWER RESEARCH INSTITUTE, Survey and Characterization of Feedwater Venturi Fouling at Nuclear Power Plants, EPRI TR-100514, 1992
11. UNITED STATES NUCLEAR REGULATORY COMMISSION, 10 CFR Part 50, Appendix B, Quality Assurance Criteria for Nuclear Power Plants, Office of the Federal Register, National Archives and Records Administration, USNRC, 2015.