AMP 213 WHISKERS AND CAPACITORS WITH LIQUID ELECTROLYTE (VERSION 2021)

Programme Description

The purpose of this ageing management programme (AMP) is to provide a description for a periodic inspection of whiskers and capacitors with liquid electrolyte to identify age-related degradation of the electronic and electrical equipment.

Whiskers

The growth of whiskers is a monocrystalline metallurgical phenomenon which occurs mainly on printed circuit boards and other components of electronic equipment. Small metal hair-like structures grow out from the metal surface. These outgrows can be found especially on zinc, tin, and cadmium.

Factors that may promote the growth are e.g.:

* Inclusion of hydrogen, especially under the presence of oxygen in the tin
* Mechanical stress caused by scratching, punched holes, bending or strain hardening
* Elevated temperatures (50 °C to 60 °C)
* Use of galvanically applied pure tin
* Surface conditioning method

Whiskers occur in unalloyed or low-alloyed material. Some research results indicate that whiskers don’t occur in new materials if there is a moderator in the material. An example is that a percentage of 4 % of lead in tin prevents whiskers’ growth. An incubation time of one month up to many years is required. Growth rates vary from 0.06 mm/year up to 7.3 mm/year and length can reach 10 mm.

Whiskers can cause short circuits and loss of electrical function in the equipment.

Capacitors

Capacitors that use liquid electrolyte are the most sensitive components of electronic equipment for ageing effects. They deplete electrolyte due to evaporation, particularly at higher temperatures. Depletion or dry-out of electrolyte results in loss of capacitance and/or increase of equivalent series resistance (ESR). Capacitors with failures in the dielectric cause malfunctions e.g. drift or time failures of the equipment.

Predicted lifetime of electrolyte capacitors is limited between 40000 and 20000 hours and depends on the mounting, the technical data, the circumstances of the operation and the environmental temperature. High amplitude ripple currents can also accelerate ageing.

Evaluation and Technical Basis

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

This AMP manages the age-related degradation effects of the electronic and electrical equipment (for example, connectors, relays, sensors and transmitters), due to whiskers and degradation of capacitors with liquid electrolyte.

In both cases the age-related degradation can result in the loss of function of the equipment, because of the possible short circuit (whiskers) and the abnormal operation of electronic, due to loss of capacity (capacitors).

1. Preventive actions to minimize and control ageing degradation:

This is a condition monitoring programme and no direct actions are taken as part of this programme to prevent ageing degradation. Nevertheless, keeping operating environmental temperature low slows down ageing degradation on electrolyte capacitors.

1. Detection of ageing effects:

Whiskers:

Tin whiskers normally grow with a speed of < 0.14 mm/year [1] and can reach a length of 10 mm.

Zinc whiskers grow from galvanized (electroplated) metal surfaces at a rate of up to 1 mm per year with a diameter of a few micrometers.

Detection of these kinds of ageing processes is possible only through regular visual inspection [2] of components by the means of a microscope with at least 10 times magnification and suitable lighting (ring light). Inspection programmes need to be developed for the periodic control of the suspected components. Regarding the large number of equipment that was inspected in the past and will be inspected in the future, a random inspection technique is preferable.

Capacitors with liquid electrolyte:

Detection of ageing progress of capacitors is most simply possible by checking the original technical data, the inbuilt data and the time of use considering the environmental temperature.

The periodic measurement of residual capacity is a possible action of detection of ageing progress [3]. That means that after switching off the printed board from the circuit we measure the discharge time of the capacitor by oscilloscope. Other possible solution is the direct measurement of the capacity by the means of capacitance measurement, but sometimes it is difficult to be performed because of the construction of the printed board. Under some circumstances of construction, the equivalent series resistance is also preferable to be periodically measured. Generally, after 7-9 years of operation these kinds of measurements are advisable to be annually performed.

1. Monitoring and trending of ageing effects:

Trending actions are not included as part of this AMP, because the ability to trend inspection results is limited.

1. Mitigating ageing effects:

This programme is a condition monitoring programme. This programme has no specific operations, maintenance, repair or replacement mitigation aspects. If whiskers are growing from a surface and it is not possible to prevent their growth, certain mitigation action, such as screening of sensitive parts from area where whiskers grow, could be taken to hinder the whiskers from having negative effects on the electrical functions of the sensitive parts.

1. Acceptance criteria:

Whiskers:

Acceptance criteria can possibly not be set up regarding the progress of whiskers. If whiskers are found at the random inspection, the scope of the inspection is widened. If necessary, the further processes based upon engineering decision includes the removal of whiskers up to the replacement of the effected component.

Capacitors with liquid electrolyte:

Acceptance criteria are individually developed based upon the actual component type and configuration. These criteria can be the allowable values of residual capacity, discharge time, equivalent series resistance.

1. Corrective actions:

During the lifetime management work, actions are taken by the responsible technical or operational organization, based on the ageing management experience, to mitigate or, in specific cases, to eliminate the degradation.

Regarding capacitors with liquid electrolyte, if the relevant methods and criteria are available for performing measurements and we find the residual capacity below a predetermined time of discharge the capacitor needs to be replaced. Also, in case of nominal capacitance and the equivalent series resistance if an individual acceptance criteria was determined, and we find an unacceptable value, the capacitor needs to be replaced. If there is no possibility to perform measurement generally from 9 years as a minimum up to 15 years as a maximum of operation the periodic replacement is probably the only possible solution to handle the ageing process.

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.

Industry experience has shown that whiskers have occurred on printed circuit boards and on other components of electronic and electrical components, causing failures for the equipment. [4-7].

There were also operating experiences on the degradation of capacitors with liquid electrolyte [8].

At the time when this AMP was produced, no relevant R&D was identified.

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 [9]).

References

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[2] Action plan for the whiskers issue, Ringhals NPP, 1885110/2.0 document.

[3] Inspection of electrolyte capacitors applied in the reactor protection system of Paks NPP, Maintenance procedure TIV-226, PAKS, Hungary.

[4] Dr. Henning Leidecker (NASA Goddard), Jay Brusse (QSS Group, Inc): Tin Whiskers: A history of Documented Electrical System failures, A briefing Prepared for the Space Shuttle programme Office, April, 2006.

[5] UNITED STATES NUCLEAR REGULATORY COMMISSION, NRC Information Notice 2005-25. Inadvertent reactor trip and partial safety injection actuation due to tin whiskers, USNRC, 2005.

[6] GRS Weiterleitungsnachricht 2002/01: „Whiskerbildung an leittechnischen Baugruppen in deutschen Kernkraftwerken“, Gesellschaft für Anlagen- und Reaktorsicherheit (GRS), 2002

[7] GRS Weiterleitungsnachricht 1993/04: „Defekte Keramik-Kondensatoren auf Trennverstärkerbaugruppen und Grenzwertmeldern im Kernkraftwerk Würgassen“, Gesellschaft für Anlagen- und Reaktorsicherheit (GRS), 1993

[8] GRS Weiterleitungsnachricht 1997/02: "Ausfall von Baugruppen zur Stromversorgung von Messumformern", Gesellschaft für Anlagen- und Reaktorsicherheit (GRS), 1997.

[9] 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.

[10] ELECTRIC POWER RESEARCH INSTITUTE, Guidelines for the Monitoring of Aging of I&C Electronic Components, EPRI 1008166, EPRI, Palo Alto, CA