AMP 216 LEAD BATTERIES NOT SUBJECT TO ENVIRONMENTAL QUALIFICATION REQUIREMENTS (VERSION 2017)

**Programme Description**

The purpose of the AMP described herein is to provide reasonable assurance that the intended functions of the batteries are maintained consistent with the current licensing basis through the period of operation. The metallic and polymer parts as well as the electrolyte of the battery that are susceptible to age-related degradation resulting in decreased capacity due to corrosion and chemical processes are therefore monitored and periodically checked.

Batteries are designed to provide power in case of loss of all alternate current sources, offsite (power grid) and on-site (emergency power generators).

Each battery set is, without a battery charger, capable of meeting all required load demands and conditions (including duty cycles and electrical transients) that occur in the plant states specified in the design basis, with account taken of such factors as design margins, temperature effects, any recent discharge and deterioration with age [1].

Although the previous failure experience mostly indicated failures in single cells of batteries only, the programme ensures that the reliability and safety significance of this uninterruptible power supply system as a whole is adequately addressed.

The programme was written specifically to address the lead battery of wet cell design with a liquid electrolyte, although gel cells have sometimes been installed for the same purpose.

The programme applies to emergency power generation with batteries and rectifier units, as shown in picture 1 [2].

Almost all of the time, the battery is in standby mode, i.e. in parallel operation where the battery delivers current only when the supply from the rectifier is not available (e.g. during startup of the diesel generator).

The characteristic physical parameter is the battery’s capacity, i.e. the amount of electric charge it can store.

Storage life of secondary batteries is limited by chemical reactions that occur between the battery parts and the electrolyte. Internal parts may corrode and fail, or the active materials may be slowly converted to inactive forms. Since the active material on the battery plates changes chemical composition on each charge and discharge cycle, active material may be lost due to physical changes of volume; this may limit the cycle life of the battery [3].

Although rechargeable batteries have their energy content restored by charging, some deterioration occurs on each charge–discharge cycle.



Figure 1: Battery facilities shown for one division [1]

Because designed lifetime of batteries important to safety installed in nuclear power plants is limited. periodic replacements are needed during period of plant operation. Nevertheless, during operation of batteries, ageing management is needed to ensure at least the specified lifetime.

Evaluation and Technical Basis

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

Wet cell lead batteries in standby operation, parallel to rectifier units (where the battery delivers current only when the supply from the rectifier is not available) are in the scope of this AMP.

1. Preventive actions to minimize and control ageing degradation:

This is a condition monitoring program, and no actions are taken as part of this programme to prevent or mitigate ageing degradation.

1. Detection of ageing effects:

This AMP focuses on the demands for the visual inspections and the surveillance test programme.

Batteries are periodically tested to demonstrate the operability of the system and to detect any degradation.

The monitoring programme includes the check of the voltage and current delivered by the rectifier. The monitored parameters at the rectifier unit covers at least the output voltage and the output current. The compensating charge voltage is checked on site.

If the values exceed the limit values, the rectifier is switched off for eliminating damage to the battery. The output current and the related output voltage are monitored with a collective alarm in the control room, additionally.

At the battery, monitoring the current for a break inside the battery and between the battery and the rectifier is recommended.

Battery capacity and battery lifetime are temperature dependent. Therefore, the room temperature is monitored continuously.

Periodic testing will usually be based on recommendations for each type of battery and typically a battery capacity test at an interval of 1–5 years, depending upon the condition of the battery [1]. In-service inspections of the battery includes visual as well as technical tests [1]:

1) The following tests and inspections are performed on a regular basis (e.g. every month):

a) Visual inspections are performed with regard to electrolyte level and external condition of the battery.

*Note: Special attention is given to damages of the battery vessels and battery pole corrosion.*

b) The floating charge voltage is tested at the rectifier unit.

c) The room temperature and the functioning of the ventilation system is checked.

d) The electrolyte density is tested in a monthly sequence on at least 10 % of the battery cells and, additionally, in those cells where the cell voltage had been too low in previous tests.

2) The cell voltage and the electrolyte density of all cells are tested during or after charge operation. The testing interval is not larger than 12 to 24 months (depending on the planned outage schedule).

3) Capacity tests are performed in maximum intervals of 5 years. These tests are performed in a staggered time sequence, e.g. each year one train.

4) In the case of paralleled battery fuses, the symmetry of the current distribution is tested. This test is performed in conjunction with the in-service capacity tests.

5) The cell connectors are tested for an impermissibly high transition resistance. This test is performed in conjunction with the in-service capacity tests.

6) Verification of temperature of representative cells

*Note: The methods based on internal impedance measurement include some uncertainties due to the complexity of the ageing phenomena and the quality of the measure’s circuits. For certain phenomena like the corrosion of the collectors of positive current in lead batteries, there are hints for a short remaining life time, when the collector (plates or thorns) starts dispersing itself and thus, the impedance of the batteries grows in a meaningful manner. Nevertheless, a first diverging element in a battery can be an early signal to take into account.*

1. Monitoring and trending of ageing effects:

Trending actions are included as part of this AMP in order to cover the performance drift of the cell voltage, of the electrolyte density, and of the capacity of each of the battery cells. This is an excellent measure and provides adequate information on the rate of degradation.

1. Mitigating ageing effects:

This programme is a condition monitoring programme. This programme has no specific operations, maintenance, and repair aspects except the replacement before the end of the expected lifetime of the battery.

1. Acceptance criteria:

All of the physical parameters mentioned in attribute 3 shall be within the predicted acceptance criteria.

Deviations of the expected trends can provide significant information in an early stage. Evaluations are then performed, and appropriate countermeasures can be taken.

1. Corrective actions:

An engineering evaluation is performed that considers the extent of the condition. Corrective actions are taken if acceptance criteria are not met.

Because in almost all of the reported events, deviations of physical parameters occurred at single cells only, an additional survey programme such as increased inspection frequency of the affected cells is sufficient.

If the countermeasures program, like the exchange of the electrolyte, is not sufficient, corrective actions are performed. This may include replacement or repair of the affected cells or even the battery in total.

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.

Some relevant operating experience events were identified for the batteries. Vital battery individual cell voltage that was below the Technical Specification allowable value was identified during the quarterly surveillance test [4]. The cause of this event was a small internal short circuit, causing a low voltage condition on one vital battery cell.

Low cell voltage for two battery cells resulting from battery plate material shedding was registered [5].

Events of inoperable battery resulting from loose intercell connecting were registered [6].

Accelerated ageing and degradation of station battery due to manufacturing impurities resulting in shortened service life was reported [7].

Pole corrosion due to insufficient tightness of the pole inlets which led to formation of lead sulfate on the poles above the inlets after sulfur acid was drawn through them (capillary effect) [8]

Operating experience has shown that most of the detected failures have occurred on batteries caused by manufacturing defects such as failures of plates due to changes in the manufacturing process. Changes in sulfuric acid concentration were also found long before the end of the desired lifetime. Chipping (or shedding) of cell plates that might lead to a short circuit within the cell were detected as well.The programme includes provisions for the continuous review of plant-specific and industry operating experience, including research and development results, such that the impact on the programme is evaluated and any necessary actions or modifications to the programme are performed.

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

1. IAEA, Design of Electrical Power Systems for Nuclear Power Plants, Specific Safety Guide No. SSG-34, 2016.
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4. UNITED STATES NUCLEAR REGULATORY COMMISSION, Licensee Event Report 2502002001 - Vital Battery Cell Voltage Below Technical Specification Allowable, 2002.
5. UNITED STATES NUCLEAR REGULATORY COMMISSION, Licensee Event Report 2602005006 - Low Voltage on Shutdown Battery Cells Results in Condition Prohibited by Technical Specifications, 2005.
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7. UNITED STATES NUCLEAR REGULATORY COMMISSION, Licensee Event Report 3822009002 - Voluntary Report: Shortened Service Life of Station Battery 'B' due to Manufacturing Impurities, 2008.
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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.