## **AMP 147 CONTAINMENT BELLOWS (VERSION 2017)**

**Programme Description**

In nuclear power plant designs, containment bellows are used where piping or other components penetrate the containment boundary. These containment bellows provide for differential movement at the penetrations to accommodate construction misalignment, potential settlement differentials, and movement caused by temperature, pressure, or other operational or accidental loadings. These containment bellows form an integral part of the primary containment pressure boundary in nuclear power plants. Containment bellows are typically made of austenitic stainless steel such as SA-240 Type 304 [1]. Other designations, such as SB-443 alloy 625 have been used in some cases. The ageing management of non-bellows parts used in the penetration assembly is beyond the scope of this containment bellows programme.

This programme manages the ageing of containment bellows used in PWRs, BWRs and CANDU/PHWR NPPs.

**Evaluation and Technical Basis**

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

This programme manages the ageing of containment bellows used in PWRs, BWRs and CANDU/PHWR NPPs. The potential for age related degradation of containment bellows is mainly due to fatigue and transgranular stress corrosion cracking (TGSCC) [1-2]. The environment (e.g., presence of chlorides or other chemical agents) is a major factor that has contributed to development of TGSCC in containment bellows.

The containment bellows are usually welded to containment structure penetration components that are made of low carbon steel. Galvanic corrosion of any carbon steel material in the penetration assembly welded to containment bellows can be potentially significant.

1. ***Preventive actions to minimize and control ageing degradation:***

Periodic cleaning of containment bellows may be performed coincident with periodic inspections or during related maintenance to minimize and control degradation caused by TGSCC. The manufacturer's guidance is consulted before using any substance for cleaning penetration components.

1. ***Detection of ageing effects:***

Based on applicable standards, such as [3-4], the region of containment bellows having the highest load or stress ratio is subjected to inspection. The inspection area includes longitudinal seam welds and attachment welds within the bellows and surrounding material (e.g., within 150 mm on either side of the longitudinal seam weld [3]). The inspection may be limited to one accessible side of the bellows and the inner or outer convolution radii of the bellows. The inspection detects degradation of containment bellows by using the following non-destructive examinations (NDE) methods:

* 1. Visual — this includes direct visual inspection and inspection using visual aids (e.g. closed-circuit television) for evidence of unanticipated vibration, for presence of dirt, dust, contamination, moisture/humidity, chemicals, or corrosion products, for determining discoloration, scratches, cracking, gouges and leaking; and
  2. Surface — this includes inspection for determining discontinuities by methods such as liquid penetrant.

Degradation of containment bellows can also be identified through leak rate tests in accordance with applicable standards (e.g., [5]), regulatory requirements (e.g., [6]), and Technical Specification requirements. If the leak rate observed in the test exceeds the acceptance criterion, NDE methods mentioned above are used to locate defects (e.g., pin-holes and cracks). In-situ metallography/replication can also be used to reveal microstructure changes.

The frequency of the inspections and leak testing is determined by the service and environmental conditions involved, degradation detected, and in compliance with applicable Code, standards, regulatory requirements and industry guidelines.

1. ***Monitoring and trending of ageing effects:***

The ageing of containment bellows is routinely assessed and monitored through a combination of periodic inspection and leak rate testing [3,5].

AMP 101 is implemented to monitor and trend the fatigue of containment bellows.

1. ***Mitigating ageing effects:***

The containment bellows inspection results are evaluated to determine the need for mitigating actions.

Since the environment (e.g., presence of chlorides or other halides) is a major factor contributing to development of TGSCC in containment bellows, improvement of the environment conditions (such as periodic cleaning of containment bellows) can mitigate the effects of TGSCC.

The mitigating actions may include repair or replacement. For replacement of the containment bellows, mitigating actions may focus on selection of TGSCC resistant materials, development and implementation of a process to relax residual tensile stresses, and to improve the environment conditions of the containment bellows.

1. ***Acceptance criteria:***

Unless otherwise specified, the acceptance criteria based on national standards (e.g. [3]), the station safety analysis and the regulatory requirements (e.g. [6]) will apply.

Assessment of the cumulative usage factor is an acceptable means to demonstrate potential of the fatigue crack initiation. However, it should be pointed out that the fatigue assessment may not be conservative if the containment bellows is also degraded by TGSCC.

To the satisfaction of the regulatory authority, containment bellows may not require corrective action provided it can be demonstrated that the leak rate, projected to the end of the next inspection interval, will not exceed the acceptance criteria for leak rate specified in Technical Specifications, the station safety analysis and the regulatory requirements (e.g. [6]).

1. ***Corrective actions:***

Indications of corrosion-related cracking are evaluated in accordance with applicable standards, such as the ASME BPVC, Section XI, IWB-3600 [4].

If the excessive leak rate is caused by degradation of the containment bellows, corrective action is taken as necessary. For containment bellows, corrective actions may include repair, environmental improvement, and replacement of the entire bellows.

Following the repair and replacement, a retest is performed to ensure that the containment bellows is leak tight.

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 [7] 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.

Periodic inspection programme and leak rate testing programme for containment bellows have been widely used over a long period, and have been shown to be generally effective in managing ageing effects in nuclear power plants [8].

In Canada, Canadian utilities established action plans for fatigue assessment of bellows expansion joints against the requirements of ASME Section III, subsection NE [9]. The selected expansion joints included steam generator penetration seal bellows, main moderator seal bellows, vacuum building vacuum duct expansion joint bellows, and primary heat transport pump penetration seal bellows. The results demonstrated that there are significant margins against the initiation of fatigue cracking.

Sources of external operating experience include Owner’s Groups, EPRI, OECD-NEA, IAEA and NRC generic communications.

Research and development activities relevant to this AMP are outlined as follows:

A comprehensive review of currently available information regarding bellows used in containment penetrations is presented in [1], where the currently available methods used to monitor ageing of containment bellows are reviewed; the ageing mechanisms are discussed; inspection methods currently in use described, and a typical industry approach to managing bellows ageing are addressed.

Reference [10] discussed the laboratory examinations of bellows for determining leak areas, local leakage rate in details. Crack growth from corrosion and fatigue mechanisms were examined, and methods for predicting and extending operating life were discussed.

Reference [11] proposed two parameters, QW and QDT which are function of elbows pitch, convolution depth, mean diameter, and material thickness after thinning to predict fatigue life of bellows, and concluded that the consideration of strain concentration clarifies the fatigue data and will permit greater accuracy in estimate of bellows for fatigue.

Reference [12] proposed amendment to the hypothesis of linear accumulation of fatigue damage for expansion joints in the approach using Fuzzy sets theory. A sample example was given to explain the Miner’s hypothesis and amendment.

Reference [13] was a experimental research on effect of environmental medium on corrosion fatigue life of expansion joint. It was concluded that existence of corrosive media will reduce fatigue life for metal bellows expansion joints. The location of corrosion fatigue cracks is the same as that of fatigue crack under atmosphere, both of which are at the point of maximum stress.

1. ***Quality management:***

Site QA 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 [14]) or the different national standards (e.g., CSA N286-05 [15]).

### References

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