Guillotine Break Claims for Moderate Energy Lines

Case study

During the generic design assessment (GDA) process for the UK EPR nuclear reactor the Office for Nuclear Regulation (ONR) stipulated that the failure mechanism of double ended (2A) guillotine break must be adopted for all internal flooding assessments pertaining to loss of divisional segregation. Previously a leak rate associated with a breach size of DT/4 had been assumed for moderate energy pipework, as per common practices within the international nuclear industry.

The problem

The client challenged the requirement to consider 2A guillotine breaks in moderate energy pipework systems on the basis that it is judged not to be a credible failure mechanism within the design basis for the plant.

The objective of the work EASL undertook was to investigate if structural integrity arguments and high level demonstrations can be used to form part of the case being developed by Design Authority to support the project position.

The scope of the systems considered were:

- Protection and distribution of the nuclear island fire-fighting (JPI) system;
- Essential service water (SEC) system; and
- Demineralised water distribution (SED) system.

Our approach

The proposed approach incorporated four elements:

1. Review of the relevant failure and degradation mechanisms for the design conditions, duty and materials of construction for the JPI, SEC and SED systems;
2. Investigate typical failure rates for piping systems and applicability to the systems considered within this task;
3. Conduct simplified structural assessments covering the relevant failure mechanisms; and
4. Review worldwide operational experience (OPEX) on nuclear power plant pipework failures and the use of leak-before-break (LBB) as a mitigation.

The materials of construction, the design conditions and the duty for the systems were established from the system design manuals.

These were assessed against a comprehensive set of failure and degradation mechanisms to identify the significance of each one in turn and determine how they are covered within the design basis. All failure modes and degradation mechanisms were covered either by demonstrating design code compliance or by maintenance and operating procedures, except for brittle fracture of crack-like defects.

Figure 1 Examples of pipework failures

A short literature review was carried out to establish typical failure rates for piping systems designed using established design codes and OPEX of known pipework failures. This helped to understand the types and frequency of observed failures. These were then used to demonstrate support of the project position.

The extent of available information relevant to nuclear pipework failures is limited. However, the findings were related to the systems in the scope via a statement on the failure mechanisms judged to be most likely from the relevant degradation mechanisms. The review indicated that the frequency of 2A guillotine breaks is low, however not demonstrably as low as the client's design basis frequencies.

The limiting lengths of postulated fully penetrating, part circumferential defects were calculated based on the R6 defect tolerance assessment procedure for pressures bounded to the design limits for the considered systems. The limiting lengths of such postulated defects are calculated to be long, thereby confirming the defect tolerance system pipework. On this basis it was judged that a stable, leaking defect is far more likely to occur than a double-ended guillotine failure for the design loading and design plant state.

The crack opening areas were estimated for fully penetrating, circumferential defects of sub-critical length. A postulated 'DT/4' breach size is pessimistic in terms of a flooding risk compared to the crack opening areas of postulated defects. However, the small calculated crack opening areas would make leaks more difficult to detect.

Conclusion

Brittle fracture of crack-like defects is the only credible failure mode that can lead to significant pipework breaches. A stable, leaking defect is far more likely to occur than a double-ended guillotine failure. Typical crack opening areas of sub-critical defects are far smaller than a postulated 'DT/4' breach, hence flooding would be far less severe.

By applying a blended approach, combining OPEX and specific research EASL has strengthened the project position on flood prevention. This work assisted to avoid costly re-design of flood protection measures and mitigation against requirement for divisional segregation, resulting in cost savings and reducing lead times.

EASL always work with clients to identify cost effective solutions to operational challenges.

If you would like to discuss how EASL can help your business please get in touch.

engineering analysis services ltd.
2 Edward Court, George Richards Way, Altrincham, WA14 5GL
0161 923 0070 www.easl-stress.co.uk