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Performance-oriented and risk-based regulation for containment testing

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Abstract

In August 1992, the US Nuclear Regulatory Commission (NRC) began a major initiative to develop requirements for containment testing that are less prescriptive and more performance oriented and risk based than current requirements. This action was a result of public comments and several studies that concluded that the economic burden of certain present containment testing requirements was not commensurate with their safety benefits. The rule-making included considering relaxing the allowable containment leakage rate, increasing the interval for the containment integrated leak rate test, and establishing intervals for the containment local leak rate tests on the basis of the performance of containment isolation valves and penetrations. A study has been conducted to provide technical information to establish the preformance criterion for containment tests, i.e. the allowable leakage rate, commensurate with its significance to total public risk. For the study, the results used were from a comprehensive study conducted by the NRC (NUREG-1150, 'Severe accident risks: an assessment for five U.S. nuclear power plants') to examine the sensitivity of containment leakage to public risk. Risk was found to be insensitive to a containment leakage rate up to levels of about 100% volume per day for certain types of containments. Probabilistic risk assessment methods have also been developed to establish risk-based intervals for containment tests on the basis of experience. Evaluations show that increasing the interval for the integrated containment leakage test from three times to once every 10 years would have an insignificant impact on public risk. Analyses of operational experience data for local leak rate tests show that performance-based testing (valves and penetrations that preform well are tested less frequently) is feasible with a marginal impact on safety. These technical studies have been used to develop efficient (cost-effective) requirements for containment tests.

1. Introduction

The US Nuclear Regulatory Commission (NRC) published a notice in the *Federal Register* (NRC, 1992), presenting its planned initiative to begin eliminating requirements that are marginal to safety, yet impose significant regulatory burdens on licensees. In this continuing effort, the NRC will analyze existing regulations to eliminate or relax burdens on licensees when the burdens are not commensurate with the safety significance of the regulations.

In NRC (1992), the NRC concluded that decreasing the prescriptiveness of some regulations could increase their effectiveness, by giving the licensees the flexibility to implement more cost-effective safety measures. The regulatory process could also be made more efficient. To increase flexibility, the detailed and prescriptive technical requirements contained in some regulations could be improved and replaced with performance-based requirements and supporting regulatory

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guides. The regulatory guides would allow alternative approaches, although compliance with current detailed regulatory requirements would still be acceptable. The performance-based requirements would reward superior operating practices.

Containment leak testing was identified as an area in which regulations could be made more performance oriented. The primary safety objective in this area has been, and continues to be, containment integrity. However, information on reactor accident risks derived from probabilistic risk assessments (PRAs) indicates that the containment leak rates currently allowed can be increased without significantly affecting the accident risk. Although the availability and reliability of containment integrity are important, the extremely low leak rates prescribed by current regulations and the testing measures taken to ensure these extremely low leak rates may not be necessary. Reactor accident risk is dominated by low probability, high consequence scenarios in which the containment fails or is bypassed. In these types of accident, little benefit is derived from a high degree of containment leaktightness.

Economic and occupational exposure costs are directly related to the frequency of containment testing. Containment integrated leak rate tests (ILRTs) (Type A), by their nature, preclude any other reactor maintenance activities, so are on the critical path for return to service from reactor outages. In addition to the costs of the tests themselves, ILRTs impose the added burden of the cost of replacement power. Containment penetration leak tests (Types B and C) can be conducted during reactor shutdowns without interfering with other activities, so tend to be less onerous. However, the typically large number of penetrations imposes a substantial burden on the utilities.

2. Technical Studies

This section presents the technical studies (NRC, 1995a) in support of the information needs for the NRC's rule-making.

2.1. Risk

With respect to the risk to the public and workers, the key technical issue that a revised regulation in Appendix J to Part 50 of Title 10 ('Energy') of the Code of Federal Regulations (10 CFR) must address is: Can revised containment leak testing requirements have only a marginal impact on safety comparable with the level of safety achieved by the current requirements in Appendix J to 10 CFR Part 50?

Past studies (summarized in Fig. 1) based on the risk insights from WASH-1400 (NRC, 1975) and related studies have shown that overall population risks from severe reactor accidents are not very sensitive to the assumed containment leak rates, because the predicted reactor risks are dominated by accident scenarios in which the containments are predicted to fail, or in which the containments are bypassed.

The results of the recently completed effort, which are based on NUREG-1150 (NRC, 1990), although quantitatively different from the results of earlier studies, confirm the previous observations of the insensitivity of population risks from severe reactor accidents to containment leak rates. The differences between the earlier results and those of the study are because of different approaches, increased understanding of severe accident phenomenology, and significant advances in the state of the art in PRAs.

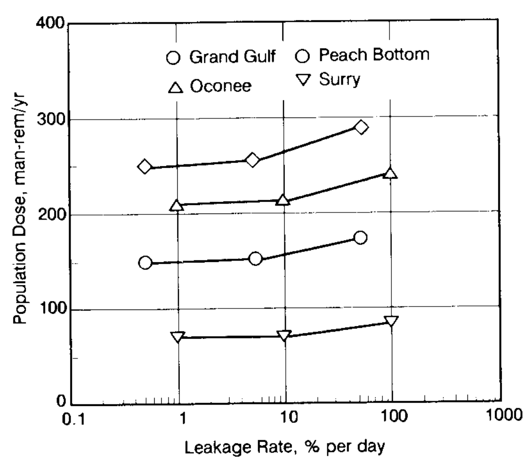

Fig. 1. Sensitivity of risk to containment leakage.

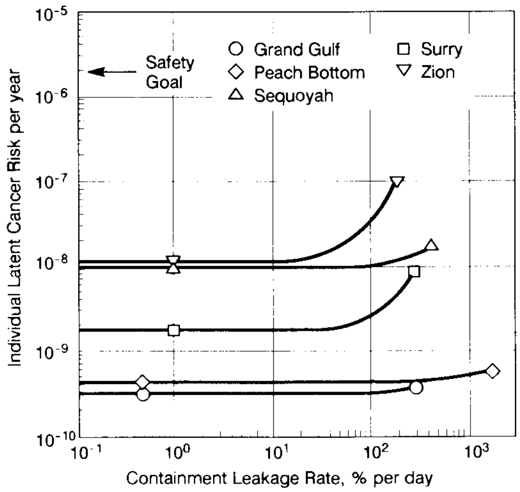

Fig. 2. Comparison of individual latent cancer risk with NRC safety goal.

The present effort includes comparisons of the predicted reactor accident risks as a function of the containment leak rate with the NRC's safety goal. Details of the analysis process are included in NURE. 1493 (NRC, 1995). As shown in Fig. 2, the calculated risks are well below the safety goal for all the reactors considered, even at assumed containment leak rates several orders of magnitude above current requirements. An uncertainty analysis was conducted (see NRC, 1995a) for the calculated risks from containment leakage and were found to be small compared with uncertainties of the risks from early containment failure.

2.1.1. Leak testing intervals

Using the above information, analyses indicate that reducing the frequency of Type A tests (ILRTs) from the current three every 10 years to one every 10 years was found to lead to an imperceptible increase in risk. The estimated increase in risk is very small, because ILRTs identify only a few potential contaiment leak paths that Type B and C testing cannot identify, and the leaks that have been found by Type A tests have been only marginally above existing requirements.

As assessment of Type B testing of electrical penetrations at a single station (two operating units) indicates that leaks through these penetrations are both infrequent and small (about 1% of the total allowable leak rate). Similar findings are reported in an industry survey of containment leak testing experience. The vast majority of leak paths are identified by local leak rate tests (LLRTs) of containment isolation valves (Type C tests). On the basis of the detailed evaluation of the experience at a single two-unit station, almost no correlation of failures with type of valve or plant service could be found. However, it has been possible to correlate failures with time and with repeated failures of individual components.

On the basis of a model of component failure with time, analyses indicate that performance-based alternatives to current local leak testing requirements are feasible without significant risk impacts. For example, the model suggests that the number of components tested could be reduced by about 60% with less than a threefold increase in the incremental risk caused by containment leakage. Since, under existing requirements, leakage contributes less than 1.0% of the overall accident risk, the overall impact is very small.

2.1.2. Allowable leak rate

Analyses indicate that the allowable leak rate can be increased by 1–2 orders of magnitude without significantly affecting the estimates of the population dose in the event of an accident. The PRA for Surry Unit 1 — which was performed assuming a containment leak rate a factor of 10 greater than the nominal 0.1% per day established in the plant's technical specifications — indicates that accident scenarios during which the containment does not fail and is not bypassed contribute only about 0.05% of the population risk from all core-melt accidents. Comparable or even lower risk contributions from leakage were found for other plants.

The impact of increased leak rates on routine airbourne effluent releases has not been quantitatively assessed. Doses from current airborne releases have been evaluated by the Environmental Protection Agency as resulting in doses of less than a few rem per year. Because only about 10% of containment penetrations constitute a potential direct pathway to the environment during the normal operating mode, impacts (if any) are likely to be small.

2.2. On-line monitoring systems

Continuous monitoring methods exist that appear to be technically capable of detecting leaks in reactor containments. Although on-line monitoring (OLM) does not have the accuracy of Type A testing, it does seem to offer enough accuracy and speed to detect gross leakage. It is capable of detecting leaks within 1 day to several weeks.

OLM can detect only gross containment leakage (NRC, 1988). It cannot detect leaks through systems that do not normally communicate with the containment atmosphere. Gross leaks are most likely to occur from systems left open, such as air locks, purge or vent pathways, or similar direct air path system valves or penetrations. Gross leaks may also occur from failures in isolation mechanisms in such systems.

OLM cannot be considered as a complete replacement for Type A tests, because it cannot challenge the structural and leaktight integrity of the containment system at elevated pressures. As noted for the Surry plant, containment isolation failure has been found to contribute approximately 0.05% of the total latent accident risk. Given this low contribution and the limitations of OLM systems noted above, the potential risk benefit of OLM appears to be quite limited.

French and Belgian utilities have installed OLM systems at their pressurized water reactor units and monitored containment leakage during power operations. They reported that these systems are capable of detecting leaks in the plant radiation monitoring system, nuclear island vent and drain system, containment purge system, and containment atmosphere monitoring system.

The usefulness of OLM systems depends on the resolution of several issues that require further evaluation. Specifically, the limitations are as follows:

(1) difficulty in accounting for the effect of temperature and moisture gradients and variations on the test results;
(2) the possibility of an actual leak being masked by containment air/gas in-leakage;
(3) the inability to account for leaks in closed pressurized systems inside the containment that would probably not be measured during OLM;
(4) potential 'false alarms' from OLM;
(5) the need for stabilized conditions in the containment during reactor operation.

3. Cost

With respect to cost, the key issue is: Can a revised containment testing rule, which has a marginal impact on safety, also significantly reduce the finanical burden on utilities?

Costs of Type A tests, which are performed on the critical path, are dominated by the cost of replacement power. Replacement power is estimated to account for almost 80% of the total costs of Type A testing. Reducing the frequency of ILRTs will reduce future industry testing costs by approximately US $330m–$660m if tests are conducted once every 10 years rather than the current three times every 10 years. These savings represent about 65% of the remaining costs of current Appendix J requirements. Performance-based LLRT alternatives are estimated to reduce future industry testing costs by $40m–$55m. These savings represent about 5% of the total remaining costs of Appendix J testing.

4. Conclusions

On the basis of the technical findings discussed above, the NRC has finalized a performance-oriented, risk-based revision to its containment testing requirements in Appendix J to 10 CFR Part 50 (NRC, 1995b). The revised regulation is accompanied by an industry guideline which will be utilized by licensees to implement the new regulation.

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