Item B-6: Loads, Load Combinations, Stress Limits

DESCRIPTION

Historical Background

This issue was identified as a generic problem in NUREG-0471[1] and concerns the design of pressure vessels and piping systems components which must be designed to accommodate individual and combined loads due to normal operating conditions, system transients, and postulated low probability events (accidents and natural phenomena). This issue became more controversial in recent years because postulated large LOCA and SSE loads were each increased by a factor of 2 or more to account for such phenomena as asymmetric blowdown and because better techniques for defining loading have been developed. The work efforts to investigate and establish a position on dynamic response combination methodology was completed and reported in NUREG-0484,[2] Revision 1. NUREG-0800,[3] Section 3.9.3, was revised to reflect the new position on load combinations and stress limits.[4] SEB concluded from studies completed (NUREG/CR-2039[5] and NUREG/ CR-1890[6]) that seismic loads and LOCA and SRV loads on containment structures should continue to be combined using the absolute sum method.[7] Hence, the only work remaining is research on decoupling LOCA and SSE events. It is on this aspect that this prioritization focuses. Reports on two investigations addressing this issue have been released: NUREG/CR-2136[8] and NUREG/CR-2189.[9]

The Code of Federal Regulations requires that structures, systems, and components that affect the safe operation of nuclear power plants be designed to withstand combinations of loads that can be expected to result from natural phenomena, normal operating conditions, and postulated accidents. An example load combination requirement mandated for nuclear power plants includes coupling the effects of SSE with a LOCA. In a recent evaluation, these combined loads were increased to further account for phenomena such as asymmetric blowdowns in PWRs and because improved techniques for defining loading have been developed.

These changes have raised questions concerning implementation of new regulations, increased construction costs, increased radiation exposure of maintenance crews performing increased inspection and maintenance actions, and reduced reliability of stiffer systems under normal operating transients.

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[1] NUREG-0471, "Generic Task Problem Descriptions (Categories B, C, and D)," U.S. Nuclear Regulatory Commission, June 1978.
[2] NUREG-0484, "Methodology for Combining Dynamic Responses," U.S. Nuclear Regulatory Commission, September 1978, (Rev. 1) May 1980.
[3] NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants," U.S. Nuclear Regulatory Commission, (1st Ed.) November 1975, (2nd Ed.) March 1980, (3rd Ed.) July 1981.
[4] Memorandum for W. Minners from R. Bosnak, "Comments on Generic Issue B-6," August 26, 1982. [8209280601]
[5] NUREG/CR-2039, "Dynamic Combinations for Mark II Containment Structures," U.S. Nuclear Regulatory Commission, June 1982.
[6] NUREG/CR-1890, "ABS, SRSS and CDF Response Combination Evaluation for Mark III Containment and Drywell Structures," U.S. Nuclear Regulatory Commission, June 1982.
[7] Memorandum for W. Minners from F. Schauer, "Generic Issue B-6," September 2, 1982. [8401170090]
[8] NUREG/CR-2136, "Effects of Postulated Event Devices on Normal Operation of Piping Systems in Nuclear Power Plants," U.S. Nuclear Regulatory Commission, May 1981.
[9] NUREG/CR-2189, "Probability of Pipe Fracture in the Primary Coolant Loop of a PWR Plant," U.S. Nuclear Regulatory Commission, September 1981.

Possible Solutions

Research Information Letter No. 117,[10] in addressing the probability of large LOCA-induced earthquakes, identifies the following results:

(1) Through-wall cracks are about a million times more likely to occur than double-ended guillotine breaks. This supports the leak before break hypothesis.

(2) Fatigue crack growth due to all transients, including earthquakes, is an extremely unlikely mechanism for inducing a large LOCA. The contribution of earthquakes to the occurrence of this unlikely event is a small percentage of the total probability.

(3) An upper bound estimate of the probability of asymmetric blowdown loads (resulting from rupture of in- cavity piping) due to direct and indirect mechanisms is 10^{-4} over the 40-year plant life, the primary contribution to this estimate being indirect seismically induced asymmetric blowdown. It is felt that the best estimate of the probability is several orders of magnitude lower.

While the described research was performed on PWRs, it is assumed that BWRs are similar for this analysis. This assumption may need revision if additional studies for BWRs are completed.

The proposed resolution for this issue is to decouple the SSE-LOCA load requirements. This would permit: (1) the removal of some snubbers, (2) the removal of pipe whip restraints, and (3) the deletion of the requirements for asymmetric blowdown analyses for forward-fit plants which would eliminate the additional stiffening of the reactor pressure vessel.

PRIORITY DETERMINATION

Assumptions

In the quantitative analysis of this issue by PNL,[11] it was assumed that there will be a small reduction in risk to the public due to the removal of appropriate snubbers in systems designed to withstand SSE + LOCA- induced loads. This reduction in system stiffeners should help preclude potential lockup of snubbers during normal operating transients, thus reducing large stresses on piping under normal operating conditions. The actual removing of equipment (snubbers and pipe restraints) will introduce an added (one-time) occupational dose for those plants having the devices installed. However, the deleted snubbers will result in a reduction in occupational exposure because inspection and maintenance will no longer be necessary on these deleted items. The removal of the pipe restraints will improve the access to many equipment items and, as a result, will reduce plant personnel time in high radiation areas for maintenance and inspection, providing a further reduction in occupational exposure.

The risk reduction and cost estimates are based on all reactors built since 1972 or yet to be constructed. Reactors constructed prior to 1972 did not have design requirements which included SSE, LOCA, and pipe cooling considerations.

Frequency/Consequence Estimate

It has been suggested that removing the snubbers required for the combined LOCA and SSE loads would reduce the stiffness and potential lockup of the snubbers during normal operation. This would result in a reduction in the probability of pipe rupture during normal operating transients (e.g., startup, thermal transients, etc.). The best estimate, by engineering judgment, is that the probability of pipe rupture would be reduced by 25% across the board. This estimate reduces S_1, S_2, and S_3, (the initiating event

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[10] Memorandum for H. Denton from R. Minogue, "Research Information Letter No. 117, "Probability of Large LOCA Induced by Earthquakes, April 10, 1981. [8104220512]

[11] NUREG/CR-2800, "Guidelines for Nuclear Power Plant Safety Issue Prioritization Information Development," U.S. Nuclear Regulatory Commission, February 1983, (Supplement 1) May 1983, (Supplement 2) December 1983, (Supplement 3) September 1985, (Supplement 4) July 1986, (Supplement 5) July 1996.

probabilities for the PWR) and the S value for the BWR by 25%. These changes, applied to the dominant cut sets, produced a change in

core-melt frequency which in turn reduced the frequency of each release category (e.g., PWR-1). The computed reduction in core-melt frequency is 6.4 x 10^{-6}/RY for PWRs and 1.2 x 10^{-6}/RY for BWRs. The reduction in frequency of the various release categories results in a public risk reduction for PWRs of 13 man-rem/RY

and a risk reduction for BWRs of 8.2 man-rem/RY. This public risk reduction when applied to the total reactor population lifetime results in a risk reduction of 31,700 man-rem for PWRs and 8,500 man-rem for BWRs, for a total of 40,200 man-rem.

Cost Estimate

Industry Cost: The total plant user cost estimate is based on the cost of engineering efforts to design the change, the labor costs to incorporate the change, and the increase in test and maintenance cost to maintain the equipment for the remaining plant life.

The implementation manpower requirements were based upon confirmatory analyses performed at PNL in conjunction with reviews prior to the granting of operating licenses.

The labor requirements per reactor for analyses and craft work is computed to be 360 man-weeks for PWRs and 391 man-weeks for BWRs, of which 250 man-weeks are utilized for the analysis of each type of reactor. This results in backfit implementation costs of $39.6M ($27.6M for PWRs and $12M for BWRs) and forwardfit costs of

$17.3M ($11.5M for PWRs and $5.8M for BWRs). Therefore, the total industry implementation cost is $56.9M.

It is assumed for the maintenance and operating costs that approximately 50% of the pipe snubbers associated with LOCA and SSE as well as many unnecessary pipe restraints can be removed following leak before break

concept. As reported in NUREG/CR-2136,[12] there are approximately 800 snubbers in a typical PWR and 950 snubbers in a typical BWR. If we assume that 50% are removed, then the number of snubbers removed is 400 in a PWR and 475 in a BWR.

Using labor hour estimates from NUREG/CR-2800,[13] it is calculated that a reduction in labor costs will be attained due to the decrease in the number of snubbers to be inspected and maintained. In addition, there will be improved access to pumps, valves, etc., due to the removal of pipe whip restraints.

The total estimated saving in labor time (inspection, testing, and maintenance) resulting from the deletion of snubbers and pipe restraints is calculated to be 1,120 man-hrs/RY or 28 man-weeks/RY for PWRs and 1,140 man-hrs/RY or 36 manweeks/RY for BWRs.

This results in an industry cost for operation and maintenance of -$53,800/ reactor for PWRs and -$69,000/ reactor for BWRs. For all reactors built since 1972, it results in operation and maintenance costs of -$57.9M for backfit PWRs, -$77.5M for forward-fit PWRs, -$26.7M for backfit BWRs, and -$47.6M for all forward-fit BWRs.

Thus, the total maintenance and operating costs are -$209.7M. Therefore, the total industry cost for this issue is as follows:

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[12] NUREG/CR-2136, "Effects of Postulated Event Devices on Normal Operation of Piping Systems in Nuclear Power Plants," U.S. Nuclear Regulatory Commission, May 1981.
[13] NUREG/CR-2800, "Guidelines for Nuclear Power Plant Safety Issue Prioritization Information Development," U.S. Nuclear Regulatory Commission, February 1983, (Supplement 1) May 1983, (Supplement 2) December 1983, (Supplement 3) September 1985, (Supplement 4) July 1986, (Supplement 5) July 1996.

Best Estimate	-$	152.3M
Upper Bound	-$	5.6M
Lower Bound	-$	300.0M

NRC Cost: The NRC costs for this issue are based upon the time used to review the proposed changes prior to the implementation of equipment modifications. It is estimated that the following support will be required:

Generic issue resolution	20 man-weeks
Backfit plant implementation	15 man-weeks/plant
Forward-fit plant implementation	10 man-weeks/plant

These manpower expenditures result in an NRC cost for development and implementation of $3.1M. There will be no change in NRC cost due to the review of operation and maintenance resulting from this change. Therefore, the total NRC cost for this issue is as follows:

Best Estimate	-$	$3.5M
Upper Bound	-$	$5.2M
Lower Bound	-$	$1.8M

Value/Impact Assessment

Based upon the best estimates of total risk reduction and industry NRC cost, the value/impact score is given by:

$$S = \frac{40{,}000\ \text{man} - \text{rem}}{\$3.5\text{M} + (-\$152.3\text{M})}$$

$$= -270\ \text{man} - \text{rem} / \$\text{M}$$

The negative value results from the reduced costs of operation and maintenance because of the deleted snubbers and pipe restraints.

Other Considerations

Of further importance to this issue is the reduction in ORE brought about by the reduction of work time to perform ISI in a radiation environment. An accumulated exposure of 1,100 man-rem/plant for PWRs and 1,410

man-rem/plant for BWRs is expected in the removal of snubbers and pipe restraints.[14] For all backfit

[14] NUREG/CR-2800, "Guidelines for Nuclear Power Plant Safety Issue Prioritization Information Development," U.S. Nuclear Regulatory Commission, February 1983, (Supplement 1) May 1983, (Supplement 2) December 1983, (Supplement 3) September 1985, (Supplement 4) July 1986,

plants, this results in an exposure of 4.5 x 10^4 man-rem for all PWRs and 2.26 x 10^4 man-rem for BWRs. The removal of snubbers and the elimination of pipe restraint removal to accomplish pipe inspections is estimated to save 1,120 man-hours/year/plant for PWRs and 1,440 man-hours/year/plant for BWRs in maintenance and operation time in radiation environments. For all applicable reactors' lifetimes, this accumulated exposure reduction is calculated to be 6.77 x 10^5 man-rem for PWRs and 3.68 x 10^5 man-rem for BWRs. This results in a total reduction in ORE of 9.8 x 10^5 man-rem.

CONCLUSION

This issue was given a high priority issue because both risk and cost had a large potential for reduction. Since no pipe failure due to excessive restraint had been reported up to the time of prioritization, the estimated 25% reduction in pipe break frequency and public risk may be overstated. It was concluded that, even if the risk reduction were less and some costs were incurred rather than saved, the priority would still be high.

Research completed for **W** and CE plants showed that the yearly probability of having a large LOCA induced directly by seismic loads was no greater than 10^{-10}; the yearly probability of having a LOCA induced indirectly by structure or support failures under seismic loads was found to be 10^{-6}. Based on the research results, the staff proposed a position that would decouple SSE and LOCA for all PWR primary loops. Research work for decoupling of LOCA and SSE loads for GE plants was also performed; indications were that pipe rupture probabilities in GE reactor coolant loops are substantially greater than in any of the PWR loops. Inaddition, a limited application of the leak-before-break hypothesis for PWR main coolant loops in 16 **W** Owners' Group plants, based on deterministic fracture mechanics analysis, was approved in Generic Letter 84-04. For decoupling of SSE and LOCA loads, the probability of a LOCA occurrence due to an earthquake was to be addressed in the resolution of Issue 119.1, "Piping Rupture Requirements and Decoupling of Seismic and LOCA Loads," with a possible revision to SRP1l Section 3.9.3. In January 1987, all staff work on the resolution ofItem B-6 was terminated because of the parallel effort in addressing decoupling of SSE and LOCA loads in the resolution of Issue 119.1.[15] Thus, the resolution of Item B-6 is covered in Issue 119.1.

(Supplement 5) July 1996.

[15] Memorandum for K. Kniel from R. Bosnak, "Request for Subsumption of Generic Issue B-6 (GI B-6) Into Generic Issue 119.1 (GI 119.1)," January 8, 1987. [8701200186]