Safety Balance for the Elimination of Reactor Coolant System Main Loop Pipe Break Protective Devices

Vogtle Electric Generating Plant

Units 1 and 2

Prepared for

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by

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I. Introduction

This report presents a safety balance evaluation of the consequences of eliminating the protective devices currently employed in the design of the Vogtle Electric Generating Plant, Units 1 and 2 (VEGP) to mitigate dynamic effects associated with postulated breaks in the reactor coolant system (RCS) main loop piping. This assessment uses methods suggested in the "Leak Before Break Value-Impact Analysis" attached to the Nuclear Regulatory Commission's (NRC) Generic Letter 84-04 (Reference 1). Plant specific data and the generic data developed in Reference 1, as well as various public documents, are used to perform the safety balance evaluation for VEGP. The evaluation is performed in terms of public health and occupational accident risk avoidance attributable to the protection provided for dynamic effects associated with postulated breaks in the RCS primary loop versus the reduction in Occupational Radiation Exposure (ORE) resulting from a decision not to use such protection.

The man-rem savings is presented in tabular form and listed as lower, upper, and nominal values. These represent the range of values expected at VEGP; however, there are conservatisms included in the analysis of the ORE which tend to lower the estimated man-rem savings over the entire range of values. These are explained as follows:

A. The man-rem savings associated with not installing jet impingement barriers are not included in this analysis. The elimination of jet impingement barriers and associated supporting structures will result in increased work efficiency due to improved access for

maintenance. These factors are not considered in this analysis. Only man-rem savings associated with not installing pipe whip restraints are analyzed.

B. Conservatively low estimates of man-rem exposures are used when calculating the total exposure due to the removal and reinstallation of pipe whip restraints for access to perform inservice inspection (ISI). It is assumed that it takes two persons, two shifts to remove each pipe whip restraint and another two shifts for reinstallation. The expected exposure rates in the vicinity of the reactor coolant piping are in the range of 0.02 to 0.2 rem/hr. This corresponds to an expected dose of 1.3 to 12.8 rem per restraint per ISI. 40 man-rem per restraint per ISI is used as a maximum based on industry experience. The 1.0, 10 and 40 man-rem per restraint per ISI values used in this analysis are conservative when compared to the expected values based on expected dose rates near reactor coolant piping.

C. Conservatively low estimates of the increased work efficiency due to improved access for ISI or maintenance (based on fewer interferences with the pipe whip restraints and supporting structural members) are used. An increased work efficiency of 1% is used for ISI and reactor coolant pump (RCP) maintenance. Actual increases in work efficiency are expected to exceed 10% when considering the instruments and equipment that must be manipulated during these activities and the general difficulty of working in protective clothing. An increased work efficiency of 5% (with a low of 1% and a high of 10%) is used

for special maintenance of the steam generator. This value is higher than the ISI and RCP maintenance value of 1% due to the close proximity of two of the pipe whip restraints to the area below the steam generator. However, it too is anticipated to be greater than 10%, and may be as high as 20%, when considering the tightness of this area and the need to manipulate the type of equipment necessary for performing tube plugging, tube welding, and sludge lancing while wearing protective clothing.

As these conservatisms affect values which are the major contributors to the man-rem savings, the overall analysis is similarly conservative in its expression of man-rem savings.

II. Safety Balance Assessment Summary and Conclusions

A summary of the results of the safety balance is shown below. The nominal dose estimates support the request to not require consideration of the dynamic effects of pipe breaks in the RCS main loop in the VEGP design basis.

Value (man-rem)	Nominal Estimate	Lower Estimate	Upper Estimate
Public Health[a]	-1.0	-8	0
Occupational Exposure (Accidental)[a]	-0.3	-5	0
Occupational Exposure (Operational)			
a) Inservice Inspection	649	68	2576
b) Maintenance	79	14	221
Total Quantified Value	727	69	2797

(a) The estimates shown here are given in negative terms to reflect the decrease in man-rem savings. The upper and lower estimates are transposed from the values presented in section III.A to reflect a more conservative estimate of the total quantified upper and lower values by presenting larger upper estimates and smaller lower estimates.

III Development of Safety Balance

A. Risk Avoidance Attributable to Protection from Dynamic Effects Associated with Pipe Breaks

1. Public Health

Dose estimates derived in Reference 1 are found to be conservative and bound the results calculated for VEGP for the following reasons:

a. Reference 1 assumed a uniform population density of 340 people per square-mile around the reactor site and a 50-mile release radius model. The expected average population density at the VEGP site is 117 people per square mile in the year 2028. A total of 99.7 percent of that population is expected to live between 10 to 50 miles away from the plant (Reference 3, Section 2.1).

b. As calculated in Reference 1, the off-site population doses are 5.4×10^6 man-rem, 4.8×10^6 man-rem, 5.4×10^6 man-rem, 2.7×10^6 man-rem, 1.0×10^6 man-rem, 1.5×10^5 man-rem, and 2300 man-rem for the seven WASH-1400 release categories. The calculated offsite population dose from a large LOCA at the VEGP site is 3.26×10^3 man-rem thyroid dose and 13.6 man-rem whole body dose (Reference 3, Section 7.1).

The nominal estimate of added risk to public health for plants that use a two-loop configuration was estimated to be 0.006 man-rem/plant year (py) in Reference 1. For VEGP this number is adjusted to account for the four loop design. This results in a nominal risk of:

$$\text{Risk} = \frac{4}{2} \times 0.006 = 0.012 \text{ man-rem/py.}$$

Upper estimate risk calculations are made using procedures similar to those of the nominal estimates. No corrections are necessary for the number calculated in reference 1 because this frequency is per plant year and not based on the number of loops. The upper estimate risk is:

$$\text{Risk} = 0.1 \text{ man-rem/py.}$$

The lower estimate is assumed to be 0.

Multiplying each of the risk calculations by the number of years of expected plant life (2 plants x 40 yr = 80 py) results in the VEGP public risk increase of:

	Total Added Risk (man-rem)
Nominal Estimate	1.0
Upper Estimate	8.0
Lower Estimate	0

The nominal estimate from Reference 1 of the total increase in core melt frequency for not providing protection against dynamic effects associated with pipe breaks is used and adjusted for the larger number of loops in the VEGP design. This results in a core melt frequency increase of:

$$\text{core melt frequency increase} = \frac{4}{2}\ 01 \times 10^{-7}o = 2 \times 10^{-7}$$

The upper estimate of core melt frequency increase of 2 x 10^{-6}/py (Reference 1) is applicable for the VEGP analysis. No correction for the number of loops is necessary because this number is per plant year. A lower estimate of 0 is used for VEGP. The resulting total core melt frequency increase estimates are as follows:

	Increase in Core Melt Frequency (events/py)
Nominal Estimate	2 x 10^{-7}
Upper Estimate	2 x 10^{-6}
Lower Estimate	0

Probabilistic analysis of the potential for increased risk to the public health due to the increase in core melt frequency demonstrates that there is no credible increase in the risk to public health. Because of the uncertainties in the core

melt frequency estimates (References 6 and 7), the increase in core melt frequency is not statistically significant enough to establish a credible difference in the core melt frequency and hence the estimated added risk to public health.

2. Occupational Exposure (Accidental)

The increased occupational exposure from accidents is estimated to be the product of the change in total core melt frequency and the occupational exposure likely to occur in the event of a major accident. The nominal change in core melt frequency was estimatated as 2×10^{-7} events/py. The occupational exposure in the event of a major accident has two components. The first is the "immediate" exposure to the personnel onsite during the span of the event and the time necessary to achieve short term control. The second is the longer term exposure associated with the cleanup and recovery from the accident.

The total avoided occupational exposure is calculated as follows:

$$D_{TOA} = NTD_{OA}; \; D_{OA} = P(D_{IO} + D_{LTO})$$

where

D_{TOA} = Total avoided occupational exposure

N = Number of affected facilities = 2

T = Average plant lifetime = 40 yrs.

D_{OA} = Avoided occupational dose per reactor year

P = Change in core melt frequency

D_{IO} = "Immediate" occupational exposure

D_{LTO} = Long-term occupational exposure

Results of the calculations are shown below. Uncertainties are conservatively propagated by the use of extremes (e.g., upper bound D_{TO} + upper bound D_{LTO}).

	Increase in Core Melt Frequency (events/ plant-yr	Immediate[a] Occupational Exposure (man-rem/ event)	Long Term[a] Occupational Exposure (man-rem/ event)	Total Avoided Occupational Exposure (man-rem)
Nominal Estimate	2×10^{-7}	1×10^{3}	2×10^{4}	0.3
Upper Estimate	2×10^{-6}	4×10^{3}	3×10^{4}	5
Lower Estimate	0	0	1×10^{4}	0

(a) Based on cleanup and decommissioning estimates, Reference 2.

B. Reduction in Occupational Radiation Exposure (ORE) Resulting from a Decision Not to Use Protection Against Dynamic Effects Associated with Pipe Breaks.

1. Occupational Exposure - Operational

a. Inservice Inspection (ISI)

Review of the VEGP design indicates that the RCS pipe whip restraints are located such that there is sufficient access to the RCS piping welds for performing ISI, with the exception of the crossover leg pipe whip restraints. There are some interferences posed by the crossover leg pipe whip restraints during ISI and it is assumed that they must be removed to facilitate crossover leg piping weld ISI which is required four times over the life of the plant (once

every 10 years). Industry experience shows that the radiation exposure associated with removal and reinstallation of the crossover leg pipe whip restraints ranges from 1 man-rem to 40 man-rem per restraint per ISI with a nominal value of 10 man-rem per restraint per ISI. Since in the VEGP design there are eight pipe whip restraints per unit which require removal, the nominal reduction in ORE for not installing these pipe whip restraints is estimated as follows:

$$\text{reduction in ORE} = 2 \text{ units} \times 8\frac{\text{restraints}}{\text{unit}} \times 10\frac{\text{man-rem}}{\text{ISI, restraint}} \times 4\frac{\text{ISI}}{\text{plant life}}$$

$$= 640 \text{ man-rem}$$

The upper estimate is based on a 40 man-rem dose per ISI per restraint. The lower estimate is based on a value of 1 man-rem per ISI per restraint.

In addition, with all the RCS pipe whip restraints and supporting structural members removed, improved access is provided for ISI of the following:

1) Reactor coolant piping (including removal and reinstallation of the insulation from the vessel nozzle and coolant piping)

2) Steam generator welds (lower shell)

3) Steam generator tube eddy current testing

The annual radiation exposure for performing the above ISI is estimated to be 11.65 man-rem averaged over a 10 year period (Reference 4, Table 12.4.1-11). It is further estimated that removal of the pipe whip restraints will provide improved access and increase the inspection efficiency by 1 percent. Therefore, the nominal reduction in ORE due to improved access for ISI is:

reduction in ORE = 2 units x 0.01 x 11.65 man-rem/yr x 40 yr.
= 9 man-rem

The upper and lower estimates are based on engineering judgement that the exposures will be 20 man-rem/yr and 5 man-rem/yr, respectively.

The total reduction in ORE for operational occupational exposure due to ISI if the pipe whip restraints are not installed is:

	Occupational Radiation Exposure (man-rem)
Nominal Estimate	649
Upper Estimate	2576
Lower Estimate	68

b. Maintenance

1. Routine Maintenance

a) During power operation

There is no identifiable routine maintenance activity which must be performed inside the steam generator compartment or primary shield wall where the RCS pipe whip restraints are located. However, as a good practice, the utility anticipates performing pipe whip restraint gap verification once every 10 years. It is estimated that an average exposure of 0.1 man-rem will result from gap verification of one pipe restraint. There are 24 pipe whip restraints per unit at VEGP. The nominal reduction in ORE for not installing pipe whip restraints, and thus not performing gap verification is:

$$\text{reduction in ORE} = 2 \text{ units} \times 24 \frac{\text{restraints}}{\text{unit}} \times \frac{4 \text{ verifications}}{\text{plant life}}$$

$$\times\ 0.1 \frac{\text{man-rem}}{\text{restraint, verification}}$$

$$= 20 \text{ man-rem}$$

The upper and lower estimates are based on engineering judgement that the exposures will be 0.5 man-rem and 0.01 man-rem per restraint per verification, respectively.

b) During Refueling

Routine maintenance will be required on the reactor coolant pump (RCP) seals. As outlined in NUREG-0933 (Reference 5) each RCP is expected to require maintenance once every 2 years, resulting in a nominal exposure of 7 man-rem per maintenance activity. Assuming that pipe whip restraint removal will increase efficiency by 1 percent, the nominal reduction in ORE due to improved access is:

$$\text{reduction in ORE} = 2 \text{ units} \times 4 \frac{\text{RCPs}}{\text{unit}} \times 0.5 \frac{\text{maintenance activity}}{\text{RCP, year}} \times 40 \text{ yr}$$

$$\times\ 0.01 \times 7 \frac{\text{man-rem}}{\text{maintenance activity}}$$

$$= 11 \text{ man-rem}$$

The upper and lower estimates are based on engineering judgement that the exposures will be 15 man-rem and 1 man-rem per RCP maintenance activity, respectively.

2. Special Maintenance

Substantial improvement in access may be realized for the following special maintenance activities if the pipe whip restraints on the crossover leg and vertical piping at the outlet of the steam generator are eliminated from VEGP:

a) Steam Generator tube plugging

b) Steam Generator tube welding

c) Sludge lancing

The annual exposure from performing the above special maintenance activities is estimated to be 12.1 man-rem averaged over a 10 year period (Reference 4, Table 12.4.1-11). It is assumed that the removal of the pipe whip restraints will provide improved access and increase work efficiency by

5 percent. Therefore, the nominal reduction in ORE due to improved access for special maintenance is:

$$\text{reduction in ORE} = 2 \text{ units} \times 0.05 \times 12.1 \frac{\text{man-rem}}{\text{yr}} \times 40 \text{ yr} = 48 \text{ man-rem}$$

The upper and lower estimates are calculated based on assumed work efficiency improvements of 10 percent and 1 percent, respectively.

The total reduction in ORE for operational occupational exposure due to maintenance if the pipe whip restraints are not installed is:

	Occupational Radiation Exposure (man-rem)
Nominal Estimate	79
Upper Estimate	221
Lower Estimate	14

IV. References

1. U.S. NRC Generic Letter 84-04 "Safety Evaluation of Westinghouse Topical Reports Dealing with Elimination of Postulated Pipe Breaks in PWR Primary Main Loops" dated February 1, 1984.

2. NUREG/CR-2601, "Technology, Safety and Costs of Decommissioning Reference Light Water Reactors Following Postulated Accidents," November 1982.

3. Vogtle Environmental Report, sections 2.1 and 7.1

4. Vogtle FSAR, section 12.4

5. NUREG 0933, "A Prioritization of Generic Safety Issues," 3/31/83

6. WASH 1400 (NUREG-75/014) "Reactor Safety Study," October 1975

7. German Risk Study, NRC Translation 729, May 1980