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January 21, 1985

Mr. Harold R. Denton, Director
Office of Nuclear Reactor Regulation
U.S. Nuclear Regulatory Commission
Washington, DC 20555

Subject: Byron Generating Station Unit 1
Fluid Jet Impingement Analyses
NRC Docket No. 50-454

Reference (a): August 16, 1984 letter from D. L. Farrar to J. G. Keppler.

Dear Mr. Denton:

This letter is intended to fulfill the requirements of License Condition C(16) of the Byron 1 Operating License, NPF-23. NRC review of this information is needed prior to the authorization of operation at power levels exceeding 5% power.

Attachment A to this letter explains the use of NUREG/CR-2913, "Two Phase Jet Loads", in the review of the design of Byron Station which was provided in reference (a). This document was developed specifically to address the issues identified in License Condition C(16). Please address further questions to this office.

One signed original and fifteen copies of this letter and the attachment are provided for NRC review.

Very truly yours,

T. R. Tramm

T. R. Tramm
Nuclear Licensing Administrator

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cc: Byron Resident Inspector

Attachment

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USE OF NUREG/CR-2913

NUREG/CR-2913, "Two Phase Jet Loads," is a document which provides a methodology for calculating HELB fluid jet loads on targets located at various distances from jet sources for different fluid properties. Sandia National Laboratory created the methodology to be consistent with test data obtained from various facilities. This data simulated typical nuclear plant high energy line conditions and the resultant methodology is also consistent with EPRI-NP-3419. The methodology in NUREG/CR-2913 is considered to be the best available representation of the configuration of a steam or two phase jet and the resulting force on objects or surfaces near the break location. NUREG/CR-2913 does not address non-flashing subcooled liquid jets.

The Byron design includes many features which eliminate or mitigate damaging effects of postulated High Energy Line Breaks (HELB's). These features include design, routing, and locations of the high energy lines and the safety systems. As noted in the FSAR (Section 3.6.1.1.2) the basic design preceded NUREG/CR-2913 and also the Standard Review Plan (NUREG-75/087). The design does follow the SRP to the extent practicable in that the requirements of General Design Criteria (GDC) 4 of 10CFR50 are addressed by the design approach. This design approach follows the guidelines of Branch Technical Position APCSB 3-1 (Section 3.6.1 of the Standard Review Plan (SRP)). These guidelines state that plant designs should protect essential systems and components from the effects of high energy line failure. The preferred method of protection is separation of essential systems from HELB's by adequate distances or by structures. In the event separation cannot be used, redundant design features which are protected should be provided. If this separation or redundancy cannot be provided restraints or barriers must be incorporated to protect essential systems.

The Byron design approach centered around the early identification of the systems used for safe shutdown as well as the systems used to support safe shutdown systems. These systems were designed with adequate redundancy and functional diversity to insure that postulated events and single failures would not result in a loss of safe shutdown capability. This design was accomplished by providing separation between redundant equipment. Additional protection from HELB effects was provided by separating high energy lines from safe shutdown systems by distance or by structures (such as pipe tunnels). These separation approaches provide a high degree of protection from HELB effects such as pipe whip and jet impingement.

The Auxiliary Building compartmentalization lends itself to the separation discussed above. The auxiliary building structural walls and floors were designed to withstand the applicable jet impingement loads, calculated in accordance with FSAR Section 3.6.2, so that separation is maintained. More specifically, design jet loads were calculated based on Sargent & Lundy Technical Procedure No. 24 which is an application of ANS 58.2.

The Containment Building contains fewer structural barriers and, as a result, protection is, in some cases, provided by separation of HELB's from essential components by distance or separation of redundant essential components by distance. Piping systems inside containment are separated as a direct result of the 4-loop Westinghouse PWR layout. Each primary loop is located in a different quadrant of the containment. Shield walls, which are capable of withstanding dynamic pipe rupture loads, separate the primary from the secondary loops.

At the time electrical cables and instrument sensing lines were being routed, methodology was not available to realistically predict the extent of jet forces. In order to proceed with the design, a guideline was established for separation of redundant safe shutdown components. A separation distance of 20 feet was established. The basis for this separation distance is the very low probability of a line breaking and causing a jet that could damage two redundant cables or lines when these lines are separated by more than 20 feet. This probability is low because the breaks are postulated at discrete locations and the area affected (assuming a 10^{o} half angle per ANS 58.2) prior to reaching a significant structural component is unlikely to include two components separated by 20 feet or more. Any limitations which can be placed on jet force (beyond the effect of jet area increase) will further reduce the probability of damage.

It should be noted that this approach was only applied to dynamic effects. Environmental qualification was required for safe shutdown equipment regardless of proximity to break locations.

NUREG/CR-2913 was not used in the design of the Byron Station. However, it was utilized in the Byron design verification study completed in August 1984. The NUREG was used as additional justification for a "screening" criteria to identify the potentially important effects of jet impingement, and, in a few cases described later, to calculate jet loads on components.

Each component required for safe shutdown of the plant after a HELB was identified and the potential for jet impingement was reviewed. Many of the components could be easily shown to be unaffected because they were protected by structural barriers, or were located such that a jet would not be oriented in the proper direction to strike the component.

Most of the components which are not obviously protected as described above are widely separated from redundant components. To avoid the lengthy process of checking lines of sight from all postulated break locations for all safe shutdown components to verify that no single jet could unacceptably damage the redundant components of a system, a screening criteria was defined to limit the review to those jets and components which could be actual concerns. NUREG/CR-2913 predicts very low loads for all applicable break conditions when the component is separated from the break by more than 10 break diameters.

Although the NUREG indicates lower loads than the methodology endorsed by the Standard Review Plan, the differences are not very significant for most of the applicable situations with separation greater than 10 break diameters. The NUREG is applicable to steam breaks and liquid breaks which flash. Most breaks are liquid. Following the Standard Review Plan and ANSI N176 the flashing liquid break jet loading would be less than 20 psi. Loads in this range would not be expected to damage components such as structure and piping which may not be redundant. The steam line breaks, following ANSI N176, would result in a loading of up to 100 psi 10 diameters from the break. However, the only large steam breaks inside Containment are in the main steam piping which is removed from most safe shutdown components. The main steam lines exit the top of the steam generators and travel to the containment wall through a partially enclosed piping chase which limits the jet effects. Because of the arrangement of the piping, only the arbitrary intermediate breaks are near safe shutdown components. NUREG/CR-2913 also shows that the ANSI N176 predictions for steam jet loading beyond 10 break diameters is excessively conservative.

The screening criteria was used to divide the Verification Procedure into steps. Potential pipe movement due to pipe whip was considered as well as jet spreading as predicted by NUREG/CR-2913. The components were considered undamaged by jet impingement if they were located more than a distance of ten diameters of the broken pipe away from the jet source. Components within ten pipe diameters were assumed to fail. Specific load calculations were done using NUREG/CR-2913 only in those instances where failure of all components, when combined with a limiting single active failure, could adversely affect safe shutdown capability. Because the design approach utilized separation to a large extent, the number of specific calculations utilizing NUREG/CR-2913 were very few. No safe shutdown equipment or cabling required specific calculations. A limited number of instrumentation lines were shown to be loaded with insignificant loads despite being within 10 diameters of a break. These instrument lines are identified in Appendix B of the Confirmatory Jet Impingement report. The break in question in each of these cases was an arbitrary intermediate break which will be eliminated when the Commonwealth Edison submittal of November 15, 1984 is approved.

Four breaks were identified which could impinge upon piping that is required to be functional following the specific HELB's. All four of these breaks are arbitrary intermediate breaks. Also, in all cases, the target pipe was of equal or greater diameter and schedule than the failed pipe. Although the NRC guidelines for pipe whip analysis would preclude the potential for damage to the target pipe, the effects of the jet impingement load was evaluated. Two of these cases involved failure of a Safety Injection accumulator line and were evaluated using the methodology in ANS 58.2. The other two were Feedwater line breaks and were evaluated using NUREG/CR-2913. In all four cases the design of the target pipe was shown to be adequate. Structural steel was also reviewed to determine if jet impingement loads could potentially cause failures which would result in a loss of structural integrity. Nineteen structural steel elements were identified using the screening procedure described above. All but two of these items were affected by jets predicted from arbitrary intermediate breaks only. Loads were calculated and assessed using NUREG/CR-2913 for all nineteen elements. The existing design was shown to be adequate in all cases.

The two structures loaded by jets from postulated terminal end breaks were reviewed in more detail. The separation between the break and targets for these cases was 7.8 and 8.4 break diameters. The load was recalculated for the closest case (7.8D) using methodology consistent with the Standard Review Plan. This calculated load was 14% higher than the load, calculated using NUREG/CR-2913. The structure was shown to be adequate using the higher load.

The utilization of NUREG/CR-2913 leads to a conservative assessment of the design adequacy. Although the load predictions should be considered "best estimate" loads, the screening criteria is conservative because, for the applicable system conditions, loads generally become negligible at distance of less than 10 break diameters. In those cases where loads were calculated, data was used corresponding to the maximum conditions in the system. Pressure losses due to the high break flow velocity are usually very significant but were not considered for the confirmatory study.

As noted, most components were evaluated and found acceptable not on the basis of separation from the break, but because failure will not affect safe shutdown capability. This was demonstrated even though credit was not taken for some potential shutdown methods (primary system feed and bleed, equipment repair, use of non-qualified equipment).

The limited number of components within the screening distance is a result of the basic design approach used. As demonstrated by the results of the confirmatory study these components are generally affected only by intermediate breaks, which is also a result of the design approach. If arbitrary intermediate breaks are eliminated, only two structural steel beams would remain within the NUREG/CR-2913 screening distance. These beams have more than adequate margin for the predicted loads as described earlier.