UNITED STATES
NUCLEAR REGULATORY COMMISSION
ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
WASHINGTON, D. C. 20555

September 10, 1997

Mr. L. Joseph Callan
Executive Director for Operations
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555-0001

Dear Mr. Callan:

SUBJECT: BOILING WATER REACTOR PRESSURE VESSEL SHELL WELD INSPECTION RECOMMENDATIONS (BWRVIP-05)

During the 444th meeting of the Advisory Committee on Reactor Safeguards, September 3-5, 1997, we reviewed the BWRVIP-05 report and the associated staff interim Safety Evaluation Report. During this review, we had the benefit of discussions with representatives of the NRC staff and of the documents referenced. Our subcommittees on Materials and Metallurgy and on Severe Accidents also reviewed this matter during a meeting on August 26, 1997.

The Commission has required in 10 CFR 50.55a(g)(6)(ii)(A)(2) that all boiling water reactor (BWR) and pressurized water reactor (PWR) vessel weld inspections comply with the requirements specified in Item B1.10 of Examination Category B-A, "Pressure Retaining Welds in Reactor Vessel," in Table IWB-2500-1 of subsection IWB of section XI, Division 1, of the ASME Boiler and Pressure Vessel Code. The requirement is for 100-percent inspection of all welds. The requirement for 100-percent inspection represents the culmination of a consistent, conservative shift that has occurred over the years in the ASME Code requirements. Licensees with BWRs are requesting that the requirement be modified to allow inspections of only axial welds in the vessel.

The reactor vessel is a fundamentally important barrier to prevent the release of radionuclides from a nuclear power plant. It is essential that there be very high confidence in the integrity of vessel welds to have confidence in the plant safety. Compliance with the requirements for 100-percent inspection of all reactor vessel welds can be viewed as an element of the defense-in-depth regulatory philosophy to ensure protection of the public.

The NRC staff and industry agree that welds in BWR vessels are, on the whole, less vulnerable to inservice failure than welds in PWR vessels. The PWR vessels, however, have, in general, received 100-percent inspection of all welds in accordance with the code requirements and thus have an additional degree of assurance against the existence of gross defects. The lower vulnerability of the BWR vessel welds is due primarily to the lower probability of events that pose threats to the welds and to the lower neutron fluences to the vessel walls.

Reactor vessel welds were inspected during fabrication using radiography, magnetic particle, and dye penetrant methods, which are effective for detecting flaws that break the metal surface and volumetric defects. These methods are insensitive for detecting subsurface, crack-like flaws. During fabrication, some welds were even inspected using ultrasonic techniques of the day that are inferior to techniques now available.

The prudency of inservice vessel weld inspections in BWRs does not appear to be a contentious issue. Both the staff and industry agree that it is necessary to ensure against inservice degradation such as stress corrosion cracking and to mitigate concerns that undocumented repairs, which could introduce defects, may have been made to the welds. The contentious issue is how complete must be the inspection and whether anything less than 100-percent inspection of all welds will erode defense-in-depth. The staff and industry calculations show that the failure probabilities of reactor vessels due to fabrication flaws in circumferential welds are very low ($< 10^{-8}$/yr). Inspection lowers these failure probabilities by about a factor of three. Since the failure probabilities are already so low, there is little contribution to defense-in-depth from inspection of these welds.

Industry argues that inspections should focus on the axial welds, since these pose the most risk. The proposed 100-percent inspection of the axial welds, which constitute about 40-percent of the total welds, provides assurance against inservice degradation. The results of the analyses performed by the staff, although not directly comparable to those done by the industry, support the conclusion that circumferential welds are orders of magnitude less vulnerable to inservice failures than axial welds.

The industry proposal to inspect less than 100-percent of the vessel welds is essentially a request for a change in the current licensing basis for BWRs as a class. This request should be handled using the risk-informed process now being developed by the NRC staff. The staff appears to be proceeding in accordance with the guidance in proposed Regulatory Guide DG-1061, "An Approach for Using Probabilistic Risk Assessment in Risk-Informed Decisions on Plant-Specific Changes to the Current Licensing Basis," subject to the constraint that the defense-in-depth regulatory philosophy is preserved. The analyses performed to date by the staff and industry appear to suggest that the relaxed inspection requirements produce minimal changes in risk.

Some additional efforts are needed, however, to address uncertainties associated with these analyses, such as showing that flaw size distributions input to the models are justifiable and consistent with available data, including those obtained in past inspections of the welds.

Data from inspections of welds in PWR vessels may also be of use in the definition of realistic flaw distributions. The adequacy of the Marshall flaw size distribution, which is used by both the staff and industry in probabilistic fracture mechanics calculations, needs careful consideration. This distribution predicts that the fraction of flaws larger than a specific size decreases exponentially with flaw size. It is this exponential decrease that is chiefly responsible for the very large differences in failure probability between axial and circumferential welds. It is not clear that the experts who formulated this distribution as a bound on the frequency of large flaws intended for the distribution to be used to compare the relative frequencies of the approximately 2 cm flaws that lead to failure in axial welds and the approximately 4 cm flaws that lead to failure in circumferential welds. Indeed, models like RR-PRODIGAL suggest that the frequency of large flaws does not decrease exponentially with flaw size, although the departure from the exponential behavior may occur only for flaw sizes greater than those responsible for the large differences in failure probabilities between axial and circumferential welds.

The uncertainty in the nature of the flaw distribution is the most critical factor in determining the relative probability of failure between circumferential and axial welds. Additional uncertainties need to be addressed to more accurately assess the actual failure probabilities of BWR vessel welds. To address such uncertainties, a comprehensive analysis is needed of accident sequences that pose threats to the welds. Careful consideration should be given to operator actions that affect the probability of challenges to the integrity of BWR vessel welds. The uncertainty analysis should address conservatisms inherent in existing calculations, including the assumptions that weld flaws penetrate through the cladding and that all flaws are located on the inner surface of the vessel.

The staff should consider the relative value of partial inspections of the welds. In truth, 100-percent inspection of welds will seldom be practicable because equipment configurations in BWRs will limit access to some welds. Limitations in the capability to detect flaws by inspections need to be recognized as well.

It may not be possible to make risk-informed decisions concerning inspections of BWR vessel welds as a class. Decisions will probably have to be made on a plant-specific basis. The probability of vessel failure by loss of weld integrity will be dependent on irradiation-induced embrittlement of the vessel and the frequency of challenges to weld integrity. In this regard, we encourage the staff to continue development of a database on vessel embrittlement specific to BWRs.

The staff and industry analyses done to date consider only the 40-year licensing life. These analyses show that conditional risks of vessel failure increase rapidly in the later years of plant life. Indeed, the failure probabilities at the end of 40 years of plant life are predicted for some plants to be surprisingly high, approaching or surpassing bounding vulnerabilities assumed for plant probabilistic risk assessments. There are a number of conservatisms in the staff and industry analyses, which were primarily intended to compare the relative probability of failure of axial and circumferential welds. The apparent rapid increase of vessel failure probability at 40 years, however, suggests that it is important to also analyze failure probabilities for plant life extensions beyond the current license limit. In these analyses, the contributions of base metal failure should be included.

We plan to review the staff's proposed Final Safety Evaluation Report and related matters.

ACRS member Dr. William J. Shack did not participate in the Committee's deliberations regarding this matter.

Sincerely,

R. L. Seale

R. L. Seale
Chairman

References:
1. Letter dated September 28, 1995, from J. T. Beckham, Jr., Southern Nuclear Operating Company, to U. S. Nuclear Regulatory Commission, Document Control Desk, Subject: BWR Vessel and Internals Project, BWR Reactor Pressure Vessel Shell Weld Inspection Recommendations
2. Letter dated August 14, 1997, from Brian W. Sheron, Office of Nuclear Reactor Regulation, NRC, to Carl Terry, Niagara Mohawk Power Company, Subject: Transmittal of NRC Staff's Independent Assessment of the Boiling Water Reactor Vessel and Internals Project BWRVIP-05 Report and Proprietary Request for Additional Information
3. SECY-97-088, Memorandum dated April 22, 1997, from L. Joseph Callan, Executive Director for Operations, NRC, for the Commissioners, Subject: NRC Staff's Position on Augmented Examination Requirements for Boiling Water Reactor Pressure Vessels Pursuant to 10 CFR 50.55a(g)(6)(ii)(A)
4. U.S. Nuclear Regulatory Commission, Office of Nuclear Reactor

Regulation, NRC Information Notice 97-63: Status of NRC Staff's Review of BWRVIP-05, August 7, 1997