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NUCLEAR REGULATORY COMMISSION  
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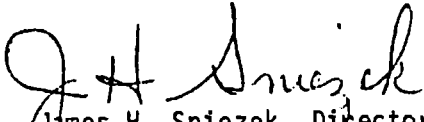
MEMORANDUM FOR: G. Fiorelli, Chief, Projects Branch No. 2, Division of Resident  
and Project Inspection, Region III

FROM: James H. Sniezek, Director, Division of Resident and Regional  
Reactor Inspection, IE

SUBJECT: EVALUATION OF DEFECTIVE CADWELDS AT MARBLE HILL UNITS 1 AND 2

As part of the "Construction Verification" program at Marble Hill Units 1 and 2, Public Service of Indiana, Inc. (PSI) has performed inspections of accessible cadweld splices. The results of the inspections showed that there were numerous cadwelds with visual deficiencies which exceeded the acceptance criteria of the Marble Hill project and the manufacturer's specifications. There have been several discussions with IE (Region III and IE:HQ) and PSI on this issue and a meeting was held on January 8, 1981 in Bethesda, Maryland. As a result of this meeting, PSI has submitted Supplement 1 to Section 6.0 of "The Construction and Material Verification Program Final Report."

We have reviewed the results of PSI's investigation and evaluation of the cadwelds at Marble Hill and agree with PSI that the affected structures will perform acceptably under postulated loads, including the affects of potentially defective cadwelds. The results of the cadweld evaluations and the bases for our recommendation for acceptance of the existing structures with replacement or repair of accessible defective cadwelds are provided in Enclosure 1.

  
James H. Sniezek, Director  
Division of Resident and  
Regional Reactor Inspection, IE

Enclosure: As stated

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EVALUATION OF CADWELDS  
AT MARBLE HILL UNITS 1 AND 2

Public Service of Indiana, Inc. (PSI) has reinspected all accessible cadwelds, a total of 2431, of which 1927 met visual acceptance criteria and 504 (21%) were found to not meet the visual acceptance criteria. The accessible cadwelds are in Unit 2 structures. In order to evaluate the overall character of the inaccessible cadwelds in Units 1 and 2 a random selection of 59 cadwelds from the accessible population were chosen. Of these 59 cadwelds, 48 were found acceptable, 8 had gage mark deficiencies (5 passed radiography testing, 3 failed radiography), and 3 had other visual criteria deficiencies. The 3 cadwelds that failed radiography and the 3 which had visual deficiencies were tensile tested with acceptable results.

The gage mark deficiencies were further evaluated by selection of 58 additional cadwelds based on biased sampling. Since gage marks are not required to be permanent markings, these cadwelds were subjected to radiographic examination to determine if the bar ends were actually centered in the cadweld sleeve. The method of radiography and the interpretation of the results were reviewed and accepted by the Region III Office. Of the 58 cadwelds selected, 55 cadwelds passed the radiographic examination, while 3 did not pass. Tensile testing of these 3 cadwelds demonstrated that the applicable Regulatory Guide and project specification for strength were met. There was no apparent relationship between the gage marks and the actual distances off center. Of the total of 6 cadwelds not passing the radiographic testing, 3 were marginally out of alignment (bar ends less than 3/4 of an inch from the center of the tap hole) and 2 were unique cases in which the rebar had to be bent to avoid post-tensioning sheaths. In addition, all 6 of these cadwelds were No. 18 vertical Type T splices and it was observed that the No. 18 vertical Type T splices did not suffer from the additional deficiency of excessive voids. Therefore, the centering deficiency is most likely not compounded by excessive voids. Additionally, from discussions with the cadweld supplier (ERICO), the rebar suppliers at Marble Hill are considered to have provided rebar with adequate deformation patterns.

Based on the review and testing of the additional cadwelds, the acceptable tensile test results, the low incidence of true gage mark rejects (verified by radiography), the conclusion that certain of the identified rejects are a unique situation, the fact that Cadwelds were typically staggered, the evaluation that true gage mark rejects do not have void deficiencies, and the acceptability of the rebar deformation patterns, it is our opinion that the gage mark deficiencies can be accepted without significantly affecting the design margin of the structure.

From those reject cadwelds without gage mark deficiencies 21 additional cadwelds were selected for tensile testing on a worst case bases. The tensile testing results showed that these cadwelds failed at 84,445 to 109,764 psi and the lowest 15 had an average ultimate strength greater than 90,000 psi; therefore, the strength requirements were met. In addition, the 351 Category I sister and production splice test results show all those splices passed the minimum and average strength criteria. Due to previous findings of the Region III office, all type B and T cadwelds of Unit No. 1 were reinspected between August 1978 and February 1979 for excessive voids and porosity. The corrective

actions taken by the licensee were reviewed and accepted by the Regional office. Since excessive void and porosity rejects accounted for 90% of the non-gage mark rejects identified in Unit 2, the reinspection program on Unit 1 would have eliminated the potential for a large majority of similar types of rejects in Unit 1.

Even though tensile strength requirements for the cadwelds were met, there was still the question of the potential effect splices with a reduced stress-strain relationship may have on structural integrity or functionality of the structures. The ability of the structures to perform their intended function was demonstrated in stress and crack analyses performed by PSI. The containment internal structures and containment shell were analyzed assuming that the identified deficient cadwelds (non-gage mark deficiencies) were nonexistent. The calculated steel stresses were below the ACI 318-71 allowable of 54 ksi ( $0.9 F_y$ ) and crack analyses of the containment internals and shell structures demonstrate the location and degree of cracking is insignificant. Evaluations by PSI of these structures for the effects of splices with a reduced stress-strain relationship on deflection of the structures indicate that (1) for the containment internal structures, for which shielding requirements not strength governs design, deflections are insignificantly affected and (2) for the containment shell, deflections are also insignificantly affected. The basemats were also evaluated by PSI to be structurally unaffected by potentially degraded cadwelds due to staggering the cadwelds and the short term nature of localized effects, if any.

These results are also confirmed in limited tests of beams performed by the University of Illinois. The tests showed that at service loads and at the ultimate load the "soft" splices have no effect on deflection. At yield loads, deflections are increased 15 to 20% for "soft" splices. Also, ultimate moment capacities are not affected. Considering the parameters of porosity, void area, Poisson's effect on the sleeve, and the degree of structural "softening", we agree with PSI that the University of Illinois test conditions were more severe than the actual condition of structures at Marble Hill.

In the letter dated January 23, 1981, PSI has committed to keep in effect the original Marble Hill specification for cadwelds. Therefore, visually rejectable cadwelds produced in the future will be removed and replaced. In addition, those existing cadwelds which were identified with non-gage mark deficiencies will be removed and replaced or repaired. An increase of 10% in the allowable void criteria was permitted due to the lack of precision in the void area determination, the acceptable tensile test results on the worst case voids, and the acceptability of the stress and crack analyses of structures.

Based on the results of the sampling program, the additional testing of worst case cadwelds, the acceptable results of production and sister splice testing, previous reinspection of Unit 1 cadwelds, consideration of the typical staggering of splices, results of previous testing at the University of Illinois, and the evaluation of stress, cracking, and deflection due to potentially defective cadwelds, we have the following findings:

1. Through reinspection of the accessible cadwelds, PSI was not able to demonstrate with 95% reliability and a 95% confidence factor that cadwelds at Marble Hill meet the original visual acceptance criteria. However, not meeting the visual acceptance criteria does not necessarily imply structural inadequacy under the design loads. Analyses, evaluations, and additional testing were performed to demonstrate that structures would still perform to design requirements (see 2 and 3 below).
2. The structural adequacy of the cadwelds and associated structures has been demonstrated by: --the-sample-testing program; the testing (radiography and tensile) of cadwelds; the acceptable results of production and sister splice testing; previous reinspection of Unit 1 cadwelds; evaluation of previous test results performed at the University of Illinois; and the evaluation of the effects due to potentially defective cadwelds on stress, cracking, and deflection.
3. The testing performed by PSI did, however, demonstrate that a 95% reliability with a 95% confidence factor that cadwelds at Marble Hill will meet the visual, radiograph, or tensile test acceptance criteria. In addition, the effect on structures of potentially "soft" splices on stresses, cracking, and deflections were shown to be insignificant by analyses and evaluation.
4. Since the adequacy of existing cadwelds and structures has been sufficiently demonstrated, additional testing is not necessary.
5. This investigation of the Marble Hill cadwelds should not be viewed as a precedent for accepting non-conforming cadwelds. It should remain the policy of the NRC to reject those cadwelds not meeting the visual acceptance criteria. The evaluation of the accessible cadwelds was done to demonstrate the adequacy of those cadwelds already embedded in concrete.