Thornburg

Stephen H. Howell
Vice President

Consumers Power Company

General Offices: 212 West Michigan Avenue, Jackson, Michigan 49201

January 3, 1975

MIDLAND PLANT
Reactor Containment Building
Reinforcing Bar Spacing
Dockets No. 50-329 and 50-330

Dr. Donald F. Knuth, Director
Directorate of Regulatory Operations
US Atomic Energy Commission
Washington, DC 20545

Dear Dr. Knuth:

On December 4 and 5, 1974, prior to placement of concrete at the 642'-7" to 652'-9" level of the Unit No. 2 containment wall, Consumers Power Field Quality Assurance Engineers surveyed the area to determine if the steel reinforcing bar had been located in accordance with the requirements of the Bechtel engineering drawings and specifications.

The Bechtel specification requirements used for the surveillance were those of Specification 7220-C-231 Q, Revision 5 which, among other things, requires:

"8.7.1 Unless otherwise specified by the Project Engineer, reinforcement shall be placed within the following tolerances:

C. Spacing of reinforcement: Bars shall be placed with a variation in spacing between adjacent bars of not more than 1/6 of the spacing shown on the plans, except about openings, penetrations, etc, where minor adjustments are required, but with the same total rebar area provided."

The Bechtel drawing requirements used for the surveillance were those of Drawings C-311(Q), Rev 2; C-312(Q), Rev 2; and C-313(Q), Rev 3 which, among other things, required that vertical No. 11 steel reinforcing bar (rebar) be placed "@ 8" Typ."

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Therefore, Consumers Power Field Quality Assurance Engineers expected to find No. 11 vertical rebar to be spaced at 8" spacings ± 1/6 of 8" or ± 1-1/3" resulting in actual rebar spacings from 6-2/3" to 9-1/3". An exception to this would be in areas about openings and penetrations where minor adjustments would be allowed by specifications. Actual No. 11 vertical rebar spacings as small as 4-1/2" and as large as 15" were found. These deviations were found to be in areas where there were not openings or penetrations. The deviations were found at the 652'-9" (top of the proposed pour) level.

Upon discovering these deviations, Consumers Power Field Quality Assurance Engineers reviewed the Quality Control Field Inspection Plan No. C-231-2-400, Rev 0 "Forming, Placing and Curing of Concrete (Preplacement)" for this pour. This field inspection plan requires in Section 2.40 b that: "Rebar (is) properly spaced, tied and supported as shown on the drawings."

This requirement should have been verified by means of inspection by Bechtel Quality Control Engineer. The Field Inspection Plan was signed off on November 29, 1974 by a Quality Control Engineer indicating that this inspection was done.

In view of the deviations in rebar spacing and the signed off inspection plan which indicated that the rebar was properly spaced, Consumers Power issued a Nonconformance Report to Bechtel describing the deficiencies noted and recommended the following corrective action:

1. Correct the rebar spacing or provide adequate rational to "use as is."

2. Reinstruct personnel in proper spacing of bars.

3. Provide instruction to inspection personnel as to what course of action to follow if apparent discrepancies are found.

4. Provide assurance that the same situation does not exist in past Q-list pours, or if it does, why the structural integrity has not been compromised in these pours.

Associated with this Nonconformance Report, Consumers Power issued a Stop Work on all Class I concrete pours until Consumers Power could be assured that preplacement inspections can be properly conducted. In addition, the concrete pour scheduled to be made where the rebar spacing deviations were found was stopped until the rebar location could be corrected or adequate rationale for the existing rebar location could be provided.

In response to this Nonconformance Report and Stop Work, Bechtel promptly relocated the improperly spaced rebar at the top, but an inspection of the rebar at the bottom of the proposed pour revealed that the embedded rebar was also improperly spaced with spacings as small as 4-1/2" and as large as 12" observed. Relocation of this embedded rebar would have been difficult and the decision was made to first analyze the safety implications.

This problem was evaluated for reportability under the requirements of 10 CFR 50:55e. In addressing the question of whether these deficiencies could have, if they had remained uncorrected, adversely affected the safety of operations of the nuclear power plant; it was decided based on inputs from the Architect-Engineer and Consumers Power Engineering Services Department that the deviations in rebar spacing probably would not have affected the safety of operations of the power plant but proof of this position was not available on December 5, 1974. It therefore was decided that the question of effect on the safety of the plant was indeterminate.

On the other hand, it was decided that the spacing problem could represent a significant breakdown of the quality assurance program in that rebar spacing apparently did not meet specification and drawing requirements and the Quality Control inspector had signed off that they had been met.

It was also apparent that either extensive evaluation or extensive repair would be necessary in order to establish the capability of the containment wall to fulfill its intended safety function.

In view of the indeterminate nature of the possible effect on the safety of the plant it was decided to verbally notify Mr. T. E. Vandel, the Region III Principal Inspector, of the deficiencies discovered and corrective actions being taken. This notification was made by Messrs. G. S. Keeley, the Consumers Power Director of Project Quality Assurance Services, and H. W. Slager, the Consumers Power Midland Project Quality Assurance Administrator, at 4:45 PM on December 5, 1974. Consumers Power Company did not consider this reportable under the requirements of 10 CFR 50:55e.

On December 12, 1974 during an AEC inspection Mr. T. E. Vandel informed Consumers Power that the AEC considered the deficiencies relating to rebar spacing to be reportable under the requirements of 10 CFR 50:55e.

All corrective actions have not been completed at this time, therefore this letter represents an interim report as is required by 10 CFR 50:55e.

1. Analysis of Safety Implications

An analysis of the safety implications of the deviations in rebar spacing has been completed. This analysis addressed questions of average rebar spacing and stresses in the rebar and the concrete resulting from spacings of 16 inches and 4 inches rather than 8 inches.

In addressing the question of average rebar spacing, the average rebar spacings for nine different 5-foot segments of containment wall were computed. (These segments represented rebar with spacings as small as 4 inches and as large as 12 inches) These average spacings for 5-foot segments ranged from a low of 7.09" to a high of 8.23" demonstrating that the average rebar spacing was close to the correct value. In fact a total count of the rebar indicated that there was one more No. 11 rebar than was required at this elevation. As discussed below this establishment of approximately the correct total number of rebar is important in establishing the ability of the rebar to perform its safety related function.

In Paper #1818 published in the "Journal of The American Society of Civil Engineers" dated October, 1958 titled "Concrete Beams and Columns with Bundled Reinforcement" by N. W. Hanson and Hans Reiffenstuhl reports tests of identical pairs of reinforced concrete beams. These beams differ only in that one of each of a pair had the reinforcing bars spaced as required by the then-current ACI 318-56 and the other had the same reinforcing placed as three or four bar bundles in the extreme corners of the stirrup bars. The results of load tests indicate and the synopsis of the paper states: "No significant difference in behavior or ultimate strength was found for bundled as compared to spaced bars." The paper later reports no systematic difference in strength except that due to the slightly greater effective depth of the bundled bars. This paper was later reprinted in the 1960 issue of "Transactions of the American Society of Civil Engineers" as Transactions Paper 3047.

The condition at Midland is not directly comparable to the test reported in the paper but the test results indicate that the total amount of reinforcing steel installed rather than the physical distribution of that steel will govern the strength and behavior of a beam, other conditions being similar. We can find no reference to similar tests having been made on a wall or slab but if the distribution of reinforcing steel over small segments of the wall is considered, the similarity of strength and behavior should hold true.

As further evidence to show that rebar area unevenly distributed is effective, it is an accepted practice to place in the space between rebars (say #11 @ 12") additional rebars (say #6 @ 12") of a different size, in order to meet design requirements for area of steel. (For example see ACI 315-65, Drawing 8-18) Accordingly, #11 bars at an alternate spacing of 6 inches and 10 inches could be substituted for #11 @ 8". An analysis of individual four-inch panels of a

wall constructed in accordance with Drawing 8-18 would indicate a wide range of stresses if each bar were assumed to act alone. The normal practice assumes the stresses will be distributed uniformly among the bars. The analogy is drawn that unequal bars at uniform spaces is the equivalent of equal bars at non-uniform spacing.

The preceding two discussions relating to Paper 1818 and Drawing 8-18 of ACI 315-65 establish the importance of the consideration of the total numbers of rebar and these discussions also indicate that there was sufficient rebar to perform the safety related function of the wall. On the other hand, consideration must be given to possible excessive spacing within 5-foot segments. It is worth noting here that ACI 318-71 does allow rebar spacings, for walls at the thickness of the Midland containment wall, to be up to 18 inches and this limit was not exceeded.

In order to determine the effect of observed rebar spacings on stresses in both the rebar and the concrete, stresses in these components were computed resulting from thermal forces on the wall. (The selection of thermal forces rather than internal pressure, prestress or dead loads was made because the vertical rebar in question mainly control thermal cracking.) The maximum observed rebar spacing was 15 inches therefore a cracked section analysis was performed on a 1-foot wide wall section assuming a rebar spacing of 16 inches. This analysis demonstrated that the resultant stresses in the rebar would be 12.86 Ksi whereas they would have been 11.91 Ksi had the spacing been the required 8 inches. This represents an increase in stresses in the rebar from 19.9% to 21.4% of the 60 Ksi minimum yield strength of the rebar. This increase in stresses does not represent a safety hazard for the containment wall.

Contrary to rebar stresses, concrete compressive stresses are highest when the rebar spacing is minimized. The smallest observed rebar spacing was 4 inches, therefore a cracked section analysis was performed on a 1-foot wide wall section assuming a rebar spacing of 4 inches. This analysis demonstrated that the resultant compressive stresses in the concrete would be 735 psi whereas they would have been 549 psi had the spacing been 8 inches. This represents an increase in stresses in the concrete from 9.15% to 12.25% of the 6000 psi minimum compressive strength of the concrete. This increase in stress also does not represent a safety hazard for the containment wall.

Based then on a combination of studies which address average rebar spacing as well as actual observed individual rebar spacings it appears that if this rebar spacing problem had remained undetected it would have not adversely affected the safety related function of the containment wall.

2. Corrective Action Taken

Even though the safety related functions of the containment wall would not have been affected, Consumers Power did require that the contractor take corrective action to insure the correct implementation of Bechtel engineering specification C-231.

To date, the following corrective actions have been taken:

a. At the 652'-9" level the rebar has been relocated to a proper spacing.

b. The embedded rebar at the 642'-7" level has not been relocated. The spacing has undergone a safety analysis (described above).

c. Bechtel Quality Control Engineers have been reinstructed in requirements for the inspection of spacing between rebar.

Based on the above corrective action, the Stop Work on concrete pours was lifted on December 19, 1974.

The one item of corrective action yet to be completed is resolution on a matter of specification interpretation between Consumers Power and Bechtel.

Until this is resolved, in order to assure no additional problems occur, Consumers Power Company is assigning a Consumers Power Company Field Quality Assurance Engineer for surveillance of each Class I concrete rebar placement before the pour. This is in addition to the normal Bechtel Quality Control Inspections and the normal Consumers Power Company Quality Assurance surveillance.

Adequate corrective action should be completed in the near future and it is anticipated that a final report can be sent to you by February 1, 1975.

Yours very truly,

SHH/sjb

CC: JGKeppler, USAEC