



TABLE OF CONTENTS

	<u>Page</u>
I. Introduction . . . . .	.1
II. Opinion . . . . .	.3
A. Embedded Plates . . . . .	.3
B. Honeycombing in Reactor Building Base Mat . . . . .	31
C. Honeycombing in Reactor Building Dome . . . . .	44
D. SA-358 Piping . . . . .	51
E. SA-312 Piping . . . . .	55
F. Piping Subassembly Deficiencies . . . . .	66
G. Quality Assurance Contention. . . . .	69
III. Findings of Fact. . . . .	70
A. Embedded Plate. . . . .	70
B. Honeycombing in the Reactor Building Base Mat . . . . .	81
C. Honeycombing in the Reactor Building Dome . . . . .	93
D. SA-358 Piping . . . . .	96
E. SA-312 Piping . . . . .	99
F. Piping Subassembly Deficiencies . . . . .	104
G. Quality Assurance . . . . .	105
IV. Conclusions of Law. . . . .	109
V. Order . . . . .	111
Appendix I - Witness List	
Appendix II - Contentions Text	

## I. INTRODUCTION

This is a partial initial decision on an application of the Union Electric Company of St. Louis, Missouri for an operating license at its Callaway facility. The Applicant is one of five utilities that jointly submitted construction permit applications under a Standardized Nuclear Unit Power Systems (SNUPPS) option which provides for, within the Commission's standardization policy, a simultaneous review of the safety-related parameters of a limited number of duplicate plants.<sup>1/</sup>

The Applicant's construction permit was granted by the Commission on April 16, 1976 and notice of an opportunity for a hearing on the operating license application was published in the Federal Register on August 26, 1980.<sup>2/</sup> Intervention as parties was granted to the Joint Intervenors (Coalition for the Environment, Missourians for Safe Energy and the Crawdad Alliance) and John G. Reed, an individual. Representatives of local governments and the Missouri Public Service Commission were also admitted to the proceeding. Nineteen contentions on quality assurance, environmental protection and emergency planning issues were admitted by the Board. However specification of emergency

---

<sup>1/</sup> See 10 CFR Part 50, Appendix N.

<sup>2/</sup> Clarification of this notice was published in the Federal Register on November 21, 1980 after Applicant indicated it intended to proceed only with Unit 1.

planning contentions was deferred pending development of offsite  
... onse plans and the contention on environmental issues has been  
withdrawn by its sponsor. This decision then is concerned only with  
the quality assurance controversy.

Of ten contentions alleging failures in the Applicant's and  
contractor's quality assurance programs, three were eliminated from the  
proceeding by motions for summary disposition granted by the Board. An  
evidentiary hearing was held during November and December of 1981 and  
time was provided for limited appearance statements. The Joint  
Intervenors (Intervenor), sponsor of this contention, provided no  
direct testimony, relying on extensive cross examination for proof of  
its allegations. The Applicant and Staff provided individual or panel  
witnesses on all contentions and a complete list of witnesses is  
included in Appendix I.

## II. OPINION

The Intervenors in this proceeding allege a failure in the Applicant's quality assurance program in that various inspection and surveillance functions were inadequately performed. And as this negligence, Intervenor contends, constitutes a breakdown in meeting or satisfying the criteria of 10 CFR Part 50 Appendix B, the quality of safety-related materials cannot be assured, thus jeopardizing the safe operation of the plant. Accordingly, the Intervenors conclude, the facility should not be licensed to operate. The inadequacies were attributed to the Applicant, the Bechtel Corporation, the Daniel Corporation, and various inspectors among others. In support of their claim of deficient performances, Intervenors submitted six contentions which were at issue in the hearing. We treat the contentions here seriatim.<sup>3/</sup>

### A. I.A. Embedded Plates

The embedded plate contention consumed a major part of the hearing sessions on Intervenor's quality assurance issue. The deficiencies cited are that defective embeds were fabricated and installed in the plant contrary to the requirements of the quality assurance criteria established in 10 CFR Part 50, Appendix B. In support of its claim Intervenors state that inspection, surveillance and testing activities

---

<sup>3/</sup> The complete text of the contentions is included in Appendix II.

were improperly performed and that exceptions from welding code requirements were also improperly permitted.

The essential assertion of the Intervenor is that embedded plates with possible defective welds were installed in the facility and, in the event of an emergency, weld and plate failure could result in the collapse of critical structural members and piping systems necessary for a safe shutdown of the plant.

Embedded steel plates with welded studs or anchors to transmit forces between steel and concrete have been utilized in construction projects like Callaway for many years. See Tr. pp. 947-957. At Callaway, the Bechtel Corporation, the Applicant's principal architect/engineer, provided for the use of two different plates in its construction specifications for the facility. The plates' function is to support various members such as steel floor beams, HVAC components and piping and are installed as fixtures in concrete walls through the use of welded steel studs and welded steel anchor rods embedded in the concrete. Studs are welded to embed plates by an automatic machine operation while anchor rods are attached through a manual weld process. (Board Findings 1, 2, and 3)

The Applicant is one of several utilities that participated, under NRC regulations, in an organized Standardized Nuclear Unit Power Plant System (SNUPPS) for the construction and operation of a nuclear power plant. Under the SNUPPS concept and the regulations in 10 CFR Part 50, Appendix B, the SNUPPS organization, the Applicant, Bechtel Corporation and its plate supplier, the Cives Company and the Applicant's

construction contractor, the Daniel International Company, have quality assurance programs and responsibilities. See Schnell Testimony, ff. p. 216 at 4-34. In exercising these responsibilities, the Bechtel Corporation is required to provide a quality surveillance during fabrication of embedded plates, the Cives Company is charged with inspecting all plates to contract and code requirements and the Daniel Company had the responsibility of a receipt inspection, generally limited to verifying the quantities of plates received on site and damages occurring during shipping. On July 8, 1977, subsequent to the commencement of the investigations referred to herein, the Daniel Company was also directed to perform a quality control receipt inspection of all Bechtel procured safety-related items. (Board Finding 4)

As a result of a NRC routine inspection on June 9, 1977, stop work orders were issued by the Daniel Corporation on installing embedded plates after machine welded plates with apparent defects were discovered. The plates, which did not have full 360 degree flash material, had not been tested as required by the American Welding Society (AWS) code. (Board Finding 5) The orders stopped work, pending a complete reinspection, on all uninstalled plates, manual as well as machine welded. Up to that point, facility construction was less than 10 percent complete and 255 machine welded plates and 225 manual welded plates had been installed in support of safety-related loads. (Board Findings 6 and 7) Starr, Tr. 1397. The Intervenor argues that failures on the part of Bechtel and Daniel Corporation

employees to discover welding defects and to perform quality control inspections on machine welded plates were infractions of 10 CFR Part 50, Appendix B criteria. See Intervenor's Proposed Findings, pp. 3-5. Although the Intervenor refers correctly to Licensee's failure in meeting Criterion X as being cited by an NRC inspector (Intervenor's Ex. 28, p. 7) this deficiency was overcome by the NRC's later agreement that plates installed before June 9, 1977 met requirements. (Staff Ex. 6) The Intervenor misconstrues the separate and different inspection responsibilities of the Daniel and Bechtel Corporations. See Schnell Testimony, infra and Applicant's Embed Testimony, ff. 510 at 13-14. In connection with Intervenor's claim that missing documentation regarding the manufacture of embeds was also in violation of quality assurance criteria, this documentation was supplied and the matter closed satisfactorily to NRC inspectors. (Staff Ex. 4, p. 6)

Prior to welding deficiencies alleged to exist in June 1977, the SNUPPS organization quality assurance manager brought to the attention of the Applicant certain deficiencies in Cives manufactured materials that were being reflected in Bechtel inspection documents. The Intervenor alleges that this evidences early warnings of manufacturing defects which did not result, as they presumably should have, in corrective changes in procedures by the Bechtel and Daniel Corporations. This could have, the Intervenor believes, resulted in stopping the installation of defective embedded plates by at least six months. On receiving the above information from SNUPPS, the Daniel Corporation was directed to inspect 10 percent of the embed plates on

site, which produced a finding that only four pieces out of 374 pieces inspected had deficient welds. However, the defects were considered minor in nature and the conclusion was reached that the material was being manufactured according to the quality required. Tr. pp.

1234-36; Joint Intervenor, Ex. 18. One of the pieces found deficient, a door frame, was later found to be acceptable and was installed, an explanation found satisfactory to NRC inspectors. See Intervenor Proposed Finding 14 and Intervenor Ex. 34, p. 10. (Board Finding 7)

After the stop work orders issued in June 1977, the Cives Company and the Daniel Company were independently directed to reinspect all plates on site that had not been installed and the Daniel Company also was given a continuing added responsibility to provide complete quality receipt inspection of all safety-related material supplied by the Cives fabricator. (Board Finding 8) Inasmuch as the evaluation efforts involving machine welded and manual welded plates used different methods of analysis and review, the results are discussed separately in the Board's opinion and findings. We do this for purposes of clarity, for the record reflects an ambiguity on occasion when cross-examination fails to distinguish between the two kinds of embeds and Intervenor's proposed findings do not, as required by our regulation (10 CFR 2.754(c)), always cite to the record nor make clear that some of the exhibits referred to were admitted solely for purposes of impeachment, e.g., Tr. 592-594. In discussing first the machine welded

plates and then the manual welded plates, we also follow here the order in which evidence on those issues was presented during the hearing.

#### Machine Welded Plates

Welded studs on machine welded embeds were required to be inspected to conform to the requirements of the American Welding Society (AWS) Structural Welding Code D1.1-75. (Applicant Embed Testimony at 13) The Cives Company had been inspecting the studs correctly pursuant to a section of the Code that required bend testing only on one out of every hundred studs. Bend testing was performed by striking the stud to a fifteen degree angle in a direction opposite to a missing weld fillet. Subsequent to the stop work orders, Cives was required to conform its inspection to a more rigorous requirement where every stud not having a 360 degree weld fillet would have to be bend tested. (Board Finding 10)

The reinspection effort of the Cives and Daniel Companies, which called for a visual inspection of all studs and bend testing where 360 degree fillet welds were missing resulted in a failure rate of .08 percent and .11 percent respectively. This rate compared favorably with industry standards. (Board Findings 9 and 12) The bend test produces much higher stresses on studs and stud welds than the design loads applied to the embedded plates. (Board Finding 11)

In its proposed findings, the Intervenor suggests that NRC quality assurance criteria requires, as a protection against bias, that individuals other than those from companies interested in the outcome

should be used to do inspections. They also maintain that a single inspector could not have performed all of the stud inspections recorded on several of the days reported. See Intervenor Proposed Finding 24 n. 8 and Proposed Finding 25. It seems clear that Criterion X prohibits the use of the same personnel for quality inspections where those employees performed the welding tasks in question. This is not the case here. And further, there is no convincing evidence or testimony that only a single inspector was used on the dates indicated by Intervenor. The studs that failed the bend test procedure--66 out of 81,673 studs inspected--were replaced with acceptable studs. (Applicant Embed Testimony at 20) The low rate of failure during the reinspection was an assurance to the Bechtel Company, which designed and contracted for the plates, that the embeds installed prior to June 9, 1977 met the requirements of the welding code. This confidence was based on the fact that the reinspected plates were fabricated by the same Company in the same time framework using the same procedures as the plates installed before June 9, 1977. (Board Finding 13)

A second step in the review of previously installed machine welded embeds was the performance by Bechtel of an engineering analysis, using data from the reinspection effort, to develop the probability of plate failure. This probability, found to be on the order of one in one billion, was analyzed as being the product of the probability of having a defective stud, the probability of the plate with an assumed defective stud supporting a safety-related load, the probability of

that load exceeding the plate capacity due to an assumed adjacent ineffective stud, and the probability of the design load actually occurring. (Board Finding 14)

Although Applicant's expert witnesses testified that the analysis represented a very conservative approach and provided additional assurances of the structural integrity of embeds installed prior to June 9, 1977, (See Applicant Embed Testimony at 26), the Intervenor challenges the results on several grounds: first, it cites the fact that the NRC did not rely on the analysis; second, no attempt was made to ascertain how many of the installed embeds may have been fabricated in the same time period as those where the greatest number of defects were found during the reinspection program and finally the analysis did not consider the possibility of multiple stud failures. The evidence does indicate an apparent lack of confidence in the probability analysis by the NRC investigators, (See Staff Ex. 6, Schnell letter, April 24, 1980, p. 2) but Staff testimony that the analysis was unnecessary to prove the structural integrity of the installed plates went unchallenged. See Tr. Gallagher, pp. 1327-28. The record reflects that plates which were generally interchangeable, when assembled at the site, were mixed so that their use did not necessarily follow a pattern of first in-first installed. (Board Findings 15-16) Accordingly, no consideration could have been given to the period in which such plates were fabricated. On the multiple stud issue, the evidence reveals that adjacent stud failures--the only significant alignment that could affect the statistical analysis--would result in a

plate failure rate only slightly more than single stud rate failures. The Intervenor's attempt to demonstrate a fallacy in the analysis by using a possible defect in all studs on all plates fails with assumption that other parts of the analysis remain equal, an assumption that is not possible in fact since the other parts are dependant on each other.

As a final step in reviewing the integrity of installed machine welded embeds, the Applicant, at the request of the NRC, had live load tests made on six plates installed prior to June 9, 1977. The plates were randomly selected on the basis of accessibility and the feasibility of mounting a test rig for the plates and their selection was concurred in by NRC officials. The tests, under the supervision of the Applicant's expert witnesses, Drs. Slutter and Fisher from Lehigh University, utilized a thirty-ton hydraulic jack which subjected the plates to loads slightly in excess of their design loads without any evidence of plate or stud failure, cracking or yielding. The tests were also witnessed by NRC personnel. (Board Findings 17-20) The Intervenor alleges a possible bias tainting the tests on the basis of a prior relationship between Applicant's experts and a company that manufactured machine welded studs and also claim that similar tests on embedded plates performed for the Applicant several years prior to the instant one, was possibly a "dry run." We believe these claims to be without merit since the relationship of former consultants to a stud manufacturer on a question of the welding integrity of studs which pass through an intermediate fabricator does not present any possible

conflict of interest and we fail to see any problem even if the Applicant had in fact performed--which we do not subscribe to as happening--the prior tests as an additional precaution against failure of the installed plates.

Despite contrary allegations in Intervenor's contention, the testimony indicates that the location and loads of all machine welded embeds installed before June 9, 1977 are known. Of significant importance to the issues in this controversy is the conservative design of embed plates and studs with maximum load capacities producing a minimum safety factor of at least 2.0 against the applicable limit state of the plate or studs. And since the actual loads applied to an embedded plate are considerably less than the allowable load, the factor of safety for a majority of plates is higher than 2.0. Further discussion of this matter and its importance will be found subsequently in this opinion. As a final comment here on machine welded embeds, the Applicant testified, in response to one of the allegations in Intervenor's contention, that the possibility of a plate failing to support "critical piping" systems was remote since such systems were designed to have a safety factor of 1.64 against their yielding state and a much greater factor against exceeding their limit state. In addition, the systems required to maintain a safe shutdown following a design basis accident are composed of two independent subsystems, both of which could not be affected by the failure of a plate in one system. (Board Finding 21)

Manually Welded Plates

As in the case of studs on machine welded plates, all welding of anchor rods to manually welded plates was required to be in conformity with the American Welding Society (AWS) D1.1-75 Code. (Board Finding 22) After June 9, 1977, the Daniel Corporation undertook a quality inspection of safety-related materials supplied by the Cives Company and finding some deficiencies in manual welds, the Cives organization was then directed to inspect all manually welded plates not yet installed and to identify the nature, degree and number of all welding nonconformances. (Board Finding 22)

There is adequate testimony in the record that the precise location and loads on all manually welded embeds installed prior to June 9, 1977 are known. See Intervenor Ex. 78. Manual welded embeds are used in the Callaway facility to support structural steel framing members, (Board Finding 26) and the anchor rods that are attached to them are welded, due to their large size, by manual instead of machine welding processes. (Board Finding 24) The Applicant's prepared testimony, which was not contradicted, indicated that deficiencies in meeting the welding requirements of AWS D1.1 were due to the physical difficulty of a welder maintaining proper access and rod orientation in welding among multiple anchor rods. It was Bechtel's conclusion that the Code requirements were not developed for the type welds involved in the Callaway construction, and as will be discussed later, exceptions to relevant sections of the Code were recommended and approved. (Board

Finding 25) Manually welded plates, like machine welded plates, had included in their design load capacity a minimum safety factor of 2.0 against the yield limit state of the plates and tensile capacity of the anchor rods. (Board Finding 27)

The Bechtel Company was advised by Cives during its reinspection that welding deficiencies were found in manual plates which were not in conformity to Code welding requirements. The deficiencies discovered were insufficient weld size, unequal leg size, unacceptable weld profiles (excessive convexity) and excessive undercut. (Board Finding 28) Based on this information, Bechtel performed an engineering evaluation on what was considered to be a "worst case" basis: namely, it developed new load carrying capacities by assuming that all anchor rods had 1/8 inch undersized welds for the total perimeter (360 degrees) of the rod, both legs of the weld were undersized and that all rods had a 1/16 inch undercut. (Board Findings 29-30) With these assumptions, Bechtel calculated a reduced load carrying capacity for each plate which, when compared to the actual applied loads, demonstrated that, in all but four cases, where it was equal, the load carrying capacity exceeded the actual loads. In its embed testimony, the Applicant stated the load carrying capacity exceeded the design loads in all cases. The Intervenor placed in evidence, however, a letter from Bechtel to the Applicant dated April 9, 1980 which indicated that in four instances, the actual loads equalled the load capacity. (Board Finding 31)

Intervenor in proposed findings has framed a substantial number of its criticisms challenging the validity of Bechtel's engineering evaluation. Summarized, these objections amount to the following: first, Bechtel performed its calculations with limited information from the Cives reinspection effort since Cives had completed only its first of four days of reinspection at the time that Bechtel performed its calculations on reduced load capacities; second, the data reported by Cives on undersize and undercut did not reflect Bechtel's assumptions that the maximum undersize was 1/8 inch and undercut was 1/16 inch; third, the reduced load capacities did not produce an adequate safety margin since at least four plates had a reduced capacity equal to the plate loads and fourteen other plates had actual loads within 96 to 98 percent of the reduced design capacity; fourth, if the installed plates had larger deficiencies than the 1/8 inch undersize, which Bechtel reported to be the critical weld parameter, then plate failure of manually welded embeds could be expected, and last, there was substantial evidence of a significant number of manually welded plates reinspected after June 9, 1977 with an average weld undersize greater than 1/8 inch. See Joint Intervenor Proposed Findings, p. 20-27.

Considering Intervenor's arguments in order, the hearing record makes clear that Bechtel did not rely on written reports from Cives reinspection efforts to document their assumptions on undersize. Instead, Bechtel's engineering evaluation was based on information communicated orally. Tr. 724 (Meyers). The Applicant implicitly

concedes Intervenor's position when it proposes as it did in its reply findings that it sees nothing wrong beginning calculations using unconfirmed assumptions subject to subsequent confirmation when final Cives data was available. There is a weakness in this response however since it ignores the fact that Bechtel's final August 10, 1977 report on its investigation of welded embeds--which included the results of its engineering evaluation--actually preceded the termination of Cives reinspection program. (Board Finding 33) It appears that Bechtel may have decided that weld deficiencies were not significant after Cives completed its first day of the reinspection effort since there is evidence that its engineering department did not consider the conditions detrimental to the integrity of the embeds by June 30, 1977. Joint Intervenor Ex. 20, p. 4.

On Intervenor's second issue above, it is argued that Cives data reports reflected limited amounts of information concerning the amount of undersize and no information of the amount of undercut or the amount of undercut that extended around the anchor rod's circumference. Applicant's response is that Cives had been directed to identify only the nature and maximum extent and not the number of such deficiencies. It indicates that it merely sought to obtain the amount of undersize on the one or more anchor rods with the worst undersize condition. See Applicant's Reply to Proposed Findings, p. 15; also Tr. 796 (Meyers). For its engineering evaluation, Bechtel sought to determine, based on information received orally as indicated earlier, what the maximum average undersize and undercut was on individual welds. And it was

advised that the maximum oversize was always less than 1/8 of an inch and the maximum undercut always less than 1/16 of an inch and that these deficiencies were never around the full circumference of the weld. Tr. 724, 796, and 1241 (Meyers). Bechtel had the information on undersizing verified at a later date by the Cives Company when it subsequently was evaluating supposedly conflicting data supplied by the Daniel Corporation, which is discussed later in this Opinion. Tr. 796 (Meyers); Board Ex. 1, Encl. 2. We conclude that Intervenor's criticism is well founded to the extent that the Bechtel Corporation had no written support for its assumption that the maximum undersize was always less than 1/8 inch but relied solely on oral communications. And we also conclude that Applicant's letter to NRC's Regional Director of March 10, 1978 is somewhat misleading in indicating a documentation that no deficiencies were undersized greater than 1/8 inch. A communication from the Cives Company that its records do not indicate any welds more than 1/8 undersize is not, in our view, "documentation" as that term is normally understood. Applicant Ex. 6, p. 1 of attachment; Board Ex. 1, Encl. 2. Nor can the Board believe that verification of the same matter from field inspection reports referred to by the Bechtel Company in its August 10, 1977 Investigation Report on welded studs was other than by oral communication although a different conclusion would be reached by an ordinary reading of that statement. Applicant Ex. 4, p. 3. Whether these amount to a failure in quality assurance requirements we discuss at a later point in this opinion.

The Intervenor's third point, that revised load estimates presented an inadequate margin for error, was repeated in a number of its proposed findings of fact. See Joint Intervenor Proposed Findings 2, 30, 36, 37, 52 and 53. The case essentially states that the Applicant and Bechtel misrepresented the safety issue by indicating that despite the reduced loading capacity a sufficient design margin still existed and none of the plates embedded prior to June 9, 1977 possessed the potential to fail when in actuality four plates had an equal capacity to the reduced margin and 14 others were within a close margin (96 to 98 percent) of their actual loads. The Applicant's response does not substantially contest Intervenor's numbers but relies instead on the design safety factor of at least 2.0 against the yield limit state of the plate and the tensile capacity of the anchor rods, a determination of safety with which the Board concurs. Additional weight must be given to the fact that other conservative assumptions were made in the engineering analysis. Applicant Embed Testimony at 37. The testimony indicates that even though it is accepted engineering practice to load a plate to full capacity, there, nevertheless, remains a margin of safety in the design for embedded plates that at a minimum is slightly less than 2.0. Applicant Ex. 20, pp. 3-4. The fourth argument of Intervenor--if Bechtel's assumption about 1/8 inch undersize was erroneous, then plate failure could be expected--merges with its fifth point, that there was in fact substantial evidence of a significant number of plates reinspected with average weld undersize in excess of 1/8 inch. We treat both together

because they involve discussion of the reinspection effort conducted by the Daniel Company, a controversial subject that occupied much of the Board's time and that of the parties during the hearing.

Subsequent to the discovery of possible welding defects in embeds by NRC inspectors on June 9, 1977, the Daniel Corporation was directed by the Applicant to inspect all embeds procured from the Cives Company. This inspection, covering all embeds at the site and those to be received thereafter, was different from and in addition to the Cives site reinspection which was initiated by Bechtel officials. (Board Finding 34) Some time after Bechtel submitted its final report--based on Cives reinspection information--on the welded embed problem, (August 10, 1977), which concluded that the plates were a completely acceptable product, inspection reports compiled by Daniel which contradicted the Cives data were furnished to Bechtel. The Daniel data indicated the existence of a number of plates with weld undersizes in excess of 1/8 inch. (Board Finding 35) There was extensive interrogation during the hearing on Bechtel's claim that it had no knowledge of the conflicting Daniel information prior to Bechtel submitting its final report nor that Daniel was even inspecting plates on-site. See Tr. 797 et seq. (Meyers, Schnell). Regardless of where the truth lies, it is clear to the Board that if Bechtel did not know of Daniel's activities, it should have had such knowledge. The Applicant had directed the performance of Daniel's inspection work and Bechtel was the Applicant's design architect/engineer. It strains our

credulity to believe that the Applicant would not advise Bechtel of an order to Daniel which impacted a Bechtel supplier, i.e., Cives. Nor is it easily understood why Cives would have failed to notify Bechtel of Daniel's activities when both Cives and Daniel personnel were involved in a similar activity at the same place at the same time. There is evidence in the hearing that the Applicant knew in August 1977 of the large number of welding defects in manually welded plates that Daniel was discovering and there is also testimony that Daniel and Cives personnel knew of each other's efforts at the time. (Board Findings 36-37) Whether the Applicant or Bechtel knew of the Daniel information or ignored it, it is clear that it was an NRC investigatory team that initiated the review that attempted to reconcile the Cives and Daniel conflicting data. (Applicant Ex. 7, p. 1; Board Ex. 1, Encl. 4, p. 1) An explanation provided by the Applicant and Bechtel for their lack of information concerning Daniel's inspection results is that the surveillance reports from those inspections were accumulated in a nonconformance report procedure for on-site rework, which, being internal to Daniel, would not ordinarily be communicated to others. Nevertheless, due to the severity of the problem being investigated, in the Board's judgment, a lack of knowledge is not plausible.

In an effort to reconcile the differences between the Cives and Daniel inspections, a two month review was undertaken by both Daniel and Bechtel to clarify the inconsistent data. This resulted in a conclusion by Bechtel that due to poor documentation, inconsistencies

and errors, an engineering analysis of the Daniel data was inappropriate and, actually, impossible to accomplish. (Board Findings 38-39) The inadequate reporting of data by Daniel was attributed to the fact that its function during inspection was not to determine the amount or extent of weld deficiencies but to record only enough information to provide a basis for rework if that were required. This information was verified during the hearing by two employees from Daniel who were witnesses called by the Board. (Board Finding 40) In its review, Bechtel found that only 8 plate data reports out of 532 showed an average weld undersize greater than 1/8 inch and with information further refined by the Daniel review effort, the Applicant found only 10 of 364 embeds with such an average. Both Bechtel and the Applicant concluded that these data reports were too few and too unreliable to be used to characterize the embedded plates delivered at the site. Applicant Ex. 7, p. 3 and Ex. 6, p. 4. The Daniel Company also indicated that an engineering evaluation similar to what Bechtel had performed using Cives data, which assumed the maximum undersized condition around the complete weld-circumference, would not represent a true picture of actual conditions. And finally, Bechtel, the Applicant and Daniel reinspected 45 plates that had not been repaired which had been previously rejected by Daniel and agreed that the deficiencies observed were less than reported. (Board Findings 42 and 43)

Intervenors argue, in relation to the Daniel's data, that adequate evidence was presented of a significant number of manually welded plates with average weld undersize greater than 1/8 inch. They point

to both Bechtel's and Applicant's review of the Daniel data which reflected that 8 or 10 plates contained such deficiencies. Further, they insert in proposed findings a composite table purporting to show, based on Bechtel's calculations, a comparison between Daniel and Cives data which shows 26 plates having average weld undersize in excess of 1/8 inch with the Cives data in agreement with Daniel on 13 of the 26 plates. The Board cannot subscribe to Intervenor's arguments on either point. Leaving aside any discussion whether the Daniel data package, Intervenor Ex. 12, which was admitted for a limited purpose, or the composite table which makes its presence felt for the first time in proposed findings can be relied on for probative evidence by the Board, we believe neither can overcome a more fundamental objection. Neither allegation is substantive in the case. In order to arrive at a finding that Bechtel's assumptions were erroneous, based on Daniel data that either 8, 10 or 26 embedded plates possessed average weld undersize greater than 1/8 of an inch, one has to also assume that the weld undersize extends around the entire circumference of the anchor rod. There is no evidence in the record of the validity of that assumption. In addition, we have the testimony of Daniel's Project Manager, who was responsible for the compilation of the Daniel data, that the original inspection data was not sufficient for the performance of an engineering evaluation. Tr. Holland, p. 1358. Finally, there is uncontradicted evidence from one of Applicant's expert witnesses that even assuming the validity of the welding defects reported in the Daniel data, with such defects going around the full circumference of

the anchor rods, it would not have affected the margin of safety or the load carrying capacity of the plates. In the expert's opinion, the weldments in the embedded plates could have been 25 percent smaller than required by the specifications and he testified that the Code was being changed to effect such a revision. (Board Finding 44)

When Bechtel calculated reduced load capacities, in its engineering analysis, it assumed, in addition to the 1/8 inch undersize, a 1/16 inch undercut for all anchor rods. It also concluded that deficiencies in the welds reported by Cives of unequal weld legs and poor weld profile (excessive convexity) did not affect weld performance. Based on this evaluation, and its analysis that safety of the plates was still assured with a reduced design capacity, Bechtel then requested and received the approval of SNUPPS and the NRC for exceptions to the Structural Welding Code. The exceptions permitted additional allowances for the vertical legs of the welds and undercutting, acceptance of unequal legs and the elimination of profile requirements. (Board Finding 45) Exceptions to Code requirements are the responsibility of architect/engineers on construction jobs since the Code requirements are considered as conservative guidelines.

Fisher Tr. 773. The Intervenor challenged Bechtel's finding that a 1/16 inch undercut did not affect the load carrying capacity of the anchor rods since its (Bechtel's) analysis ignored the fact that some anchor rods were unthreaded. However, in addition to the fact that there is no evidence in the record to support this argument, the Applicant successfully counters the objection with its reply that an

additional margin of safety is provided in the case of unthreaded anchor rods. See Applicant Reply to Proposed Findings, 27-28.

After Bechtel and the Applicant concluded that the conclusions reached in the 1977 report on the acceptability of manually welded plates embedded prior to June 9, 1977 was not contradicted by the Daniel data, the NRC ordered additional testing to be performed. It also inspected visually embedded plates substantially loaded by floor slab dead loads without seeing any signs of distress or overstress. (Board Finding 46) In the tests performed by the Applicant's consultants from Lehigh University, the testing was done to demonstrate the structural integrity of the welds in the 45 plates that had been rejected by Daniel but not as yet repaired. Six anchor rods on six different plates were selected by the NRC for bend testing and the direction of the bend was also directed by the NRC. Six anchor rods on six additional plates were selected by the Applicant for tension testing to their ultimate load. The tests were performed on welds selected with having the worst visual defects and appearances. (Board Finding 47) Six anchor rods were bend tested to 30 degrees without any signs of cracking or failure and six rods were tension tested to failure with three failing in the weld and the other three failing in the rod itself. Th ultimate strength of the welds tested was greatly in excess of their design loads. The tests were observed by the NRC. (Board Findings 48-49) The Intervenor argues that the welds selected for the tests were not as defective as the worst welds found in the

Daniel or Cives inspections nor did the tests deal with the kind of loads that the manually welded plates have to support. We believe these allegations unsupportable since the plates were ones previously rejected by Daniel and contained the worst available welds and finally the tests subjected the welds to the same shear forces that exist in the embeds that were embedded prior to June 9, 1977. Fisher  
Tr. 1150-1151.

Based on the engineering analysis of reduced load capacities, the review of the reinspection data of plates manufactured in the same time period and the additional testing that was done on manually welded embeds, the Applicant and the NRC both concluded that the plates embedded prior to June 9, 1977 were capable of supporting their design loads. (Board Finding 50)

The Board is obligated in this summary of the manual weld issues to express a deep concern over the handling of the embed plate problem by the Applicant, the Bechtel Company and the NRC Staff. That concern relates solely to the manually welded plate controversy since we conclude the review procedure for machine welded plates was prepared satisfactorily and followed adequately. We also, however, need to state our apprehensions over the quality of work performance manifested in these proceedings by the Daniel and Cives Companies. The following reflects the Board's uneasiness as a result of the evidence produced in this hearing:

1. Performing an evaluation of reinspection data without written documentation as the Bechtel Company did in this case is not only a questionable procedure but a violation of quality assurance requirements.

2. Assuming the truth of statements by the Applicant and Bechtel that they were unaware of Daniel's inspection data for a period of months--statements of which we have some doubt--this lack of knowledge does not foster confidence in either Company that they were carefully monitoring construction developments and progress at the Callaway facility.

3. The inconsistent reporting of weld deficiencies by Daniel inspectors demonstrates a supervisory weakness at the Daniel Company irrespective of any instructions that its employees were to inspect embeds on an accept or rework basis.

4. The acknowledgement by the Cives Company that it repaired 20 percent of the 400 embeds it reinspected at the facilities site raises, in our judgment, serious questions of the quality of work that was received from that fabricator.

5. Finally, we must express an overriding concern that NRC inspection officials permitted the question of the integrity of embeds installed prior to June 9, 1977 to stay unresolved for such a lengthy period of time. Over three years elapsed from the date of reporting the original suspected weld deficiencies until NRC's final evaluation was transmitted. It is clear from the evidence that the issue of the acceptability and adequacy of the manual welded embeds was referred to

NRC Headquarters both in November 1977 and April 1978. It is also clear that no action ensued until the Inspection and Enforcement Office of Region III of the NRC again initiated its own review in April 1980. No information has been provided in the record for this inaction on the part of the NRC Headquarters Office. (Board Finding 51)

#### Quality Assurance Failures

Many of the activities discussed herein were considered by Intervenors to be violations of quality assurance requirements. We agree with certain of the Intervenor's conclusions, but not with others.

The Board does not concur with Intervenor's argument that testimony showing there was some difficulty with the use of embeds at other nuclear facilities or that there were welding problems at Callaway in meeting Code specifications indicates a failure to establish measures for selecting appropriate materials as Criterion III of 10 CFR Part 50, Appendix B requires. As we have indicated, infra, the evidence reflects the industrial usage of embedded plates and also, reflects that welding codes are designed to be adaptable to revisions in welding requirements.

The Board has already expressed its judgment that the apparent lack of knowledge concerning Daniels inspection data was a failure in communication and under the circumstances here a potentially serious breakdown in the fabrication of safety-related materials, i.e., embedded plates. The negligence represents a violation of the quality

assurance criteria of XVI of Appendix B. Further, it is the Board's view, that the failure to require the Cives Company to produce in its reinspection effort, a more extensive report of the results thereof, was a violation of Criterion XVII. The Cives effort aimed at finding the extent of a problem that could affect quality. The adequate recording of activities affecting quality is one of the objectives of Criterion XVII. Accordingly, it would have been more in keeping with the purposes of effective quality assurance for an adequately documented record to be compiled of Cives reinspection activities.

The Intervenors also cite the Applicant's failure to notify the NRC of the manual embed deficiencies as is required by 10 CFR Part 50, 55(e) for significant deficiencies that need extensive evaluation, redesign or repair. Although the Board has expressed its concern with the length of time NRC took to review the Applicants handling of the manual embedded matter, we are unable to fault the Applicant with not filing a 55(e) report since it completed its original analysis of the problem in a prompt manner. It is a moot question, in any event, since the NRC certainly had notice of possible embedded deficiencies from the date its own inspectors reported welding defects in June 1977.

Outside of the failures reflected herein, the Board finds no other negligence affecting quality assurance requirements on the embed contention. The Applicant did undertake an analysis of the welding deficiencies, effected a revision in Code specifications to accommodate changes in the fabrication of embeds that were found necessary and also imposed stricter inspection requirements. These actions, occurring

shortly after the suspected problem of welding defects, were compatible with proper quality assurance activities. Whether the Applicant's actions were adequate to assure the safe functioning of the embeds installed at the facility before June 9, 1977 we discuss in our conclusion below.

### Conclusion

As we have indicated above, the Board finds a serious disregard by the Applicant and its major contractors for quality assurance considerations in the handling of certain aspects of the manual welded embed plate problem. The question before us is whether or not these activities constitute such a level of negligence that the quality of safety-related materials cannot be assured and as a consequence, the safe operation of the Callaway plant is thereby threatened. The central issue of this contention then is: If the assumption used by Bechtel in its engineering evaluation, that no weld deficiency was more than 1/8 inch undersize was an incorrect assumption, could plate failure among those embedded prior to June 9, 1977 be anticipated. We think not. We conclude the Applicant has carried the burden of proof on this issue on the following grounds:

1. A factor of safety has been designed into the load capacities of both machine welded and manually welded embeds of at least 2.0 against the yield limit state of the plate and the tensile capacity of studs and anchor rods.

2. The actual loads imposed on most embedded plates is considerably less than the allowable design capacity, thereby increasing the design safety factor to more than 2.0.

3. Tension tests to failure were performed on weldments of manually welded plates that had been rejected by Daniel inspectors but not repaired and a safety factor in excess of 3.0 was demonstrated.

4. Evidence that welding code revisions will permit weldments in the future to be 25 percent smaller than those required for the embed plates at Callaway.

5. Testimony of Dr. J. W. Fisher, an expert in weldments and structural analysis from Lehigh University whose opinions and competence were persuasive to the Board, that, even assuming the validity of the Daniel data with the weld defects reported extending completely around the circumference of the anchor rods, that neither the required margin of safety nor the load carrying capacity of the manually welded embeds would have been affected.

Finally, we also conclude that the Applicant has submitted adequate evidence of the safety of machine welded embeds based on the inspections conducted by the Cives and Daniel organizations, the probability analysis carried out by the Bechtel Corporation and the load tests performed successfully on selected machine welded plates installed before June 9, 1977.

B. I.C.1 Honeycombing in the Reactor Building Base Mat

In this contention Intervenor challenge whether there exists adequate assurance that there are no defects in concrete of the reactor building base mat beyond those already known. They challenge the reliability of the methodology that was used for testing the base mat as well as the inferences drawn from the tests. Additionally, they question the adequacy of the quality control and quality assurance procedures that were used before, during and after the placement of concrete for the base mat. Relevant to this consideration is whether individual deficiencies in quality control are sufficiently numerous and serious that when considered collectively they would indicate a failure or breakdown of the Applicant's quality assurance program as a whole.

The reactor building base mat is a flat circular slab of concrete which is 154 feet in diameter and 10 feet thick. The base mat serves as a foundation and base for the reactor building. The tendon access gallery is located directly below and along the outside edge of the base mat and continues around its circumference. The lower surface of the base mat forms the ceiling of the tendon access gallery. Tendons are steel cables which cross over the reactor dome for the purpose of applying compressional stress to the reactor building shell and dome after the concrete hardens. The tendons are anchored at both ends by steel structures called trumplates. The trumplates are embedded in the concrete ceiling of the tendon access gallery. There are 172

trumplates in the Callaway reactor building. Applicant Base Mat Testimony, ff. 227, at 9-11 and Figure 1; Varela Testimony, ff. 396, at 2-3.

Concrete for the reactor building base mat was placed over a 62-hour period from April 6 to April 9, 1977. Six thousand seven hundred and twenty (6720) cubic yards of concrete were used. Two shifts, each involving approximately 190 construction crafts, engineering, quality control and supervisory personnel, were used in alternate fashion to accomplish the concrete placement. Three NRC Staff inspectors were present during the concrete placement and one or more of these inspectors observed most of the operation. (Board Finding 52)

Honeycombing in the concrete ceiling of the tendon access gallery was found by construction personnel after the concrete had hardened and the forms and shoring were removed. Honeycombing is a defective condition in hardened concrete which consists of small voids dispersed through the concrete giving it a popcorn appearance and, of course, causing it to be weakened. The defect may or may not be a serious safety concern depending on its location and extent. Honeycombing that was found on the ceiling of the tendon access gallery, which is part of the reactor building base mat, was taken as a serious matter by both Applicant and Staff since there were 14 locations where it undermined the base of the tendon trumplates which ultimately would be loaded in excess of 1,400,000 pounds each. (Board Findings 53, 54, 55)

The honeycombed areas were chipped out to sound concrete to determine the extent of the defect at each location and to prepare the cavities for repair. Repairs were done by filling each cavity with a high strength grout which formed a bearing surface for the trumplates having a strength at least as high as the sound concrete of the base mat. (Board Findings 54, 61)

The Applicant had performed nondestructive testing of the concrete in the base mat above the tendon access gallery to determine whether hidden concrete imperfections existed in the interior concrete above the trumplates. Testing was performed with a soniscope which measures the velocity of sound as it travels through concrete. High sound velocity (above 12,000 feet per second (ft/sec)) indicates uniform dense concrete; low velocities (5000 ft/sec) reveals poor concrete containing voids, honeycombing or cracks. Soniscope testing is an accepted technique that has been utilized for more than 15 years. (Applicant Base Mat Testimony, at 23-27; Varela Testimony, at 5)

Multiple soniscope measurements were taken at each of 44 trumplates in the tendon gallery which represent 25 percent of the trumplate locations in the tendon gallery. Seven hundred and sixty (760) individual measurements were made of which 103 were unsuccessful. Unsuccessful shots or signals are caused by poor contact between a transducer and rough concrete or by a minute plane of separation between concrete and a steel plate which blocks the signal but does not

indicate internal voids or honeycombing. (Applicant Base Mat Testimony, at 25-28; Applicant Ex. 2, pp. 15-17)

Measurements were taken: (1) vertically through concrete, (2) vertically through concrete and a steel plate which was part of the trumplate, and (3) at an angle through the concrete behind the trumplates. All measurements showed velocities in excess of 15,000 ft/sec. Coefficients of variation ranged between 1.0 and 2.1 percent for these measurements indicating reliable and reproducible data. (Applicants Ex. 2, p. 15-19)

The tests showed: (1) concrete above the gallery and the trumplates uniform in composition and strength, (2) concrete tested has a high compressive strength, (3) no evidence of internal honeycombing in concrete in the 44 trumplate areas, and (4) the results indicate that, based on a 25 percent sample, internal honeycombing probably does not occur in the base slab. (Applicant Base Mat Testimony, at 25-28; Applicant Ex. 2, p. 21) (Board Finding 60)

Staff concluded the test was appropriate and the number of sample locations was conservative. (Varela Testimony at 6, 8; Staff Ex. 5)

Our review of the evidence pertaining to causes of honeycombing, repairs, soniscope testing, and loading of structures in the tendon access gallery lead to the conclusion that there exists reasonable assurances that no concrete defects of importance to safety exist in the tendon access gallery portion of the base mat. Intervenor's issue related to dry pack repairs was found to be insignificant to the safety of the base mat. (Board Findings 64, 65, 66, 67, 68)

The tendon access gallery, however, constitutes only 19 percent of the entire base mat. Because of the nature of the soniscope which was used for nondestructive testing, it could not be used to test the remaining 81 percent of the base mat. Thus, if reasonable assurance of integrity of the remaining base mat is to be obtained, it must be done by indirect means since few direct observations exist to confirm it.

The indirect evidence for base mat integrity, however, is substantial. The physical evidence from the tendon gallery shows that honeycombing was a surface phenomenon. All that was ever discovered was first discovered by visual observation of surfaces. The soniscope tests for interior defects throughout the full thickness of concrete, on the other hand, did not reveal a single instance of faulty concrete above the tendon gallery. (Board Findings 56, 60)

The cause of surface honeycombing in the tendon gallery is due principally to inadequate vibration of fresh concrete in areas specially congested and hampered by steel embedments. Since no such cause existed in the interior of the base mat, there is no reason for suggesting that concrete was not vibrated adequately during placement. (Board Findings 57, 58, 81)

The base mat placement began on one side of the base mat and progressed to the other without special reference to the tendon gallery. It is unlikely that substantial changes in materials, workmanship, equipment, or methodology could take place unnoticed during such a relatively short intense work period which would lead to either better or worse workmanship focused in the tendon gallery as

compared to the rest of the base mat. We therefore conclude that the base mat pour was accomplished with reasonable consistency and uniformity of materials and workmanship from beginning to end. The direct observations of the integrity of interior concrete in the tendon gallery, therefore, apply to the base mat as a whole even though the sampling technique used by the contractor cannot be regarded as a true random sample of the entire base mat.

Similar reasoning leads us to conclude that we cannot rule out with certainty the existence of honeycombing on the lower surface of the base mat (i.e., that portion resting on earth and therefore inaccessible to inspection). We note, however, that the accessible surfaces of the base mat (top and vertical sides) were inspected and no imperfections were found. (Board Findings 79, 83)

The frequency and magnitude of honeycombing in the tendon gallery gives us a fair sample of what reasonable constancy in materials and workmanship might produce on other lower surfaces in the base mat. Considering, however, that the tendon gallery was more congested with embedded steel items than the lower surface of the base mat in general, we conclude that whatever honeycombing might exist on the remaining lower surface its frequency and magnitude is not likely to exceed that already found. (Board Finding 81)

The honeycombing that was found, however, would be harmless to the overall safety of the reactor building if located in other parts. The concern in the tendon gallery stemmed from the fact that honeycombing undermined the base plates of some special structures--the tendon

trumpets--which would ultimately carry very high loads. No such special load bearing structures exist over the lower surface of the base mat in general. The Board therefore concludes that even though honeycombing of the general frequency and magnitude as that already found might exist on the lower surface of the reactor base mat, such imperfections would not jeopardize the function of any special load bearing structure nor would they create a concern for the general integrity of the base mat. (Board Finding 84)

#### Adequacy of Applicant's Quality Assurance and Quality Control

##### Procedures

The Board has been unable to find serious defects in the overall quality assurance procedures followed by the Applicant in connection with construction of the reactor building base mat. The evidence shows that the essential components of an overall program were present in this case. These components include preplanning and inspection, supervision and inspection during concrete placement, and inspection, testing and repairs of defects after the task was finished. (Board Finding 74)

It appears that Intervenor's objections stem from an unrealistic assumption that the only acceptable performance of a constructor would be flawless work in the first instance. While that is an important goal we conclude that it is an unrealistic approach to safe construction since prevention of flaws is only one aspect of a multifaceted program. In this instance it is apparent that defects in

concrete of the reactor base mat occurred in spite of reasonable efforts to prevent them. However, subsequent inspections disclosed the defects, they were reported internally and to NRC, tests were made to determine the extent of the imperfections, and repairs were made. (Board Findings, 66-72)

These are actions we expect of a functioning quality assurance program. A serious deficiency in any of the components might lead to serious questions about the overall program. However, in this case the program worked properly and it led to the desired result which is a structurally sound base mat.

Intervenor asserts a number of reasons why the Applicant's testing may not demonstrate the integrity of the tendon gallery. Their assertion that the sonoscope method is faulty because it does not take account of the fact that sound waves may go around defects in concrete reflects a misinterpretation of the physical principles of the instrument. The deflection of sound waves around defects in concrete is the phenomenon which enables the detection of such defects. The added time required for sound to traverse a tortuous pathway relative to an unobstructed pathway is what is measured and what leads to the interpretation of reduced velocity and faulty concrete if it exists. (Board Findings 75-76)

Intervenor's argument that the velocity of sound in steel may account for the high sound velocity measured in tests of the base mat is similarly misguided. Expert testimony shows that the interface between steel and concrete often results in a degraded signal or

complete obstruction of the signal. Many of the soniscope measurements attempted failed because they were taken from steel surfaces which were interfaced with concrete. While sound might well have a high velocity in steel, we need not take notice of that fact as urged by Intervenor since it is beyond dispute that the base mat consists of concrete containing embedded steel. It is the existence of concrete-steel interfaces which might influence the velocity of sound; the sound signal may be halted by interfaces or simply go around the obstruction. In either case the result could not be an apparent increase in sound velocity. (Board Finding 77)

Intervenor's discussion of the errors possible in aligning a cross hair on an oscilloscope which is necessary to measure the velocity of sound is also without merit. They assert that the testing report does not discuss the margin of error or with what bias such factors might have been resolved. This is simply inconsistent with the facts, since the Wiss, Janney, Elstner report (WJE was the firm selected by the Applicant to perform testing), Applicant Ex. 2, p. 19, lists a table showing average velocities of sound as transmitted through concrete and standard deviations and coefficients of variation for each average. We expect nonsystematic errors of measurement including instrument reading errors to be reflected in the calculated standard deviations and coefficients of variation. The coefficients of variation actually observed range from 1.0 to 2.1 percent. These errors are sufficiently small to conclude with confidence that the measured sound velocities

reliably exceed the threshold of concern (12,000 ft/sec) below which the integrity of concrete could be in doubt. (Board Finding 78)

Intervenor's assert that the Applicant's quality assurance program failed to provide proper documentation regarding the reactor building base mat problems. They believe that the documentation that exists demonstrates weaknesses in work procedures and quality control procedures that were governing at the time of base mat placement. Intervenor's specifically object that: (1) concrete placement reports were not submitted by all quality control inspectors after the base mat was poured and (2) that the documentation of the existence of honeycombing in the reactor base mat was not submitted in a timely fashion since more than a month passed after completion of concrete placement before a nonconformance report was written. (Board Finding 85)

The Staff inspector who was present at the time of concrete placement subsequently cited the Applicant for an infraction because each of the Applicant's quality control inspectors did not submit individual concrete placement reports. After the citation was issued the Applicant undertook to remedy the deficiency in documentation by having each inspector who was present during the time of concrete placement sign a concrete placement report. Each concrete placement report was similar in information content and appearance and was signed by the individual inspectors during a period covering July and the first part of August of 1977. In the Applicant's view the signatures

and the absence of comment on the concrete placement reports provides assurance that the individual inspector observed no deficiencies during the pour. It could not be ascertained directly from the reports, however, what activities the signature of each inspector was verifying that he had witnessed. (Board Findings 86, 87, 88)

The NRC Staff inspector interviewed some of the inspectors after receiving the concrete placement reports and verified that they had observed no deficiencies during concrete placement. (Board Finding 89)

The Board concurs with Intervenors that the procedure followed here was defective. We criticize the documentation procedure but do not find evidence that the inspectors failed to perform their duties at the time the concrete was actually placed. Specifically, we find that the placement reports signed without comment some three months after the event took place to be essentially worthless. (Board finding 90)

We are unable to determine from the belated reports whether they were signed by the inspectors in a perfunctory manner as simply another burden of paperwork or whether the signatures have genuine meaning. While some interviews were done by the Staff inspector, the interviews were not documented. Thus, no genuinely useful written record exists which would document the observations of inspectors during the placement of concrete in the base mat. Assuming that such documentation is necessary, as appears to be the case from the Staff citation, we should insist that it be substantive and not a mere paper shuffling exercise. In this instance the Board concludes that an appropriate

procedure might have been to interview each inspector and produce a written record of the interview for the inspector's signature. (Board Findings 90, 91)

The Board, however, can find no deficiency with regard to the timing of the nonconformance report. Concrete placement was finished on April 9 and a nonconformance report from Daniel Corporation to Bechtel was filed on May 11, 1977. In the approximate month between completion of the base mat pour and the filing of the first nonconformance report, the concrete was left to harden, the concrete forms were then removed, inspections were performed and honeycombed areas were chipped to sound concrete. The chipping operation was an essential prerequisite to determining the extent of unsound concrete. In light of the actions that had to be taken, the elapsed time of one month from the termination of the pour appears reasonable. Upon receiving the May 11 nonconformance report, Bechtel rejected it, requesting more detail before disposition. The Daniel Corporation then proceeded to draw detailed maps of the extent of honeycombing in the tendon access gallery and outlined in detail a proposed repair method. The second nonconformance report which was acceptable to Bechtel was filed on June 27, 1977. (Board Finding 92)

The Board finds no reason for concluding that there was a general breakdown in Applicant's quality assurance procedures. The quality assurance procedures employed in this instance worked properly in that precautions were taken to prevent deficiencies; deficiencies that occurred in spite of the precautions were found promptly; appropriate

reports and tests were made; and repairs were made which restored the defective areas to original design specifications. While we found deficiencies as regards the handling of concrete placing reports on the part of both Staff and Applicant and in the requirements for testing dry-pack concrete, these appear to be isolated matters and not evidence of gross failure of the Applicant's quality assurance program.

#### Conclusions

The Board concludes that the Applicant took reasonable steps in advance of concrete placement to prevent the occurrence of concrete imperfections. The concrete imperfections occurred in spite of precautions and not due to neglect of quality assurance. When concrete imperfections were discovered they were reported both to Bechtel and the NRC and reasonable plans were established for testing and repair. The sonoscopic testing demonstrated that there were no hidden concrete imperfections in the base mat above the trumplates. The surface repairs that were undertaken assured adequate bearing surfaces for the trumplates, which would ultimately carry very high loads. Loads were later imposed on the trumplates, as high as 1,600,000 pounds without failure of trumplates or distress in concrete. The issues raised by Intervenor concerning the use of dry-pack are insignificant and have no bearing on safety of the structure. The Board concludes that there is no reason to doubt the integrity of the reactor base mat or the performance of the tendon trumplates.

C. I.C.2. Honeycombing in Reactor Building Dome

The Board denied a motion for summary disposition of this contention prior to hearing after concluding that there existed a substantial factual dispute as to the integrity of the reactor dome and quality control procedures that were followed for discovery, reporting and resolution of this matter. Nevertheless, Intervenors announced at hearing that while they did not abandon the contention they would not conduct cross-examination of Applicant's or Staff's witnesses since they did not feel that they could contribute to development of a sound record on this subject.

After reviewing the prefiled testimony of both Applicant and Staff the Board concluded that there were remaining matters to be explored and it called the witnesses for Board examination. The Board questioned the witnesses on both quality assurance procedures and the reliability of the testing and analysis that was done that led Applicant and Staff to conclude that there were no undiscovered defects in the reactor dome which would jeopardize its integrity. The Board found the witnesses of Applicant and Staff to be forthright and credible. No evidence was uncovered in the Board examination which was at variance with their prefiled testimony.

In this contention Intervenor challenges whether there exists adequate assurance that there are no imperfections in the concrete of the reactor building dome beyond those already discovered and repaired by the Applicant.

The reactor building dome is the roof of the reactor building. It is constructed in the shape of a hemisphere with an inside radius of 70 feet. The concrete in the dome is 3 feet thick. Layers of reinforcing steel run both horizontally and vertically within the concrete near both the inside and outside surfaces. The inner side of the concrete dome is lined with a one-quarter inch carbon steel liner plate which assures leak tightness of the building. The liner plate also served as a concrete form for the inside surface of the dome during concrete placement.

Concrete for the hemispherical reactor dome was poured in a series of "lifts" or layers placed sequentially starting from the vertical walls of the reactor building and working upward towards the top of the dome. Most of the concrete was placed without special problem; however, difficulties were encountered as construction approached the top. This portion of the dome was poured without the use of outer forms which would constrain the flow or movement of concrete after placement. The angle of the dome ranged from 45 degrees to near horizontal at the top. At these angles and without forms, the freshly placed concrete tended to subside downward as it was being consolidated by workmen using vibrating machines. The migrating concrete was moved to upper levels by workmen to restore the desired surface. Movement of concrete was a surface phenomenon because of the lack of external constraint at the surface. (Board Findings 94, 95)

When the concrete hardened, workmen noted surface honeycombing in four areas of the dome. Upon chipping these areas to sound concrete,

it was found that there was some loss of bond between concrete and steel reinforcing bars at depths of 4 to 6 inches from the surface. The defects consisted of small gaps 1/4 to 1/2 inch in diameter on the lower side of the reinforcing bar. Later when some blockout forms were removed, three additional areas of honeycombing were found making a total of seven areas known to contain defects. (Board Findings 96, 99)

The Daniel Corporation, acting in its role as constructor for the Applicant, filed a nonconformance report for approval by Bechtel Corporation on November 10, 1980. NRC was not notified at this time since Daniel inspectors determined that the imperfections did not represent a significant deficiency in quality control, construction or engineering and were not reportable under the provisions of 10 CFR Part 50.55e. Bechtel and Union Electric personnel, however, questioned whether a more rigorous investigation of the significance and extent of the imperfections should be performed since there existed the possibility that additional areas of imperfections might be present. Union Electric then notified the NRC Staff on December 5, 1980 of a potentially significant deficiency. (Board Finding 98)

Union Electric and Bechtel decided to conduct tests of the dome using both destructive and nondestructive methods to determine whether there were other areas of concrete imperfections. Techniques used included nuclear densometer testing, boroscopic examination, microseismic (pulse echo) examination, selective excavation and engineering analysis. The nuclear densometer and boroscope

examinations did not reveal further evidence of unsound concrete near the outer surface of the dome which is the only area in which they are effective. (Board Finding 100)

The pulse-echo technique was used at 1,671 locations as a means of searching for imperfections throughout the three foot thickness of the dome. This technique works by generating a sound pulse in the surface of concrete which passes through the test section and reflects from the opposite surface back to a detector at the surface. The time of passage is measured with the aid of an oscilloscope. In normal concrete the oscilloscope display shows two pulses or peaks separated along a horizontal axis. The first pulse is from the initial signal and the second is from the reflected signal. Imperfections are detected because they reflect sound back to the detector from an interior location. This results in an additional pulse being displayed on the oscilloscope screen between the two normally present. The pulse-echo method has been used extensively for similar applications and is reliable and accurate. (Board Finding 101)

The results of the pulse-echo testing showed that of 1671 tests, 28 or 1.68 percent were of possible structural significance. The readings, however, were sporadic in occurrence. None of the areas tested showed a sufficient number of such readings to classify the area as structurally defective. (Board Finding 102)

The Applicant excavated concrete at six test points which had shown defects by the pulse-echo method. At two of these points no imperfections were found, while at four points small air gaps on the

downhill side of the reinforcing bar were found. The excavations confirm that a correlation exists between the pulse-echo readings and the actual imperfections. The nature of the imperfections serve to confirm the original conclusion that they were caused by subsidence. (Board Finding 103)

The results of testing and evaluation of the reactor building dome are contained in Bechtel's "Final Report of Containment Dome Concrete Imperfections at Callaway Unit 1" dated March, 1981. Staff review of that document concluded that more testing was needed. Additional pulse-echo tests were done and Applicant and Staff concluded that the extent of imperfections was clearly identified. (Board Finding 104)

The effect of the concrete imperfections was to reduce the bonding between the reinforcement bar located near the outside dome surface and the concrete. (Ma Testimony, at 3) This kind of imperfection was not critical because (1) the imperfections are primarily limited to the hoop bars and do not affect the meridional reinforcement; (2) the type of load placed upon the hoop bar (an axisymmetric loading) is such that there is no change of stress along the bar and therefore sporadic imperfections would not affect their load carrying capabilities and (3) the design margins for the hoop bars and radial ties are more than adequate to overcome any minor lack of bond due to the sporadic imperfections. (Applicant Dome Testimony, at 25)

An engineering analysis made by the Applicant showed that even if the bond between concrete and steel were lost for 50 percent of the entire reinforcing bar near the outer surface of the dome, the

structure would retain sufficient strength to meet all design and accident load conditions. The actual loss of bond was minor and sporadic (consisting of 1/4 to 1/2 inch voids along reinforcing bar near the outer surface at 28 locations). The design strength margins of the dome far exceeds the minor loss of strength that could be attributed to the small voids in concrete. (Board Finding 105)

The Staff concluded by independent analysis that the concrete had higher than required compressive strength and that the minor loss of bonding would not affect the structural integrity of the dome since ample margins of safety exist principally because of extra steel reinforcements. (Board Findings 106, 107)

No repairs of imperfections revealed by the pulse-echo investigation were necessary because of the design margins of safety in the structure. The areas which had previously been chipped to sound concrete, however, were repaired by filling with concrete of the same characteristics used for the dome construction after first preparing the cavities to insure adequate bonding. (Board Finding 99)

#### Adequacy of Applicant's Quality Control

No evidence was brought out in the Board's questioning of witnesses which would call into question the quality control procedures used by the Applicant in relation to inspection and discovery of defects, reporting, testing of the dome, or the repairs.

The evidence from the dome episode shows that the Applicant's actions demonstrated an affirmative commitment to quality of

construction. The Applicant and Bechtel might have rested on an easy concurrence with Daniel Corporation's initial assessment that the defects were minor. (This later proved correct but could not be known with certainty at the time.) The Applicant instead ordered additional testing which would ascertain the full extent of concrete imperfections in the dome. The testing itself was comprehensive in that it utilized several different methods and many individual measurements. As indicated, the pulse-echo testing alone was systematically performed at 1671 points. The defects that were revealed proved in final analysis to be structurally insignificant. (Board Finding 108)

The Staff also demonstrated a skeptical and analytical approach during the resolution of this problem. At one point it requested removal of additional forms in the dome which subsequently revealed more imperfections and at another required even further pulse-echo testing to satisfy itself that the full extent of imperfections were known. The Staff engineering analysis was independently performed rather than relying on review of the Applicant's analysis.

#### Conclusion

The Board concludes that the Applicant has adequately discharged its burden of proof on contention I.C.2. Contrary to the contention, the full extent of concrete imperfections in the reactor building dome is known from tests. Engineering analysis shows that the integrity of the structure is not in doubt because of the minor nature of the imperfection and the compensating design margins inherent in the structure. Additionally, there is no evidence related to the discovery

or resolution of this matter which would suggest an overall failure or breakdown of the Applicant's quality assurance or quality control programs.

D. II.A.1. SA-358 Piping

SA-358 is an ASME material specification for a type of welded stainless steel pipe which is widely used for pipe sizes greater than eight inches in diameter. The pipe is made from plate by forming and rolling the plate into a continuous tubular shape. The resulting longitudinal seam is then welded, usually by the submerged-arc process, with the weld made from both the inside and outside surfaces.

(Finding 109)

A Daniel pipefitter in the process of preliminary work on the pipe spool piece prior to fit-up for welding noticed an internal weld surface irregularity in the SA-358 pipe in question. He brought the matter to the attention of Daniel quality control personnel, who observed the irregularity and possible ovality/thin wall conditions. The inspector had an ultrasonic test performed on the pipe which indicated that a thin wall did exist. A nonconformance report (NCR) was generated and a "hold tag" was placed on the pipe. (Finding 110)

The Material Specification for SA-538 piping allows an outside diameter variation of 1 percent. The pipe in question has a nominal outside diameter of 10.75 inches, not including the allowable weld reinforcement of 0.125 inches. Measurements taken at the request of

the NRC Staff showed a maximum outside diameter variation of 0.092 inches or 0.86 percent, within the 1 percent limit. (Finding 111)

The pipe in question has a specified minimum wall thickness of 0.874 inches. An actual minimum thickness of 0.814 inches was found in the pipe's inservice inspection weld preparation area, which had been counterbored. Bechtel performed two calculations as provided in ASME Section III, Article NC-3640 to determine the acceptable minimum wall thickness for this piece of pipe. The calculations yielded acceptable minimum wall thicknesses of 0.711 and 0.795 inches, respectively. Independent calculations were performed which verified Bechtel's findings. (Finding 112) The Board agrees that the counterbored area did result in a wall thickness below the specified minimum thickness, but finds that the actual minimum thickness of 0.814 inches is adequate.

The third irregularity raised in the contention is that the pipe "had rejectable weld defects on the inside of a longitudinal seam weld." The hearing on this claim addressed irregularities, and their potential causes, of several types--including excess reinforcement, overlap, and fissures.

Daniel measured an area of weld reinforcement on the inside of the SA-358 pipe with a reinforcement height of 3/16 inch and documented it in a nonconformance report dated April 30, 1979. While Bechtel initially erroneously dispositioned this NCR, it is clear that there was a nonconformance as to the reinforcement height, since 1/8 inch is the maximum permitted by SA-358. Apparently recognizing the error,

Daniel elected to rework the item in accordance with its approved procedures, to bring the weld into compliance with the ASME code. The excess weld reinforcement was reworked by simple removal of the excess material by localized grinding. Joint Intervenors have alleged that this nonconformance was not repaired or reworked in accordance with documented procedures. However, Daniel could have first initiated a deficiency report for rework (rather than an NCR), and simply reworked the item. Instead, a more conservative approach was taken by first seeking the designer's review of the matter. (Board Finding 113) The Board finds that Daniel acted properly in assuming the responsibility to correct the nonconformance.

The Daniel NCR also identified a condition described as overlap in the same area as the excess weld reinforcement. The overlap apparently was excess weld material which had rolled over onto the surface of the pipe material. Bechtel advised, in its disposition of the NCR, that overlap is not listed in the ASME code as a rejectable condition for radiography. This is because overlap does not affect the volumetric quality of the weld. Overlap is a condition that occurs at the intersection of the weld with the pipe material surface, but could not propagate through the thickness of the weld because it is in the wrong plane for propagation. Nevertheless, the overlap was reworked by the grinding process discussed above with respect to excess reinforcement. (Finding 114)

Counsel for Intervenors extensively cross-examined the witnesses on the possibility that the weld defect might have been caused by "drop

through" or "melt through." In addition, questions were asked on whether there might be cracks or fissures in the weld. (Board Finding 115)

Melt-through occurs in a submerged arc weld of the type used to weld SA-358 piping when total passage of both weld metal and the flux to the other side of the weld occurs. Drop-through is a similar condition, although less extensive. Both melt-through and drop-through are visible conditions. There are no reports that melt-through was visually noticed, and photographs of the weld in question reveal no evidence of drop-through. Not only would melt-through be visible, it would also be detectable on radiographs because of the resultant development of porosity in the weld. Radiographs of the weld reveal no such defect. In addition, testimony indicated that the presence of overlap indicates drop-through could not have occurred. Findings 116, 117) The Board concludes that no drop-through or melt-through occurred in this weld.

In NRC's investigation of this piece of pipe, an allegation was addressed that the weld was cracked. Photographs of the weld exhibit two fissures which could have been mistaken for a crack. The indications identified as fissures were in the excess material and not in the weld itself. There was testimony that the indications described as fissures were actually the result of overlap where the excess weld metal came out on the surface of the pipe without wetting the pipe. If fissures existed in the weld, they would have been visible in radiographs. Radiographs reveal the weld to be free from defect.

(Finding 118) The Board, therefore, finds that there were no cracks or fissures in the weld of the pipe.

The excess weld material was removed from the pipe by grinding, although the pipe would have been able to perform its function without this removal. The Staff reviewed both the pipe itself and radiographs of the pipe taken subsequent to grinding. The Staff found that the pipe in its present condition is free from defects. The Board agrees.

#### Conclusion

The Board finds that the record developed with respect to SA-358 piping does not reveal a breakdown in Applicant's quality assurance program. The weld defect in question, a relatively minor one, was discovered by Daniel personnel and dispositioned by Daniel. The weld defect was removed, and the pipe was shown to be adequate with respect to ovality and wall thickness.

#### E. II.A.2. SA-312 Piping

SA-312 is an ASME material specification for both seamless and welded stainless steel pipe. Welded SA-312 pipe is made from plate by forming and rolling the plate into a tubular shape. The longitudinal seam is then autogenously welded (without filler metal) by the gas tungsten arc method. The weld is made from both the inside and outside surfaces for double-welded pipe. (Finding 119)

Those safety-related systems which contain double-welded SA-312 pipe are designated as ASME Class 2 and 3 (seamless pipe only was used for systems designated as ASME Class 1). Under the rules of the ASME Code, welded piping is required to meet all the tests and examinations

prescribed by Section III of the ASME Code. The material specification for SA-312 requires chemical analysis, tension tests and flattening tests to be performed on each lot of pipe. The material specification also requires each length of pipe to be hydrostatically tested. ASME Section III requires that welded pipe for use in Class 2 systems be non-destructively examined by one of the following methods: ultrasonic, eddy current, magnetic particle, liquid penetrant, or radiographic examination. It is usual for pipe manufacturers to select the ultrasonic method for SA-312 pipe as other methods are not suitable for large diameter pipe. (Finding 120).

The problem addressed in Subcontention II.A.2 with SA-312 pipe is centerline lack-of-penetration (CLP). CLP occurs in autogenously double-welded SA-312 pipe when complete through-wall fusion does not occur between the inside and outside welds during welding of the longitudinal seam. A plane then exists in the center of the pipe wall between the two weld passes where the original plate edges are tightly abutted but not fused. (Finding 121)

This problem with SA-312 piping is not limited to the Callaway facility, but is generic in nature. On September 27, 1978, the Arizona Public Service Company informed the NRC that Pullman Power Products (PPP), a fabricator of safety-related piping spools for use in the Palo Verde Nuclear Generating Station, discovered longitudinal weld defects in ASME SA-312 type 304 austenitic stainless steel pipe supplied to Pullman by the Youngstown Welding and Engineering Company (YWEC). The defects were identified during the radiographic examination of

circumferential shop assembly welds. Forty-four percent of the completed and partly fabricated subassemblies were rejected, the majority because of CLP. Less than two months later, Southern California Edison reported similar defects in pipe supplied for one of its nuclear facilities. Documentation provided with the pipe indicated that YWEC had performed the required ultrasonic examination, but the rejectable indications had not been identified. (Finding 122)

This determination resulted in a special investigation at YWEC by NRC inspectors. They determined that the apparent cause of the identified defects was inadequate control of welding parameters, including welding current, voltage and travel speed. The NRC Staff then issued Bulletin 70-03. (Exhibit XI to Staff Exhibit 7). This Bulletin required that licensees: (i) determine whether double-welded SA-312 pipe manufactured by YWEC had been incorporated or would be incorporated into safety-related piping systems, (ii) identify the system, location, pipe size and pressure/temperature parameters where the double-welded SA-312 pipe was or would be used, and (iii) develop a program for the volumetric examination of the longitudinal welds and provide suitable corrective action for non-conforming material. (Finding 123)

With this discovery of a potential problem with SA-312 pipe in a number of nuclear plants where it was involved, Bechtel determined that a detailed test program should be initiated to look into this generic problem. The test program was designed both to assess the ability of ultrasonic examination to detect CLP and to assess the effects of CLP

on various mechanical properties of double-welded SA-312 pipe. The results and conclusions of Bechtel's investigation are contained in Bechtel's "Report on Investigation of Weld Imperfections in ASME SA-312 Double-Welded Austenitic Stainless Steel Pipe for Compliance with NRC I&E Bulletin 79-03" (Applicant Ex. 11). (Finding 124)

During this investigation, it was determined that the principal cause of CLP was the wide range of allowable welding parameters permitted by the YWEC qualified welding procedure. The significant welding parameters include arc voltage, amperage, travel speed, and weld head oscillation. Differences in the allowable settings for these parameters affect the depth of penetration of the upper and lower weld passes. Thus, as amperage is decreased to the minimum allowable setting under the YWEC qualified welding procedure, less heat is transmitted to the weld surface and the weld is relatively shallower. Similarly, an increase in arc travel speed will result in a shallower weld as will an increase in the weld head oscillation rate. The effect of any combination of settings depends on the thickness of pipe being welded. The range of parameters in the YWEC qualified welding procedure was approved for a thickness range of 1/16 inch to 3/8 inch. Therefore, settings which would produce acceptable penetration for a 1/16 inch pipe might result in some CLP if used for a thicker walled pipe. An additional factor which can contribute to CLP is arc misalignment in which the upper and lower weld arcs are not aligned with the longitudinal seam and with each other. As a result, the weld penetrations may be sufficient, but the upper and lower weld beads will

not meet in the center of the pipe thickness because the point of deepest penetration in the top weld is not aligned with the deepest penetration point in the lower weld. (Board Finding 125)

The Bechtel investigation concluded that the ASME Code-required ultrasonic examination cannot reliably detect CLP in double-welded SA-312 pipe. Bechtel's investigation included review of the ultrasonic testing techniques used by PPP and Ultralabs, and testing of four special test weldments fabricated by Bechtel with intentionally produced CLP, varying in amount from 35 percent to 60 percent. The Code-mandated ultrasonic examination was not able to detect the CLP in the four samples. Bechtel concluded that the two unfused base metal edges of the rolled plate are in such intimate contact that the ultrasonic sound waves are transmitted without interruption across the unfused area and are not reflected back to the ultrasonic transducer and displayed as an indication. Furthermore, the geometry of the CLP is such that even if the ultrasonic sound wave is reflected from a CLP condition, the majority of the energy would not be returned to the transducer and displayed as an indication. Accordingly, Bechtel concluded that the Code-specified ultrasonic examination will not reliably detect the presence of CLP in SA-312 piping. (Finding 126)

As part of its investigation, Bechtel determined the maximum amount of CLP in the SA-312 piping produced by YWEC. Bechtel examined 71 cross-sections of longitudinal welds in over 500 feet of double-welded SA-312 pipe supplied by YWEC to PPP. Of the specimens, 25 showed some degree of CLP. The greatest amount of CLP was 26

percent of the wall thickness of the pipe. There is ample evidence that the extent of CLP that may exist in Callaway SA-312 piping will be no greater than that examined in the Bechtel generic investigation. The Callaway pipe was fabricated by the same process, same machines, same personnel and within the same time period as the pipe supplied to PPP and examined by Bechtel. Furthermore, in intentionally producing test samples with greater than 26 percent CLP, Bechtel was required to use welding parameters outside the range of parameters used by YWEC. (Finding 127)

Bechtel performed tests to determine the effect of CLP on the mechanical properties of the pipe, but, in order to obtain data on welds which contained more than 26 percent CLP, the testing was done on a series of welded plates which were prepared so as to simulate welds in production pipe containing CLP. The same material type was used as the base material from which the SA-312 welded pipe was made. The intentionally produced CLP in the test plates ranged from 14 percent to 47 percent. The yield strength, ultimate tensile strength and elongation were measured, and it was shown that even with 25 percent CLP, SA-312 piping will meet all the ASME mechanical property requirements. Bechtel also had three hydrostatic burst tests performed. The first test was performed on a piece of YWEC pipe containing 15 percent centerline lack of penetration. The other two tests were performed on specially welded pipes with intentionally fabricated CLP of 40 percent and 55 percent. The pipes were plugged at each end and hydrostatically pressurized until fracture occurred.

Normal hydrostatic test pressure for this size pipe and schedule is calculated to be 882 psi. The pipe with 55 percent CLP burst at the lowest pressure between 3000-3100 psi. (Finding 128)

In addition to the Bechtel test program, two engineering analyses of SA-312 pipe with CLP were performed by Aptech Engineering Services, Inc. (Aptech). These included a fracture analysis study and a subsequent fatigue analysis. The results of these studies are contained in two Aptech reports introduced into evidence as Applicant Exhibits 12 and 13. The fracture analysis demonstrated that because of the very ductile nature of the stainless steel material used in SA-312 piping, the failure mode of the pipe would not be brittle fracture, but rather, a "leak-before-break" and ductile fracture mode. A limit load analysis was therefore used to calculate critical flaw sizes for a range of pipe stress conditions, pipe diameters and wall thicknesses. These calculations were conservatively confirmed by the actual results of the Bechtel burst tests. Using these results from the Aptech fracture analysis and assuming the highest hoop stress values in piping systems at Callaway containing double-welded SA-312 pipe, it was concluded that the CLP condition of the magnitude identified will not result in the initiation of a leak in such piping and that the possible presence of CLP is not a concern. Testimony at the hearing established that under the design conditions at Callaway, CLP on the order of 85 percent of wall thickness would have to exist before a pipe would leak. Even assuming initiation of a leak, the fracture analysis demonstrated that the critical CLP size (amount of CLP above which catastrophic

failure will occur) is greater than the wall thickness of the pipe and thus catastrophic failure cannot occur. (Board Finding 129)

Aptech considered CLP more important from a fatigue point of view than from a fracture point of view because of the SA-312, Type 304 material's ductile behavior. Aptech's fatigue analysis was based on linear elastic fracture principles which link together flaw size, fatigue crack growth rate and applied stresses. The thrust of the analysis was to establish acceptance criteria based on worst-case assumptions. The result of the analysis was a series of flaw size versus life curves for a range of cyclic stresses so that the effect of any amount of CLP in any piping system could be assessed. When the results of Aptech's analysis were compared with actual conditions at Callaway, Aptech determined that the actual combined worst case parameters at Callaway are well below the assumed worst case conditions used during the fatigue analysis. (Finding 130)

In summary, the testing and analyses performed during this generic investigation of the CLP problems established that double-welded SA-312 piping, even with amounts of CLP substantially in excess of that found in production pipe, will function as intended with an adequate margin of safety. However, since it was also established that the ASME Code-required ultrasonic examination was ineffective in detecting the presence of CLP, Bechtel, in its report (Applicant Ex. 11), recommended a two-tiered response to the CLP problem in which the level of further examination for SA-312 piping would depend upon the hoop stresses in the system in which such piping was to be used. (Finding 131)

In Bulletin 79-03A, (Exhibit XII to Staff Exhibit 7), the NRC had indicated that 85 percent of ASME allowable code stresses was an appropriate screening mechanism for the use of SA-312 pipe. For systems subject to design stresses less than this level, the NRC found that a satisfactory design margin exists. This conclusion was supported by the Aptech fracture analysis, the Bechtel burst tests, the worst case of CLP actually found, and the level of CLP that can be expected to be detected by non-destructive examination. (Finding 132)

Double-welded SA-312 pipe is used in Callaway in the following systems: residual heat removal system, accumulator injection system, fuel pool cooling system, and the refueling water storage tank.

Bechtel performed a series of calculations in responding to Bulletin 79-03A to determine the maximum hoop stresses in any piping systems containing double-welded SA-312 pipe. All of the affected piping systems had hoop stresses less than 85 percent of the ASME allowable.

Based on all the evidence, the Board finds that the designed use of SA-312 pipe at Callaway does not affect the safe operation of the plant.

Intervenor also raised questions about the safety of SA-403 fittings. SA-403 is a specification for wrought austenitic stainless steel pipe fittings, such as elbows, tees and reducers. SA-312 is frequently used as the raw material for such fittings; SA-403 fittings made from double-welded SA-312 pipe would contain CLP to the same extent as the straight-run pipe. (Board Finding 133)

The record reveals that no SA-403 fittings at Callaway made from double-welded SA-312 pipe are included in piping systems which have hoop stresses in excess of 85 percent of the stresses allowed by the ASME code. While fittings theoretically may be subject to different stresses than straight legs of piping, the nature of the systems using SA-403 fittings at Callaway is such that no separate analysis need be made. (Board Finding 134)

The NRC Staff has also concluded, based on the analytical and experimental effort described above, that failure of double-welded SA-312 piping due to the possible presence of CLP is highly improbable. Rutherford Testimony at 4-7.

#### Conclusion

The Board, therefore, finds substantial evidence in the record to conclude that the double-welded SA-312 piping installed at Callaway is structurally sound and can safely perform its design function. Even if it is hypothetically postulated that a system containing that piping became overpressurized to the point that failure occurred in the longitudinal seam weld, the failure would occur in the "leak-before-break" mode. Under no circumstances would a brittle fracture resulting in a catastrophic failure occur. Rather, a small leak would form in the longitudinal weld and stable propagation would occur only if the internal pressure were maintained or increased. This is unlikely to occur because of the instrumentation and control systems which would provide plant operators with appropriate information whenever conditions in a safety-related system exceed design conditions, so that appropriate action can be taken.

Contrary to the general allegation of Joint Intervenors, the incorporation into the safety-related systems at Callaway of SA-312 piping which may contain CLP cannot be considered a breakdown in the quality assurance/quality control programs in effect at Callaway. The CLP problem was generic in nature. While its cause may have been inadequate process control by the piping vendor, the means prescribed by the ASME Code to detect this imperfection were later determined to be inadequate.

Furthermore, the Intervenor's contention that the evaluation and acceptance of SA-312 piping with CLP were not performed according to the requirements of the ASME Code has also been shown to be without merit. Apart from the required destructive testing (hydrostatic, tension and flattening) which was performed, all welded pipe which may contain CLP underwent ultrasonic examination and met the ASME criteria for this examination. It was the examination procedure itself which was found to be deficient. It has been established that the use of the efficiency factors in the ASME Code provides a conservative and satisfactory alternative to the ultrasonic examination. Accordingly, all SA-312 piping at Callaway complies with the ASME Code requirements. More significantly, however, the exhaustive investigation of the nature and extent of CLP in double-welded SA-312 pipe, including tensile tests and hydrostatic tests, along with the Aptech fracture and fatigue analyses that were performed, demonstrates that this type of pipe meets the design and service conditions specified in the ASME Code, and will

safely and properly perform its intended function throughout the life of the Callaway plant.

F. II.B. Piping Subassembly Deficiencies

As indicated in the contention (Appendix II), Gulf & Western ("G&W") supplied preassembled piping formations for use at Callaway. Preassembled pipe formations are pre-designed, manufacturer-fabricated formations containing piping, fittings, valves, pumps, strainers, tanks and other similar equipment. The formations are discrete portions of piping systems that are completely assembled at the manufacturer's plant, delivered to the construction site and set in place as a unit, rather than being fabricated piece-by-piece at the construction site. The preassembled pipe formations serve the same purpose as all other piping systems in the plant, i.e., to transfer fluids and are designed and manufactured to minimize the amount of on-site craft labor, thereby realizing cost and schedule efficiencies. (Board Finding 135)

In accordance with ASME Code requirements and Bechtel Specifications, nondestructive examinations ("NDE") were performed on welds by G&W in order to detect any conditions not in conformance with ASME Code criteria. Liquid penetrant examinations were performed on all welds in all Class 3 formations and radiographic examinations were performed on all welds in all Class 2 formations. Pursuant to Bechtel's procedures and specifications, in-process and final surveillance inspections were conducted by a Bechtel supplier quality representative at the G&W facility. The Bechtel representative was to

have inspected numerous stages of the fabrication and post-fabrication review and testing of the formations. Upon delivery at Callaway, Daniel personnel performed a receipt inspection of the formations to check for proper paperwork and shipping damage, but did not normally inspect the quality of the welds in the formations. (Board Finding 136)

Potential deficiencies in the G&W formations were first detected by Daniel construction (welding) personnel at the site of Kansas Gas & Electric Company's Wolf Creek plant, which is another SNUPPS unit, in March 1979. The discrepancies were identified while the formation was being installed and were brought to the attention of a Daniel Welding Inspector who performed a visual examination of the formation and identified possible concerns with respect to both the quality of the formation welds and the quality of the radiographic examination techniques utilized by G&W. This information was passed along to Union Electric to determine if the potential deficiencies applied to Callaway. (Board Finding 137)

Applicant and Daniel personnel proceeded with an audit of G&W formations at Callaway, including a physical review of the formations and welds themselves and a review of G&W radiographs. The results of the audit indicated that there were noncompliances with Bechtel specifications and ASME requirements in the areas of both radiographic technique and weld discrepancies. A SNUPPS audit was then performed at the G&W facility. At the close of the audit, G&W conducted a 100 percent review of the weld radiographs. This review revealed

radiographic technique deficiencies which prohibited a definitive determination as to the extent and significance of defects in the welds. (Board Finding 138)

In order to resolve the deficiencies, G&W agreed to review and radiograph all welds, and rework the welds as necessary. Three formations were returned for rework to G&W's manufacturing facility; most formations were to be reworked by G&W personnel at the Callaway site. G&W's performance in these endeavors were monitored by Union Electric, Daniel and Bechtel inspection personnel. The monitoring indicated continuing unsatisfactory performance by G&W. (Board Finding 139)

Following the discovery that G&W's rework effort was unacceptable, Applicant directed G&W to cease its rework efforts and turned the matter over to Daniel. Daniel performed visual inspections of the welds; when necessary, ground the weld surfaces in order to meet NDE requirements and visual acceptance standards; performed the required radiographic work; and rewelded welds that were found to be rejectable. All repaired welds were then given the appropriate nondestructive examination to ensure that the new welds met applicable acceptance criteria. The NRC Staff has reviewed the condition of the welds after Daniel finished its rework. The Staff found the quality of the repair work to be acceptable and the formations to be now adequate for use at the facility. (Board Finding 140)

#### Conclusion

The Board finds that the work performed by Daniel and the Staff to review the pipe and welds in their present condition provide

adequate assurance that the preassembled piping formations in their present condition will not affect the safe operation of the plant.

G. Quality Assurance & Contention

Intervenor established prior to hearing that their individual contentions were intended to be considered together as a whole to show that a breakdown of the Applicant's quality assurance program occurred during construction at Callaway. The evidence developed on the contentions showed that there were deficiencies in certain elements of the Applicant's QA/QC program. (Board Finding 141)

The Board has considered whether these deficiencies indicate a programmatic breakdown in Quality Assurance and concludes that they do not. We base this conclusion on the fact that (1) an extensive QA/QC program exists, (2) the deficiencies found were disclosed and remedied within the program itself, (3) the reactor building is safely built and (4) the Applicant displayed a generally affirmative commitment to quality in the discovery and resolution of the problems we considered. (Board Findings 142-146)

While we have expressed concern over some of the deficiencies found, we conclude that they are of limited extent and have no broader implications regarding the overall effectiveness of the Applicant's QA/QC program.

### III. FINDINGS OF FACT

#### A. Contention IA. Embedded Plates

1. Embedded steel plates, to support piping, electrical conduits, cable trays, HVAC components and structural steel framing are utilized in the Applicant's Callaway plant. (Applicant Embed Testimony, at 11, 28, 34; Staff Embed Testimony, at 2)<sup>4/</sup>

2. The plates are attached to the surface of concrete walls by means of welded steel studs and steel anchor rods positioned in the concrete. (Ibid at 2; Applicant Embed Testimony, at 10-11)

3. Two different types of plates are used in the plant: machine welded plates with studs that are welded by an automatic process, and manually welded plates with anchor rods that are welded manually. (Applicant Embed Testimony, at 12; Staff Embed Testimony, at 3)

4. The facility's architect engineer, Bechtel Corporation, has responsibility for embed plate design, load capacities and quality surveillance during fabrication; the plate manufacturer, Cives Steel Company, has responsibility for quality inspection of all embed plates, and until July 1977, Daniel International, the facility's construction company, had responsibility for receipt inspection limited to quantities of plates received and shipping damage. In July of that

---

<sup>4/</sup> Applicant Embed Plate Testimony, ff. Tr. 501, hereafter cited as Applicant Embed Testimony. Staff Embed Plate Testimony, ff. Tr. 1261, hereafter cited as Staff Embed Testimony.

year, Daniel was directed to broaden its duties to include inspecting all safety-related items received at the plant. (Applicant Embed Testimony, at 13-14; Schnell, Tr. 663-666)

5. On June 9, 1977, an NRC Inspector identified machine welded plates at the plant site which lacked full 360 degree weld (flash) material that had not been bend tested to 15 degrees as required by the applicable code. (Applicant Embed Testimony, at 14-15; Staff Embed Testimony, at 3)

6. Prior to June 9, 1977, there had been 255 machine welded plates and 225 manually welded plates installed in safety-related buildings to support safety-related loads in the facility. (Applicant Embed Testimony, at 28, 34; Staff Embed Testimony, at 3)

7. On June 9, 1977, the Daniel Company issued stop work orders on installing additional plates. A reinspection was authorized by the Applicant, of all machine welded and manually welded plates at the manufacturer's plant and at the Callaway site. (Schnell, Tr. 663; Meyers, Tr. 1227) An earlier reinspection (November-December 1976) provided no indication of defective materials being supplied by the Cives Company. (Intervenor Ex. 18, 19; Starr, Tr. 1451-1452)

8. The Cives and Daniel Companies were separately directed to reinspect the welds machine welded plates not installed and to bend test any studs to 15 degrees where a visual inspection showed the stud to have less than a 360 degree weld fillet. (Applicant Embed Testimony, at 18-19, 32-33; Staff Embed Testimony, at 4; Schnell, Tr. 661-662)

9. The Cives reinspection demonstrated a failure rate in machine welded studs of 0.08 percent or 66 studs in the 81,673 examined. The Daniel reinspection, which was conducted over a longer period of time, showed a failure of 0.11 percent or 106 studs out of 96,472 studs examined. (Applicant Embed Testimony, at 18-19; Staff Embed Testimony, at 4; Schnell, Tr. 1239-1240)

10. The 15 degree bend test was a more rigorous inspection requirement than that called for by the American Welding Society (AWS) Structural Welding Code, D1.1-75. (Applicant Embed Testimony, at 14-17)

11. The bend tests impose higher deformations and stresses into the studs and welds than the design loads applied to the plates. (Applicant Embed Testimony, at 19)

12. The rate of failure in the machine welded studs reinspected compares favorably with normal industry standards. (Applicant Embed Testimony, at 20; also see Staff Embed Testimony, at 4, and Applicant Ex. 4, Appendix A)

13. The reinspected plates were fabricated by the same company in the same time period using the same procedures as the plates which were installed in the facility before June 9, 1977. (Applicant Embed Testimony, at 20-21)

14. Using the failure rate data from the Cives reinspection, the Bechtel Company performed an engineering analysis that shows a probability of failure on the order of  $1 \times 10^{-9}$  for a machine

welded plate installed prior to June 9, 1977. (Applicant Embed Testimony, at 21-26; Applicant Ex. 4, pp. 2-4)

15. Although the fabrication of a majority of the defective weld studs (59 percent or 39 of 66) on machine welded plates took place during a five month period in 1976, the plates, on receipt at the plant, were intermingled with other plates and were generally interchangeable. (Thomas, Tr. 1218-19; Applicant Ex. 4, Appendix A)

16. The Staff did not rely on the Applicant's engineering analysis to base its conclusion that plates embedded prior to June 9, 1977 did not jeopardize the safety of the Callaway facility. (Gallagher, Tr. 1327-28)

17. The Staff requested the Applicant to test some machine welded embedded plates installed prior to June 7, 1977 as further evidence that the plates did not represent a safety problem. (Staff Embed Testimony, at 4)

18. Drs. Fisher and Slutter of Lehigh University performed tension tests on six machine welded embedded plates with loads in excess of design capacities without signs of plate failure. Plate selection was approved by the NRC. (Applicant Embed Testimony, at 27-28; Staff Embed Testimony, at 4-5; Staff Ex. 6, p. 6)

19. The Staff witnessed the tests performed on the machine welded embeds. (Staff Testimony, Tr. 1418-19; Staff Ex. 6, Attachment E, p. 1)

20. The plates chosen for the embedded plate test were selected randomly on the basis of their accessibility and the feasibility of mounting a test rig on them. (Applicant Embed Testimony, at 27)

21. The precise location within the Callaway plant of machine welded plates installed before June 9, 1977 and the loads they carry are known. Machine welded plates have been designed to provide load capacities with a minimum safety factor of at least 2.0 against the limit state of the plates or studs. These embeds do not support main floor beams and for critical piping systems are designed with a significant safety factor against failure. (Applicant Embed Testimony, at 28-31)

22. The requirements of the American Welding Society (AWS) Structural Welding Code D1.1-75 were applicable to welded studs and anchor rods on all embed plates in the construction of the Callaway facility. (Applicant Embed Testimony, at 13, 18)

23. The Cives Company was directed to reinspect all manually welded embeds not as yet installed at the Callaway site. The precise location of manual welded embeds and the loads they carry are known. (Applicant Embed Testimony, at 32-34)

24. Manual welding is required for anchor rods on embed plates as the rods are too large for automatic welding operation. (Applicant Embed Testimony, at 12)

25. Welding details, required by D1.1-75, are extremely difficult to accomplish by the manual welding process as a welder's orientation and access are hampered by the use of multiple studs. The

pertinent sections of D1.1-75 were developed for linear welds and not for the kind of welds involved in the controversy here. (Applicant Embed Testimony, at 35-36; Applicant Ex. 4, p. 1)

26. Manually welded plates at Callaway are used to support structural steel framing members. (Applicant Embed Testimony, at 34)

27. Manually welded plates are designed for loads with a minimum safety factor of 2.0 against the yield limit state of the plate and tensile capacity of the anchor rods. (Applicant Embed Testimony, at 34; Meyers, Tr. 772-777)

28. The Bechtel Company was advised early in the reinspection effort that a number of welds did not meet the requirements of D1.1-75 on weld (leg) size, length of weld sizes, weld undercutting and weld profile (convexity). (Applicant Embed Testimony, at 32-35; Applicant Ex. 4, p. 1)

29. Based on "worst case" welding defects, the Bechtel Company performed an engineering analysis to evaluate the safety of manually welded plates installed prior to June 9, 1977. (Applicant Embed Testimony, at 37; Staff Ex. 6, p. 8)

30. Relying on reinspection information from Cives that the worst weld undersize was 1/8 inch, two legs of the weld were of unequal length, the welds exhibited excessive convexity, and the maximum undercut was 1/16th inch, Bechtel calculated reduced design capacities for every installed manually welded plate using the assumptions that all anchor rods were considered to have 1/8 inch undersized welds for a 360 degree perimeter of the anchor rod, both legs were considered to be

undersized and all rods were to have a 1/16th undercut. (Applicant Embed Testimony, at 35-38; Meyers, Tr. 792; Applicant Ex. 4, p. 2)

31. In comparing the calculated reduced design capacity with the actual applied load on each embedded plate, Bechtel found the reduced capacity still exceeded the design load with the minimum safety factor against exceeding the plastic limit state of the plate of not less than 1.92. On four plates, however, the design load and the reduced design capacity were the same. (Applicant Embed Testimony, at 37-38; Intervenor Ex. 78)

32. The Bechtel engineering analysis was found acceptable by the Staff and the Applicant's expert consultants, Drs. Fisher and Slutter. (Applicant Embed Testimony, at 39; Staff Ex. 6, pp. 7-8)

33. The Bechtel engineering analysis was not based on final reinspection data from the Cives Company since the analysis was completed prior to the conclusion of Cives reinspection reports. (Intervenor Ex. 22; Applicant Ex. 4; Meyers, Tr. 724. Also see Applicant Reply to Proposed Findings, No. 25.)

34. Subsequent to June 9, 1977, the Applicant directed the Daniel Corporation to inspect all safety-related plates at the Callaway site and those to be delivered by Cives in the future. (Applicant Embed Testimony, at 40-41; Applicant Ex. 6, p. 1)

35. After Bechtel's final report on August 1977 concluding that welded studs at Callaway were a completely acceptable product, the Daniel Corporation reported inspection results contradicting the assumptions used in Bechtel's engineering analysis. These assumptions

were based on Cives reinspection information. (Applicant Embed Testimony, at 41; Applicant Ex. 6, pp. 1-2)

36. The Applicant and Bechtel claim to have had no knowledge of the results of the Daniel inspection, which began in June 1977, until November 7, 1977. (Holland, Tr. 1384; Applicant Ex. 7, p. 1)

37. However, the evidence shows Daniel reporting a large number of defects in manually welded plates to the Applicant in August 1977. (Intervenor Ex. 39) The testimony also reflects that Daniel and Cives personnel were aware of each other's inspection efforts. (Starr, Tr. 1359-60)

38. Subsequent to the receipt of the Daniel Company's inspection reports an investigation commenced, involving the Applicant, the Bechtel Company and Daniel, in an effort to resolve the differences between the Daniel and Cives data on manually welded plates. (Applicant Embed Testimony, at 41; Applicant Ex. 6, p. 2; Applicant Ex. 7)

39. After a series of meetings, the Bechtel Company stated its incapability of analyzing the Daniel inspection data on manually welded plates due to poor documentation, inconsistencies in reporting and possible errors in the data. (Applicant Embed Testimony, at 42; Applicant Ex. 7, pp. 1-4)

40. The reason assigned by the Applicant and Daniel for the lack of complete data information was that Daniel was only required to record sufficient information to enable the welded plate to be accepted or rejected, and not to provide a complete picture of the amount and

extent of the welding deficiencies. (Applicant Embed Testimony, at 43; Starr, Tr. 1357-58; Holland, Tr. 1380-84)

41. Bechtel completed its review by concluding its previous analysis supporting the acceptability of manually welded embeds was not contradicted by the Daniel's data. This decision was based on the following: first, that after eliminating inconsistent and incomplete data from the Daniel reports, only eight (8) embeds, which have since been repaired, out of 532 reported showed an average weld undersize greater than 1/8 inch; and second, that reinspections of 47 unrepaired but rejected embeds still at the site showed different results from the original Daniel inspections, with the average weld undersize not in excess of 1/8 inch. (Applicant Embed Testimony, at 43-44; Applicant Ex. 7, pp. 2-4; also see Applicant Ex. 6, pp. 3-5; Staff Ex. 6, p. 8)

42. The Applicant's review of Daniel's final effort at revising its inspection reports of manually welded embeds found that ten (10) embeds out of 364 reported had an average weld undersize exceeding 1/8 inch. This number was calculated on the assumption, however, that the undersize indicated extended around the circumference of the stud. (Applicant Ex. 6, p. 4)

43. In its submittal of its final report, Daniel's project manager stated that, since Daniel's inspectors only recorded the greatest, and not the average, undersize, any assumption that the maximum undersize condition went around the complete weld circumference

would not represent a true image of the actual conditions. (Intervenor Ex. 14, p. 2)

44. Applicant's expert consultant, Dr. Fisher, testified that the manually welded embeds could safely carry their design loads even assuming that the worst weld deficiencies in the Daniel data extended around the circumference of the anchor rods. Dr. Fisher stated these weldments could have been 25 percent smaller and that existing welding codes were being changed to accommodate that additional margin. (Fisher, Tr. 742-45, 1136)

45. Based on its investigation and the difficulty of meeting code welding requirements for circular manual stud welding, Bechtel sought and received approval for exceptions to AWS D1-1 for welding between anchor rods and plates. The exceptions provided for smaller vertical leg welds, unequal legs, elimination of profile requirements and a 1/16 inch undercut for up to 10 percent of the weld length. The Staff endorsed these exceptions as minor in nature and as not affecting the capacity of the connection. (Applicant Embed Testimony, at 39-40; Applicant Ex. 4, Appendix C; Staff Embed Testimony, at 5)

46. Three years after manually welded embeds had been installed, the Staff (NRC) visually inspected plates substantially loaded with floor slab dead loads and reported no signs of distress. (Staff Ex. 6, p. 5)

47. On inspecting the rejected but unrepaired manually welded embeds at the Callaway site, the NRC staff requested Applicant to perform load tests on selected welds, which appeared to have poor

workmanship, in order to test their structural integrity. (Staff Ex. 6, p. 9; Applicant Embed Testimony, at 45)

48. Bend tests to 30 degrees on six anchor rods on six different plates and tension tests on an additional six anchor rods from six other plates were conducted at Lehigh University by Drs. Fisher and Slutter. The bend test plates were selected by NRC Staff as well as the direction of the bend and the tension test plates were selected by the Applicant and reviewed by the Staff. Both tests were witnessed by the NRC. (Applicant Embed Testimony, at 45; Staff Ex. 6, p. 9 and Attachment E, p. 1; Applicant Ex. 5, p. 1)

49. The bend tests were conducted without any signs of cracking or weld failure and the tension tests, which tested the specimens to failure, demonstrated a minimum ultimate weld strength of 46,200 pounds for welds with a design load strength of 13,650 pounds. The remaining five welds tested showed an ultimate strength of 50,000 pounds or over. (Applicant Embed Testimony, at 46; Applicant Ex. 5, pp. 2-4; Staff Ex. 6, p. 9)

50. The Applicant and the NRC Staff both conclude that based on reinspection of plates fabricated in the same time frame, the engineering analysis of reduced load capacities due to weld deficiencies, and the actual load tests that were performed, the plates installed in the Callaway facility prior to June 9, 1977 were capable of safely supporting their design loads. (Applicant Embed Testimony, at 48; Staff Embed Testimony, at 5; Staff Ex. 6, pp. 9-10)

51. The NRC Regional Office which inspected and investigated events at the Callaway facility referred to NRC Headquarters--for review and a determination of adequacy--the Applicant's report of March 10, 1978, that approved the embeds installed prior to June 9, 1977 as acceptable in meeting design load requirements. The question of adequacy of embeds had been brought to Headquarters' attention at even an earlier date. After NRC Headquarters failed to act, the Regional Office again assumed responsibility for technical review of the report. (Intervenor Ex. 34, p. 4-5; Gallagher, Tr. 1298-1299)

B. Contention I.C.1: Honeycombing in the Reactor Building Base Mat

52. Concrete for the reactor building base mat was placed over a 62 hour period from April 6 to April 9, 1977. One hundred and ninety (190) construction crafts, engineering, quality control and supervisory personnel, were used in shifts to accomplish the concrete placement. NRC Staff inspectors were present and observed most of the operation (Applicant Base Mat Testimony, at 11-12; Staff Base Mat Testimony, at 3, 6-7)<sup>5/</sup>

53. Honeycombing in the concrete ceiling of the tendon access gallery was found by construction personnel after the concrete had hardened. Honeycombing is a defective condition that consists of

---

<sup>5/</sup> Applicant Base Mat Testimony, ff. Tr. 227 hereafter cited as Applicant Base Mat Testimony. Staff Testimony of A. Varela, ff. Tr. 396 hereafter cited as Staff Base Mat Testimony.

small air pockets in hardened concrete giving a "popcorn" appearance. (Applicant Base Mat Testimony, at 16, 17; Varela, Tr. 401, 402)

54. All honeycombed areas were chipped to sound concrete, to determine the extent of the imperfections and to prepare the surface for repair. In all, 19 areas of honeycombing which required 24 separate excavations were found in close association with trumplates in the tendon access gallery ceiling. (Applicant Base Mat Testimony, at 15; Staff Base Mat Testimony, at 3)

55. The honeycombing was structurally significant because it called into question the performance of 14 of the 172 trumplates. (McFarland, Tr. 256; Applicant Base Mat Testimony, at 15)

56. The size of the honeycomb areas ranged from less than 1 square foot to a maximum of approximately 22 square feet. Most of the excavations were less than 4 square feet in area. The depth of the individual excavations averaged approximately 10 inches with a localized maximum of 17 inches. Lower layers of reinforcing bar embedded in the concrete were exposed. (Applicant Base Mat Testimony, at 15, 16; Staff Base Mat Testimony, at 3, 4; Staff Ex. 3, at 21, 22)

57. The cause of the honeycombing in the base mat was inadequate consolidation of the concrete during the placement operation. Consolidation is achieved by workmen using handheld vibrating tools which are inserted into the still wet concrete. The vibration causes the concrete to liquify temporarily and to flow around the steel reinforcing bar filling void spaces. (Applicant Base Mat Testimony, at 18; Staff Base Mat Testimony, at 6, 7)

58. Incomplete concrete consolidation was due to localized congestion of reinforcing steel, embedded plates and trumplates in the area above the tendon gallery roof. The area of the trumplates contained more than a normal complement of reinforcing steel. This congestion by steel embedments hampered the placement of the vibrating tools by the construction workers. (Applicant Base Mat Testimony, at 13-14, 29-30; Staff Base Mat Testimony, at 7-8; McFarland, Meyers, Tr. 357-359)

59. Daniel Corporation quality control personnel were present to assure the timely coordination and relocation of vibratory equipment and craft personnel during the pour. The NRC Staff inspector did not note any quality control deficiencies on the part of construction personnel during the pour. (Staff Base Mat Testimony, at 7-8)

60. Soniscope tests of interior concrete above the tendon trumplates showed that concrete was sound and that there were no hidden defects in the base mat above the gallery. (Applicant Base Mat Testimony, at 23-28)

61. Visible honeycombed areas were repaired by pumping a high strength grout into the voids to bond reinforcing steel. The repairs were equal in strength to the original concrete. (Applicant Base Mat Testimony, at 19-21, 28; Staff Base Mat Testimony, at 8; Varela, Tr. 406)

62. A concrete mixture called dry-pack was used to repair noncritical areas between trumplates which were shallow and

structurally insignificant. The dry-pack repairs were done principally for cosmetic purposes. (Meyers, Tr. 375; Applicant Base Mat Testimony, at 21)

63. A stop work order was issued on dry pack use because no specification required that the dry pack be tested, and in fact, it was not being tested prior to use. Subsequent tests of the dry-pack material showed that it possessed compressive strength above the minimum required, and Bechtel determined that previously repaired areas could be used as is. (Applicant Base Mat Testimony, at 21)

64. There was a failure on the part of the Applicant to provide a testing specification for the dry-pack which proved harmless since the material was in fact structurally sound. The material was used for cosmetic repairs only.

65. After repair of the honeycombed area and the sonoscopic testing a post-tensioning operation was conducted by applying high tension to the tendons and anchoring them in the trumplates. During the post-tensioning operation a force as high as 1,600,000 pounds was imposed on the area surrounding each trumplate. When the load was transferred to the tendon anchorage, the load on each trumplate was at least 1,400,000 pounds. These are the most severe loads that will ever be imposed on the trumplates. All tendons have been tensioned and anchored in trumplates with no evidence of distress in the concrete. (Applicant Base Mat Testimony, at 31)

66. NRC Staff inspected preparations for concrete placement including adequacy of reenforcing bar installation before concrete

placement in the base mat and found no deficiencies. (Staff Base Mat Testimony, at 1; Staff Ex. 1)

67. Each phase of the concrete placement was planned in advance and discussed by the Applicant to assure that participants were aware of their responsibilities, the placement method, and the areas of congestion from reinforcing steel. A scaled model of the reinforcing steel was used during the planning sessions. (Applicant Base Mat Testimony, at 12; McFarland, Tr. 371)

68. Difficulty of concrete workability in areas of congestion had been anticipated in the planning for concrete placement. Engineers, inspectors, and laborers involved in concrete placement and consolidation were positioned within the steel assembly on the first layer of reinforcement to maintain close control of placing requirements and vibration of the concrete. (Applicant Base Mat Testimony, at 11-13; Staff Base Mat Testimony, at 7; McFarland, Tr. 334-339, 353-358)

69. Applicant's quality control inspectors, supervisory personnel and NRC inspectors were present during concrete placement. The Staff inspectors concluded that performance of the quality control personnel to maintain the quality of concrete was satisfactory. (Staff Base Mat Testimony, at 6-8)

70. Imperfections in concrete were reported by Daniel Corporation to Bechtel as required in a Nonconformance Report NCR 2-0655-C-A dated May 11, 1977. Bechtel rejected the report and requested more detail (Joint Intervenors Ex. 4). A second report filed

on June 27, 1977, showed detailed sketches of the defective concrete and a repair plan which Bechtel approved. Union Electric notified NRC by telephone of the concrete deficiency. (Applicant Base Mat Testimony, at 15; Applicant Ex. 1; Staff Base Mat Testimony, at 3, 4)

71. The Applicant conducted additional training of its personnel after the deficiencies were discovered to prevent their recurrence in future concrete placement operations. (Applicant Base Mat Testimony, at 21, 22; Staff Base Mat Testimony at 8)

72. The concrete testing and repair were inspected and reviewed by NRC regional inspectors and were found to be satisfactory. (Staff Base Mat Testimony, at 5, 8; Staff Ex. 5)

73. The concrete imperfections in the base mat occurred in spite of precautions and not due to neglect of quality assurance.

74. The quality assurance procedures followed in this instance were consistent with the essential elements of a quality assurance program for inspection, identification of nonconformances, repairs of defects, and documentation and reporting. (Schnell Testimony, ff. Tr. 216, at 22-27)

75. Intervenors claim that the concrete in the reactor base may be faulty because the tests performed in the tendon access gallery may be faulty, and might not demonstrate there is no honeycombing other than that initially discovered. (Intervenors Proposed Finding 155)

76. Intervenors assertion that the soniscope method is faulty because it does not take account of the fact that sound waves may go around defects in concrete reflects a misinterpretation of the physical

principles of the instrument. The deflection of sound waves around defects in concrete is the phenomenon which enables the detection of such defects. The added time required for sound to traverse a tortuous pathway relative to an unobstructed pathway is what is measured and what leads to the interpretation of reduced velocity and faulty concrete if it exists. (Pfeifer Tr. 306-307)

77. Intervenors' argument that the velocity of sound in steel may account for the high sound velocity measured in tests of the base mat is misguided. Expert testimony shows that the interface between steel and concrete often results in a degraded signal or complete obstruction of the signal. While sound might well have a high velocity in steel, we need not take notice of that fact as urged by Joint Intervenors (Proposed Findings, p. 9-3) since it is beyond dispute that the base mat consists of concrete containing embedded steel. It is the existence of concrete-steel interfaces which might influence the velocity of sound; the sound signal may be halted by interfaces or simply go around the obstruction. (Pfeifer, Tr. 308-309) In either case the result could not be an apparent increase in sound velocity.

78. Intervenors discussion of the errors possible in aligning a cross hair on an oscilloscope which is necessary to measure the velocity of sound is without merit. (Proposed Findings, p. 94) The WJE report (Applicant Ex. 2, p. 19) lists a table showing average velocities of sound as transmitted through concrete and standard deviations and coefficients of variation for each average.

Nonsystematic errors of measurement including instrument reading errors will be reflected in the calculated standard deviations and coefficients of variation. The coefficients of variation range from 1.0 to 2.1 percent. These errors are sufficiently small to assure that the measured sound velocities reliably exceed the threshold of concern (12,000 ft/sec) below which the integrity of concrete could be in doubt.

79. It was not possible to examine directly by nondestructive methods the remainder of the base mat which is not part of the tendon gallery. That portion of the base mat constitutes 81 percent of the entire structure while the tendon gallery constitutes only 19 percent. The exterior surfaces of the entire base mat including the top and vertical walls were inspected and found to be without defect. (McFarland, Tr. 381-382) Portions unavailable for inspection include the lower surface, i.e., that resting on earth and the interior concrete of the base mat. (Pfeifer, Tr. 246, 247) Since these areas could not be inspected directly, the Applicant relied on indirect evidence to establish their integrity.

80. The Applicant asserts that the random selection of soniscope test locations around the entire 360 degree circumference of the tunnel, the large number of readings taken at these locations, the fact that three different types of soniscope measurements were made yielding uniform results, the high velocities recorded, and the low statistical variation in the data all lead to a high degree of confidence that there is no occurrence of internal honeycombing in the base slab not

only above the tendon gallery but also in the remainder of the base mat. (Applicant Base Mat Testimony, at 29-30)

81. Indirect evidence of interior integrity of base mat concrete comes from understanding the causes of surface honeycombing. The inadequate consolidation was due to the high congestion around the trumplates from embedded steel items, which hampered access and visibility of construction personnel when the concrete was being placed. (Applicant Base Mat Testimony, at 18) Although reinforcing bar occurs throughout the interior of the concrete base mat, it is less congested than at the top and bottom of the mat and it presents fewer difficulties of concrete workability. (Applicant Base Mat Testimony, at 13)

82. The soniscope investigation did not reveal a single instance of interior defects in the tendon gallery, and there is no other evidence that inadequate consolidation occurred in areas of low congestion from steel embedments. (Applicant Base Mat Testimony, at 27-28)

83. Honeycombing in concrete of the lower surface of the inaccessible portions of the base mat cannot be ruled out with certainty. However, the lower surface of the remainder of the base mat is less congested with steel reinforcing bar than in areas where honeycombing was found. It was therefore more accessible to vibration by construction crews than the tendon gallery. (Applicant Base Mat Testimony, at 29)

84. The magnitude of honeycombing that was found in the tendon access gallery would be of no safety significance if found elsewhere on

other surfaces of the base mat. The concern for that in the tendon access gallery relates to the possibility of degrading the function of the tendon trumplates and not to the general concrete stress over the entire base mat. (Applicant Base Mat Testimony, at 30; Meyers, Tr. 240)

85. Intervenors object that: (1) concrete placement reports were not submitted by all quality control inspectors after the base mat was poured and (2) that the documentation of the existence of honeycombing in the reactor base mat was not submitted in a timely fashion since more than month passed after completion of concrete placement before a nonconformance report was written. (Intervenors Proposed Findings, at 96, 97)

86. The Staff inspector who was present at the time of concrete placement subsequently cited the Applicant for an infraction because each of the Applicant's quality control inspectors did not submit individual concrete placement reports. A single concrete placement report was submitted which was signed by the inspector who was present at the termination of the pour. The concrete placement report did not include the attributes of concrete placement which were to be verified by the quality control inspector. (Staff Ex. 3, at 22, 23)

87. The Applicant and Staff disagreed on the required number of concrete placement reports. The Applicant believed a single concrete placement report signed at the termination of the pour was adequate. The Staff's view is that a concrete placement report was required from

each inspector present at the time of the pour. (McFarland, Tr. 330-331)

88. The Applicant undertook to remedy the deficiency by having each inspector present during the time of concrete placement sign a concrete placement report. Each concrete placement report was similar in information content and appearance and was signed by the individual inspectors during a period covering July and the first part of August of 1977. (McFarland, Tr. 328; Intervenors Ex. 5) In all but one case, the concrete placement reports were signed without individualized comment by the inspector. (Each report referenced the same quality control procedure (QCP 109)). In the Applicant's view the signatures and the absence of comment on the concrete placement reports provides assurance that the individual inspector observed no deficiencies during the pour. It could not be ascertained directly from the reports, however, what activities the signature of each inspector was verifying that he had witnessed. (McFarland, Tr. 322-324; 351)

89. NRC Staff interviewed some of the inspectors after receiving the concrete placement reports and verified that they had observed no deficiencies during concrete placement. (McFarland, Tr. 329; Staff Ex. 4, p. 4)

90. The Board concurs with Intervenors that the procedure followed here was defective. We criticize the documentation procedure but do not find evidence that the inspectors failed to perform their

duties at the time the concrete was actually placed. Specifically, we find that the placement reports signed without comment some three months after the event took place to be essentially worthless.

91. The Board is unable to determine from the belated reports whether they were signed by the inspectors in a perfunctory manner as simply another burden of paperwork or whether the signatures have genuine meaning. While some interviews were done by the Staff inspector, the interviews were not documented. Thus, no genuinely useful written record exists to document the observations of inspectors during the placement of concrete in the base mat.

92. The Board finds no deficiency with regard to the timing of the nonconformance report. In the approximate month between completion of the base mat pour and the filing of the first nonconformance report, the concrete was left to harden, the concrete forms were then removed, inspections were performed and honeycombed areas were chipped to sound concrete. In light of the actions that had to be taken, the elapsed time of one month from the termination of the pour appears reasonable. (McFarland, Tr. 255, 256)

93. The quality assurance procedures employed in the construction of the basemat worked properly in that precautions were taken to prevent deficiencies, deficiencies that occurred in spite of the precautions were found promptly, appropriate reports and tests were made except as noted above, and repairs were made which restored the defective areas to original design specifications.

C. Contention I.C.2: Honeycombing in the Reactor Building Dome

94. The top of the reactor building presented an unusual and difficult problem of concrete placement which resulted from angles of placement ranging from 45 degrees to nearly horizontal at the top of the dome and also due to the placement being accomplished without the use of an outside concrete form. (Applicant Reactor Dome Testimony, at 9, 10; Tye, Tr. 2012, 2036)<sup>6/</sup>

95. Freshly placed concrete in this region of the dome was vibrated to produce consolidation. Vibration near the outside face of the concrete caused subsidence in a downward direction. Concrete had to be replaced from lower to upper levels while the vibration process continued. (Applicant Reactor Dome Testimony, at 10)

96. After the concrete hardened, four areas of honeycombing were found on the outer surface of the dome. The honeycombed areas were chipped to sound concrete. The chipping process revealed air gaps of approximately 1/4 to 1/2 inch in diameter between the horizontal reinforcing steel and the concrete approximately 4 to 6 inches from the outer surface of the dome. Chipping was completed November 6, 1980. (Applicant Reactor Dome Testimony, at 11, 12; Board Ex. 6)

---

<sup>6/</sup> Applicant Reactor Dome Testimony, ff. Tr. 2010 hereafter cited as Applicant Reactor Dome Testimony. Staff Testimony, ff. Tr. 2067 hereafter cited as Staff Ma Reactor Dome Testimony or Staff Hawkins Reactor Dome Testimony.

97. The gaps were caused by the downward movement or subsidence of the concrete away from the reinforcing bars when it was being placed. (Applicant Reactor Dome Testimony, at 11)

98. The Daniel Corporation filed a nonconformance report to Bechtel Corporation on November 10, 1980. Bechtel and Union Electric personnel questioned Daniel whether more investigation was needed since additional imperfections might be present. Union Electric notified the NRC Staff on December 5, 1980 of a potentially significant deficiency. (Applicant Reactor Dome Testimony, at 12, 13)

99. On December 13, 1980, three additional areas of honeycombing were discovered in the dome area following removal of grease vent blockouts at the request of NRC Staff. At that point there were seven known areas of concrete imperfections in the dome. Repairs of these areas involved chipping and shaping each cavity to receive replacement concrete which was of the same class and mix as originally used. (Applicant Reactor Dome Testimony, at 13-15; Staff Ex. 8, at 4)

100. A number of nondestructive and destructive examinations of the dome were done including nuclear densometer testing, boroscopic examination, microseismic (pulse echo) examination, selective excavation and engineering analysis. (Applicant Dome Testimony, at 18) The nuclear densometer and boroscope examinations did not reveal further evidence of unsound concrete. (Applicant Reactor Dome Testimony, at 18-19; Applicant Ex. 19, at 11-15)

101. The pulse-echo technique was used at 1,671 locations as a means of searching for imperfections throughout the three foot

thickness of the dome. (Applicant Reactor Dome Testimony, at 19-20; Goddard, Tr. 2056-59) The pulse-echo method has been used extensively for similar applications and is reliable and accurate. (Staff Hawkins Reactor Dome Testimony, at 4; Hawkins, Tr. 2075-76 and 2078)

102. The results of the pulse-echo testing showed that 28 of 1671 tests or 1.68 percent were of possible structural significance but none of the areas tested showed a sufficient number of such readings to classify the area as structurally defective. (Applicant Reactor Dome Testimony, at 21-22; Applicant Ex. 19, at 22-24)

103. The Applicant excavated concrete at six test points which had shown defects by the pulse-echo method, and excavations confirm that a correlation exists between the pulse-echo readings and the actual imperfections. (Applicant Reactor Dome Testimony, at 22-23; Applicant Ex. 19, at 24-26)

104. Staff review of test results indicated that more testing was needed. Applicant and Staff then concluded after additional testing that the extent of imperfections was clearly identified. (Applicant Ex. 19, at 35-41; Applicant Reactor Dome Testimony, at 24-25; Staff Hawkins Reactor Dome Testimony, at 4; Hawkins, Tr. 2073)

105. An engineering analysis showed that the structural integrity of the dome would not be jeopardized when subjected to all design load conditions including postulated accidents even if 50 percent of the mechanical bond were completely lost around the entire perimeter of the bars in the outside layer of reinforcing steel. (Applicant Reactor Dome Testimony, at 26)

106. The Staff performed an independent engineering analysis and concluded that the dome is adequate as built. This is based on findings that the original design contained more than enough extra steel reinforcement to compensate for the small deficiencies found in the concrete. (Staff Ma Reactor Dome Testimony, at 3; Ma Tr. 2077-78)

107. The strength of the concrete in the dome exceeds the design strength by a considerable margin and the overall quality of the concrete is not in question. (Applicant Reactor Dome Testimony, at 11, 12; Staff Ma Reactor Dome Testimony, at 6)

108. Imperfections in the reactor dome were discovered through routine inspections. The imperfections were reported to Bechtel, the architect engineer, who in turn initiated further examinations. Reports were made to NRC. The extent of defects was fully investigated and repairs were properly made. The Applicant's quality assurance program functioned properly in this instance. (Applicant Reactor Dome Testimony, at 27; Staff Hawkins Reactor Dome Testimony, at 5)

D. Contention II A.I: SA-358 Piping

109. SA-358 is an ASME material specification for welded stainless steel pipe. (Stuchfield, Tr. 1545, 1456) This material specification provides a series of limits and permissible variations

for several dimensional requirements for the finished pipe. (Applicant SA-358 Piping Testimony, at 5)<sup>7/</sup>

110. Daniel employees observed a spool piece irregularity and after an ultrasonic test (UT) confirmed a thin wall area, a nonconformance report (NCR) was issued. (Applicant SA-358 Piping Testimony, at 5, 6)

111. NRC Staff and Applicant personnel conducted measurements of the ovality of the pipe, determined that the actual maximum ovality is 0.86 percent, and therefore was within the one percent difference between major and minor outside diameters permitted by material specification SA-358. (Applicant SA-358 Piping Testimony, at 5, 8; Staff Foster SA-358 Piping Testimony, at 2; Staff Beeman SA-358 Piping Testimony, at 2, 3)

112. The measured minimum wall thickness of the pipe in question was 0.814 inch. (Applicant SA-358 Piping Testimony, at 8, 9; Staff Foster SA-358 Piping Testimony, at 2, 3) Bechtel and the NRC Staff performed independent calculations and concluded a minimum wall thickness of 0.814 inch is acceptable. (Staff Beeman SA-358 Piping Testimony, at 3; Staff Ex. 7, at 8)

113. Daniel measured weld reinforcement on the inside of the SA-358 pipe with a reinforcement height of 3/16 inch and documented it in a nonconformance report. Bechtel initially erroneously

---

<sup>7/</sup> Applicant SA-358 Piping Testimony, ff. 1537, hereafter cited as Applicant SA-358 Piping Testimony. Staff SA-358 Testimony, ff. Tr. 1681 hereafter cited as Staff Foster, Beeman or Key SA-358 Piping Testimony.

dispositioned this NCR. (Applicant SA-358 Piping Testimony, at 9, 10) Daniel elected to rework the item to bring the weld into compliance with the ASME code by localized grinding. (Id., at 16-17; Foster, Key, Tr. 1706, 1707; Laux, Tr. 1625-1627)

114. The Daniel NCR identified overlap in the same area as the excess weld reinforcement. Bechtel advised that overlap is not listed in the ASME code as a rejectable condition for radiography, as overlap does not affect the volumetric quality of the weld. (Applicant SA-358 Piping Testimony, at 11, 12) The overlap was reworked by grinding. (Id., at 16; Foster, Key, Tr. 1706, 1707)

115. Intervenors assert that the overlap condition could have been caused by a "melt through" or "drop through"--i.e., the first weld pass from the outside of the pipe melting through the pass made from the inside. (Applicant SA-358 Piping Testimony, at 12; Staff Key SA-358 Piping Testimony, at 2)

116. The overlap indicates that drop through could not have occurred. (Beeman, Tr. 1752) Melt through would have resulted in a surface condition on the inside of the pipe which would be readily detected. (Applicant SA-358 Piping Testimony, at 13; Stuchfield, Tr. 1563-1564, 1642-1643) If melt through had occurred, surface porosity would have quickly occurred and no such porosity was detected. (Applicant SA-358 Piping Testimony, at 13, 14) No radiographic reviews of the area by Union Electric and Daniel personnel resulted in this weld being declared unacceptable. (Id., at 15)

117. NRC Staff witnessed radiograph tests (Staff Foster SA-358 Piping Testimony, at 3; Applicant SA-358 Piping Testimony, at 17), inspected the SA-358 pipe, reviewed the pipe's documentation, inspected the radiographs of the weld seam taken after the rework and concluded the weld to be free of defects and within ASME code acceptance criteria. (Staff Foster SA-358 Piping Testimony, at 3; Applicant SA-358 Piping Testimony, at 17; Staff Key SA-358 Piping Testimony, at 1, 2 Key, Tr. 1751. See also, Beeman, Tr. 1751-1752)

118. Two fissures in the questionable weld were reported in NRC IE Inspection Report No. 50-483/81-04. (Staff Ex. 7) Applicant's and Staff's witnesses concurred that there is no evidence of fissures. (Applicant SA-358 Piping Testimony at 15, 16; Key, Tr. 1710, 1750; Beeman, Tr. 1712-1714; Stuchfield, Tr. 1648)

E. Contention II.A.2.: SA-312 Piping

119. SA-312 is an ASME material specification for both seamless and welded stainless steel pipe. (Applicant's SA-312 Piping Testimony, at 19 and Figure 18/; Stuchfield, Tr. 1794-1795, 1809-1810)

120. Those safety-related systems at the Callaway Plant which contain double-welded SA-312 pipe are designated as ASME Class 2 or Class 3. For use in Class 2 systems, ASME Section III requires that welded pipe be nondestructively examined, usually by the ultrasonic

---

8/ Applicant SA-312 Piping Testimony, ff. 1773, hereafter cited as Applicant SA-312 Piping Testimony. Staff Testimony, ff. Tr. 1898, hereafter cited as Staff Rutherford SA-312 Piping Testimony.

method. (Applicant SA-312 Piping Testimony, at 16-17; Hurd, Tr. 1782-1788; Stuchfield, Tr. 1824-1825)

121. Centerline lack-of-penetration (CLP) occurs in double-welded SA-312 pipe when complete through-wall fusion does not occur between the inside and outside welds during welding of the longitudinal seam. (Applicant SA-312 Piping Testimony, at 17 and Figure 1; Staff Rutherford SA-312 Piping Testimony, at 3)

122. The CLP problem in SA-312 piping was first identified in the fall of 1978. Imperfections, principally for lack of center line of penetration, were found in the longitudinal welds of double-welded SA-312 pipe being fabricated into piping subassemblies for the Palo Verde Nuclear Generating Station. A similar rejection was reported by Pullman Power Products (PPP) on pipe purchased from Youngstown Welding and Engineering Company (YWEC) for the San Onofre 2 and 3 Nuclear Generating Stations. The Palo Verde and San Onofre owners reported these findings to the NRC. (Applicant SA-312 Piping Testimony, at 17, 18; Staff Rutherford SA-312 Piping Testimony, at 1-2; see Applicant Ex. 11, at 1)

123. The NRC Office of Inspection and Enforcement issued I&E Bulletin 79-03 in March, 1979, requiring all operating licenses and construction permit holders to determine if similar pipe had been or would be incorporated into safety-related piping systems. In response to this Bulletin, Applicant determined that pipe manufactured by YWEC had been used in piping subassemblies fabricated for the Callaway Plant. A complete schedule of the location of all YWEC-supplied pipe

was provided to the NRC and a program for ultrasonic examination of longitudinal welds was established as required by the Bulletin.

(Applicant Ex. 10; Applicant SA-312 Piping Testimony, at 19)

124. A generic investigation into the CLP problem was undertaken by Bechtel.

125. This investigation determined that the principal cause of CLP was the wide range of allowable welding parameters permitted by the YWEC qualified welding procedure. (Stuchfield, Tr. 1799-1804; Applicant SA-312 Piping Testimony, at 20-21; Intervenor Ex. 61; Egan, Tr. 1807)

126. The Bechtel investigation concluded that the ASME Code-required ultrasonic examination cannot reliably detect CLP in double-welded SA-312 pipe. (Applicant SA-312 Piping Testimony, at 23; Stuchfield, Tr. 1797, 1827, 1828; see also Applicant Ex. 11, at 2, 3, 7, 8)

127. Bechtel determined the maximum amount of CLP in the SA-312 piping produced by YWEC to be 26 percent. (Applicant SA-312 Piping Testimony, at 24-25; Stuchfield, Egan, Tr. 1811-1814; see also, Staff Rutherford SA-312 Piping Testimony, at 4; Applicant Ex. 11, at 2-3)

128. Tensile and hydrostatic (burst) tests established that with 26 percent CLP, SA-312 piping will meet all of the ASME mechanical property requirements and that even with 47 percent CLP, yield strength requirements are met. (Applicant SA-312 Piping Testimony, at 25-26; Applicant Ex. 11, at 2, 3, 7) Tests were performed on three SA-312 pipe sections with known CLP of 15 percent, 40 percent and 55 percent.

The lowest burst pressure recorded was for the pipe with 55 percent CLP which burst at 3000 psi, far in excess of the ASME Code-required hydrostatic test pressure of 882 psi for the same size and schedule pipe. (Applicant SA-312 Piping Testimony, at 27-28; Staff Rutherford SA-312 Piping Testimony, at 6; Applicant Ex. 11, at 2, 3, 14-19; see also, Rutherford, Tr. 1906)

129. Two engineering analyses of SA-312 pipe with CLP were also performed by Aptech Engineering Services, Inc. (Aptech). The first, a fracture analysis, demonstrated that because of the very ductile nature of the stainless steel material used in SA-312 piping, the failure mode of the pipe would not be brittle fracture, but rather, a "leak-before-break" and ductile fracture mode. (Applicant SA-312 Piping Testimony, at 28-30; Staff Rutherford SA-312 Piping Testimony, at 5; Applicant Ex. 12, at p. iii) A load limit analysis showed that the possible presence of CLP is not a concern. (Applicant SA-312 Piping Testimony, at 30-32; Staff Rutherford SA-312 Piping Testimony, at 5, 6; Egan, Tr. 1881; see Applicant Ex. 12, at pp. 7-5 to 7-7, 10-1, 10-2)

130. The second fatigue analysis determined that fatigue failure as a result of the possible presence of CLP was not a concern. (Applicant SA-312 Piping Testimony, at 33, 34; see Applicant Ex. 13, at 9-1)

131. The testing and analyses performed during this generic investigation of the CLP problems established that double-welded SA-312 piping, even with amounts of CLP substantially in excess of that found

in production pipe, will function as intended with an adequate margin of safety. (Applicant SA-312 Piping Testimony, at 34-35)

132. The NRC adopted a Bechtel recommendation in issuing I&E Bulletin 79-03A which made several changes to the directives originally contained in I&E Bulletin 79-03. Inasmuch as all piping systems containing double-welded SA-312 pipe at Callaway are subject to maximum hoop stresses less than 85 percent of the ASME Code allowable stresses, no further action was required by Applicant. (Applicant SA-312 Piping Testimony, at 38; Staff Rutherford SA-312 Piping Testimony, at 2; Applicant Ex. 14; Applicant Ex. 11, at 4)

133. Intervenors questioned the use in Callaway piping systems of SA-403 fittings which may contain CLP. SA-403 is a specification for wrought stainless steel pipe fittings, such as elbows, tees and reducers. The double-welded SA-312 pipe used to manufacture fittings is no different than the double-welded SA-312 pipe used for straight-run pipe, and could contain CLP to the same extent as straight-run pipe. (Applicant SA-312 Piping Testimony, at 38, 39; see also, Applicant Ex. 16; Joint Intervenor Ex. 64)

134. No SA-403 fittings are used in Callaway piping systems which have hoop stresses greater than 85 percent of the ASME Code allowable stresses. (Applicant SA-312 Piping Testimony at 39; Stuchfield, Tr. 1777; Hurd, Tr. 1790-1793)

F. Contention II.B : Piping Subassembly Deficiencies

135. Preassembled pipe formations are pre-designed, manufacturer-fabricated formations containing piping, fittings, valves, pumps, strainers, tanks and other similar equipment. (Applicant G&W Testimony, at 8-9)<sup>9/</sup>

136. Nondestructive examinations ("NDE") were performed on welds by G&W in order to detect any conditions not in conformance with ASME Code criteria. In-process and final surveillance inspections were conducted by Bechtel and Daniel personnel performed receipt inspections. (Applicant G&W Testimony, at 10-11; Staff Hansen Testimony, at 4)

137. In March, 1979, a Daniel construction worker informed a Daniel welding inspector at the Wolf Creek site of potential deficiencies in a preassembled piping formation supplied by Gulf & Western. (Applicant G&W Testimony, at 11; Powers, Laux, Tr. 1929, 1930; see also, Intervenor Ex. 69)

138. Applicant's Construction QA group conducted an extensive audit of the G&W formations at the Callaway site which determined that the G&W formations exhibited noncompliances to the Bechtel Specification and to ASME Code requirements in the areas of both radiographic technique and visible weld discrepancies. SNUPPS QA Committee audit reviewed G&W's manufacturing and inspection activities

---

<sup>9/</sup> Applicant's Gulf and Western Testimony (Piping Subassembly Deficiencies), ff. Tr. 1920, hereafter cited as Applicant's G&W Testimony. Staff Testimony, ff. 1979, hereafter cited as Staff Hansen Testimony.

G&W agreed to conduct a 100 percent review of the weld radiographs.  
(Applicant G&W Testimony, at 12, 13; Staff Hansen Testimony, at 2)

139. G&W was required to rework all safety-related formations and on-site rework was monitored by Union Electric, Daniel and Bechtel. Radiographic technique deficiencies and weld deficiencies continued to be encountered and G&W was directed to cease its on-site rework efforts. (Applicant G&W Testimony, at 13-16; Staff Hansen Testimony, at 3; Intervenor Ex. 69, Final Report, at 1-2)

140. Daniel assumed responsibility for on-site rework and all repairs have been completed and all welds now meet the applicable criteria. (Applicant G&W Testimony, at 16, 17; Staff Hansen Testimony, at 3; Key Testimony, ff. Tr. 1979, at 2)

#### G. Contention on the Quality Assurance Program

141. The Board has found deficiencies in certain elements of the Applicant's quality assurance or quality control program. We tabulate our findings below for each contention.

##### Embedded Plates

1. Bechtel evaluation of weld reinspection data without written documentation was inadequate.
2. There was a lack of awareness on the part of Applicant and Bechtel of Daniel weld inspection data for a period of months leading to doubts of careful monitoring of construction at Callaway.
3. There was inconsistent reporting of weld deficiencies by Daniel indicating supervisory weakness.

4. Serious questions were raised as to the quality of welded embeds fabricated by Cives Company.
5. And finally, there was an elapsed time of three years from discovery to final resolution of the embed problem on the part of NRC headquarters officials.

Concrete in the Reactor Base Mat

1. There was inadequate resolution of the inspection documentation problem related to concrete placement reports for the reactor base mat.
2. The use of untested dry-pack concrete for repairs was questionable. (In this instance the failure proved harmless to structural integrity and we consider it here only as incremental evidence pertinent to the effectiveness of the quality assurance program)

Concrete in the Reactor Dome

No defects relevant to the adequacy of the Applicant's quality assurance program were found.

SA-358 Piping

No defects relevant to the adequacy of the Applicant's quality assurance program were found.

SA-312 Piping

No defects relevant to the adequacy of the Applicant's quality assurance program were found.

Piping Subassembly Deficiencies

No defects relevant to the adequacy of the Applicant's quality assurance program were found.

142. In judging the adequacy of the Applicant's quality assurance program we compare actual performance against the functional standards stated in the testimony of Mr. Schnell who is Vice President Nuclear for Union Electric. (Schnell Testimony, ff. Tr. 216, at 23-27)

143. It is uncontroverted that the Applicant has in place a comprehensive QA/QC program at Callaway. (Schnell Testimony, ff. Tr. 261, at 35)

144. There is no evidence from the contentions in this case that all or a substantial part of the overall QA program failed to function during construction at Callaway. The program had effective overall control of construction quality and it coped effectively to resolve problems that were identified in the contentions in this case. However as noted in our comments on the individual contentions, there were several significant quality control problems.

145. The ultimate resolution of each problem identified in this case assures, however, that there are no safety concerns in the Callaway plant relative to those contentions tried in this case.

146. The deficiencies in quality assurance noted in this decision do not collectively show a pattern of programatic breakdown in the QA program. While there is no cause for complacency regarding the deficiencies noted, particularly those related to the embedded plate

problem, we conclude that the deficiencies are isolated problems having no broader implication for the overall effectiveness of the QA program.

IV. CONCLUSIONS OF LAW

The Board has considered all the evidence submitted by the parties and the entire record of this proceeding consisting of the Commission's Notice of Hearing, the pleadings filed by the parties, the transcripts of the hearing and the exhibits received into evidence. All issues, contentions, and proposed findings presented by the parties, but not addressed in this decision, have been found to be without merit or unnecessary to our decision. The findings of fact presented above are supported by reliable, probative and substantial evidence in the record.

The Board has not yet heard evidence with respect to, and this Partial Initial Decision does not address, the emergency planning contentions raised by Intervenor Reed. Based upon a review of the entire record in this proceeding and the foregoing findings of fact, the Board enters the following conclusions of law.

This is a contested proceeding on an application for an operating license for a utilization facility, and the Board has made findings of fact and conclusions of law on the matters put into controversy by Joint Intervenors with respect to construction defects at Callaway and Applicant's quality assurance program. Contentions in regard to radioactive releases have been withdrawn. The matters put into controversy by Intervenor Reed are still pending before the Board. The Board has not determined that a serious safety, environmental, or common defense and security matter exists. See 10 CFR § 2.760a. Other

findings required to be made prior to the issuance of an operating license, except for the remaining matters in controversy, are to be made by the Director of Nuclear Reactor Regulation. See Id. and 10 CFR § 50.57.

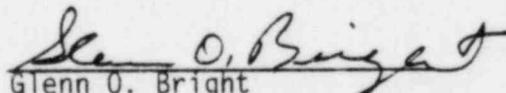
Having decided all matters in controversy raised by Intervenors, in favor of authorizing operation of the facility, the Board concludes that as to the matters decided herein, the Director of Nuclear Reactor Regulation would be authorized, upon making the requisite findings with respect to matters not resolved in this Partial Initial Decision, and subject to the Board's resolution of outstanding matters in controversy, to issue to Applicant a license to operate Callaway Plant, Unit 1. Such authorization is not now granted by the Board, however, and will not be granted until the Board resolves the outstanding matters in controversy or issues a further order to the contrary.

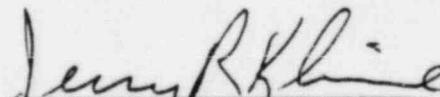
V. ORDER

WHEREFORE, IT IS ORDERED, in accordance with 10 CFR §§ 2.760(a) and 2.762, that this Partial Initial Decision shall constitute the final action of the Commission thirty (30) days after the date of issuance hereof, unless exceptions are taken in accordance with Section 2.762 or the Commission directs that the record be certified to it for final decision. Any exceptions to this Partial Initial Decision or designated portions thereof must be filed within ten (10) days after service of the decision. A brief in support of the exceptions must be filed within thirty (30) days thereafter (forty (40) days in the case of the NRC Staff). Within thirty (30) days of the filing and service of the brief of the appellant (forty (40) days in the case of the NRC Staff), any other party may file a brief in support of, or in opposition to, the exceptions.

IT IS SO ORDERED.

THE ATOMIC SAFETY AND  
LICENSING BOARD

  
Glenn O. Bright  
ADMINISTRATIVE JUDGE

  
Mr. Jerry R. Kline  
ADMINISTRATIVE JUDGE

  
James P. Gleason, Chairman  
ADMINISTRATIVE JUDGE

Dated at Bethesda, Maryland  
this 13th day of December 1982.

APPENDIX I

WITNESS LIST

Contention

Witness

Transcript

Embedded Plates

Applicant

Donald F. Schnell  
V.P., Union Electric Co.  
Bernard L. Meyers  
Project Mgr., Snupps  
Bechtel Power Corp.  
Eugene W. Thomas  
Supervisor, Snupps  
Bechtel Power Corp.  
Kirit Parikh  
Civil Eng. Supervisor  
Bechtel Power Corp.  
John W. Fisher  
Professor, Lehigh Univ.  
Civil Engineering  
Roger G. Slutter  
Professor, Lehigh Univ.  
Civil Engineering

501

Staff

Eugene W. Gallagher  
Civil Engineer, Office  
of Inspection and Enforcement  
Nuclear Regulatory Commission

1261

Licensing Board

Harold J. Starr  
Project Manager  
Daniel International Corp.  
John A. Holland  
Project Piping Engineer  
Daniel International Corp.

Honeycombing-Base Mat

Applicant

Bernard L. Meyers  
Thomas H. McFarland  
Construction Supervisor  
Union Electric Company  
Donald W. Pfeifer  
Project Manager, Wiss,  
Janney, Elstner & Associates

227

Staff

Anthony A. Varela  
Civil Engineer  
Nuclear Regulatory Commission

(Witness List Cont'd.)

<u>Contention</u>	<u>Witness</u>	<u>Transcript</u>
<u>Honeycombing-Reactor Dome</u>		
<u>Applicant</u>	Eugene W. Thomas Guy H. Goddard Deputy Group Supervisor Bechtel Power Corp. B. Christopher Tye Process Consultant Bechtel Power Corp. Richard A. Muenow Pres., Muenow & Associates Consulting Engineers	2010
<u>SA-358 Piping</u>		
<u>Applicant</u>	Michael F. Stuchfield Area Office Manager Bechtel Power Corporation Joseph V. Laux Supervising Engineer Bechtel Power Corp.	1537
<u>Staff</u>	Gordon Beeman Research Engineer Battelle Memorial Institute James Foster Investigator, Nuclear Regulatory Commission William Key Inspector, Nuclear Regulatory Commission	1681
<u>SA-312 Piping</u>		
<u>Applicant</u>	Bernard L. Meyers Michael F. Stuchfield John D. Hurd Snupps Group Supervisor Bechtel Power Corp. Geoffrey R. Egan Technical Director Aptech Engineering Services	1773
<u>Staff</u>	William R. Rutherford Senior Mechanical Engineer Formerly with NRC and now a Consultant	

(Witness List Cont'd.)

<u>Contention</u>	<u>Witness</u>	<u>Transcript</u>
<u>Piping Subassembly Deficiencies</u>		
<u>Applicant</u>	Joseph V. Laux Bernard L. Meyers Michael F. Stuchfield Robert L. Powers Superintendent, Site Q.A. Union Electric Company Harry J. Porter Quality Manager, Snupps Project Bechtel Power Corp.	1920
<u>Staff</u>	William Key William A. Hansen Senior Resident Inspector Nuclear Regulatory Commission	1977
<u>Quality Assurance</u>		
<u>Applicant</u>	Donald F. Schnell	216

## APPENDIX II

### INTERVENORS' CONTENTIONS

#### FAILURE OF THE QUALITY ASSURANCE PROGRAM

Surveillance and inspection functions of Applicant Union Electric Company, and others, including Bechtel Power Corp. (lead architect/engineer), Daniel International Corp. (construction contractor) and Code Authorized Nuclear Inspectors, failed to ensure the quality of safety-related material, structures, systems and components through all phases of their fabrication, construction, testing and inspection contrary to the quality assurance criteria of 10 CFR Part 50 Appendix B. Many vendor-supplied components were on the construction site and were approved for installation before code-defined deficiencies and nonconformances were identified. During construction deficiencies and nonconformances were accepted against code requirements. Without effective surveillance and inspection by the Applicant, and others, of material suppliers, component vendors, and construction contractors, all safety-related material, structures, systems, and components must be considered of questionable integrity. Because effective surveillance and inspection were not performed, the safe operation of the Callaway Plant is in jeopardy and should not be licensed.

Deficiencies and nonconformances which evidence the failure of the quality assurance program include but are not limited to the following:

#### I. SUBSTANDARD REINFORCED CONCRETE CONSTRUCTION

##### A. Embedded Plates

Embedded plates, or embeds, so called because they are embedded in concrete, are fixtures installed in concrete walls to support the ends of load-bearing steel beams, piping and other structures. The plates are made of steel with short steel studs welded to one face, like the bristles of a brush. They are mounted flush with the wall surface, with the studs extending into the concrete. The exposed surfaces of the plates serve as point of attachment for girders and other structural members. If an embedded plate tears loose from a wall, the result could be the collapse of an entire floor, breakage of critical pipes in the primary and emergency core cooling systems, and even core melt-down (Class 9 accident).

When the Callaway Plant was approximately five and one-half to seven percent complete, a stop-work order was issued on June 9, 1977, when it was discovered that some of the studs were not properly welded to the embedded plates. (See NRC Report No. 50-483/77-10, p. 8). Prior to June 9, 1977, 480 plates had been installed in the plant. (See NRC Report No. 50-483/80-14, p.4). The NRC and the Applicant do

not know how many of those 480 plates contain faulty welds, they do not know where those plates are located in the plant, they do not know what loads each plate must bear, and they do not know what the consequences of plate failure would be to the safe operation of the plant and to the health and safety of the public. (See, e.g., NRC Report No. 50-483/80-14, Attachment A - item 17, pp. 4-5 and Attachment B - item 17, pp. 5-6).

The Applicant and NRC staff do know that after the June 1977 stop-work order, many unused plates had to be repaired (See NRC Report No. 50-483/77-10, p. 8) or were returned to the manufacturer. There is evidence of multiple defects on some plates. (See NRC Report No. 50-483/80-14, Attachment B, p. 3). Although it is not known whether the manufacturer inspected the plates before shipping them to Callaway (see NRC Report No. 50-483/80-14, Attachment B, p. 2), none of the 480 installed plates were removed and reinspected, and, none were repaired or replaced.

During the process of evaluating the question whether the embedded plates presented a safety-significant problem, the Applicant improperly determined, with the NRC's apparent approval, that certain exceptions to structural welding code standards would be tolerated. (See, e.g., NRC Report No. 50-483/80-14, pp. 7-10).

We contend that inadequate and incomplete inspection and testing were performed. Omissions include the failure to conduct live-load tests and the failure to consider whether defective plates could withstand the effects of an earthquake as per 10 CFR Part 100, Appendix A, Section VI.

#### B. Cracks in Concrete<sup>\*/</sup>

There exist several cracks in concrete structures at the Callaway Plant that affect its safe operation. Examples include, but are not necessarily limited to, the following:

1. A crack up to 1/4 inch wide was discovered in the Reactor Building in the reactor cavity moat area in May 1977, a month after the concrete mat was poured. The crack extended approximately 270 degrees around the circumference. Upon visiting the site in June 1977, an NRC inspector was unable to view repairs performed on this crack because work had progressed to an extent that made physical inspection of the repair impossible. (See, NRC Report No. 58-483/77-06, pp. 20-21.)

2. The NRC was notified by a Callaway Plant ironworker in January 1978 that a lift of the north wall of the Control Building had been poured above a part of the wall which contained a crack approximately 12 feet long and 8 inches deep, and which extended from the inside to the outside of the wall and which apparently had been overlooked by the

---

<sup>\*/</sup> Eliminated from proceeding by grant of summary disposition.

Applicant's quality assurance personnel. (See, NRC Report No. 50-483/78-01, p. 20.)

### C. Honeycombing

Instances of air pockets or voids, known as honeycombing, have been found in concrete structures at the Callaway Plant. As described in NRC Regulatory Guide 1.55, "Concrete Placement in Category I Structures":

[T]he presence of numerous concrete voids which have been detected at or near the surfaces of nuclear containment buildings raises concern about the density of portions of these and other concrete structures that cannot readily be inspected. For such unaccessible areas, the only method of assuring a quality concrete structure is through good planning and control of the placement of concrete and all items embedded in it.

The instances of honeycombing at Callaway include but are not limited to:

#### 1. Reactor Building Base Mat

On May 31, 1977, voids described by the NRC as up to six inches, but described by a worker as big enough for a man to crawl into, were found in the tendon access gallery of the reactor base mat. (See, NRC Report No. 50-483/77-06, pp. 21-22). Repairs were undertaken at this time, but during the NRC inspection of August 31-September 2, a stop-work order was issued because of a discrepancy in work specifications concerning the testing of dry-pack group. (See NRC Report No. 50-483/77-07, p. 13). The stop-work order was lifted on December 7, 1977, after the necessary changes in specifications were made (see, NRC Report No. 50-483/78-01, pp. 2-3), but no information is available on whether any testing was performed on repairs done prior to the stop-work order. A report dated August 1, 1977, by Wiss, Janey, Estner and Associated, Inc., described a soniscope study performed by this firm to determine the possibility of additional honeycombing within the 10 foot thick base slab. The study states that, "Based upon a 25 percent sample . . . internal honeycomb probably does not occur in the base slab, except at those 19 areas where honeycomb was visible." (See, NRC Report No. 50-483/77-07, pp. 12-13, emphasis added.) This assessment of probability is the only assurance given that no additional honeycombing exists. According to a letter from James Keppler, Director, Region III, NRC, to Kay Drey dated January 3, 1979, the tendon access gallery represents nineteen percent of the base mat area. In the same letter Mr. Keppler described the twenty-four large holes which were repaired, as follows:

Large voids are defined as those that require approval prior to repair. The largest void in this category was approximately 22 square feet in surface area, and it was irregular in shape. Its maximum depth was 17 inches, and its average depth was 8 inches. The smallest void in this category was approximately 0.25 square feet in surface area, and its maximum depth was 5 1/2 inches. The size of the remainder of the voids in this category varied between those previously described.

## 2. Reactor Building Dome

Four areas of concrete imperfection in the Reactor Building dome were identified by Union Electric personnel during an inspection on August 22 and 27, 1980. These imperfections were attributed to "the complex nature of those portions of the dome slab where the imperfections occurred." However, on December 12, 1980, NRC personnel noticed that blockouts for the tendon grease vents had not been removed to facilitate inspection, and after the removal of the blockouts on December 13, three additional honeycomb areas were found. After conducting interviews with UE personnel concerning the three new void areas, the NRC concluded that, "There appeared no plausible explanation for their occurrence," and that ". . . there was not adequate assurance that the imperfections' existence were limited to only those areas identified." (See, NRC Report No. 50-483/80-30, pp. 3-4.)

### D. Concrete Cover<sup>\*/</sup>

There exist many areas where concrete coverage of reinforcing bars in concrete walls and floors at the Callaway Plant does not adhere to requirements. Bechtel Power Corporation's interpretation of the cover requirements was that minimum cover requirements could be reduced by one-third, but the NRC stated in a meeting between NRC, UE, Bechtel, and Daniel International personnel on January 23, 1978, that no reduction of the two-inch cover minimum is acceptable. However, the NRC indicated that it would be acceptable "if the cover requirements were fully met in the area of the sixth lift, utilizing the fifth lift as a transition area." (See, NRC Report No. 50-483/77-11, pp. 10-11.)

Some examples of nonadherence to concrete cover requirements are as follows:

1. At 340 degrees azimuth, vertical reinforcement bars and supporting bars for the horizontal tendon sheathing in the 3rd lift of the reactor containment wall had concrete cover "less than that specified by NRC requirements, but within the concrete cover requirements as interpreted by licenses and contractors." (See, NRC Report No. 50-483/77-11, pp. 4 and 9-11.)

---

<sup>\*/</sup> Eliminated from proceeding by grant of summary disposition.

2. NRC inspectors observed the preplacement preparation of the fourth lift of the exterior wall of the Reactor Containment Building, finding 14 unacceptable items, in half of which concrete cover was less than the 2 inch minimum required or more than the 9.6 inch maximum required. These items include instances where the concrete cover is as small as 5/8 of an inch (at azimuth 210 degrees) and as great as 12 inches (at azimuth 200 degrees). Some items were corrected, and the rest were within the range judged to be acceptable below the sixth lift because of the one-third placement tolerance. (See, NRC Report No. 50-483/78-01, pp. 9-11.)

## II. SUBSTANDARD PIPING

### A. Material Manufacturing Deficiencies

Safety-related pipe installed at Callaway was manufactured by a company or companies which did not have adequate control of welding parameters. This resulted in known cases of defects which did not comply with the requirements of the American Society of Mechanical Engineers (ASME) Code. The evaluation and acceptance of those defects and deficiencies were not done in accordance with the ASME Code. The safety of pipe installed at Callaway remains in question and demands further investigation before an operating license should be issued. For example:

1. In May 1979 a pipefitter discovered and reported a substandard piece of ASME Class II SA-358 piping which had been installed in the emergency core cooling system. The pipe was substantially out-of-round, was machined below the minimum wall, and had rejectable weld defects on the inside of a longitudinal seam weld. (See, NRC Report No. 50-483/80-10.) The piping was approved for shipment at the vendor's, was accepted on site, and was installed despite these deficiencies.

2. Substandard fusion welded SA-312 pipe manufactured by Youngstown Welding and Engineering Company and fabricated into safety-related pipe spools by Dravo Corporation has been installed at the Callaway Plant. (See, NRC/IE Bulletin 79-03 and 79-03A, and Union Electric letter ULNRC-314 dated May 11, 1979, to NRC - Region III). The evaluation and acceptance of this substandard SA-312 piping were not performed according to the requirements of Section III of the ASME Code.

### B. Piping Subassembly Deficiencies

Additional evidence of deficiencies in surveillance and inspection functions include the following: In 1979 it was discovered that pre-assembly piping formations with defective welds from Gulf & Western were accepted and were installed at Callaway. After installation it was also discovered that the vendor had used improper radiographic techniques. (See, SNUPPS letter SLNRC-79-20 of November 29, 1979, to NRC - Region I, and Bechtel Final Report of November 28, 1979.)