8008050200

ENGINEERING EVALUATION OF THE WNP-2

SACRIFICIAL SHIELD WALL

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I. INTRODUCTION AND SUMMARY

A. Purpose

The purposes of this report are:

- o To present the Supply System investigation findings and engineering assessment of the WNP-2 sacrificial shield wall (SSW) based on documentation and fabrication nonconformances, and

- o To update previous licensing documents on the loads and design of the SSW to document the adequacy of the as-built condition.

This report includes a presentation of the SSW review scope, design loads, weld quality and structural assessment considering the as-built condition. The investigation extended substantially beyond the original NRC Region V itemized concerns discussed in Reference I.1. As such, those concerns are addressed in the Appendix, attached to the main body of this report.

The SSW was a Post-Construction permit item (refer to Reference I.2). This report supplements previous submittals (refer to References I.3, I.4 and I.5) to the NRC which discussed the loads, fabrication procedures, and erection methods used during the design and fabrication of the SSW. The references have been reviewed and approved by the Office of Nuclear Reactor Regulation (refer to References I.6 and I.7). From a licensing standpoint, this report focuses on analytical refinements used to calculate the design loads on the SSW which were used in conjunction with the engineering assessment of the as-built SSW.

B. Findings and General Conclusions

Two major design nonconformances were identified which would prevent the SSW from performing its required functions during normal and postulated accident conditions.

- o The horizontal rings in the SSW, located above and below the interface at elevation 541'-5", are not welded together in accordance with the design requirements. As a result, the horizontal shear loads cannot be properly transmitted between the two rings. (Refer to Concern No. 1 for details.)

- o Concrete voids and shim gaps in the SSW have compromised the radiation shielding properties of the SSW. (Refer to Concern No. 2 for details.)

As a consequence of these nonconformances, two specific corrective actions had been identified by October, 1979:

- A partial penetration groove weld was proposed to accommodate the shear loads, and
- A comprehensive shielding repair program was being prepared to correct the shielding properties of the SSW to a condition equal to or better than the original shielding design requirements.

Information and results from the recent Supply System investigation and engineering assessment have established that subsequent to the above corrective actions, the SSW will be capable of performing its design functions. The findings and conclusions reached to support this statement are briefly discussed in the following paragraphs.

1. The materials selected for use in the SSW are acceptable. The mechanical strength properties for ASTM A36 and A588 provide substantial margin considering the design stresses. The selected weld filler metals were correct for the flux cored arc and shielded metal arc processes and for the use of electroslag welding with A36 material. The electrode (EM12K) used in conjunction with the A588 material and electroslag welds is acceptable considering the design stresses are less than 50% of yield.

   Ultrasonic testing (UT) performed by the SSW fabricator, Leckenby, and recent UT performed for the Supply System provide confidence that the A36 material has few laminations. The UT, the procedures implemented while making attachments to the SSW, the design loads and the multiple load paths inherent in the SSW provide assurance that the SSW material will not experience failure initiating from lamellar tearing, laminations or low, short transverse ductility.

   The application of heat straightening to A36 material during fabrication of the SSW did not degrade the material properties. Indications are that the steel temperature did not reach 1200^{o}F and A36 material properties are not damaged by short-term temperature applications in this range.

   The application of cold forming during fabrication of the SSW did not degrade the material properties of interest in the original design. This report, however, does consider the potential for brittle fracture which is related to the fracture toughness of steels. This property may be degraded by cold work, depending on the amount of induced strain. Tests are being performed to determine the cold forming impact on the SSW materials; however, based on information provided by a consultant used during this investigation (the Welding Institute), there is confidence that the resultant change in toughness will be acceptable.

2. The assembly sequence was acceptable based on the following:

   - o Minimal distortion was encountered during the fabrication of the SSW,
   - o The dimensional tolerances did not cause fabrication difficulties, and
   - o The SSW defect history does not indicate problems with high reaction stresses in members (residual stresses not due to localized welding stresses).

3. Results from recent inspections established that the quality of the SSW welds is acceptable, that Leckenby did perform the visual inspections required by the Design Specification, and that the results from the in-process, visual inspections performed by Leckenby established an adequate repair program. Recently performed UT verified that the electroslag welds are acceptable (1 potential defect in 73 welds). Magnetic particle (MT) examinations performed for the Supply System found no cracks or lack of fusion defects, and a visual inspection performed by Burns and Roe (the Architect Engineer) found primarily minor defects in 12% of the accessible welds. The significant defects identified by Burns and Roe are discussed below.

   The recently performed inspections did, however, identify defects requiring specific consideration. Incomplete penetration (IP) was found by UT in the root of welds made with the flux cored arc and shielded metal arc processes. The IP was generically evaluated by Burns and Roe to be structurally acceptable based on a conservative static analysis using accident loads. Undersized fillet welds identified during the visual examination have been evaluated with respect to plastic collapse (weld overload) and found acceptable.

   Irregularities in documentation potentially affecting the SSW weld quality, e.g., welding procedures, welder and inspector qualifications, and nondestructive examination (NDE) reports, provide implications that specific type defects may remain in the SSW even though not identified by the recently performed NDE. In addition, while making attachments to the SSW, some cracks and crack-like defects were identified and repaired by site construction contractors. Recognizing that the majority of welds in the SSW are not accessible and that the defects located by the site contractors were primarily found by MT (a more sensitive inspection than the visual required during fabrication),

caused the Supply System to perform a bounding defect assessment which enveloped both known and postulated defects. This analysis considered failure by fracture and plastic collapse. The design stresses used in this analysis are based on design loads which have been revised with respect to previously submitted reports (Reference I.5). The revised load analysis includes refinements in (a) calculations of pressure in the annulus between the reactor pressure vessel and the SSW, (b) calculations of the effect of seismic loads on the SSW, (c) structural modeling to include a dynamic analysis, and (d) calculations of the pipe whip reaction loads. The analysis conclusions are:

- o Failure by plastic collapse will not occur based on the low probability ($<1\%$) of occurrence of critical size defects and the existence of multiple load paths, and

- o Failure by fracture for most structural materials will not occur due to the SSW operating temperature ($>100^{o}F$) being sufficiently above the material nil-ductility transition temperatures (NDT) providing crack arrest conditions.

Insufficient data exists to ensure that the A588 material will be in the crack arrest condition. (It should be noted that the A588 material is only in the top channel of the top ring and constitutes less than 5% of the SSW structural material.) As a result, NDT testing is being performed on A588 material used in the SSW. If the resultant NDT plus temperature margin for the A588 material exceeds the SSW operating temperature, additional NDE will be performed to identify defects susceptible to fracture and to determine their size. Repair of unacceptable defects, if any, would then ensure that failure of the SSW by fracture will not occur.

C. Supply System Corrective Actions

A partial penetration weld substitution for the incomplete plug welds has been proposed to accommodate the shear load transfer between ring 3 and ring 4 of the SSW (pending removal of the Stop Work Order).

A comprehensive shielding repair program has been prepared to identify and correct deficiencies in the shielding properties of the SSW (pending removal of the Stop Work Order).

Additional visual inspections and nondestructive examinations have been performed to determine the weld quality of the SSW.

Additional material testing has been performed to confirm data available in welding and materials literature (NDT properties of E7028 electrode). And,

A bounding defect structural assessment has been performed to evaluate the risk of failure of the SSW by fracture and plastic collapse, considering known and postulated defects.

D. Supply System Open Items

Electroslag welding procedure qualifications are being reperformed to confirm the mechanical properties of related welds in the SSW.

A588 material is being removed from the SSW to determine its NDT properties and thereby finalize the disposition of the A588 structural assessment.

A36 material is being cold formed and tested to confirm the assumed small shift in the NDT due to cold work.

The Welding Institute will submit their final report with consideration of Supply System comments, new information, and the results of the material testing. And,

A three-dimensional, finite element dynamic analysis is being performed to confirm the design loads used in the assessments within this report.

The results from the above open items will be submitted at their completion to the NRC in an addendum to this report. It should be reemphasized that only one open item, the NDT testing for the A588 material, is considered to have a potential for further engineering corrective action, and that action has been identified.

E. References

I.1 Letter, G02-80-28, D. L. Renberger to R. H. Engelken, dated February 1, 1980.

I.2 NRC letter, W. R. Butler to J. J. Stein, transmitting minutes of October 17-18, 1973 meeting on post-construction permit items, meeting agenda item 10, dated November 20, 1973.

I.3 SSW report, WPPSS-74-2-R2, transmitted by GC2-74-41, J. J. Stein to A. Giambusso, dated March 21, 1974.

I.4 SSW report supplement, WPPSS-74-2-R2-A, transmitted by GO2-75-37, J. J. Stein to A. Giambusso, dated February 11, 1975.

I.5 SSW report supplement, WPPSS-74-2-R2-B, transmitted by GO2-75-240, N. O. Strand to A. Giambusso, dated August 19, 1975.

I.6 NRC letter, R. C. DeYoung to J. J. Stein, dated August 13, 1975.

I.7 NRC letter, R. C. DeYoung to J. J. Stein, dated October 15, 1975.

II. BACKGROUND

A. SSW Licensing History and Design Summary

1. Licensing History

Significant review has already been conducted by the Office of Nuclear Reactor Regulation (NRR) on the WNP-2 Sacrificial Shield Wall. The depth and scope of this review was extensive and will be summarized here.

- Pre-Construction Permit (CP)

  Question 12.19 (Reference II.1) on the PSAR from the NRC on January 20, 1972, requested the Supply System to evaluate results of pipe breaks between the reactor vessel and the SSW (annulus pressurization - AP). The Supply System responded that the SSW will be designed to accommodate AP and that the results of the analysis and design description would be provided before construction of the SSW.

- Safety Evaluation Report (SER) - CP

  Section 10.3.5 (Reference II.2) of the SER-CP confirmed the above and identified the SSW as a post-construction permit item, allowing the CP to be granted with the SSW design being an open item. The CP was granted in March, 1973.

- Post-CP

  On October 17-18, 1973, in Washington, D. C., a meeting was held with the then AEC to discuss post-construction permit items. The SSW was added to the agenda. The meeting notes (Reference II.3) committed the Supply System to providing the required information by March, 1974.

  On March 21, 1974, the Supply System transmitted report WPPSS-74-2-R2 with the information (Reference II.4). The report provided fundamental information on the SSW description, loads, fabrication, erection, welding techniques, tolerances, special features (reflective insulation), and protective coatings.

  The NRC responded on July 8, 1974 with a request for more detailed information (Reference II.5). Basically, the Structural Engineering Branch (SEB) requested a commitment to the then current NRC structural criteria for structures like the SSW and additional information in accordance with the Standard Format. The Containment Systems Branch (CSB) requested additional details and justifications relative to calculations and models.

The Supply System responded with part of the requested information on February 11, 1975 (Reference II.6). The SSW at the time was becoming a critical, construction schedule item and information was provided to promote gaining a release of the hold on construction of the SSW base.

On May 15, 1975, the NRC responded with additional concerns (Reference II.7). Primarily, in verifying the Supply System (Burns and Roe) AP calculations, the NRC using RELAP 3 obtained higher results by about 10-30%. The NRC noted that RELAP contained a 1.4 factor in it to account for uncertainties.

On June 26, 1975, the Supply System submitted analyses of loads on the SSW base using RELAP 3 in an effort to gain a partial release on the construction hold to permit base construction to progress (Reference II.8). The analyses included the 1.4 factor and concluded the base was acceptable.

On August 13, 1975, the NRC stated construction of the pedestal (SSW base) could proceed based on the submitted information (Reference II.9). The information was found to be acceptable. The only open item remaining was the RELAP results for the SSW above the base.

On August 19, 1975, the Supply System submitted the RELAP information for the SSW above the base and updated the previously submitted information to reflect the revised results (Reference II.10).

On October 15, 1975, based on acceptance of the submitted information, the NRC released the hold on the wall (Reference II.11).

- Operating License

  The FSAR was submitted in March, 1978. The design and assessment of the SSW is presented in FSAR Sections 3.8.3.1.1, 3.8.3.1.2, 3.8.3.2.2, 3.8.3.3.5, 3.8.3.4.1, 3.8.3.4.2, and 6.2.1.2. For the most part, these sections reference the previously submitted reports.

2. SSW Design Summary

Due to the extensive past NRC review and the documentation already submitted on the SSW, only key information will be summarized here. Appropriate references to previously submitted documents will be made for further detail. It should be noted that the information given here has been previously approved by the NRC. The balance of this report provides supplemental information and changes in the previously submitted and approved documentation to demonstrate the acceptability of the as-built SSW.

o SSW Description and Function

In summary, the SSW is a cylindrical, double-walled steel shell, filled with concrete to form a structure surrounding the reactor pressure vessel (RPV). The SSW is approximately 2 feet thick, 30 feet in outside diameter and 48 feet high. It is anchored to the reactor support pedestal and forms an annulus with the RPV which is open to the drywell at the top. Refer to Figure II.1. The SSW is classified as a Seismic Category I, Quality Class 1 structure.

The SSW performs radiation shielding and structural support functions. It minimizes radiation levels in the drywell as a result of radiation emanating from the RPV. Specifically, the shielding functions are:

- To reduce neutron activation of material and equipment inside containment,
- To minimize radiation damage to equipment,
- To provide supplemental biological shielding for the reactor building during plant operation, and
- To provide biological shielding for personnel inside the containment during plant shutdown.

As a support structure it serves:

- To support one end of a radial beam system which in turn supports mechanical and electrical equipment,
- To support the RPV in conjunction with the pedestal, stabilizer trusses and containment vessel, and
- To support piping systems, e.g., MS, RFW and RRC by hanger attachments and minimize pipe whip effects by supporting pipe whip restraints.

More complete details are provided in Section I of Reference II.4.

- o SSW Design Bases

  The design bases of the SSW are summarized in Table II.1. For more complete information refer to Section I.A.2 and Section II of Reference II.4, the response to questions 1 and 2 (pages 22, 23) from the Structural Engineering Branch (SEB) in Reference II.6, and the further revisions and additions to SEB questions 1 and 2 (pages 15, 16) in Reference II.10.

- o SSW Construction

  The requirements for the timely erection of the SSW, prior to the installation of the reactor pressure vessel, forms the underlying basis for the installation procedures established for the SSW. The entire SSW could not be constructed in place prior to the installation of the RPV because of nozzle interferences between the wall and the RPV. The SSW was designed to allow construction of a built-in-place lower portion and also to facilitate shop fabrication of an upper portion in three 120 degree segments to permit final assembly after the RPV was installed.

  Basically, the SSW consists of a series of circular, horizontal members built up of thick plates to form box beams (□) or channels (⊔), vertical members such as columns made of rolled wide flanges or built-up box sections and skin plates welded to these members.

  For more detail, refer to Sections I.A.1, III, IV, V, VI, and VII of Reference II.4 and the drawings in Attachment 5 to this report.

B. SSW Concern History

On September 8, 1978, a concrete void was located in the SSW top ring. This item was reported to NRC Region V as a potential 10CFR50.55(e) condition; later determined to not be reportable. This item was documented in the Supply System Evaluation Report No. 78-8.

In November, 1978, the 215 Contractor stated he would not issue a certificate of conformance for the SSW fabricated by the subcontractor, Leckenby, because of defects found by nondestructive examination while making attachments to the SSW. The 215 Contractor recommended a detailed review be performed by Burns and Roe of the documents and work performed by Leckenby.

Review was initiated by Burns and Roe Engineering and the WNP-2 Quality Assurance organization and continued through February, 1980. During this period the plug weld and concrete/shim gap void deficiencies were identified and corrective action recommended (refer to Concern Nos. 1 and 2 for details).

Additionally, during June, 1979, NRC Region V brought to the Supply System's attention allegations concerning SSW weld quality, concrete voids and material conditions. Due to conclusions reached during the Supply System and Burns and Roe ongoing reviews and further allegations received over the next several months, the Supply System issued a Stop Work Order on the SSW on November 21, 1979. During December, 1979, and January, 1980, NRC concerns were formalized and initially responded to by Reference II.12. These concerns were discussed with the NRC in Bethesda on February 6, 1980. In order to properly assess the general concern for weld quality in the SSW, an in-depth, broad-scoped review was determined to be necessary by the Supply System.

C. Evaluation Approach

The Supply System established a Task Force in February, 1980, to assume responsibility for review of the SSW as a whole in addition to the documented concerns. The Task Force was composed of Engineering and Quality Assurance personnel, solely dedicated to a review of the SSW with the following goals:

- Review the SSW documentation for compliance to AWS Code, Quality Assurance and Design Specification requirements, identify the nonconforming items and their implications for the as-built condition of the SSW,

- In conjunction with the documentation reviews, perform weld inspections and testing, as necessary, to determine the SSW as-built condition with respect to AWS Code requirements, Design Specification requirements, and to define the known and postulated defects and material conditions, and

- Assessthe SSW in consideration of the above findings to (1) determine the SSW capabilities with respect to performing its design functions during operation, and (2) identify any necessary repairs.[a]

    (a) Evaluation of the SSW radiation shielding properties was performed by Burns and Roe and is addresssed in Concern No. 2.

The basic investigation approach used by the Task Force consisted of the following:

- Review and evaluate the welding procedures, welder qualifications, weld filler metal controls, nondestructive examination procedures, and inspector qualifications to identify documentation implications for the SSW weld quality,

- Review and evaluate documentation containing weld and base material defect/repair information to provide insight to related trends and relationships which might affect the quality of the SSW,

- Perform additional visual and nondestructive examination to establish the weld quality of the SSW and confirm or deny implications from the documentation reviews.

- Evaluate processes used on the SSW during fabrication for affect on weld and material quality,

- Review and evaluate the material traceability system and material test reports to assist in establishing the material condition of the SSW, and

- Assess the as-built structural integrity of the SSW to perform its required functions considering the materials and processes used, the postulated accident loads on the SSW, and the known and postulated defects in the SSW.

A detailed itemization of the areas reviewed and assessed is presented in Attachment 2 to this report.

D. References

II.1 NRC Question 12.19, Amendment No. 12, WNP-2 PSAR.

II.2 Section 10.3.5, 115, WNP-2 SER-CP.

II.3 Letter, W. R. Butler (NRC) to J. J. Stein (WPPSS), "Meeting Summary October 17-18, 1973 with WPPSS, discussions of outstanding post-construction permit items", November 20, 1973.

II.4 Letter, J. J. Stein (WPPSS) to A. Giambusso (NRC), "Transmittal of Report WPPSS-74-2-R2, Sacrificial Shield Wall", GC2-74-41, March 21, 1974.

II.5 Letter W. R. Butler (NRC) to J. J. Stein (WPPSS), Request for Additional Information, July 8, 1974.

II.6 Letter, J. J. Stein (WPPSS) to A. Giambusso (NRC), "Response to Questions Sacrificial Shield Wall Design", GO2-75-37, February 11, 1975.

II.7 Letter, W. R. Butler (NRC) to J. J. Stein (WPPSS), Request for Additional Information, May 15, 1975.

II.8 Letter, N. O. Strand (WPPSS) to A. Giambusso (NRC), "Response to Questions Sacrificial Shield Wall Design", G02-75-181, June 26, 1975.

II.9 Letter, R. C. DeYoung (NRC) to J. J. Stein (WPPSS), August 13, 1975.

II.10 Letter, N. O. Strand (WPPSS) to A. Giambusso (NRC), "Response to Request for Additional Information, Sacrificial Shield Wall Design", G02-75-240, August 19, 1975.

II.11 Letter, R. C. DeYoung (NRC) to J. J. Stein (WPPSS), October 15, 1975.

II.12 Letter, G02-80-28, D. L. Renberger (WPPSS) to R. H. Engelken (NRC), February 1, 1980.

TABLE II.1
SACRIFICIAL SHIELD WALL DESIGN BASES

1. The following codes, specifications and standards were used in the fabrication and erection of the SSW:

   - ACI Codes - ACI 301, 304, 305, 306, 308, 318 and 614.
   - AISC Manual of Steel Construction including all specifications contained therein.
   - AWS Structural Welding Code (AWS D1.1-Rev. 1-73).
   - ANSI N45.2-1971.

2. The design of the SSW considered a normal or operating condition, an emergency condition which includes seismic loads, and an accident condition which also includes loads associated with a postulated pipe rupture.

   The elastic working stress method of Part I, AISC, 1969, was used in the design of the SSW. The load combinations in accordance with NRC Standard Review Plan 3.8.3 which controlled the design of SSW were:

   - $1.6S \geq D+L+P_a+Y_r+E$, and
   - $1.7S \geq D+L+P_a+Y_r+E'$.

   Where, 1.6S and 1.7S approximate yield

   D = dead load
   L = live load
   P_a = annulus pressurization
   Y_r = pipe whip load
   E = operating basis earthquake
   E' = safe shutdown earthquake

3. The primary materials used in the fabrication of the SSW were:

   - ASTM A36 for structural steel with exception to the top ring beam made of ASTM A588, and
   - Concrete with 4000 psi minimum compressive strength.

4. Welding of the SSW was performed in accordance with AWS D1.1-72 and Section 17D of the WNP-2 215 Contract.

5. The dimensional tolerances for the SSW were the following:

- o Circularity tolerance ± 0.90 inch maximum,
- o Plumb tolerance ± 0.90 inch maximum at elevation 567'-7¼", and
- o Ring beam level tolerance ± 0.25 inch maximum at elevation 567'-4½".

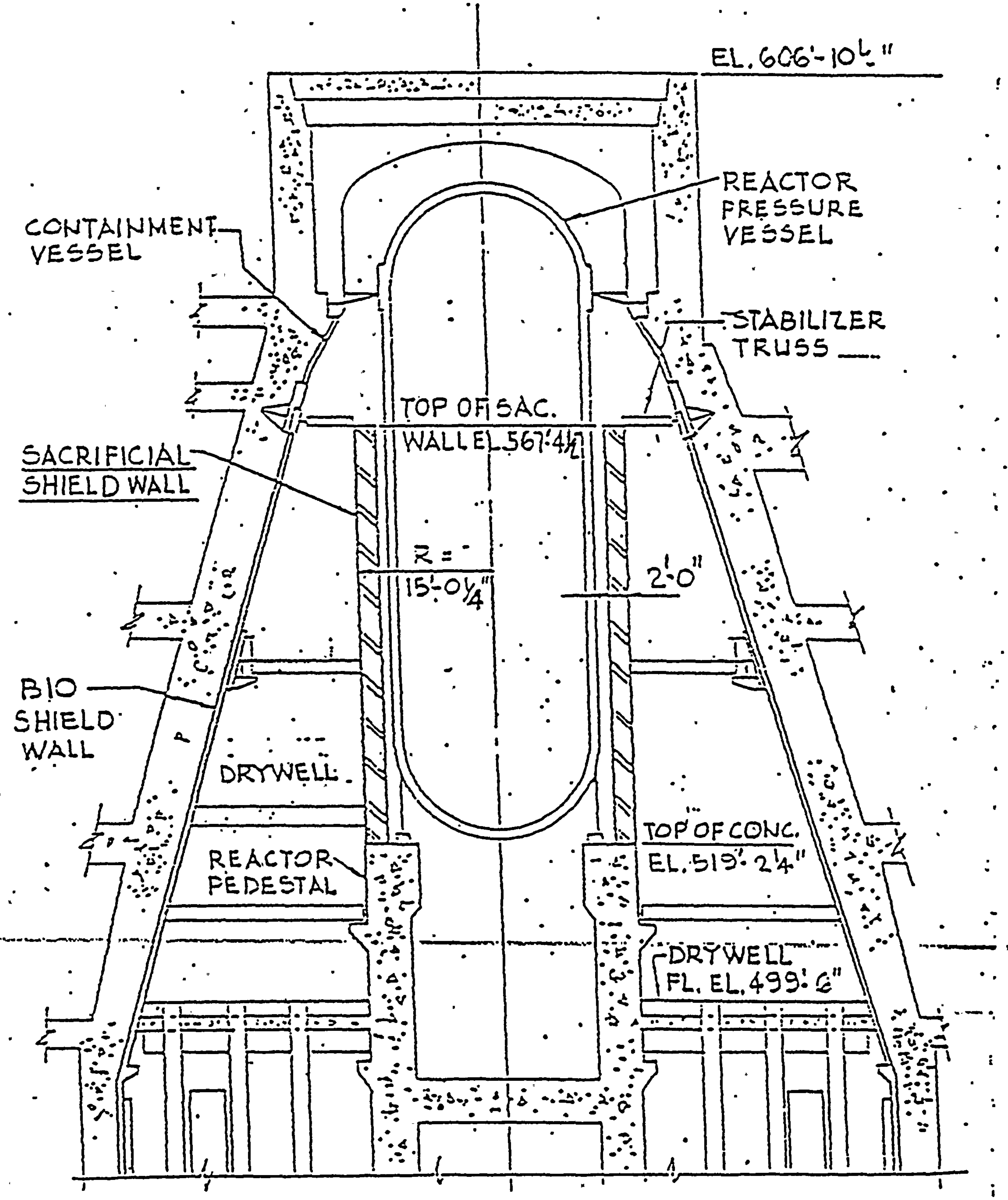


FIGURE II.1 REACTOR BLDG. DRYWELL

III. RESULTS OF INVESTIGATION

A. Introduction

In order to assess the as-built structural integrity of the SSW, three elements are required:

- The design loads must be defined and their stresses calculated,
- The weld and base material defects and mechanical properties must be known, and
- A structural assessment considering the above is required to be performed in a manner that envelopes known and postulated defects for the various failure modes.

The following subsection presents the load conditions for the SSW. Details of the load analysis refinements, assumptions and methodology are provided in Appendix B to this report.

Subsection III.C discusses the defect and repair history of the welds and material in the SSW and through evaluations and results from recent inspections establishes the as-built weld quality of the SSW.

The design stress levels and material properties in the SSW are used in conjunction with the known and postulated defects to demonstrate that failure will not occur due to brittle fracture or plastic collapse. This bounding structural assessment is presented in subsection III.D.

III.B SSW Load Conditions

1. Introduction

In order to provide a more realistic, but conservative stress environment to assess the adequacy of the as-built SSW, the design loads and resultant stresses have been recalculated. Results reported in this subsection reflect refinements in loads and analysis techniques made subsequent to submittal of Reference III.B.1. The incorporated revisions to the analysis include:

- Refinements in the calculations of pressure within the reactor pressure vessel (RPV) to SSW annulus for the feedwater line break,
- Refinements in the calculations of the effect of seismic loads on the SSW,
- Refinements in the structural modelling (development of a dynamic model) to better characterize the effect of dynamic loads acting upon the SSW, and
- Refinements in the pipe break reaction loads to incorporate the as-built location of the pipe whip restraints (PWR) and to include more realistic gaps between the pipe and the PWR.

Detailed explanations of these refinements are contained in Appendix B to this report. These refinements from previously submitted analyses (References III.B.1, III.B.2 and III.B.3) are reflected in the results reported in subsection III.B.2. Subsection III.B.3 discusses the conservatisms inherent in the calculations and subsection III.B.4 discusses the conclusions and additional confirmatory work that is being performed.

Based on the results (less than 50% of the NRC acceptable stress) of the recent evaluation, it is concluded that substantial margins exist with respect to the NRC acceptable stress levels to compensate for known and postulated defects in the SSW under postulated accident conditions.

The only refinement in this subsection that was applied to the structural assessment of the partial penetration weld at elevation 541'-5" (refer to Concern No. 1) was the use of the finite element seismic analysis. Refer to Attachment 4 and Appendix B for further details.

2. Load Conditions

- Normal Load Conditions

  Calculations of normal loads in the SSW remain unaltered from previous submittals. Under normal operating conditions, stress levels in the SSW are quite low. Using allowable stresses based on the elastic working stress method in Part 1 of the AISC design specification, stresses in the controlling columns reach about 25% of allowable (where allowable is about 2/3 of yield). For the controlling beams, stress levels reach about 15% of allowable.

- Normal Plus Seismic Load Conditions

  If seismic events occur during operation, the SSW stress levels still remain low. The stresses are due to dead (D), live (L), operating basis earthquake (E), and safe shutdown earthquake (E') loads. The applicable load combinations and section strengths were determined per NRC Standard Review Plan (SRP) 3.8.3 as presented below:

  SRP Comb. 2: $1.0S \geq D+L+E$ (a)

  SRP Comb. 3: $1.6S \geq D+L+E'$ (a)

  (a) S is the required section strength based on the elastic working stress method. SRP combination 2 provides acceptable stress levels of about 2/3 of yield; SRP combination 3 provides acceptable stress levels of about yield. These stresses are not realized for any load combinations required.

  The analysis methodology with respect to seismic events was the same as previously reported (References III.B.1, III.B.2 and III.B.3) except for the refinements documented in Appendix B. The analysis considered various controlling members in the SSW and the above load combinations. The resultant stress was the maximum normal stress on a member section. It occurs in one corner of the section due to axial force and biaxial bending. For the controlling members, the critical maximum stress levels are associated with Combination 2 and have been found to be equal to or less than 37% of the acceptable stress (for Combination 2 the acceptable stress and Code allowable stress are the same).

o Accident Load Conditions

The limiting design loads for the SSW result from postulated accident conditions. The SSW has been designed to accommodate normal loads, earthquake loads, and annulus pressure (P_a) and associated pipe reaction loads (Y_r) which would result from a postulated loss-of-coolant accident due to a break at a reactor nozzle within the boundary of the wall. Two analyses have been performed for this postulated accident loading condition, a static analysis and a simplified dynamic analysis. The dynamic analysis was performed to more accurately assess the available design margins in the SSW which in turn are used in the structural assessment provided in subsection III.D.

As discussed in previous reports (Reference III.B.1), the loads are combined per NRC Standard Review Plan (SRP) 3.8.3. Load combinations 5 and 6 were found to control design. These combinations are stated below with their acceptable stress levels and the significant load terms.

SRP Comb. 5: $1.6S \geq D+L+P_a+Y_r+E$ (b)

SRP Comb. 6: $1.7S \geq D+L+P_a+Y_r+E'$ (b)

(b) NRC acceptable stress levels of 1.6S and 1.7S correspond approximately to yield; these stresses, based on the static or simplified dynamic analyses, are not realized for any load combinations required.

The static and simplified dynamic analyses are summarized below:

Static Analysis

The static analysis uses equivalent static loads for dynamic loads. Ring beams and columns are included in the structural model as members of a space frame and skin plates are joined to the frame at the nodes as plane stress finite elements. Analysis models and methods used are the same as described in Reference III.B.1. Results reported herein include refinements made subsequent to issue of Reference III.B.1 in load definitions for seismic, pipe reaction, and annulus pressurization loads(refer to Appendix B).

In general, for the upper portion of the wall, the design is controlled by a load combination which includes a postulated feedwater line pipe break. For the lower portion of the wall, the load combination which includes a postulated recirculation line break controls the design. For local areas of the wall which receive reactions due to drywell pipe breaks, these pipe breaks control in certain cases.

Results are based on calculated maximum normal stress on the member section. Primarily this results from a summation of stresses due to the axial force and biaxial bending. Hence, only a corner or a limited portion of the member is subjected to the maximum calculated stress. For controlling members, the maximum stress levels have been found to be equal to or less than 65% of the acceptable stress levels for combinations 5 and 6. For certain members where the load combination is dominated by the pipe break reaction load, stress levels were found to be about 75% of the acceptable stress level.

Simplified Dynamic Analysis

Two considerations not taken into account in the static analysis are as follows:

o Pressures in different nodes within the SSW annulus reach their peak value at different times and for short durations, necessitating dynamic modelling to properly characterize the SSW loads and load history. In the static analysis this phasing of peak pressures cannot be accounted for. Conservative assumptions of concurrent peaks are therefore used in the static analysis.

o The advantage that the concrete within the SSW provides in reducing calculated stress in structural members is neglected in the static analysis. In reality, the concrete fill increases the stiffness of the SSW and reduces displacements under load.

To provide proper perspective of the SSW structural capability, a simplified dynamic analysis has been performed accounting for the two items above. This analysis demonstrates the reductions in calculated stress as a result of dynamic analysis. The static analysis identified the recirculation pump suction line break as the limiting break with respect to the highest design stresses on the SSW. This simplified dynamic analysis was performed using this break. The commercially available computer program ANSYS was used to calculate the structural response of the SSW to annulus pressurization and pipe reaction loads. The SSW was represented by axisymmetric thin shell elements. The openings in the SSW were not modelled, but were considered in the calculation of shell properties. Displacements calculated using this dynamic model were used as input to the more refined, three-dimensional model of the SSW given in Reference III.B.1. Additional details of the analysis and model are contained in Appendix B.

For the majority of members the maximum stress based on load combinations 5 and 6 were found to be less than 37% of the acceptable stress level. For columns between elevation 534' and 540', where the stress is dominated by seismic, dead and live loads obtained from the previous static analysis, the maximum stress is calculated to be about 48% of the acceptable stress level. Similar stresses or less will result from calculations including the other pipe breaks.

Accordingly, the maximum stress, including localized pipe break reaction loads, in the SSW is less than 50% of the NRC acceptable stress level based on results of this dynamic analysis.

3. Conservatisms Present In Annulus Pressurization Load Definition

Under postulated accident loading conditions, one of the principal SSW loads is due to an assumed pressurization of the annulus between the SSW and the RPV. The results of the simplified dynamic analysis were based on conservatively defined annulus pressurization loads. The major conservatisms introduced in the development of these loads is discussed here in order to provide a clearer perspective on the nature of more realistic loads which might be expected due to annulus pressurization, versus design basis loads used for structural design.

Figure III.B.1 illustrates the relative locations of the sacrificial shield wall, RPV, and RPV insulation. Between the RPV and the RPV insulation is a nominal 8½" annular space; between the RPV insulation and the sacrificial shield wall is a nominal 4½" annular space. Because of questions related to the movement of the insulation during the event, conservative assumptions were made. The design basis calculation has been performed assuming only 4½" of the total annular space is available to receive fluid (Reference III.B.1). This limited volume assumed in design basis calculations substantially increases the design basis loads as compared to the more realistic situation. Burns and Roe has performed calculations to quantify the importance of this assumption and has determined that with the total annular space available (less insulation thickness), the annulus pressurization loads on the SSW would be reduced to approximately 35% of the design basis annulus pressurization (AP) load. This assumption may be unique to the WNP-2 analysis of the AP loading and is a primary reason for installation of flow dividers on WNP-2 to limit to 1/16 the break flow that enters the annulus between the SSW and RPV.

A second major conservatism introduced in the design basis calculations is the assumption that the circumferential pipe break opens fully and full flow begins instantaneously. Realistically, full flow from the severed pipes could not be realized until the severed pipe ends separate to a distance equal to one-half (½) the pipe diameter. Severance of a pipe and the subsequent movement actually occurs in finite time. As reported by Messrs. J. B. Mahoney, et al, (Reference III.B.4), the opening and separation time to achieve full blowdown would be expected to be in the 10 to 100 millisecond range. Burns and Roe calculations have shown that the annulus pressurization loads on the SSW due to the postulated recirculation line break would be reduced to between 75% and 10% of the design basis loads for break opening times from 10 to 100 milliseconds.

A third major conservatism relates to the calculation of the pressure transient within the SSW annulus. This calculation was accomplished using the RELAP computer program (Reference III.B.5). As stated in subsection II.A.1, the NRC requested (Reference III.B.6) that the pressures calculated be increased by a factor of 1.4 to account for uncertainties in the fluid dynamic phenomena. Without the inclusion of this factor, SSW loads due to annulus pressurization would be reduced to about 70% of the current design basis loads.

Considered together, these three conservatisms provide insight to the actual annulus pressurization loads which might be expected. The cumulative effects are such that, realistically, net annulus pressurization loads would be reduced to less than 20% of the current design basis annulus pressurization loads.

4. Conclusions

Results of work done in 1974 and 1975 which was approved by the NRC (Reference III.B.1, III.B.2 and III.B.3) indicated that some portions of the SSW were acceptable with respect to loading, but near yield stress under certain design basis load conditions. The analytical assumptions and methodology used to calculate the loads were very conservative. As identified in Appendix B, certain refinements were made in the analyses to better assess the design margins available. The results of the static analysis reduced the calculated stress for the controlling members to 75% of the NRC acceptable stress level.

Known conservatisms in the static analysis indicated a dynamic analysis would provide further reduction in the calculated stress. As a result, a simplified dynamic analysis was then undertaken on the limiting break (recirculation line). The resultant stress for the controlling members was 48% of the NRC acceptable stress level. This work is sufficient to conclude that the design basis loads on the SSW result in stresses approximately one half that of the NRC acceptable stress level. This margin is sufficient to assure the adequacy of the as-built SSW as discussed in subsection III.D.

As followup and further confirmation of the design basis loads on the SSW, a three-dimensional, finite element dynamic analysis is being performed. The results and details of this work will be submitted in an addendum to this report.

5. References

III.B.1 SSW report supplement, WPPSS-74-2-R2-B, transmitted by G02-75-240, N. O. Strand to A. Giambusso, dated August 19, 1975.

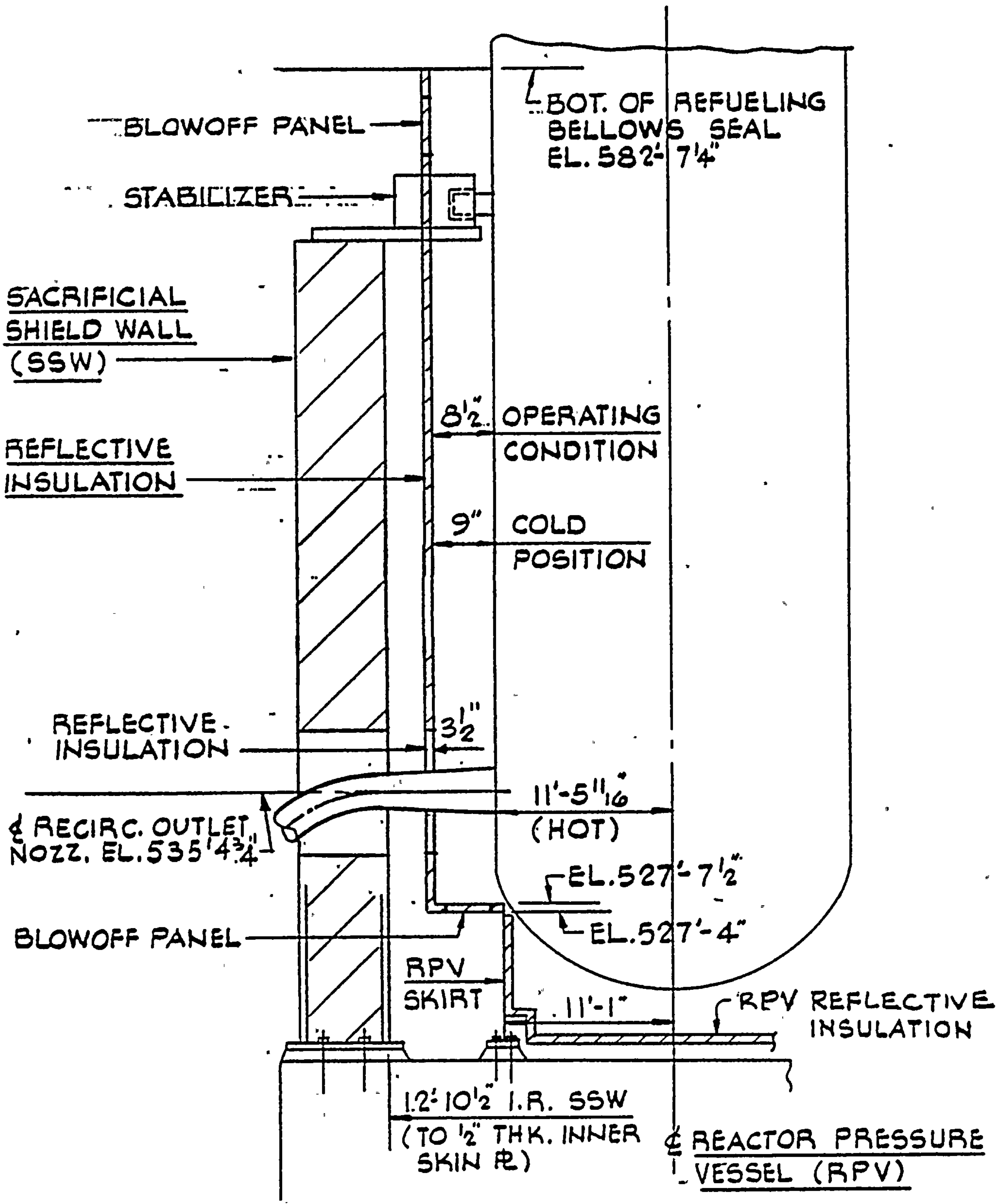
III.B.2 SSW report, WPPSS-74-2-R2, transmitted by GC2-74-41, J. J. Stein to A. Giambusso, dated March 21, 1974.

III.B.3 SSW report supplement, WPPSS-74-2-R2-A, transmitted by G02-75-37, dated February 11, 1975.

III.B.4 PVP-40, 1980 Symposium on Effects of Piping Restraints on Piping Integrity to be presented to ASME conference, San Francisco, California, August 12-15, 1980, (to be held). "Behavior of Primary Pipe Whip Supports and Secondary Operational Supports During a Postulated Pipe Break", by J. B. Mahoney, Z. Studnicka, M. Ramchandani.

III.B.5 RELAP3- A Computer Program for Reactor Blowdown Analysis, IN-1321 (June 1970, by W. H. Rettig, et al.).

III.B.6 Letter W. R. Butler to J. J. Stein, Transmitting Request for Additional Information, dated May 15, 1975 (GI2-75-75).



WASHINGTON PUBLIC POWER SUPPLY SYSTEM NUCLEAR PROJECT NO. 2	RPV/SSW ANNULAR SPACE	FIGURE III.B.1

III.C SSW Weld Quality

1. Introduction

The initial causes for concern about the weld quality of the sacrificial shield wall (SSW) were:

- Irregularities observed in Leckenby quality affecting documentation,
- Weld and base material defects (including cracks and crack-like indications) discovered during site construction contractor magnetic particle examinations of SSW attachment locations,
- Visual observation of SSW weld defects not within AWS D1.1 visual inspection acceptance criteria (the governing welding code), and
- Numerous defects had been identified by UT in electroslag welds on pipe whip restraints (PWR) previously fabricated by Leckenby under a separate contract.

During the beginning stages of the Task Force review, additional concerns associated with the SSW weld quality were identified. These concerns were as follows:

- Review of the Leckenby records indicated that Leckenby experienced difficulty with the electroslag welding process. Specifically, both cracks and lack of fusion were detected by visual inspection and repaired, and
- The visual inspection required by specification may not have identified all the cracks or planar lack of fusion defects, and as such, these type defects may exist in the SSW.

The Task Force reviewed and evaluated each of the above items in addition to many others (refer to Attachment 2). The weld quality findings are presented in this subsection and in the Concerns in Appendix A. The bounding structural assessment in consideration of the weld quality of the SSW is presented in subsection III.D.

Various types of documentation have a potential for affecting weld quality. These include, e.g., welder qualifications, welding procedure qualifications, inspector qualifications, and fabrication drawings. Concern Nos. 5, 22 and 23 address the above qualifications. This subsection discusses a design review of the Leckenby weld maps. To resolve the concerns based on previously identified defects and postulated defects, additional inspections were performed. Burns and Roe performed a visual inspection of the accessible, exterior SSW welds. In addition, the Task Force requested the baseline inservice inspection contractor to perform a number of magnetic particle (MT) and ultrasonic testing (UT) examinations of accessible welds on the SSW.

The as-built weld quality of the SSW was determined by the following:

- An evaluation of the potential for and nature of defects in the SSW due to nonconformances in documentation,
- An evaluation of the potential for and nature of defects in the SSW based on the weld fabrication history and known defects identified and repaired by site construction contractors since the completion of fabrication, and
- By performing additional visual inspections and nondestructive examinations.

In turn, the inspection results and projections for potential defects were evaluated in consideration of the design loads. These evaluations, refer to subsections III.C.7 and III.D, conclude that the weld quality of the SSW is acceptable. Details in support of defining the weld quality of the SSW are provided in the remainder of this subsection.

2. Leckenby Visual Inspection

In order to gain perspective on the weld quality of the SSW, knowledge of the weld defect and repair history must be known. This information can then be integrated with results from recent inspections and evaluations of procedures affecting weld quality to establish the as-built quality of SSW welds.

Visual inspection of the SSW welds by Leckenby was documented on the Leckenby weld maps. Weld defects were reported on shop Incomplete/ Rejection Tags, Field Inspection Reports and noted in the remarks column of the shop weld maps. The defects recorded by Leckenby were repaired. Repair verification consists of:

- Recent ultrasonic testing of welds recorded as repaired found no defects, and
- No previously recorded defects documented by Leckenby were reidentified during the recent visual inspection.

As mentioned earlier, and substantiated by the high weld rejection rate during fabrication, the electroslag weld defect history was originally cause for concern. The electroslag weld defects recorded and repaired during fabrication by Leckenby are presented in Table III.C.1. There are 1273 electroslag welds in the SSW. A total of 388 electroslag welds had recorded defects for a defect percentage of 30.5%. Table III.C.2 includes information relative to the characterization of the defects. As can be seen from the tables, lack of fusion (LOF) and undercut comprise the majority of weld defects.

The typical LOF defect has been described by former Leckenby employees in two ways:

- An accumulation of slag trapped at the weld to base material interface at the corners, and

- As a sharp, planar defect at the same location.

Reliance in the latter description is questionable due to the source's recall of the subject defect (refer to References III.C.1 and III.C.2).

Based on conversations with fabrication companies experienced in electroslag welding (refer to References III.C.3 and III.C.4), the lack of fusion defects typically observed are due to slag entrapment (excess flux) in the corner and improper placement of the consumable guide tube. The latter does not allow full penetration of the weld to the corners which results in a rounded weld profile and a sharp re-entrant angle with the base material. Neither of these type defects are equivalent to the planar lack of fusion defect. In addition, these defects can be visually identified upon copper shoe removal.

Electroslag welds were performed using temporary copper shoes and/or permanent steel backing. A large number of electroslag weld defects identified and repaired by Leckenby are due to the influence of the copper shoes. The thermal conductivity of the copper shoe creates a chilling effect at the base metal/copper shoe interface. As a result, lack of fusion associated with slag entrapment and guide tube placement has a greater tendency to occur at the corners of the weld joint. Similar problems are not associated with the steel backing since the chilling effect is substantially reduced. The defects associated with the copper shoes were identified upon shoe removal and repaired. Based upon comments in the defect related Leckenby documentation, it is clear that Leckenby was experiencing difficulty with the electroslag process, but relied upon inspection and repair as the resolution.

In the event that large excesses of flux exist during welding with steel backing, slag entrapment may occur in the weld. The steel backing was used for welding joints with subsequent inaccessibility to the backside of the joint. Based on review of the Leckenby weld maps, steel backing was used on less than 10% of the electroslag welds. Subsection III.C.7 discusses recent UT performed on electroslag welds. Seventeen of these welds had steel backing, confirmed by UT depth readings. None of the 17 welds contained defects based on the UT examinations.

In a few cases, depth information was also provided for electroslag weld defects in the documentation. It is believed that since the depth data were very few in number and more severe than what is typically experienced, that this information represents the exception rather than the rule. For example, one electroslag weld LOF defect was excavated to approximately 1/2 inch. One crack defect

was described as about 1½ inch deep, and several underfill defects were noted as 1/2 inch deep.

A review of the minimum length values in Table III.C.2 points out that Leckenby was observant of and conscientious about small defects. Since only visual inspection was required, excluding lamellar tearing UT, it is concluded that for electroslag welds only subsurface defects or very small surface defects would not have been detected and repaired by Leckenby. Based on the extensive documented repair of these welds and the good results from UT performed in May and June, 1980 (refer to III.C.7, one potential defect in 73 welds), it has been concluded that the quality of the electroslag welds in the SSW is acceptable.

Flux cored arc welding (FCAW) and shielded metal arc welding (SMAW) surface defects were likewise recorded and repaired during fabrication. Table III.C.3 presents FCAW and SMAW defect data. As indicated, cracks or crack-like defects were very few in number. Undercut comprised by far the majority of defects and was most likely due to welder technique.

3. Leckenby Ultrasonic Testing

The 215 Contract specification required ultrasonic testing (UT) of electroslag weld (ESW) tee-joints for lamellar tearing per ASTM A435-74. The Leckenby lamellar tearing UT, however, was performed prior to this contract modification requirement. This UT was primarily performed due to concern for lamellar tearing at tee-joints where buttering, an original preventive measure, had not been used. The UT was performed per Leckenby Quality Control Procedure (QCP) - 8.0. The defect repair criteria in QCP-8.0 is substantially more stringent than the specification and ASTM A435 three-inch-diameter circle criteria. QCP-8.0 defect acceptance criteria in part states:

> No linear type discontinuities are allowed if the signal amplitude exceeds the reference level and the discontinuities have lengths which exceed:
>
> 1/4 inch for T [(a)] up to 3/4 inch, 1/3T for T from 3/4 to 2¼ inch, and 3/4 inch for T over 2¼ inch.
>
> (a) T is the thickness of the thinner portion.

The Leckenby UT sampling may be represented as follows:

o	ESW tee-joints	81 straight beam
o	ESW tee-joints	2 angle beam
o	FCAW tee-joints, and	48 straight beam
o	Other SMAW and FCAW joints	58 angle beam

In addition, the number of lamellar tearing UT examinations performed by Leckenby exceeded the specification requirements and no indications of lamellar tearing were found.

SSW UT performed by Leckenby, associated with defect repair and radial beam attachment site evaluation, is discussed in detail in Concern No. 5. This UT was not required by AWS D1.1 or the specification.

4. Site Construction Contractor Visual and Magnetic Particle (MT) Examinations

Other reported defects which created concern for the SSW weld quality were found during site construction contractor visual and MT examinations. The examination requirement for the fabrication of the SSW was visual. However, due to past lamellar tearing experienced while making attachments to the containment vessel, MT inspection of SSW attachment areas was required. The MT examinations used the prod DC method. Magnetic particle examination was an upgrading of the original SSW inspection requirements.

Defect information associated with SSW visual inspections performed by site construction contractors is presented in Table III.C.4. The MT results are presented in Table III.C.5. The 11.6% MT rejection rate (726 total examinations) is not considered abnormal for a structure requiring only visual inspection during fabrication (excluding lamellar tearing UT). Characterization data for SSW defects found by this MT is presented in Table III.C.6. The available defect information in many cases lacks good definition with respect to type, size and location.

Defects found by site construction contractor visual inspection and MT have been repaired with the exception of those remaining on open nonconformance reports.

It is recognized that the detection of these SSW defects creates concern for the quality of inaccessible welds, one contributing factor being the lack of definitive information. This negative factor is overcome, however, when considering the results of the recently performed visual inspection and nondestructive examinations (refer to later subsections), the Leckenby defect repair history, and the structural assessment presented in subsection III.D which envelops all known and postulated defects.

5. Burns and Roe Visual Inspection

From December, 1979, through April, 1980, a detailed, documented visual inspection was performed by Burns and Roe of SSW exterior accessible welds. Over 90% of the accessible welds were made using the FCAW and SMAW processes. The inspection was performed to AWS D1.1 requirements. The identified defects, primarily associated with weld profile, have not been repaired to date, but are acceptable for service as discussed below. Table III.C.7 presents the visual inspection results. Defects in 12% of the welds are indicative of a lack of attention to some detail or in some cases the judgement of inspection personnel, but not gross negligence in Leckenby's visual inspection.

Also, the Burns and Roe inspection results makes a comparatively positive statement about the Leckenby inspector and welder performance. The 1170 evaluated welds were almost equally distributed to shop and field work. Based on review of the visual inspection results with respect to the Leckenby inspectors and welders, no specific trends or relationships were established. This indicates that no gross ineffectiveness can be attributed to specific Leckenby inspectors or welders.

Table III.C.8 characterizes defects found during the recent visual inspection. Information on less significant defects, e.g., porosity, overlap, craters, excess reinforcement, and arc strikes, is available, but not included in this table. Based on the design margins available in the SSW (refer to design stress levels in subsection III.B), the only defects found in this inspection which are structurally significant are undersized fillet welds. These defects were analyzed for plastic collapse in subsection III.D and found acceptable.

Table III.C.9 provides an overall defect summary by welding process based on Leckenby and Burns and Roe visual inspections.

6. Task Force MT Examination

Magnetic particle examination was performed on five FCAW and eighteen SMAW fillet welds. The MT was performed for two reasons: to obtain general fillet weld condition information to assist in the SSW evaluation and to provide information relative to undersized fillet welds for Concern No. 11. The MT examinations used the yoke AC method. The weld surfaces required further preparation in order to use the prod DC method; timing and the immediate labor situation precluded fillet weld surface preparation.

The 23 MT examinations found no cracks or lack of fusion.

7. Task Force UT Examination

As discussed earlier, additional UT was performed at the request of the Task Force to determine the SSW weld quality. In total, 90 welds were examined by UT. Specifically,

- 73 electroslag welds (ESW) were examined per AWS D1.1 (69 were acceptable, 3 had questionable discontinuities[a], and 1 was recorded as rejectable[b]),
- 9 tee-joints were examined for lamellar tearing (7 FCAW double-bevel welds and 2 ESW joints, no lamellar tearing was observed),

- 2 FCAW single-bevel welds were examined per AWS D1.1 in conjunction with the plastic collapse assessment, (both welds were reported to have incomplete penetration), and

- 6 SMAW welds were examined per AWS D1.1 for general information about the SMAW process (2 welds were acceptable with no indications, 3 welds were acceptable with minor indications, and 1 weld was rejectable).

Notes:

(a) Reflector location strongly indicates associated with backside geometry of the welds.

(b) Categorized as a large reflector. Design drawing weld thickness indicates the reflector should be in a fused steel backing shoe which was not specified by design. This specific weld is not structurally significant, in that the other immediate welds had the design function to handle the local loads.

UT of the 73 accessible electroslag welds was performed in January, May and June, 1980. An L-wave examination was performed of each general weld area (6 inches each side of the weld) to locate interfering reflectors prior to performing the 70° angle beam examination. No lamellar tearing was observed in any of the 27 joints of type A (refer to Figure III.C.1), and laminations were only located in the vicinity of one of the 73 welds.

The welds of the 9 tee-joints examined for lamellar tearing indicated incomplete penetration (IP) in 6 of the 7 FCAW double-bevel welds (refer to Figure 27.1 in Concern No. 27). The IP, located in the root, was determined to be a maximum of 5/32 inch in the through-thickness dimension (considerably less in the majority of cases) by comparison to a specially made test block. The UT indications and reject associated with the SMAW single bevel welds were also characterized as incomplete penetration in the root.

The structural impact of the IP has been assessed as acceptable (References III.C.5 and III.C.6). Since the IP appeared to not be unique, a number of FCAW and SMAW welds in the SSW were identified which were limiting in terms of design stress for the generic evaluation. The design stress for welds used to join the component plates making up the structural members is shear. The welds between structural members transmit both normal stresses which are due to axial force and bending moments, and shear stress. The minimum design margin in consideration of the defined IP, 5/32 inch, for all FCAW and SMAW welds was determined to be 1.25. For this particular case, the minimum design margin is defined as the ratio of the capacity tensile stress of the weld to the design normal stress.

In determining the design margin, the conservative static analysis discussed in subsection III.B was used. The use of dynamic analysis or consideration of plastic collapse would have produced greater margins.

To ensure the IP indications were not cracking in the heat-affected zone of the outer skin plate, UT examinations were performed to accurately measure the distance from the front of the skin plate to the indication. No indications were found at distances less than the thickness of the skin plate.

Aside from the exceptions noted above, the UT results have been acceptable. The electroslag weld UT results confirm the effectiveness of the Leckenby inspection and repair program on electroslag welds. Additionally, the UT increases confidence in the performance of the Leckenby welders and inspectors, and no conflicting results were found relative to the previous lamellar tearing UT performed by Leckenby.

8. Pipe Whip Restraint UT

It is known that the ongoing electroslag weld UT of Leckenby fabricated pipe whip restraints (PWR) has a high reject rate, 62% based on data available through April 30, 1980. Review of differences in materials, welders, or welding procedures, has provided no insight to explain the difference with respect to the SSW UT results.

The PWR electroslag weld defects recently identified are recorded as "shrink" and lack of fusion. The "shrink" defect has been excavated and repaired on several PWR's and was found to be cracks in the center of the weld. These cracks are typically caused by operating at an abnormally high amperage level when using consumable guide tubes. This creates a bad weld form factor causing horizontal grain growth and the resultant crack in the center of the weld. No PWR recorded lack of fusion defect has been excavated to date; hence, a description of this type defect does not currently exist. However, based on discussions in subsection III.C.2, an internal weld, planar lack of fusion defect is not expected to be present. The use of a high amperage level to increase deposition rates is a means available to expedite production.

The pipe whip restraints (PWR) were fabricated in a different Leckenby shop than the SSW. Differences in shop foreman, production emphasis, attitudes and/or supervision competency may explain the SSW/PWR UT results. Refer to Table III.C.10 for PWR defect information.

9. Leckenby SSW Weld Map Design Review

Burns and Roe performed a review of 166 Leckenby weld maps. All SSW structural members and associated welds illustrated on the contract drawings were shown and documented on the Leckenby drawings. Six design related concerns were identified in the detailed review of 20 Leckenby weld maps, but none have proven to be structurally significant. (Refer to Concern No. 26 for details.)

10. Conclusions

a. Based on a complete review of the weld related Leckenby quality records and the recently performed visual inspection and nondestructive examinations, it is concluded that Leckenby performed the visual inspections on the SSW required by the specification and repaired the identified defects.

b. The recently performed UT results verified that the inspection and repair of the SSW electroslag welds by Leckenby was adequate followup action on this problem process, even though Leckenby did not assess and correct their electroslag fabrication difficulties.

c. Leckenby records indicate that they performed more UT for lamellar tearing on the SSW than was required by specification. The examinations recorded no lamellar tearing or unacceptable indications. The UT defect repair criteria was more restrictive than what the specification required. The recently performed UT provided no results to indicate that Leckenby overlooked lamellar tearing or laminations.

d. The Burns and Roe visual inspection of the SSW only identified defects in 12% of the accessible welds. These defects, with exception to undersized and convex fillet welds, affect only a short part of the individual weld lengths. The defects are mainly associated with weld profile and workmanship. Most of these defects and their projections to inaccessible welds will not be detrimental to the performance of the SSW. Included are porosity, undercut, crater fill, arc strikes, and postulated slag inclusions. This conclusion is based upon the limited extent of the defects, the design loads based on the conservative static analysis in subsection III.B, and their minor significance for structures which do not experience cyclic loading. The undersized fillet welds were evaluated for plastic collapse in subsection III.D and found acceptable for service considering the design loads and projected occurrence of critical defects of this type.

e. The visually identified defects by site construction contractors were few in number. The MT they performed resulted in a 11.6% rejection rate, not considered abnormal for a structure fabricated with only visual inspection required (excepting the lamellar tearing UT). With exception to defects on open nonconformance reports, these defects have been repaired.

f. The recently performed MT on undersized fillet welds found no cracks or lack of fusion. These results in conjunction with the Burns and Roe visual inspection provide confidence in the general soundness of the fillet welds and the low probability for cracking of those that are undersized.

g. The recently performed UT identified root defects, characterized as incomplete penetration, in welds associated with the FCAW and SMAW processes. These defects were analyzed in a generic manner and found acceptable (refer to subsection III.C.7). In addition, this UT did not identify the type of defects anticipated due to unqualified welding procedures (refer to Concern No. 23).

h. Preliminary review of the initial concerns for weld quality raised the possibility of existing cracks and lack of fusion defects throughout the SSW. Careful examination of each concern, together with the findings of the Burns and Roe visual inspection and additional MT and UT establish that this is not the case. In general, as discussed above, the weld quality was found to be acceptable. Based on the Task Force investigation, it is concluded that there is not a major problem with the as-built weld quality of the SSW.

i. By extrapolation of the previous site construction contractors' visual and MT findings, it could be postulated that there are cracks and crack-like defects present in the SSW. In addition, it is recognized that defects similar to those recorded and repaired could be assumed to exist in the inaccessible welds of the SSW. An assessment of the structural significance of known and postulated defects in the SSW (refer to Table III.C.11 for a general summary) is presented in subsection III.D. This assessment considers the potential for failure by both brittle fracture and plastic collapse (weld overload) and concludes that the as-built SSW will perform its design functions under normal, seismic, and postulated accident conditions.[a]

(a) This subsection and its conclusions is addressing the general SSW weld quality, not the elevation 541'-5" plug weld issue. The partial penetration weld discussed in Concern No. 1 is required and is separate from the above statements.

11. References

III.C.1 IOM, F-80-2735

III.C.2 Telecon, D.C. Timmins to Eugene B. Hamilton, 5-27-80

III.C.3 IOM, F-80-3024 (Boeing Corporation)

III.C.4 Telecon, D.C. Timmins to Ray Heid, 6-27-80 (Newport News Shipbuilding)

III.C.5 Burns and Roe Technical Memorandum No. 1182, 6-12-80

III.C.6 Burns and Roe Technical Memorandum No. 1186, 7-15-80

TABLE III.C.1

LECKENBY ELECTROSLAG WELD VISUAL INSPECTION DEFECT HISTORY

Incomplete/Rejection Tag Data

Defect Type	No. Recorded
Cracks	2
LOF	195
Undercut	114
Porosity	28
Underfill	23
Not Welded Out	66
Miscellaneous [(a)]	26

Field Inspection Report Data

Defect Type	No. Recorded
Cracks	12
LOF	19
Undercut	9
Underfill	3

Total Electroslag Weld Defect Data

Defect Type	No. Recorded	Defect Percent(%)[(b)]
Cracks	14	1.1
LOF	214	16.8
Undercut	123	9.7
Porosity	28	2.2
Underfill	26	2.0
Not Welded Out	66	5.2
Miscellaneous	26	2.0

(a) Miscellaneous consists of burnthrough, washouts, blowouts and restarts.

(b) Number of specific defects in total electroslag weld population (1273).

NOTE: One base material crack was recorded and repaired. One base material pin hole was recorded and repaired.

TABLE III.C.2

LECKENBY ELECTROSLAG WELD DEFECT CHARACTERIZATION

Defect Type	Length (in.) Min.	Max.	Avg.	Sample Size[b]
Cracks[a]	½	9	2.6	14
LOF	½	39	6.9	202
Undercut	1	24	8.2	50
Underfill	2	24	9.1	14
Porosity[c]	3/4	19	5.7	20

(a) One 2½ inch long crack was recorded as being 1½ inch deep. Review of the fabrication drawings revealed the crack was through the weld, 1¼ inch thick by design.

(b) Sample size is smaller than the defect number recorded in Table III.C.1 due to the lack of descriptive information on all recorded defects.

(c) The maximum dimension of the area affected by the porosity.

TABLE III.C.3

LECKENBY FCAW AND SMAW VISUAL INSPECTION DEFECT HISTORY

Incomplete/Rejection Tag and Field Inspection Report Data

Defect Type	No. Recorded
Cracks	7 (5 SMAW, 2 FCAW)
Crater Fill (a)	1
Linear Indications (a)	2
Excess Reinforcement	1

Shop Weld Map Data

Defect Type	No. Recorded (d)
Undercut	389
Undersize	4
Roll (b)	7
Low (c)	8

(a) Associated with vent plug welds.

(b) Not defined, assumed related to contour.

(c) Not defined, assumed as underfill or concavity.

(d) The defects were distributed as follows:
FCAW - 366, SMAW - 42.

TABLE III.C.4

SITE CONSTRUCTION CONTRACTOR VISUAL DEFECT CHARACTERIZATION

DEFECT TYPE	LENGTH (in.)	REMARKS
Crack	2	Base material
Crack	3	Fillet weld
Crack	11/16	Base material
Crack	---	Base material
LOF	8	---
LOF	<8	---
LOF	3	---
LOF	---	Plug weld, hole repair
LOF	---	---
Undercut	---	---
Undercut	8	1/16" to 3/32" deep
Undercut	<8	---
Porosity	<8 (a)	---
Slag	---	---

(a) Affected weld length.

TABLE III.C.5

SITE CONSTRUCTION CONTRACTOR MT DATA SUMMARY

Examination Summary

Total MTs (base metal and welds)	726
Total Acceptable MTs	642
Total rejectable MTs	84
% Rejectable MTs	11.6%

MT Defect Breakdown

Defect Type	No. Recorded
Cracks	17
Porosity	3
Slag	6
Linear Indications	17
LOF	11
Miscellaneous (a)	6
Unknown (b)	24

(a) Miscellaneous consists of undercut, cold lap and gouges.

(b) Based on the majority of repair related statements, e.g., blending, grinding, etc., it is assumed that a large number of the unknown defects were surface linear indications.

TABLE III.C.6

SITE CONTRACTOR MT DATA DEFECT CHARACTERIZATION

DEFECT TYPE	LENGTH (in.)	REMARKS
Crack	≤6	---
Crack	13	≤1/8 inch deep
Crack (a)	2	<1 inch deep
Crack	≃ 4	Fillet
Crack	≃6	Fillet
Crack	---	Fillet
Crack	---	Fillet
Crack (a)	2	---
Crack (a)	---	---
Crack	---	---
LOF	1/2	---
LOF	1/2	---
Linear Ind.	2	Shallow
Linear Ind.	---	---
Linear Ind.	---	---
Linear Ind.	---	---
Slag	5/8	---
Slag	1/8	---
Slag	---	---
Porosity	---	<1/2 inch deep
Porosity	---	Shallow
Slag	1½	---

(a) Located in base material.

TABLE III.C.7

BURNS AND ROE VISUAL INSPECTION DATA

Summary

Total Welds Evaluated	1170
Total Acceptable Welds	1030
Total Welds with Visual Exceptions	140
% Exceptions by Weld	12%
No. Fillet Welds with Exceptions	128
No. Groove Welds with Exceptions	12

Defect Breakdown

Defect Type	No. Recorded
Cracks	None
Undercut	5
Porosity	58
Crater Fill	38
Underfill	1
Overlap	5
Convex Fillet	5
Excess Reinforcement	31
LOF [(a)]	5
Arc Strikes	9
Undersize Fillet [(b)]	68

(a) These incomplete fusion defects are less than 1 inch in length and may in actuality be acute fillet re-entrant angles or indications other than lack of fusion between the base metal and weld.

(b) Percentage of fillet weld length affected varies.

TABLE III.C.8

BURNS AND ROE VISUAL INSPECTION

Defect Characterization

Defect Type	Length (in.) Min.	Length (in.) Max.	Sample Size
LOF	1/16	1/2	6
Underfill [(a)]	----	4 X 1/8	1
Undercut	1/2 X 1/32	2 X 1/16	4
Undersize Fillet	1/4 X 1/8	26 X 1/4	68
Convex Fillet	5/8 X 3/16	48 X 1/8	5

(a) Dimensions given are length by depth, typical for undercut, undersize or convex fillet. Underfill is associated with a butt weld.

TABLE III.C.9

SSW DEFECT IDENTIFICATION SUMMARY BASED ON VISUAL INSPECTION[a]

Total SMAW Welds [b]	4599
Total SMAW Welds with Defects	128
% Rejectable SMAW Welds	2.8%
Total Self-Shielded (SS) FCAW Welds	3122
Total SS FCAW Welds with Defects	85
% Rejectable SS FCAW Welds	2.7%
Total Gas-Shielded (GS) FCAW Welds	3848
Total GS FCAW Welds with Defects	372
% Rejectable GS FCAW Welds	9.7%
Total Electroslag Welds (ESW)	1273
Total ESW with Defects	388
% Rejectable ESW	30.5%
Total Welds all Processes	12842
Total Welds with Defects	973
% Rejectable Welds	7.6%

(a) Includes data based on Leckenby visual inspection during fabrication and data from the Burns & Roe visual inspection.

(b) Total welds means total of that process in the SSW.

TABLE III.C.10

PWR DEFECT INFORMATION[a]

ESW UT DEFECTS

Defect Type	No. Recorded
Shrink[b]	11
LOF	7

62% ESW weld rejection rate.

ALL PROCESS UT DEFECTS

Defect Type	No. Recorded
Shrink	11
LOF	26
Incomplete penetration	53

47% weld rejection rate.

The fillet weld MT rejection rate is 41%; primarily comprised of linear indications at the weld toe.

(a) Results are through April 30, 1980, and represent approximately 25% of the PWR's.

(b) Found to be weld centerline cracking on those welds excavated to date.

TABLE III.C.11

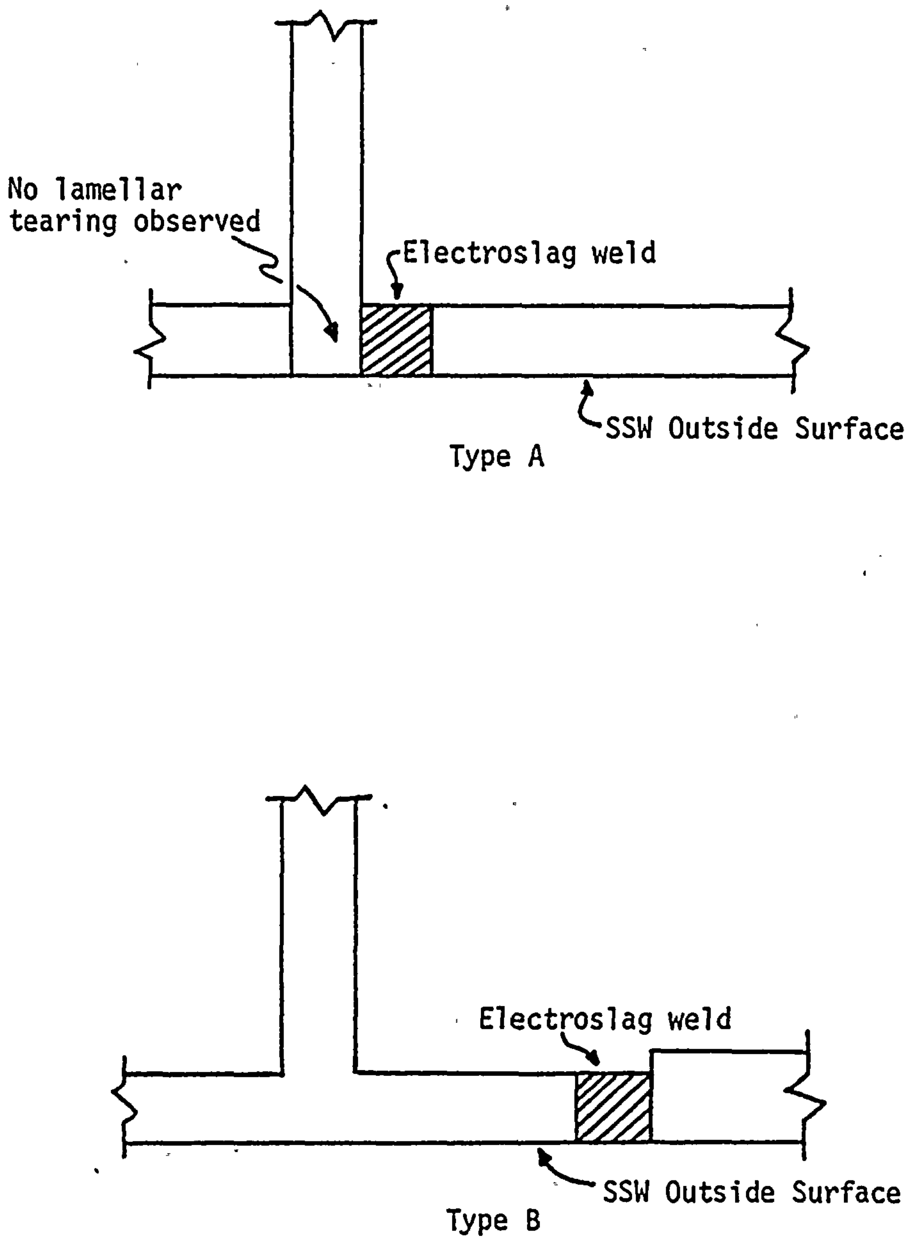
SUMMARY OF WELD QUALITY

KNOWN AND POSTULATED DEFECTS

	KNOWN DEFECTS		POSTULATED DEFECTS	
PROCESS	TYPE	SOURCE	TYPE	SOURCE
ELECTROSLAG	1. Porosity (isolated case) 2. Subsurface planar	1. (B&R) Visual inspection 2. Task Force UT	1. Porosity 2. Cracks 3. Lack of fusion at corner of joint	1. Extrapolation of known case. 2. Cracks identified by Leckenby visual inspection - No additional NDE used in problem followup. 3. Possibility of slag entrapment defects behind steel shoes.
FLUX CORED ARC	1. Underfill/undersize fillets 2. General workmanship/ process control defects (see Note 1.) 3. Incomplete root penetration	1. B&R visual inspection 2. B&R visual inspection 3. Task Force UT	1. Underfill/undersize fillets 2. General workmanship/ process control defects 3. Incomplete root penetration 4. Cracks	1. Extrapolation of B&R visual inspection data. 2. Extrapolation of B&R visual inspection data. 3. Extrapolation of known cases to other FCAW welds. 4. Extrapolation of site contractor MT data to other welds.
SHIELDED METAL ARC	1. Underfill/undersize fillets 2. General workmanship/ process control defects (see Note 1) 3. Incomplete root penetration	1. B&R visual inspection 2. B&R visual inspection 3. Task Force UT	1. Underfill/undersize fillets 2. General workmanship/ process control defects (see Note 1.) 3. Incomplete root penetration 4. Cracks	1. Extrapolation of B&R visual inspection data. 2. Extrapolation of B&R visual inspection data. 3. Extrapolation of known case to other SMAW welds. 4. Extrapolation of site contractor MT data to other welds.

Note 1. Includes undercut, porosity, craters, overlap, convex fillet, excess reinforcement, LOF, arc strikes.

FIGURE III.C.1



III.D Structural Assessment

1. Introduction

The scope of this section is to assess the effect of known and postulated defects identified in subsection III.C on the structural integrity of the sacrificial shield wall.

In performing this assessment, the services of the United Kingdom Welding Institute were retained to advise on appropriate methodologies, to provide materials data and to assist in the overall structural integrity evaluation. The Welding Institute was retained because of their wide experience in the fracture safe design and evaluation of welded structures.

The Welding Institute provided an interim report which is included as Attachment 1 to this report. The interim report was initially produced as a draft. This draft was reviewed by the Supply System and comments transmitted to the Welding Institute together with additional data and information (Reference III.D.1). The interim report includes this additional data and modifications resulting from these comments. This Welding Institute report (No. 22526) should be read before the remaining part of this section.

It should be noted that additional data has been developed since the writing of the Welding Institute report. Thus, there are discrepancies between the Supply System report and the Welding Institute report. In these cases the data in the Supply System report is more current and accurate. The new data is not judged (by the Supply System) to affect the general conclusions of the Welding Institute report, except for the conclusions and recommendations relating to the possibility of failure by plastic collapse of the pipe whip restraint attachment areas. A letter to the Welding Institute pointing out discrepancies in their report and providing additional information is attached to this report (refer to Attachment 3).

It is planned to transmit all additional data to the Welding Institute at the completion of the material testing. At this time a final report will be prepared by the Welding Institute and transmitted to the Supply System.

The sacrificial shield wall was built using visual inspection for acceptance of welds. Visual inspection does not provide a high confidence of freedom from internal weld defects in a welded structure of this type. In addition, the information presented in section III.C leads to the conclusion that some defects or deficiencies remain in the sacrificial shield wall. The primary aim of the structural integrity assessment was to determine the effect of postulated defects on the performance of the sacrificial shield wall under normal and design loadings.

This assessment consisted of the following:

- o Definition of methodology,
- o Definition of controlling material properties,
- o Definition of operating temperature,
- o Evaluation of integrity, and
- o Conclusions.

2. Methodology

a. Introduction

A general and specific discussion of the methodology is given in Attachment 1.

Failure by both fracture and plastic collapse was considered. Other failure modes such as fatigue, corrosion, and stress corrosion are not relevant.

b. Fracture Safe Evaluation

Evaluation of the fracture safe design of the sacrificial shield wall was performed using the crack arrest/failure analysis diagram approach developed by Pellini and co-workers at the Naval Research Laboratories (Reference III.D.2). Briefly, this approach suggests that if a structure operates at a sufficient margin above the nil-ductility transition temperature (NDT) then unstable fractures which initiate from preexisting defects in weld joints will arrest in the base material or weld metal. Thus, structural failure is prevented.

The margin above the NDT required to satisfy this arrest criterion is dependent on both thickness and applied stress. Required margins for various combinations of stress/thickness are given in Table III.D.1.

This approach avoids the need to predict conditions for initiation of unstable failure in the weld zone. Such predictions are difficult in welded structures which have not been stress relieved because of the combination at welded joints of residual stresses and regions of low fracture toughness.

Thus, if the crack arrest criterion is met during operation, then structural failure by brittle, elastic fracture will not occur even though defects, both cracklike and non-cracklike, are assumed to be in the weld joints. Using this approach, the size of the defects is not critical as large through-thickness flaws will arrest.

This crack arrest methodology is founded on testing (both small and large scale tests) and on engineering experience (refer to Reference III.D.2). On the one hand there are many welded structures, made from structural steels of the type used in the sacrificial shield wall, which operate successfully in the as-welded condition at or below their NDT temperature. All of these structures will contain some defects in the weld joints. Examples include bridges, buildings, and ships. A very small proportion of structures of this type do fail (References III.D.1, III.D.2 and III.D.3). The crack arrest criterion is supported by the fact that most failures occur below or at the NDT temperature. Only in very rare circumstances do failures occur above the NDT. An example was the Ingram barge (Reference III.D.3). It failed at NDT + 20 to 30°F with an applied stress of about 2/3 the yield stress. Thus, it is considered that the margins given in Table III.D.1 provide a conservative margin against brittle fracture.

In this context it should be noted that the Nuclear Regulatory Commission recommended a margin of 30-60°F above the NDT (depending on thickness) in their evaluation of the potential for low fracture toughness of NSSS component supports on operating PWR's (Reference III.D.5). A recent supplement to Reference III.D.5, Reference III.D.6, recommends a margin of 40°F with a thickness of 3 inches. Many of the structures evaluated were similar, in terms of design and fabrication requirements, to the sacrificial shield wall.

c. Evaluation of Potential for Plastic Collapse

The potentially most severe failure mode would be fracture under elastic stress and this has been discussed above. However, even though the structure operates in a ductile regime, above the NDT, the potential for failure by plastic collapse must also be considered. Plastic collapse can occur in the presence of large defects if the stress on the remaining material around the defect exceeds some critical value. This value in practice is probably close to the ultimate tensile stress.

However, for conservatism a lower stress is often used (see Attachment 1).

Whereas brittle fracture usually initiates from cracklike or sharp defects, plastic collapse can theoretically result from any defect which reduces the load bearing cross section. This includes cracks, lack of fusion, underfill, undersize welds, etc.

In Table 5 of Attachment 1 the critical flaw sizes for collapse have been calculated for various postulated defect-loading geometry-load rate combinations. All these calculations assume an acceptable design stress equal to the yield stress. It can be seen that even in the worst case large flaws are required. Recent analysis of the stresses acting upon the sacrificial shield wall (see subsection III.B of this report) indicates that the maximum stress will be close to half the yield stress rather than the yield stress. Thus, critical sizes for collapse are then much larger than those shown in Table 5 of Attachment 1. The critical defect sizes for an applied stress level of half the yield have been calculated and are presented in Table III.D.2 of this report.

3. Definition of Material Properties

a. Basic Material Properties

A tabulation of materials in the sacrificial shield wall is given in Table 1 of Attachment 1. ASTM A36 was used in the form of both plate and rolled shapes; A588 as plate only.

The tensile properties used in the plastic collapse calculations are given in Table 5 (Attachment 1). The fracture properties for each material are given in Table 3 (Attachment 1).

The fracture safe design evaluation requires knowledge of an upper bound NDT temperature for each type of material. For some materials this data is available. For others correlations based upon Charpy impact data was used. Details of this correlation together with supporting data are given in Attachment 1.

It was concluded that the upper bound NDT of A36 plate, A36 rolled sections and all weld deposits, except the electroslag weld deposits, could be adequately defined. These values are given in Table III.D.3 of this report.

For the electroslag weld deposits insufficient data was obtained to confirm an upper bound NDT value with high confidence. A program is underway to obtain this information and it is felt unlikely that the maximum NDT will exceed 20°F for the electroslag weldments. In the interim the maximum NDT values given in Table III.D.4 of this report have been assumed. These are based on the data available.

For A588 plate steel industry sources indicate a range of NDT values from 10-80°F. Because of this wide range, and the limited number of heats of A588 in the sacrificial shield wall, a program is underway to obtain and test samples of material from the sacrificial shield wall. In the interim, an upper bound NDT of 80°F has been assumed.

Most of the A588 material in the SSW is Grade B or Grade H. One heat of Grade A was used as stiffener plates in the top ring (ring 6). Charpy impact data for this heat is available and shows an energy value in excess of 100 ft. lbs. at 40°F. Thus, it is concluded that the Grade A material is not limiting in the fracture safe assessment of the SSW.

b. Effect of Cold Bending

The assumed NDT values for the A36 and A588 plate are based upon the as rolled condition. Some plates have been cold bent to the radius of the SSW. A discussion of the potential effect of this cold work on the toughness of the material is presented in Concern No. 6.

Because of this new insight, tests will be performed to measure the effect of cold bending on the NDT temperature. The results of these tests will be reported with the additional data on electroslag welds and A588 material. Indications from previous testing discussed in the Welding Institute report are that the NDT effect from this cold work should be minimal.

4. Definition of Operating Temperature

A study has been performed to provide predictions of the normal operating temperature of the sacrificial shield wall (Reference III.D.7). The inside wall temperature is controlled by the flow of air up the cavity between the sacrificial shield wall and the reactor pressure vessel. The outside wall temperature is controlled by the drywell ambient air temperature. The predicted range of normal operating temperatures is 100 to 135°F.

5. Evaluation of Sacrificial Shield Wall Structural Integrity

a. Introduction

In assessing the SSW structural integrity, failure by plastic collapse and elastic brittle fracture have been considered. The worst case defects assumed in this evaluation are tabulated in Table III.D.5. Refer to subsection III.C for a full discussion of the defects found in the SSW.

b. Brittle Fracture

Under normal operating conditions the maximum applied stresses are very low, less than 0.17 x yield stress. Under these circumstances and at a minimum temperature of 100°F, the margin between the maximum NDT temperature and the operating temperature far exceeds that required to assure crack arrest conditions for all materials in the sacrificial shield wall except ASTM A588 (see Tables III.D.1, III.D.3 and III.D.4).

Under normal and seismic loads the maximum stress levels are less than 30% of the yield stress and the margins again exceed those required for crack arrest with the exception of A588.

Even with the extremely low probability condition when seismic loads are postulated to coincide with pipe rupture, the design stresses are less than 50% of yield and adequate margin is provided to assure arrest, again with the exception of A588.

For A588 there is an indication that crack arrest conditions may not prevail if worst case material is present in the wall. To resolve this question samples are being extracted and tested. The final conclusions with respect to this material will be dependent on the results of these tests. However, the concern over the A588 is placed in perspective when it is realized that this material was used only for the top channel of ring 6, less than 5% of the SSW volume. For the electroslag weld metals, the assumptions of maximum NDT have been based on little available data. Therefore, as previously discussed, additional tests are being performed to confirm these assumptions.

The applied stresses used in arriving at these conclusions are based upon dynamic analysis with a simplified model. As discussed in subsection III.B, these analysis results are considered conservative. High confidence exists that the current stress values are upper bound and a three-dimensional, finite element dynamic analysis is being performed for further confirmation.

c. Plastic Collapse

Of those worst case defects listed in Table III.D.5 the following types cause some concern for plastic collapse:

- o Lack of fusion in the electroslag welds,
- o Cracks,
- o Undersized fillets,
- o Underfill, and
- o Lack of penetration.

The lack of fusion defects in the electroslag welds have been shown to be shallow rather than deep, corner defects.

Of the others only the undersized fillets come close to the critical defect sizes for collapse shown in Table III.D.5. It is apparent that at applied stresses of half yield very large defects are required to cause collapse and the probability of occurrence is low.

The undersize fillet data collected from the Burns and Roe visual evaluation has been analyzed. Burns and Roe examined 1170 welds from a total of 12842 in the SSW. This visual inspection included both fillet and butt welds.

Of the 1170 welds, 68 were fillet welds which were undersized or had areas of underfill in varying amounts. This represents 5.8% of the 1170 welds. Of these 10.3% had effective reductions in weld area of 50% or more. The 50% reduction in weld area represents the smallest critical defect size for plastic collapse from Table III.D.2.

Thus, 0.6% of those welds examined exceeded this criteria. As the total sample of welds examined included butt and fillet welds, it is not possible to directly extrapolate the data to the SSW. However, because of the preponderance of fillet welded skin plates on the outside of the SSW, the proportion of fillet welds will be higher than that for the SSW as a whole.

Therefore, if we extrapolate the data to the remainder of the wall, it will give a conservative estimate of the number of welds which exceed the 50% criterion. The extrapolation yields a total number of welds exceeding this criterion of 77 (0.6% X 12842). Thus only a very small number of defects may potentially approach the critical size for plastic collapse.

All of the known defects which approach or exceed the critical defect size for plastic collapse were undersized fillet welds. The specified weld sizes ranged up to 5/8 inch, with most being 3/8 inch. These welds attached skin plates to the outside of the SSW. Only one short area of underfill was found on the butt welds examined.

The primary structural member to member welds are mainly full penetration butt welds. Thus, the probability of occurrence of underfill or undersize weld defects exceeding the plastic collapse critical defect size on the primary structural welds, is extremely low; no such defects have been observed.

From Table III.D.5 it can be seen that the largest characterized cracks do not approach the critical flaw size for collapse. Also, no cracks have been identified by the additional surface and volumetric inspections performed for the Task Force.

Thus, there is no reason to assume the presence of defects which exceed the critical size for plastic collapse in the butt welds of primary structural members.

The potential for plastic collapse is further reduced by the design of the SSW. For plastic collapse to occur large strains and displacements are required. Also large amounts of energy are absorbed. The sacrificial shield wall is a redundant structure in that loads are transmitted through many members in parallel. The displacements which can be applied to a specific weld joint are limited by those permitted by parallel joints. In view of these considerations, the large size of defects required to cause collapse in a given joint and the low probability of occurrence of such a defect, it is felt that the potential for plastic collapse of the sacrificial shield wall is negligible.

Initially there was some specific concern over the potential for plastic collapse adjacent to, and underneath, pipe whip restraint attachments. It was felt that in these localized areas some members might be fracture critical with little redundancy. These concerns are discussed in the Welding Institute report. However, more close examination has shown that in most instances the pipe whip restraints are welded to several members and that multiple load paths are present as in the bulk of the SSW. Figure III.D.1 illustrates this condition.

Those cases where small pipe whip restraints were welded to only a small number of members were also reviewed, as an example (see Figure III.D.2). Sample nondestructive examination of these areas were performed and the welds surrounding the attachments were reviewed against the Burns and Roe visual evaluation data. No defects approaching the critical size for plastic collapse were observed for these attachments. Thus, it is considered that no reasonable risk of plastic collapse exists for these structures.

6. Conclusions

a. For most structural materials used in the SSW it is concluded that there is adequate margin above the maximum NDT to provide crack arrest conditions at the minimum normal SSW operating temperature, the primary exception being for A588 material.

b. For the electroslag weld joints, the assumed upper bound values of NDT are based upon available literature data. Additional data from procedure qualification weldments will be generated for confirmation due to the existing small data base.

c. Available data indicates that crack arrest conditions may not be provided for A588 Grades B and H under normal operating conditions, if worst case material is in the SSW. Additional data from specific heats used in the SSW is required to characterize their toughness. This data is currently being obtained.

d. Crack propagation in the heat-affected zones of welds other than electroslag welds is highly unlikely because of the profile of the heat-affected zone, the small size of this region and the tendency of longitudinal residual stresses to drive cracks into the base material.

e. The risk of plastic collapse in the SSW is remote because of the very low probability of occurrence of defects of critical size and the existence of multiple load paths in the structure.

f. The cold bending of the A36 and A588 plates may have increased the NDT temperatures from those assumed for as-rolled plate. Data from the Welding Institute indicates the shift should be small. Testing is being performed to confirm this assumption.

7. References:

III.D.1 Letter D. Burns to A.A. Willoughby (with attachments) 4/12/80.

III.D.2 W.S. Pellini "Principles of Structural Integrity Technology" published by the Office of Naval Research.

III.D.3 C.E. Hartbower "Reliability of the AASHTO Temperature Shift in Material Toughness Testing". Structural Engineering Series No. 7, Federal Highway Administration, August 1979.

III.D.4 J.D. Harrison and R.E. Dolby "The Safety of Steam Generator Support Structures for North Anna Units 1 and 2. Welding Institute Report LD 22055 (1976).

III.D.5 R.P. Snaider, J.M. Hodge, H.A. Levin and J.J. Zudans "Potential for Low Fracture Toughness and Lamellar Tearing on PWR Steam Generator and Reactor Coolant Pump Supports" Nureg Report 0577 (1979) (Issued for comments.)

III.D.6 Letter D.G. Eisenhut, Director, Division of Licensing, Office Of Nuclear Reactor Regulation, for USNRC, to all pending operating licensees and construction permit applicants, all licensees of plants under construction, May 20, 1980.

III.D.7 Burns and Roe Technical Memorandum No. 1180, 5/15/80.

III.D.8 Burns and Roe memorandum, V.F. Rubano to R.E. Snaith, 3/24/80, "Minimum Temperature of Sacrificial Shield Wall".

III.D.9 L.E. Steele, J.R. Hawthorne and R.A. Gray, Jr., ASTM STP 426, ASTM, 1967, pp. 346-370.

III.D.10 C.Z. Serpan, Nuclear Engineering and Design, Vol.33, 1975, pp. 19-29.

TABLE III.D.1

TEMPERATURE MARGIN ABOVE NDT
REQUIRED TO PRODUCE CRACK ARREST

Applied Stress (% of yield)	Material Thickness 1"	2"	3"
0.25	10[a]	25	40
0.5	30	45	60
0.75	45	60	75
1.0	60	75	90

(a) ^{o}F

TABLE III.D.2

CRITICAL FLAW DEPTH TO THICKNESS RATIOS FOR PLASTIC COLLAPSE ASSUMING LONG SURFACE BREAKING DEFECTS

Material	Design Stress	Static Loading σ Flow	Static Loading a/t Tension	Static Loading a/t Bending	Dynamic Loading σ Flow	Dynamic Loading a/t Tension	Dynamic Loading a/t Bending
A36	18	47	0.62	0.50	77	0.77	0.61
A588	25	60	0.58	0.48	99	0.75	0.59
E7018/A36	18	66	0.73	0.58	109	0.84	0.67
E7028/A36	18	66	0.73	0.58	109	0.84	0.67
E70T-G/A36	18	66	0.73	0.58	109	0.84	0.67
E70T-1/A36	18	66	0.73	0.58	109	0.84	0.67
EM12K/A36	18	56.5	0.68	0.54	93	0.81	0.64
E7018/A588	25	66	0.62	0.50	109	0.77	0.61
E7028/A588	25	66	0.62	0.50	109	0.77	0.61
E70T-G/A588	25	66	0.62	0.50	109	0.77	0.61
E70T-1/A588	25	66	0.62	0.50	109	0.77	0.61
EM12K/A588	25	58-74	0.57-0.66	0.47-0.53	96-122	0.74-0.80	0.59-0.63
A7018/A36/A588	25	66	0.62	0.50	109	0.77	0.61
E70T-1/A36/A588	25	66	0.62	0.50	109	0.77	0.61
EM12K/A36/A588	18	56.5	0.68	0.54	93	0.81	0.64

a - flaw depth

t - material thickness

TABLE III.D.3

UPPER BOUND NDT VALUES FOR THOSE

MATERIALS FOR WHICH ADEQUATE DATA WAS AVAILABLE

Material	Upper Bound NDT (°F)	Margin Above NDT at 100°F
A36 Plate	+40	60
A36 Rolled Sections	+54	46 *Note 1
Lincoln LH70 Weld Metal (E7018)	-12	112
Lincoln NR-203M (E70T-G)	+40	60
Chemetron 111 AC (E70T-1)	+32	68
Lincoln LH3800 (E7028)	+30	70

*Note (1) Maximum Thickness of Rolled Sections is one inch.

TABLE III.D.4

ASSUMED UPPER BOUND NDT VALUES FOR

MATERIALS FOR WHICH INSUFFICIENT DATA WAS AVAILABLE

Material	Upper Bound NDT (°F)	Margin Above NDT at 100°F
Electroslag Weld Metal (EM12K/A36)	+20	80
Electroslag Weld Metal (EM12K/A588)	+20	80
ESW HAZ-A36	+20	80
ESW HAZ-A588	+20	80
ASTM A588 Plate (Grades B & H)	+80	20

TABLE III.D.5

SUMMARY OF WORST CASE DEFECTS IN WELDMENTS

Region	Defect Type	Largest Reported Length x Width x Depth Inches (a)	Potential Failure Mode
Parent Plate	Arc Strike	3/8 x 3/8 x 1/32	F
	Lamellar Tears	None	P, (F)
Heat Affected Zone	H-cracking	None	F, (P)
	Liquation Cracks	None	F
Fusion Boundary	Lack of Fusion	8 x 0 x 0 (b) 39 x 0 x 0 (ESW) (f)	P, F
Weld Metal	Crack	13 x 0 x 1/8 (c)	P, F
	Undercut	8 x 0 x 3/32 24 x 0 x 0 (ESW)	P, (F)
	Undersized Fillet	26 x 0 x 1/4 (d)	P
	Overlap	3 x 0 x 1/8	F
	Underfill	4 x 0 x 1/8 24 x 0 x 0 (ESW)	P
	Excess Reinforcement	72 x 0 x 1/4	--
	Porosity	8 x 0 (boundary area) 19 x 1 (boundary area, ESW)	(P)
	Crater Fill	1 x 1/2 x 3/8	(P)
	Incomplete Penetration	48 x 1/8 (e) x 5/32 (subsurface)	P, F
	Slag Inclusions	1½ x 0 x 0	F

F = Fracture, P = Plastic collapse, ( ) - signifies lower probability

(a) Depth in the thru-thickness direction.

(b) 0 - signifies dimension unknown.

(c) One 2½ inch long crack extended through the 1¼ inch thick electroslag weld. No other such occurrences have been identified in the documentation.

(d) Worst case based upon percentage reduction in area from original weld size.

(e) Estimated from fit-up requirement.

(f) Available information from industry sources indicates a maximum depth for this type of corner lack of fusion of 1/2".

FIGURE III.D.1

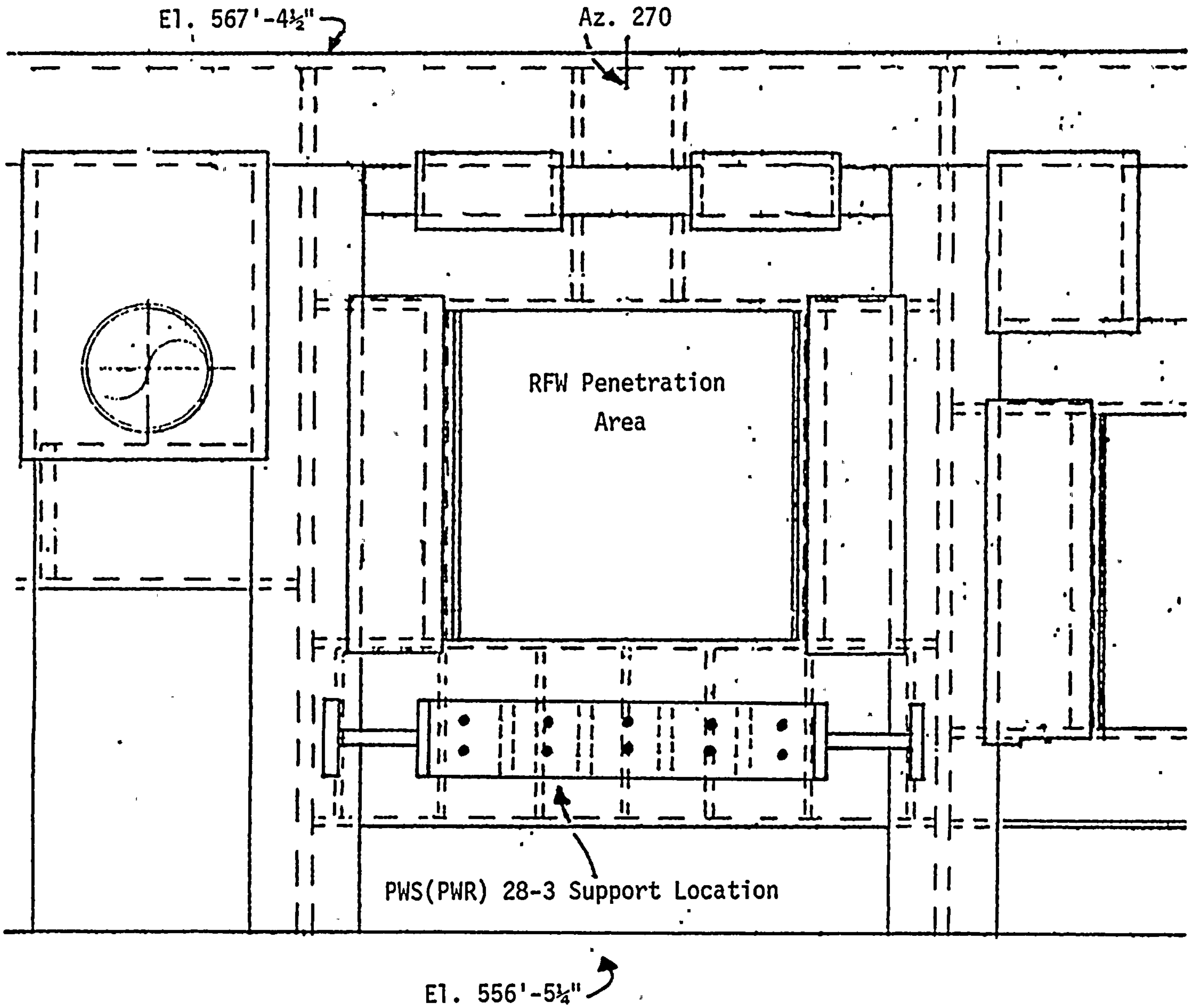
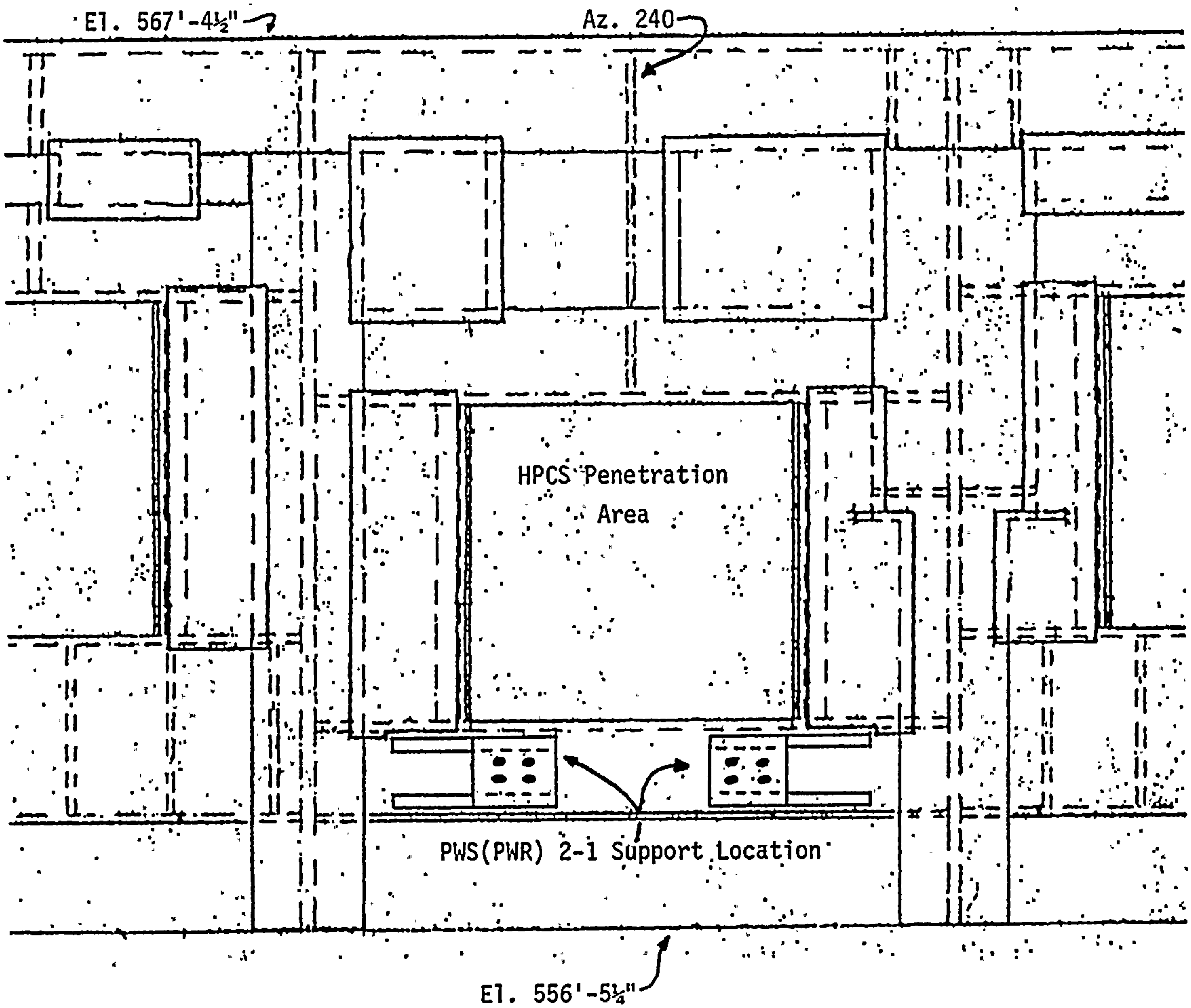


FIGURE III.D.2



IV. CONCLUSIONS

A. As discussed in subsection III.C, the general weld quality of the sacrificial shield wall is acceptable. The SSW is not untypical of a structure welded to AWS D1.1 with visual inspection being the only method of weld examination.

However, based on the fact that visual inspection does not identify subsurface defects and that defects have been found by visual inspections and nondestructive examinations subsequent to erection of the SSW, it is concluded that various defects, both known and postulated, exist in the SSW. (It should be noted that the known and postulated defects envelop potential defects associated with nonconformances in documentation.)

B. For normal operation and postulated seismic conditions, the stresses are low, 17 and 27% of the yield stress, respectively. With these stresses the potential for failure of the SSW in consideration of the known and postulated defects by brittle fracture or plastic collapse is negligible. No other failure modes are relevant to this assessment.

C. During postulated accident conditions, the maximum stresses are less than 50% of the yield stress (refer to subsection III.B). When considering the known and postulated defects in the SSW, it is concluded that the SSW operating temperature provides adequate margin above the nil-ductility transition temperature (NDT) of the SSW materials (with exception to A588) to ensure that failure by unstable brittle fracture will not occur (refer to subsection III.D).

Testing is being performed to determine the NDT for A588 material in the SSW. Final disposition of the top channel of ring 6 in the SSW is pending these test results.

D. Under postulated accident conditions, less than 1% of the welds in the SSW are projected to have defects that approximate the critical defect size for plastic collapse. Specifically, this applies to undersized fillet welds found on the outside of the SSW. In consideration that the majority of welds internal to the SSW are butt welds, the projection is very conservative. In addition, the principal structural welds are primarily butt welds, and multiple, parallel load paths exist in the SSW which would prevent large displacements of individual members (refer to subsection III.D).

Thus, it is concluded with reasonable assurance that failure of the SSW by plastic collapse will not occur.

E. A partial penetration groove weld has been proposed to correct the plug weld deficiencies at elevation 541'-5" (refer to Concern No. 1 and Attachment 4 for details). The welding procedure for the partial penetration weld has been qualified per AWS D1.1. In addition, this weld has been structurally analyzed and found acceptable with a design margin in excess of 2.0.

For details on the joint preparation, inspections, welding and structural analyses, refer to additional information in Attachment 4.

Concern No. 2 discusses the shim gap shielding repair program. This program is implemented after the joint preparation, but prior to the welding of the partial penetration weld.

F. Based on the results of the Task Force investigation, it is concluded that construction may proceed on the SSW at this time including the incorporation of the necessary repairs (refer to Concern Nos. 1 and 2).

The top channel of ring 6 of the SSW, fabricated with A588 material, should remain on construction hold pending completion of the A588 NDT testing. If the NDT results conclude that the A588 material is not susceptible to brittle fracture during operation, the top channel of ring 6 may be released from construction hold.

If the NDT results do not ensure that the A588 material will be in the crack arrest condition, nondestructive examinations will be performed to identify and characterize defects, if any, in the A588 weldments which may initiate fracture. Repair of such defects will then be performed.

APPENDIX A

ITEMIZED SSW CONCERNS

Concerns relative to documentation nonconformances have been technically evaluated by the Task Force for their influence on the capability of the as-built SSW to perform its design functions. The specific conclusions reached in some of the enclosed concerns are not a statement with respect to the importance of the Code, procedure or quality requirements. No intent is made to downgrade their significance or to relieve the Supply System of responsibility for the nonconformances.

Note: The itemized concerns not addressed in this Appendix (refer to G02-80-28) are either not applicable to the SSW or carry no additional implications from the pipe whip restraints that are not already discussed herein.

CONCERN NO. 1

Ring 3 and ring 4 of the SSW are not welded together as structurally required and as shown on the applicable design drawings. Numerous plug welds were made to shims between the rings (El. 541'-5"), rather than welding the rings together. As a result, design calculated horizontal shear loads under postulated loading conditions cannot be properly transmitted between rings 3 and 4.

BACKGROUND

Based on allegations received by NRC Revion V on the use of shims, drawing reviews and SSW field inspection, it was determined that shims between rings 3 and 4 did prevent the required joining of the rings by plug welds. Leckenby Company was requested to provide the "as-built" size and location of the installed shims. The pre-fabricated shims located at the columns showed discontinuities where plug welds were to be installed.

Pilot drilling through the shim packs (horizontally) showed no plug welds between the shims, indicating the shims were not coped in the plug weld areas. To confirm the use of plug welds, a compartment immediately above El. 541'-5" was opened and the concrete removed to inspect the plug welds from ring 4. Although plug welds were found, UT of the welds indicated ring 4 was indeed welded to the shims, not ring 3.

CONCERN RESOLUTION

The load transfer resolution is to provide a partial penetration groove weld around the SSW circumference at El. 541'-5" to join ring 3 to ring 4. The weld has 24 sections, each section located between the column splice plates. From the load transfer/design viewpoint, a minimum overall weld depth of 2 inches; corresponding to an effective weld throat of 1-7/8 inches, is maintained throughout the weld sections.

This corrective measure was selected for the following reasons:

- This type weld can be easily designed with sufficient strength,
- The methods used in preparation for the weld and the actual welding conform with normal welding practices, and
- The in-place weld contributes to and reinforces the measures adopted under Concern No. 2 to prevent radiation streaming at the El. 541'-5" ring interface.

Details of the welding procedure qualifications, joint preparation, inspections, implementing instructions and structural analyses are provided in Attachment 4.

CONCERN NO. 2

Voids in the concrete have been identified in the SSW. The voids recently identified may affect the previously accepted corrective action plan, due to the potential increase in magnitude of the void problem. This plan may involve use of the operating plant to confirm adequate shielding and/or detect additional voids. Shim gap voids also exist between rings 3 and 4 of the SSW (refer to Concern No. 1).

BACKGROUND

I. A 100% inspection survey reveals the existence of forty (40) gaps between shims at elevation 541'-5". This concern is documented by this survey and on NCR-215-5688.

II. A concrete void was discovered in an upper SSW compartment (315^{o}) while chasing a linear indication on the outside of the wall. This void was documented via NCR-215-3698. Two more concrete voids were discovered at the upper corners of a compartment located above elevation 541'-5" ($\emptyset = 0^{o}-15^{o}$) after removal of a skin plate to inspect for plug welds. This concern is documented on NCR-215-4884. Discovery of these voids makes locations of similar geometry and fill procedure suspect.

III. Shielding Design Aspects of the Sacrificial Shield Wall

A. Function

The sacrificial shield wall (SSW) is designed to shield electrical and mechanical components, some of which are safety-related, from excess operational radiation which may impair their design functions. It shields personnel in the drywell during shutdown and minimizes neutron activiation of material and equipment in the drywell. In addition, the SSW provides supplemental biological shielding for the reactor building during plant operation. These shielding functions are independent of any structural considerations.

B. Design Concept

The SSW design concept is based on General Electric criteria and consists of two feet of ordinary concrete between steel skin plates in addition to an outer two inches of steel shielding plate in the active core region.

C. Method of Shielding Analysis

The analytical method consisted of using the NRN one-dimensional removal-diffusion computer code to calculate the neutron flux distribution from the core through the vessel, sacrificial shield and biological walls. Calculated thermal neutron flux distributions were used to generate capture sources, in addition to prompt fission and fission product gamma rays, and were calculated with the QAD point-kernel computer code.

Confirmation of the SSW shield design was done with the ANISN one-dimensional discrete-ordinates computer code; in a P_8 S_8 mode, using the CASK coupled neutron-gamma ray cross section data set. This analytical approach is the current standard design tool for transport calculations of this problem type. This design method is currently being benchmarked by various organizations, including ANS, EPRI and the NRC.

The ANISN results confirm the shielding adequacy of the SSW, and, indeed, show that the original NRN results were conservative.

D. Comparisons With Other Results

Calculated dose rates in the drywell are similar to those experienced at other operating BWR plants and to calculated results reported by SAI/EPRI, S&W, and GE. Thus, the SSW shield design is adequate to shield the safety-related components from radiation during the design plant life.

CONCERN RESOLUTION

The following outline presents the resolution, implementation and verification program to be implemented to resolve the two (2) aforementioned concerns.

I. Gaps Between Shims at the 541'-5" Elevation of the SSW.

A. Examination

1. Survey at the 541'-5" elevation was performed on December 14, 1979 through December 18, 1979.

2. Location of all gaps, outline dimensions, depth of gaps, and adjacent shim penetration were all documented during this survey.

3. 100% inspection from 0^{o} to 360^{o} was performed.

B. Concerns

1. Forty (40) gaps between shims have been located and documented.

2. The gaps vary in area and radial penetration. Twenty-five (25) gaps extend the full radial thickness of the SSW. The largest gap area is 5/8" x 2-1/2".

3. The 541'-5" elevation is 2-1/2" above the bottom of the active core zone.

4. The gaps represent potential radiation windows.

C. Resolution

1. Back dam all gaps where required.

2. Apply BISCO NS-1 product (high density) into gap.

3. Allow to cure.

4. Examine gap for proper fill.

5. Insert thin sheet of insulatory material.

6. Insert backing ring (for weld).[a]

7. Make 2" circumferential weld.[a]

8. Back-up verification with Startup radiation scan program.

D. Prototype Testing and Verification of Methodology

1. Construct channels which simulate detected gaps.

2. Perform steps C.1 through C.4 above.

3. Develop procedure until fill is consistently verified.

4. Prototype testing was successfully completed at the WNP-2 site on May 29, 1980.

5. Construct mock-up (with four gaps) that simulate wall configuration for 2" circumferential weld.

(a) Refer to Concern No. 1 PEDs

6. Fill gaps with BISCO NS-1 (high density).

7. Install insulatory and backing ring materials.

8. Perform 2" circumferential weld.

9. Cut cross sections of mock-up.

10. Qualify shield material for heat input.

11. Mockup testing was successfully completed at the WNP-2 site on May 29, 1980.

E. Implementation

1. All work shall be performed after the 541'-5" elevation is arc-gouged and prepared for the 2" circumferential weld[a]

2. The 215 Contractor shall perform the following:

   a. Vacuum clean all gaps.

   b. Position man at nearest porthole to gap to observe inner gap.

   c. Back dam gaps where required.

   d. Apply BISCO NS-1 (high density) into gap as per approved final procedure based on prototype methodology.

   e. Insert insulatory material (for larger-type gaps).

   f. Cut out and insert backing ring (A36-steel) to fit outline of the gap.[a]

(a) Refer to Concern No. 1 PEDs.

3. Make 2" circumferential weld.[a]

4. Back-up verification with startup radiation scan program.

F. Back-Up Verification: Startup Radiation Scan Program

1. Purpose

a. Insure adequacy of fix program

b. Insure dose at location of safety-related components does not exceed design criteria.

2. Primary Detector Locations

a. Shim gap (Elevation 541'-5")

b. Locations of detected voids.

c. Random sampling in drywell (especially active core region) in areas of sensitive equipment.

3. Program (primary emphasis)

a. Measure total dose rate (neutron-gamma ray).

II. Concrete Voids in SSW

A. Concerns

1. "Suspect" void location is based on compartment geometry and concrete fill procedure (see Figures 4, 5 and 6 for illustration of the three Categories (I, II and III).

(a) Refer to Concern No. 1 PEDs.

2. Skin plate removed at 541'-5" elevation (0^{o} - 15^{o}) resulted in the discovery of concrete voids in the upper corners of this compartment (Category I). Another void was discovered at elevation 567' and azimuth 315^{o} which is in a Category III type compartment.

3. Possible existence of concrete voids in SSW compartments based on numbers 1 and 2 above.

4. The active core region from 539' to 552' is of primary concern because of the flux reduction beyond this region.

5. Voids in the active core zone (539' - 552') represent radiation windows.

B. Examination

1. One hundred percent (100%) inspection of "suspect" void locations for the 24 compartments (Category I) above 541'-5" elevation shall be performed. The reason for this is that these compartments were filled from the sides (rather than from the top), and because the existence of concrete voids at this location (elevation 544'-5") produces the most severe (mid-active core region) consequence.

2. One hundred percent (100%) inspection of Category III type compartments in the active core region shall be performed.

3. Random sampling inspection of other Category II and III type compartments shall be made. Sampling shall be expanded as required to achieve statistical level of confidence.

C. Résolution

1. Determine if concrete void exists at suspect location by either drilling 3/4" Ø hole and boroscoping or by using the pulse echo method developed by Portland Cement Association.

2. Based on number one (1) above, voids shall be filled by either pumping the shield material through a 1/2" Ø fill hole with a minimum 1/4" Ø vent at the top of the void location or by flowing (by gravity) the shield material through a 3/4" Ø hole at the top of the void location.

3. 1/4", 1/2", or 3/4" Ø holes shall either be plug welded or threaded and capped closed.

4. Above methodology shall be developed and verified through prototype testing.

5. Shield material shall be BISCO NS1 (high density) or Owner approved equivalent.

D. Prototype Testing

1. Identify six (6) compartments at the 541'-5" elevation (high suspect - Category I) that are accessible and where the skin plates can readily be removed.

2. Choose two (2) of the six (6) skin plate/compartments.

   a. Utilize pulse echo method (microseismic technique) to look for voids at upper corners of the compartment (high suspect).

b. Drill 3/4" Ø holes and boroscope to look for voids at upper corners of the compartment.

c. Based on b above, drill 1/2" Ø hole at most extreme distance from first hole that will still hit the void.

d. Remove skin plates.

e. Verify pulse echo technique and interpretation, drill technique and boroscopic interpretation, and location of 1/2" Ø hole with respect to actual void location.

f. Develop procedure until exploration and drill technique is consistently verified.

3. For the remaining four (4) skin plate/compartments perform alternate 'fill' techniques as follows.

a. Perform steps 2.a and 2.b above.

b. For half the voids discovered, flow (by gravity) the shield material through the 3/4" Ø hole at the top of the void location.

c. Perform step 2.c above for the remaining void locations.

d. Pump shield material through 1/2" Ø fill hole and vent air out through 3/4" top hole for the remaining void locations.

e. Allow shield material to cure.

f. Remove skin plates.

g. Develop procedure until 'fill" is consistently acceptable.

4. Note that if the six (6) compartments chosen do not provide enough voids as a data base for acceptance, then a mock-up compartment will be constructed off-site that will depict the Category I type compartment voids discovered and documented via NCR-215-4884. Prototype testing will then continue using this mock-up.

E. Implementation

1. The 215 Contractor shall perform the following work.

   a. Contractor shall explore for voids all suspect void locations commited to in II.B. This exploration shall be by an owner approved procedure based on prototype testing.

   b. The exploration program shall document thoroughly all major voids found in the SSW. [b]

   c. For all voids discovered, the contractor shall fill all voids per an owner approved procedure based on the prototype testing.

2. Back-up verification with startup radiation scan program.

F. Startup Radiation Scan Program

The scan program previsouly described will be used to provide confirmatory data.

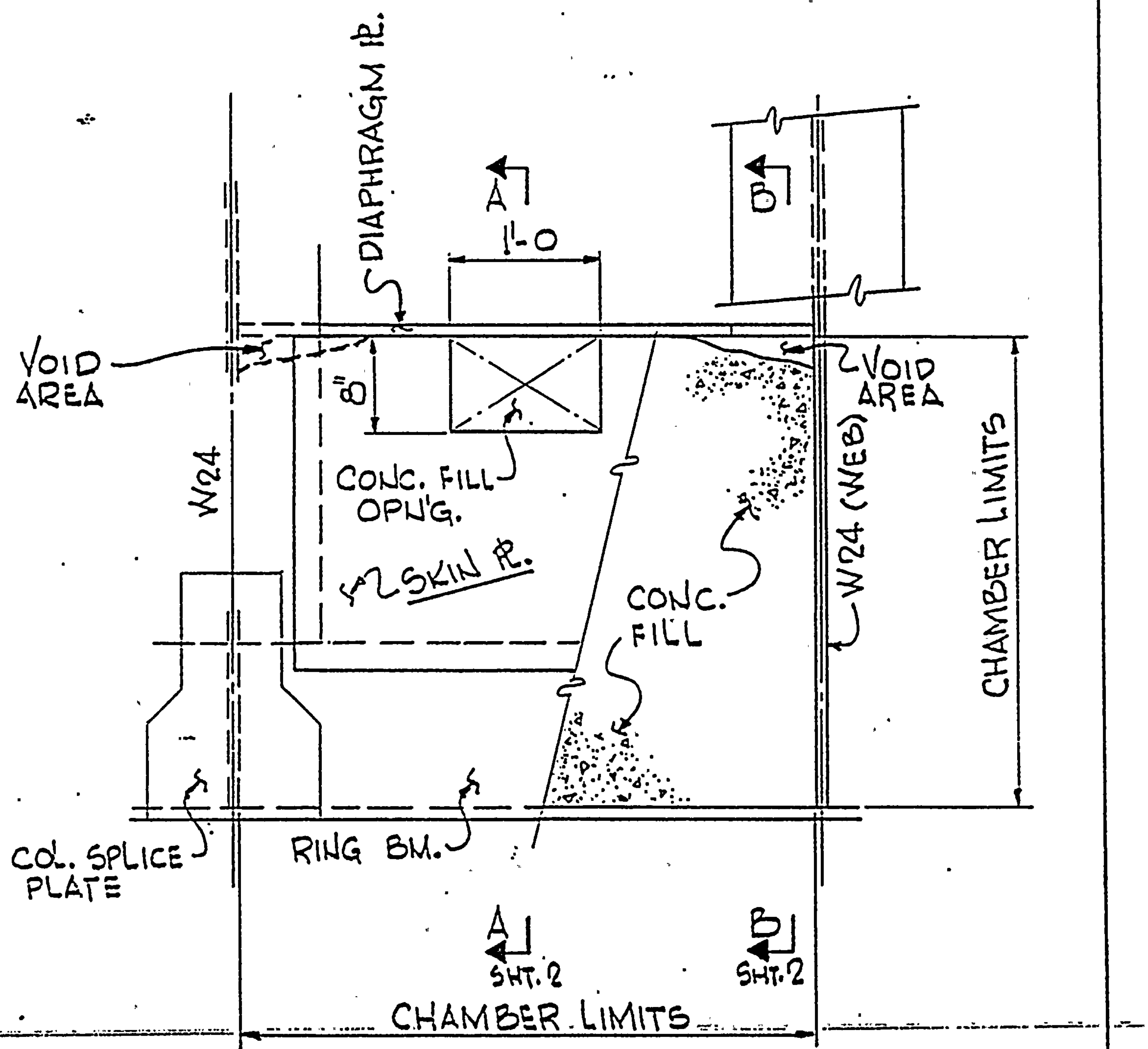
(b) Number of locations to be explored shall be expanded if numerous, large voids are found as a result of this exploratory drilling.

DISCUSSION

The resolution to the shim gap concern provides for 100% inspection and shielding repair of all gaps found at the 541'-5" elevation. The shielding material used shall be BISCO NS-1 (high density) which has the proper shielding, cohesion, adhesion, expansion, consistency and thermal properties which will insure a proper fill and has been confirmed by prototype testing. The prototype testing insures verification of methodology and of repair. The radiation scan program supplements that verification and provides confirmatory evidence of shielding adequacy. Prototype testing was successfully completed on May 29, 1980.

The resolution of the concrete void concern provides for 100% inspection and shielding repair of all highly "suspect" voids based on geometry and fill procedure (Category III in active core region and all Category I). All other locations will be random sampled and repaired as necessary. Sampling will be expanded if a statistical level of acceptance cannot be obtained. Exploration technique (drilling or pulse echo) and fill procedure (pressure grouting) will be verified through prototype testing. The radiation scan program supplements this verification while insuring shielding adequacy.

It should be noted that all work will be performed to approved procedures and shall be thoroughly documented. Full restoration of gaps and voids with material of greater shielding effectiveness than the original shield material (concrete) insures the shielding adequacy of the SSW.



ELEVATION LOOKING @ OUTBOARD FACE OF SAC-SHIELD WALL

CATEGORY I

Figure 4-1

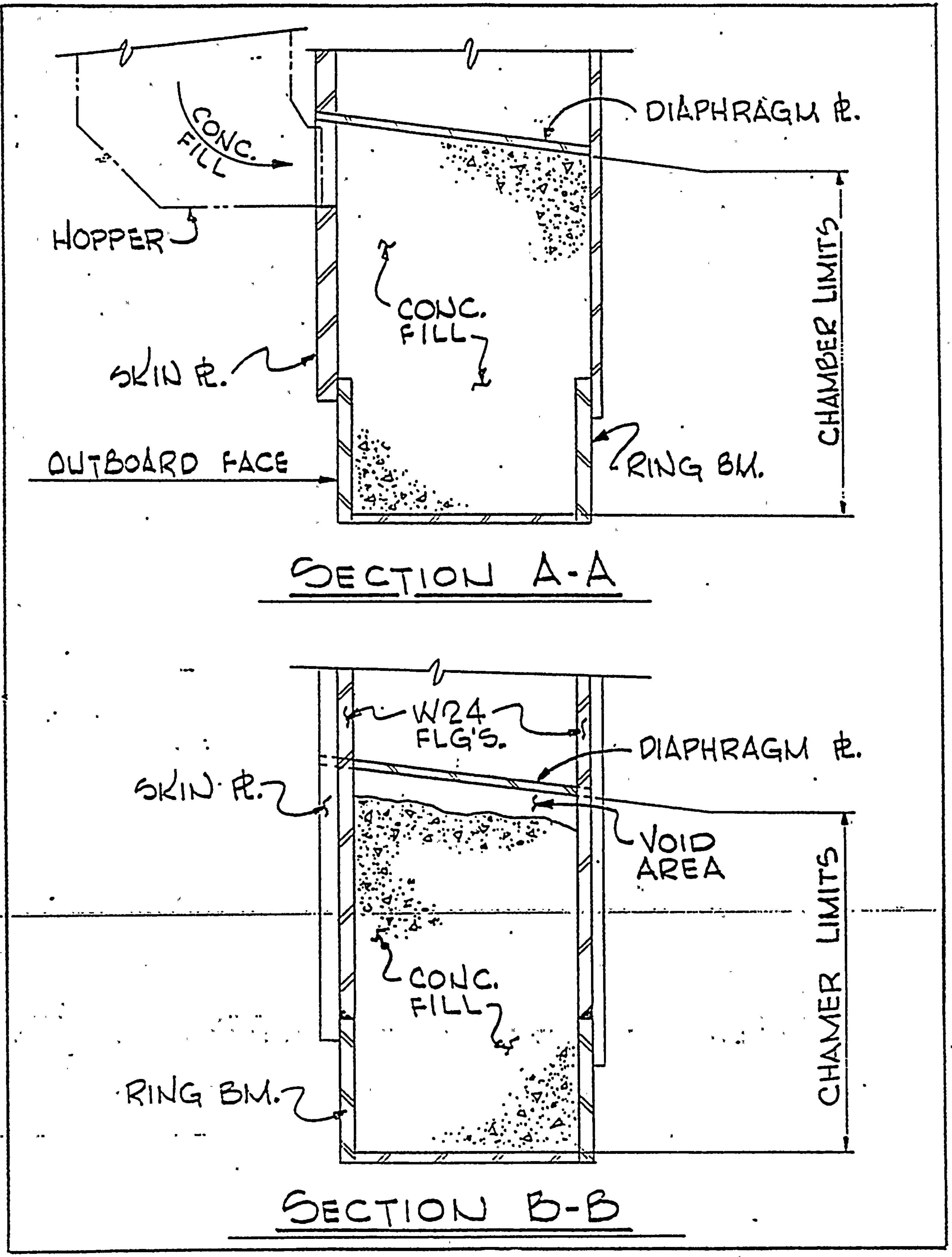
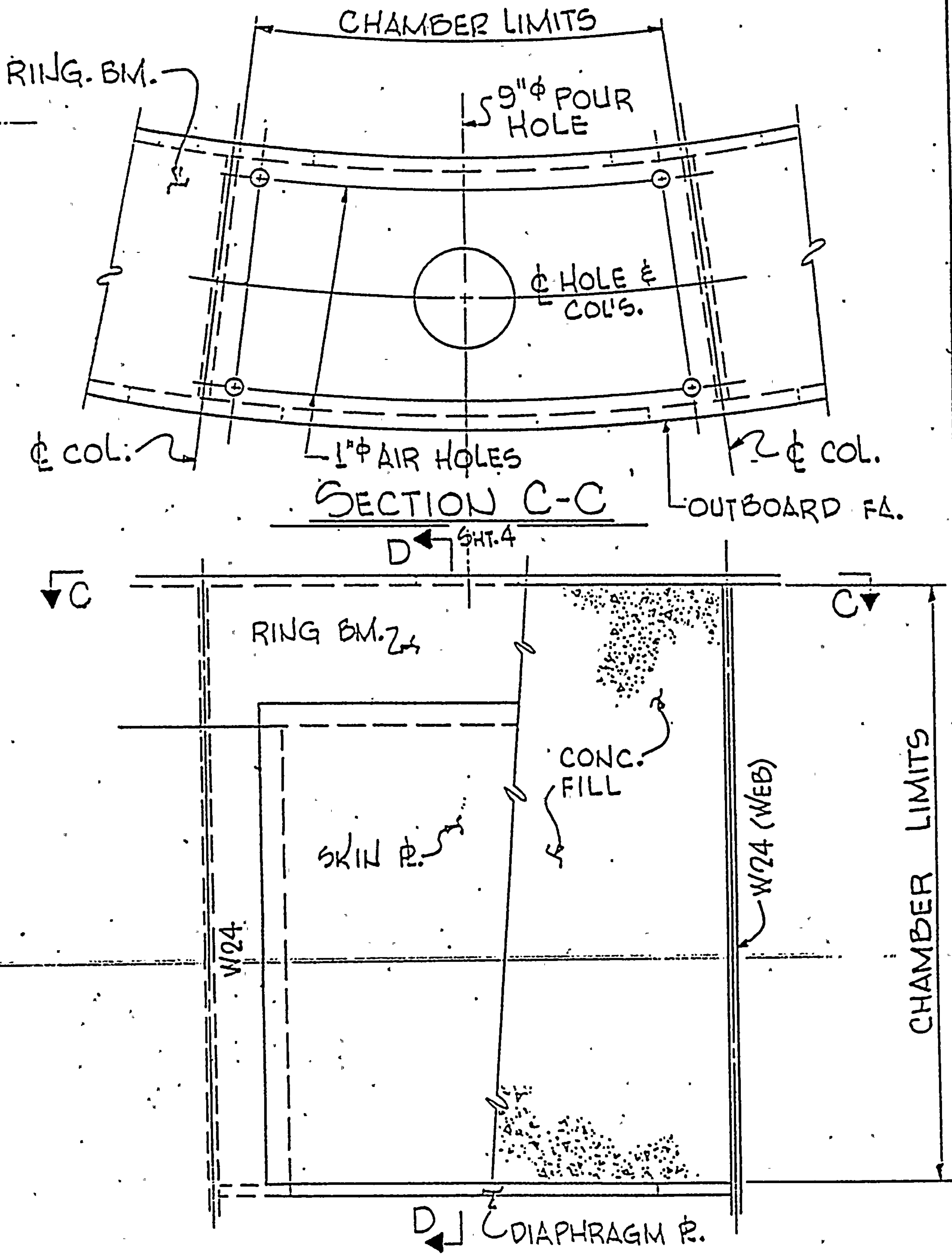

CONC.
FILL
HOPPER
DIAPHRAGM PL.
CONC.
FILL
SKIN PL.
CHAMBER LIMITS
OUTBOARD FACE
RING BM.
SECTION A-A
W24
FLG'S.
DIAPHRAGM PL.
SKIN PL.
VOID
AREA
CONC.
FILL
CHAMER LIMITS
RING BM.
SECTION B-B

Figure 4-2



ELEV. LOOKING @ OUTBOARD FA. / SAC. SHIELD WALL

CATEGORY II

Figure 5-1

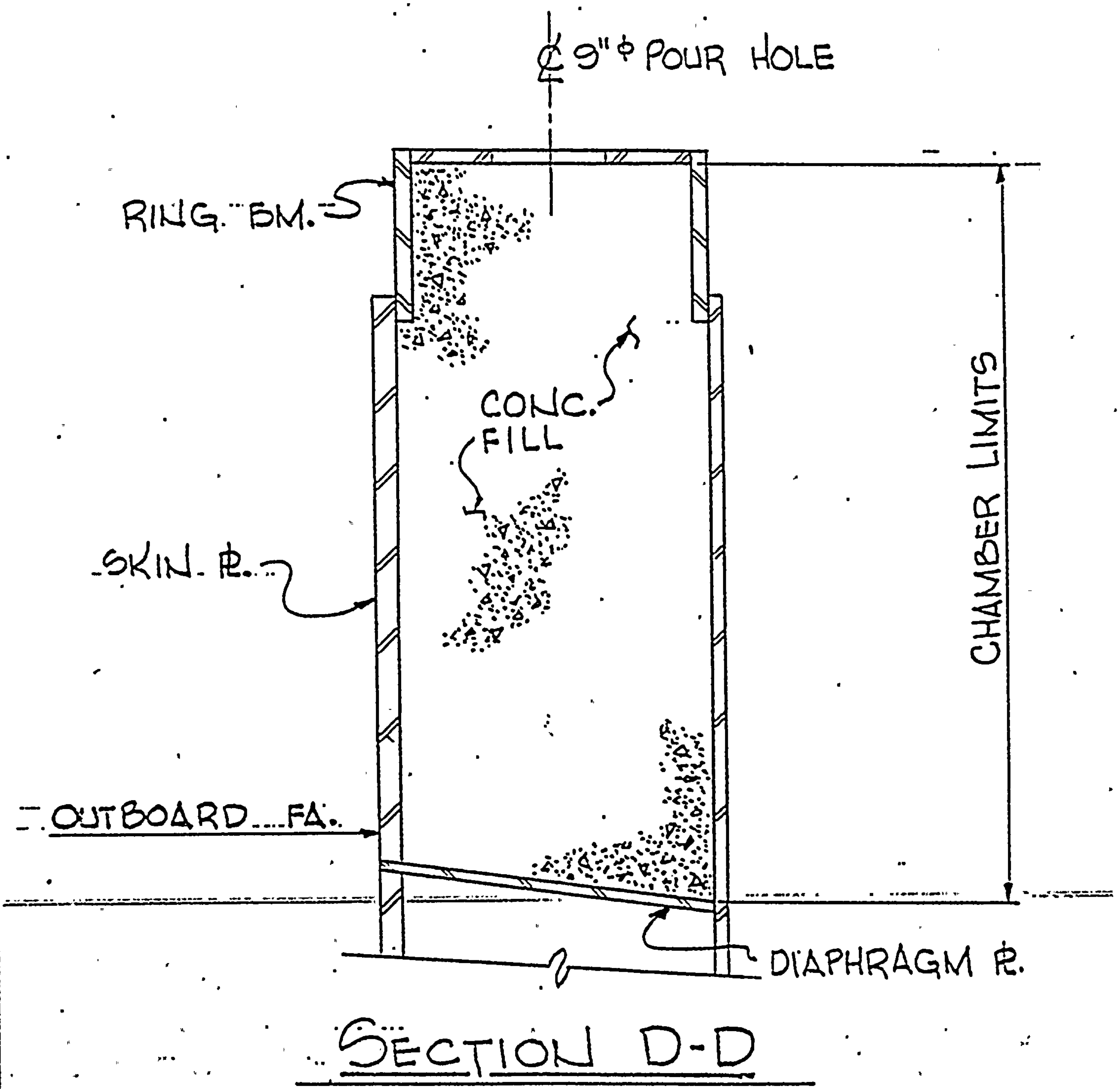
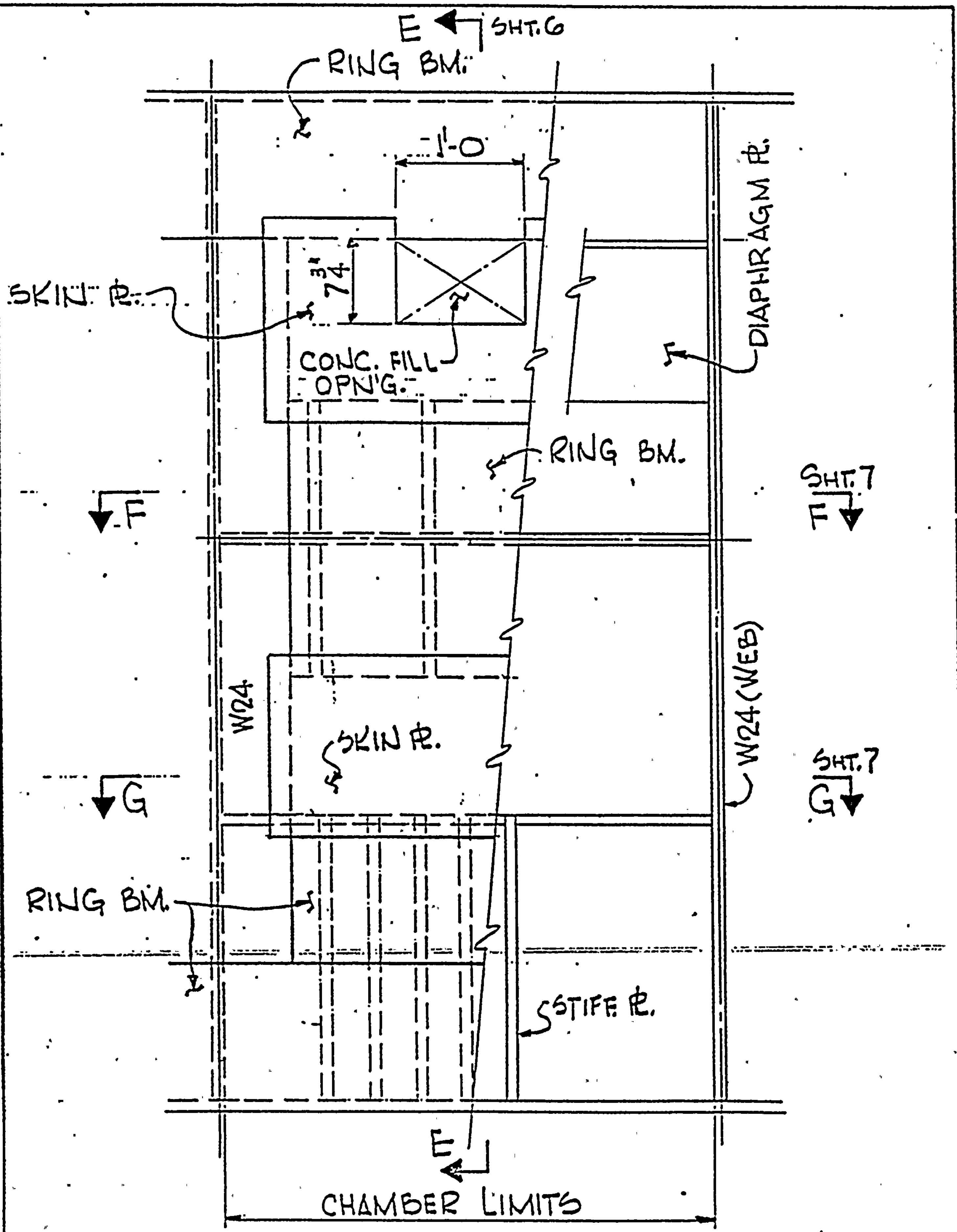


Figure 5-2

CATEGORY II



ELEV. LOOKING @ OUTBOARD FA./SAC.- SHIELD WALL

CATEGORY III

Figure 6-1

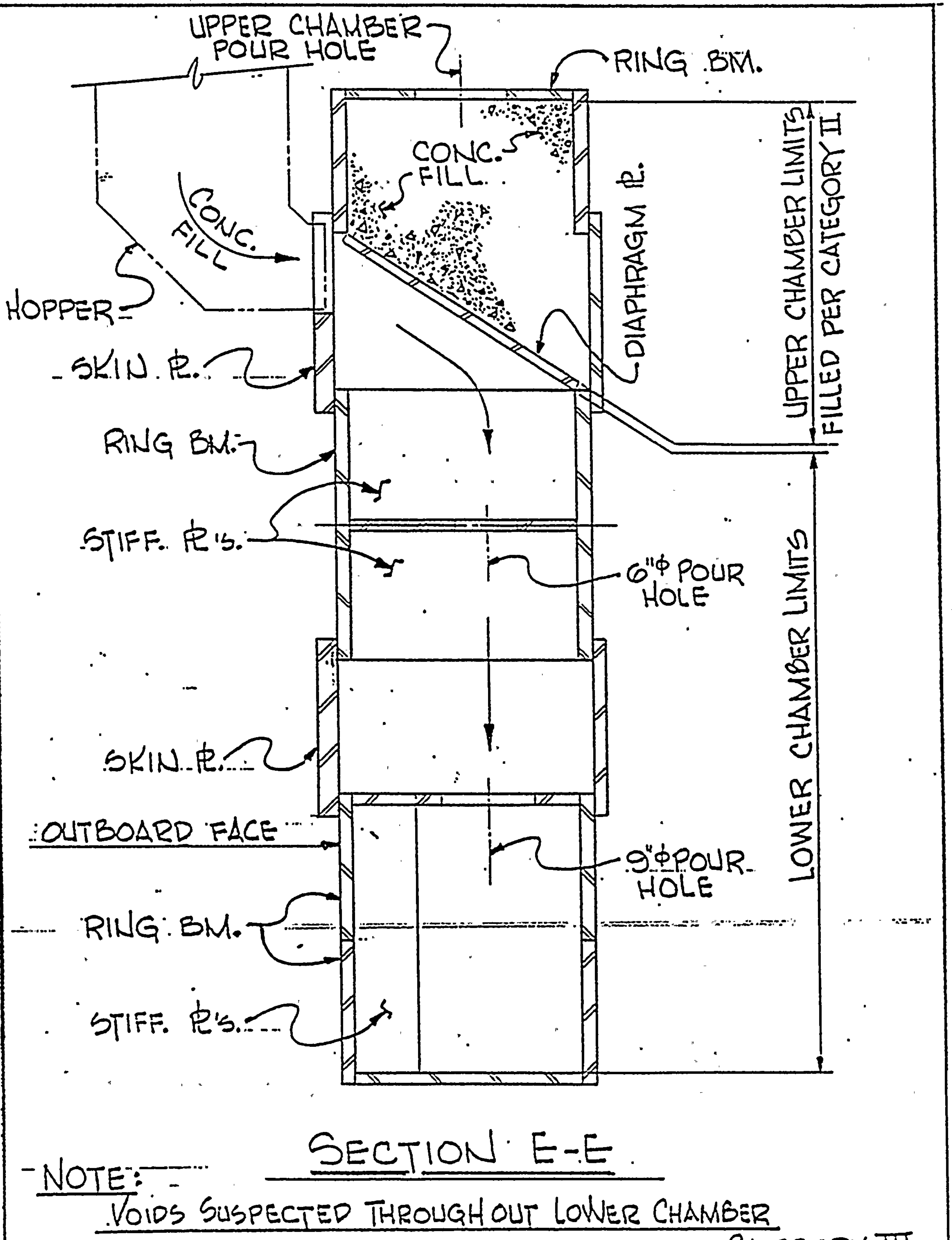
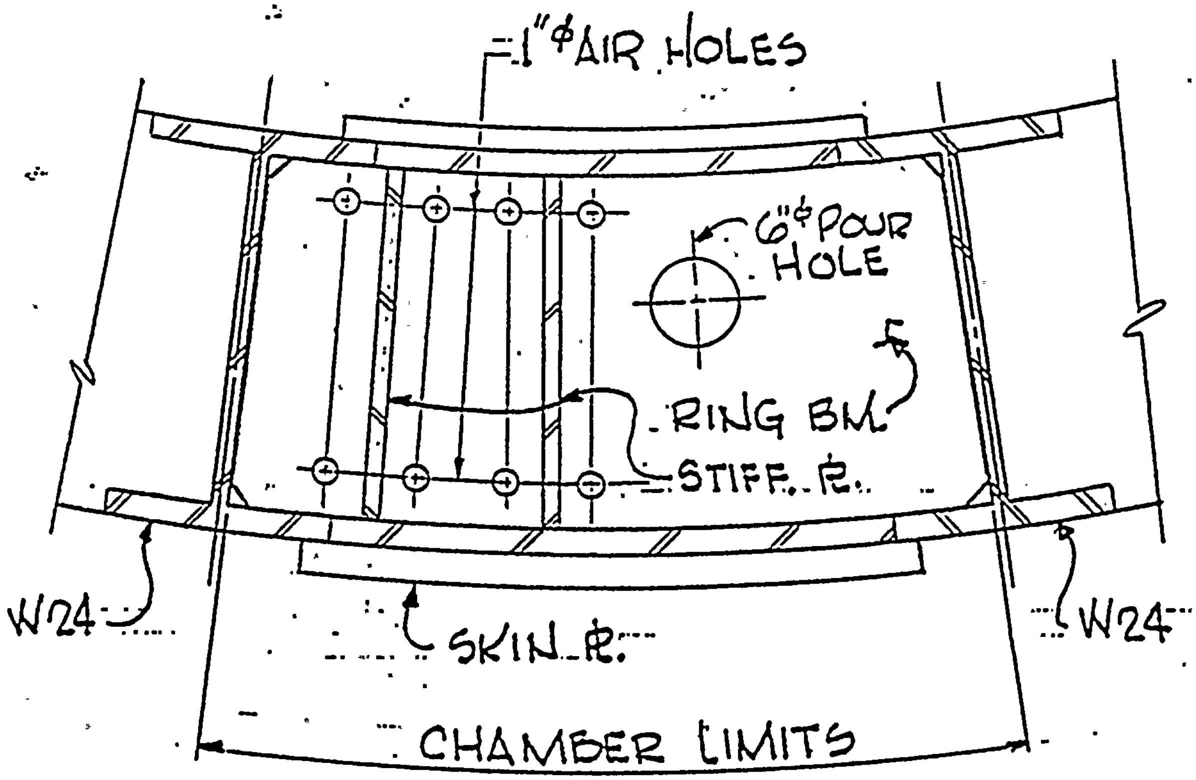
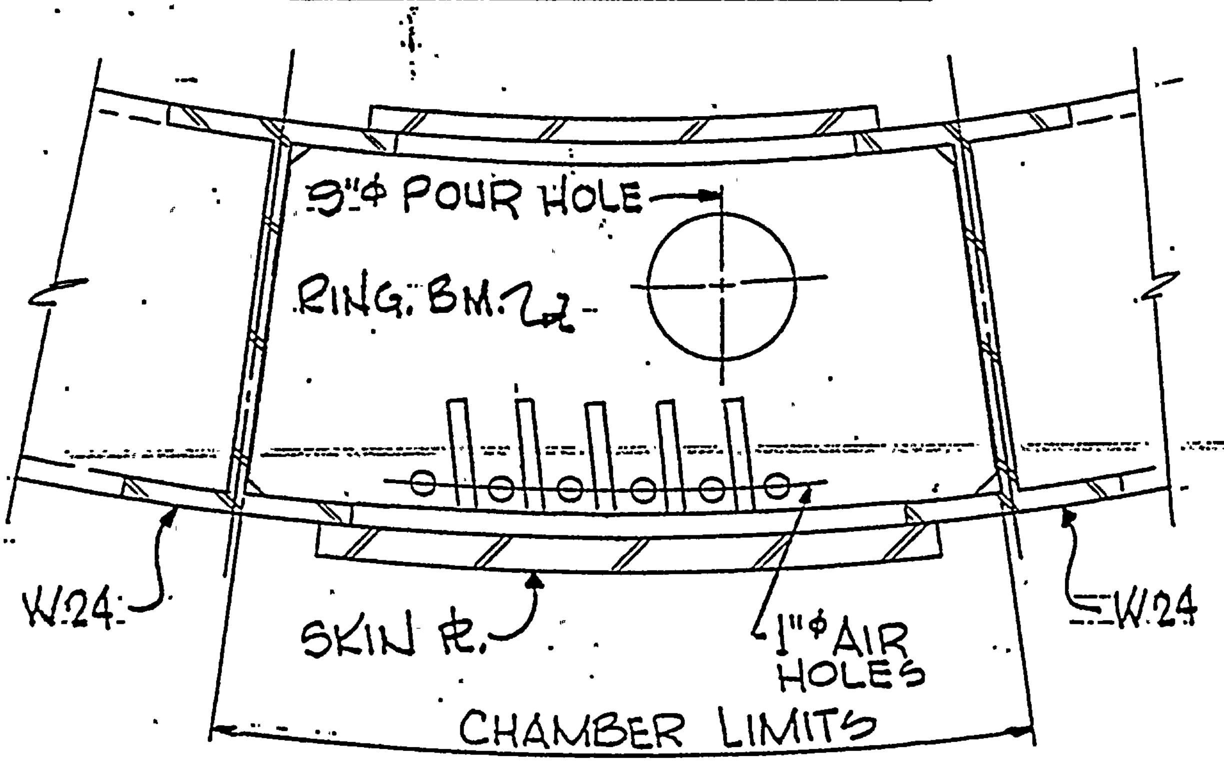

UPPER CHAMBER POUR HOLE
RING BM.
CONC. FILL
CONC. FILL
HOPPER
DIAPHRAGM ℞
UPPER CHAMBER LIMITS FILLED PER CATEGORY II
SKIN ℞.
RING BM.
STIFF. ℞'S.
6"Φ POUR HOLE
LOWER CHAMBER LIMITS
SKIN ℞.
OUTBOARD FACE
9"Φ POUR HOLE
RING BM.
STIFF. ℞'S.
SECTION E-E
NOTE:
VOIDS SUSPECTED THROUGHOUT LOWER CHAMBER
CATEGORY III

Figure 6-2



SECTION F-F



SECTION G-G

Figure 6-3

CATEGORY III

CONCERN NO. 3

Numerous deficiencies in weld quality have been identified on the SSW. The defects were identified in welds which were supposedly inspected and accepted. Defects include cracks, undercut, overlap and slag (indicating inspections could not have been properly performed).

BACKGROUND

On June 6, 1979, an allegation concerning the quality of welding on the SSW was made to NRC Region V. It was alleged that "very few welds meet the acceptance criteria by visual examination".

This allegation was noted as being substantiated by the NRC Region V Report No. 50-397/79-12 (Ref: NRC letter to WPPSS dated August 1, 1979). The NRC Inspector identified slag and other weld defects not in compliance with AWS D1.1.

As a result of the conclusions reached during reviews by Burns and Roe and the Supply System and the NRC Region V itemized concerns on the SSW, it was determined that an in-depth document review and engineering assessment was necessary. A Task Force was formed in February, 1980, to perform this overall assessment. The response to the individual concerns and the preceding main body of this report are the results of that assessment.

CONCERN RESOLUTION

Refer to the main body of this report.

CONCERN NO. 4

Leckenby NDE records associated with the SSW contain photocopied inspector's signatures on PT and UT reports.

BACKGROUND

A review of all Leckenby SSW, beam attachment and pipe whip support girder NDE reports (46 UT, 30 PT) found 15 UT reports and 26 PT reports with photocopied signatures. Of the 15 UT reports, 11 were associated with the SSW and had a single signature by Gene Hamilton. These reports were associated with examinaton for lamellar tearing for 83 electroslag weld tee-joints. No lamellar tearing was recorded in these reports. The other four UT reports were associated with the pipe whip support (PWS) girders, 3 contained weld rejections and one was acceptable.

The 26 PT reports with photocopied signatures were associated with material defects. Gene Hamilton's photocopied signature was again noted.

The portions of these reports photocopied were stated to be common practice by Leckenby (refer to sworn statement of Gene Hamilton, Exhibit A) to expedite report processing.

CONCERN RESOLUTION

The concerns associated with the PT and UT reports with photocopied signatures are:

- The examinations may not have been performed, or
- The examinations may have been performed by unqualified inspectors,
- From which both of the above imply that defects may be in the SSW as a result of inadequate inspections being performed.

In May and June, 1980, UT for lamellar tearing and/or laminations was performed on 9 welded tee-joints previously examined by Hamilton. No lamellar tearing or laminations were observed. In addition, during UT of 73 electroslag welds, no lamellar tearing was observed in susceptible joints and laminations were only detected in the vicinity of one weld. The laminations were found by the straight-beam scan prior to performing the 70^{o} angle beam examination.

To address the general concern of lamellar tearing, an assessment was made of the potential for failure by lamellar tears, laminations or low short transverse ductility. This assessment, presented in Concern No. 27, concluded that such failure will not occur.

Three photocopied PWS girder UT reports recorded rejections for defects in electroslag welds. The identification of defects, repair and subsequent acceptance by UT establish that these examinations were performed. As discussed in Concern No. 5, the inspector that performed these examinations (E. B. Hamilton) did not have the proper documentation on file to support his Level II UT qualification. Implications for defects in the PWS girders from the improper qualifications are the subject of a separate review and do not directly affect the weld quality of the SSW.

The UT reports with photocopied inspector signatures have been evaluated to have no structural significance for the SSW. This conclusion is based on the following:

- o Four of the subject UT reports are not associated with the SSW,
- o UT performed for the Task Force on joints previously examined by Hamilton found no lamellar tearing or laminations,
- o UT of 73 electroslag welds found no lamellar tearing and laminations located only near one weld,
- o Concern No. 27 concludes that failure due to lamellar tearing, laminations, or low short transverse ductility will not occur, and
- o The structural assessment in subsection III.D of this report envelops known and postulated defects.

The 26 PT reports with photocopied signatures are primarily associated with material defects which do not require surface examination during repair per AWS D1.1, e.g., laminations, blow-outs, gouges, slag inclusions, and minor material flaws. Four of the defects, however, are associated with surface cracks in base material, which by Code requires the assessment of the extent of the crack by a positive means. All defect repair instructions included excavation by grinding and/or air arc gouging to sound metal prior to repair welding. As a result, defects remaining in the SSW which may be associated with improperly performed PT are few in number and small in size.

The PT reports with photocopied inspector signatures have been evaluated to have no structural significance for the SSW based on the following:

- o The majority of defects were minor in nature and did not require surface examination,
- o The defects were excavated by grinding and/or air arc gouging prior to repair, and
- o The structural assessment in subsection III.D of this report envelops known and postulated defects.

This conclusion for the subject PT reports also resolves concern for defect implications in consideration of the lack of documentation to support Hamilton's Level II PT qualifications.

The 3 additional PT reports reviewed did not have photocopied signatures and were associated with the pipe whip support girders.

No further review or action is planned for this concern item.

(Refer to Concern No. 5 for related information.)

I, Eugene B. Hamilton, voluntarily make the following statement to Dennis P. Haist, Reactor Inspector, and Owen C. Shackleton, Jr., Investigator for the U.S. Nuclear Regulatory Commission. No threats, promises or duress were made to me to make this statement. I give this statement on my own free will. I understand that this statement might be used in a legal proceeding and will become part of a public record.

I am 34 years old. I am employed as a Chief Inspector for the Leckenby Company, 2745 11th SW, Seattle, Washington. I served my iron workers apprenticeship at Pacific Car and Foundry, Seattle, Washington from 1964 through 1968. I began inspection work in 1970. I qualified as a Level II in Ultrasonic Testing and Magnetic Particle Testing. In 1973 I came to work for Leckenby. I am qualified as a Level II in Ultrasonic Testing, Magnetic Particle Testing and Penetrant Testing for Leckenby. In March 1977 I was designated as a Level II in Ultrasonic, Magnetic Particle and Penetrant Testing.

Concerning Leckenby's activities in fabricating the Sacrificial Shield Wall (Subcontract from Bovee and Crail) and on the Pipe Whip Restraints (Contract 90) for the Washington Public Power Supply System's Nuclear Project No. 2, I recall the following information:

1. Weld traceability records, as shown on the fabrication drawings, were used in the Leckenby shop by me as working documents to record part numbers, weld procedure number, electrode identification, welder number, inspector number, type of inspection and remarks for original welding, original nondestructive examinations, repair welding and subsequent nondestructive examinations. Weld traceability records are sometines referred to as weld maps.

2. I believe the information on the weld map that bears my inspection number 5 is accurate.

3. I occasionally prepared nondestructive examination records by completing generic portions of nondestructive examination reports, signing my name, making photostatic copies of the incomplete report form, and later completing the report for each specific part examined. I used this procedure to save time in completing the examination reports.

4. Nondestructive examinations were completed by me as shown on each nondestructive examination report that bears my signature, whether original or photostatic copy.

Concerning Leckenby activities on the Sacrificial Shield Wall, I recall the following information:

1. Heat and mechanical means (jacks and come-a-longs) were used to correct distortion of all three segments of ring beam number 3 and ring segment 2A of ring beam 2.

2. To the best of my knowledge, no procedure was used to control the application of heat to correct distortion of ring beam number 3 and ring segment 2A of ring beam 2.

3. I performed longitudinal and shear wave ultrasonic examinations to AWS requirements to determine the extent of a base material crack at approximately elevation 541 feet, azimuth 233°.

Eugene B. Hamilton
Eugene B. Hamilton

Subscribed and sworn to before me this 7 day of December 1979.

Owen C. Shackleton, Jr.
Owen C. Shackleton, Jr.
Investigator, RV, NRC

Witness: Dennis P. Haist
Dennis P. Haist
Reactor Inspector, RV, NRC

CONCERN NO. 5

Nondestructive examination (NDE) records cannot be located for one individual who performed ultrasonic testing (UT) on the SSW.

BACKGROUND

All known and available Leckenby NDE reports associated with the SSW have been reviewed and inspectors identified. Mr. C. Baldinger, associated with the specific concern as stated, is no longer employed by Leckenby and his qualification papers are not available. Mr. Baldinger performed UT of 3 SMAW weld procedure test coupons, of which none required UT for qualification. The specified tensile and bend tests were performed and were acceptable. In addition, Mr. Baldinger performed UT of a test coupon associated with the qualification of FCAW welding procedures. These procedures are normally prequalified by AWS D1.1. However, Burns and Roe exempted the prequalification in order to confirm the A588 weldment mechanical properties. The test coupon was radiographed per Code. An unacceptable indication was reported which upon excavation was determined to be localized slag entrapment. The test coupon was repaired, and Mr. Baldinger subsequently found the repair area acceptable by UT. The coupon was then tested for its mechanical properties and found satisfactory. It is recognized that the repaired test coupon should not have been used for the procedure qualification per AWS D1.1.

The remaining Leckenby NDE was performed by Messrs. Hoenstine and Hamilton. Mr. Hoenstine only performed UT for lamellar tearing on two SSW weld joints recorded on one UT report. Review of his records indicate that documentation is lacking to support his level II UT qualification at Leckenby.

Mr. Hamilton performed the majority of NDE on the SSW. As in Hoenstine's case, Hamilton also lacks the documentation to support his Level II PT and UT qualifications at Leckenby.

CONCERN RESOLUTION

The FCAW procedure qualifications associated with UT by Mr. Baldinger went beyond the AWS D1.1 requirements to verify the mechanical properties, not the soundness of the weld. The test coupon was radiographed and found acceptable with exception to the localized slag entrapment. The UT performed by Mr. Baldinger was in support of the repair, not to meet the qualification NDE requirements. In consideration of the radiography results and the acceptable mechanical test results, it is concluded that the UT performed by Mr. Baldinger has not affected the quality of related FCAW welds in the SSW.

With respect to Mr. Hoenstine, as discussed in Concern No. 16, lamellar tearing was examined for on a sampling basis. The UT reported by Mr. Hamilton for lamellar tearing exceeded the specification requirements. The lack of documentation to support Hoenstine's single UT report has been evaluated to have no structural significance based on the same reasons as discussed in Concern No. 4 relative to lamellar tearing UT.

The remainder of this concern addresses UT performed by Mr. Hamilton. The discussion is separated into paragraphs based on different UT categories, e.g., lamellar tearing UT, non-Code required UT, etc.

UT for lamellar tearing performed by Hamilton was recorded on 20 UT reports. The concern associated with Hamilton's improper Level II inspector qualifications is that defects may be in the SSW as a result of inadequate inspections. For similar reasons as discussed in Concern No. 4, the defect implications associated with the UT performed by Hamilton to identify lamellar tearing have been evaluated to have no structural significance.

Hamilton performed 12 UT examinations on the SSW post-repair of defects or fabrication deficiencies. These defects/deficiencies, with exception to the door laminations, were not originally identified by UT, nor was UT directed by other documents; therefore, the followup UT was not required by AWS D1.1 or specification. The items examined were:

- 2 electroslag weld lack of fill repairs,
- 3 mislocated hole repairs (filled by plug weld or equivalent),
- 1-6 inch lack of fusion repair in an electroslag weld,
- 1 plate edge lamination repair,
- Various lamination repairs in two pipe penetration doors,
- 1 base material crack repair (dye penetrant exam was performed), and
- 1-3 inch FCAW weld crack repair.

A dye penetrant exam should have been performed on the latter crack. However, the repair direction did call for air arc gouging the defect to sound metal. Recently performed UT confirmed the repair to be acceptable.

In addition, Hamilton performed UT on the SSW at radial beam attachment sites based on direction from Burns and Roe. Hamilton's repair acceptance UT of the crack at 233° AZ. (refer to Concern No. 18) was also confirmed by a separate Northwest Industrial X-Ray, Inc. UT examination. Hamilton also identified a weld defect (slag entrapment) at the 306° Az. location. He subsequently accepted the repair by UT while being observed by a Burns and Roe QA engineer that was qualified to Level III UT.

Eight UT examinations were performed by Hamilton on the pipe whip support (PWS) girders; 3 were rejectable and 5 were acceptable. The 3 rejects were reinspected after repair by UT and found acceptable (included within the 5 previously mentioned).

The defect related UT performed by Hamilton has been evaluated to have no structural significance for the SSW based on one or more of the following:

- The component examined is not part of the SSW, or is not a load bearing member, e.g., the PWS girders and the penetration doors, respectively,

- Confirmation of Hamilton's UT is available by alternate examinations or verification by a qualified witness,

- The repairs which were examined did not require UT and the defects were excavated by grinding and/or air arc gouging, and/or

- The bounding defect structural assessment in subsection III.D envelops known and postulated defects.

Similarly, for the reasons discussed in Concern No. 4, Hamilton's improper Level II PT qualification has been evaluated to have no structural significance for the SSW.

No further action is necessary for this concern.

CONCERN NO. 6

No procedures were generated or records maintained on forming of the curved plates in the SSW.

BACKGROUND

There are no requirements for procedures or records on forming of curved plates in the specification. Leckenby subcontracted the work to Seattle Boiler Works. Leckenby has provided a statement that to cold form A36 material is common industry practice. Additionally, Leckenby has responded to a series of questions posed by the Task Force as noted in Reference 1.

CONCERN RESOLUTION

10CFR50 and the Supply System Quality Assurance program require that special processes be controlled and accomplished using qualified procedures which are in accordance with applicable codes and other controlling requirements and criteria.

There is no clear definition of a special process. However, it is usually taken to include operations which affect the quality of the item.

The quality of the item is defined by the specification and the applicable codes.

In the case of cold forming the specification does not address this process, nor does AWS D1.1. The AISC Manual of Steel Construction provides tables of acceptable radii for cold bending of structural steels. Very tight radii (4 x thickness) are listed for A36 up to 2 inches thick.

The ASME Code requires the qualification of cold forming procedures where impact testing is specified and where the cold strain exceeds 0.5%. The implication is that the major quality controlling parameter affected by cold bending is the toughness of the material. However, no fracture toughness requirements were specified in the design of the SSW.

The other quality affecting parameters which could be affected are:

- o Strength,
- o Ductility,
- o Integrity (freedom from detrimental defects), and
- o Dimensional tolerances.

For the strains used on the SSW (about 0.8%), the effect on strength and ductility is not significant. For structural steels there is no significant probability of creating defects by cold bending to these strain levels. The materials are tough and ductile at room temperature and at the strain rates used for bending. Dimensional tolerances could be affected by bending. However, these are controlled by specification and design drawings. In addition, as evidenced by visual observation and the

fabrication history, difficulty with the dimensional tolerances was not encountered with exception to tolerance stack-up as discussed in Concern No. 17.

It is concluded that cold forming can be considered to be a special process under some circumstances. However, in the context of the original design of the SSW, cold forming was not a process which affected the quality of the structure to any significant extent.

Based on discussions with Leckenby, it is understood that their subcontractor did not experience any problems during forming, and no material was subjected to repeated forming. These conclusions are based upon the following information provided by Leckenby:

- No plates were subject to repeated forming such as might occur if a plate was formed to too tight a radius,
- Pinch rolls were used which provide good control of the process,
- No heating was used,
- No problems were encountered, and
- The forming radius was large relative to typical forming radii for heat exchangers, piping, and pressure vessels.

Thus, it is felt that no engineering concern exists with respect to the acceptability of the SSW under the original design and fabrication criteria.

However, the evaluation of the as-built structural integrity of the SSW is taking into account the potential for brittle fracture in the structure. To do this the lower bound fracture toughness of the steels must be characterized. Most available data is developed from as-rolled or heat treated material. It is known that cold work can degrade the toughness of structural steels. This can be reflected by an upward shift in the nil-ductility transition temperature (NDT).

To quantify this shift, the effect of cold bending on the NDT temperature of A36 plate is being measured. The tests will reproduce the maximum strains used in the SSW. Also A588 material will be removed from the SSW and the NDT temperature measured. This material will be in the as-bent condition. The results of these tests will be presented in an addendum to this report.

Based on information discussed in paragraph 4.5.1 of the interim Welding Institute report (Attachment 1), the resultant shift in the NDT is expected to be acceptable.

References:

(1) Letter WNP2WBG-215-F-80-1452, Task Force trip report, item 3, 5/7/80

CONCERN NO. 11

Approximately 90 typical joint configurations specified on design drawings for the pipe whip restraints(PWR) use fillets which are smaller than the minimum fillet weld size specified in the applicable code. Undersize fillets on the SSW may also be smaller than the minimum size specified in the applicable code.

BACKGROUND

During an NRC Region V Site Inspection, NRC Personnel noted that specified PWR fillet weld sizes were undersized with respect to the minimum size fillet weld required by the AISC Specification for the design, fabrication and erection of structural steel buildings.

At the request of the NRC, a review of over 50 structural steel drawings were made, particularly those involving pipe whip restraints, wetwell supports and supporting steel. A total of 90 individual weld callouts did not meet the requirements of minimum size welds specified in the 1969 Edition of the AISC Specification.

A rationale by the Engineer of accepting these welds based on the required structural strength providing the quality of the welds were acceptable, was suggested to the NRC. The main concern of the NRC expressed is that the inspection phase done by this same contractor (Leckenby) is now one of the main issues at stake.

While the SSW was not addressed in the initial concern (see Reference (1)), a review of data included in Reference (2) reveals that some fillets have actual sizes which, in addition to being undersized from a structural standpoint, are undersized when compared to minimum fillet size requirements contained in References (3) and (4).

A sampling of welds revealed one weld where the specified fillet size is less than the minimum size required by References (3) and (4).

CONCERN RESOLUTION

As noted in Reference (1), the primary concern behind the minimum fillet size requirement is the possibility of cracking caused by too rapid cooling rates resultant from low heat inputs and the quench effects of heavy structural members. Twenty-nine undersized fillets (identified in Burns and Roe visual inspection) from a sampling of weld maps were identified. Base metal thicknesses were determined. Utilizing the actual fillet size and the base metal thicknesses, twenty-one (21) fillets noted in Reference (6) were identified as being below the minimum size required by References (3) and (4) (structural considerations aside). One fillet of the twenty-one had a specified size below the code minimum. The remaining eight met the minimum requirement.

No cracking was noted on these or any other undersize fillets identified during the Burns and Roe reinspection. Additionally, MT was performed on 23 undersized fillet welds. No cracking or lack of fusion was found. The existence of undersize fillets is still a consideration in regards to the structural load bearing capabilities of the SSW. This situation is addressed in subsection III.D of the report. While the sampling reveals some fillets that, in addition to being undersized from a structural standpoint, are undersize with respect to Reference (3) and (4) requirements, it is felt that the intent of the code with respect to weld cracking is met. That is, welds have been inspected and found to be free of cracks. The possible concern arising from the implications of Concern 11 on the SSW has been adequately resolved by subsequent reinspections.

It should be noted that Reference (5) indicates that "where Table 4.2 stipulates the mandatory preheat, for thickness over 3/4 in. (19mm), then fillet size limitations do not apply". While the statement in the Commentary pertains to a subsequent revision of the AWS Structural Welding Code and does not override the requirements of the applicable revision, it is indicative of the intent of the Code. Under this criteria, none of the identified fillets would be undersize with respect to the Reference (3) and (4) minimum fillet size requirement.

No further action is planned for this concern.

References:

(1) Letter: G02-80-28, D. L. Renberger (WPPSS) to R. H. Engelken (NRC), dated February 1, 1980.

(2) IOM: F-80-1665, M. E. Hunter to D. C. Timmins, dated April 16, 1980.

(3) AISC "Manual of Steel Construction", Seventh Edition (includes "Specification for the Design, Fabrication, and Erection of Structural Steel for Building").

(4) AWS D1.1-72, "Structural Welding Code".

(5) AWS D1.2-77, "Commentary on Structural Welding Code".

(6) Memo, M. E. Hunter to D. C. Timmins, "Undersize Fillets", dated June 5, 1980.

CONCERN NO. 15

Interviews with Leckenby personnel established that SSW segments 2A, 3A, 3B, and 3C were heat straightened without the benefit of controlling procedures or maintenance of quality records. Heat straightening (application of heat and mechanical force) was applied to correct weld distortion.

BACKGROUND

The specification did not require procedures or records for heat straightening. Discoloration of the SSW was cited as evidence of the application of heat. Leckenby admits that heat straightening was used to correct weld distortion in SSW segments. No procedure was available to control this operation and no records were kept. Reference (1) was supplied by Leckenby to address the acceptability of heat straightening.

CONCERN RESOLUTION

The general discussion of the definition and control of special processes presented in Concern No. 6 also applies to heat straightening.

In this case the governing code (AWS D1.1) clearly indicates that heat straightening is a process that requires careful supervision. Leckenby did not have a procedure to meet these requirements. No records were kept and measurements of the maximum temperature were not reported.

However, the information presented by Leckenby does suggest that they did comply with the intent of the Code. This conclusion is based on the following information provided by Leckenby (Reference 2).

- The segments did not reach a dull red color (para. 3.7.3 of AWS D1.1 states that this is reached at 1200°F).
- Heat was applied by rosebud torches which tend to prevent localized overheating.
- No hammer blows or similar applications of force were used.
- Heating was used in conjunction with mechanical forces - this would reduce the amount of heating required.

Thus, there is no reason to suspect that the heat straightening methods used were in any way unusual. However, a procedure should have been specified and used.

Furthermore, there is no reason to suspect that the heat straightening applied by Leckenby has reduced the quality of the structure. AWS D1.1 includes the use of many materials from, as rolled carbon-manganese steels like A36, through normalized steels to quenched and tempered low alloy steels with yield strengths up to 100 ksi. The affect of flame straightening will be different depending on the alloy type and is much more likely to be detrimental to the higher yield steels. In these steels the specified properties are much more critically dependent on heat treatment and microstructure.

A36 plate is supplied in the hot rolled condition with a typical finishing temperature of 1600°F. The high finishing temperature coupled with the relatively thick section and sparse alloy content, tends to produce a coarse microstructure consisting of upper transformation products, primarily proeutectoid ferrite and pearlite. In this condition, the application of heat within the limits specified in Reference (3) would not be expected to have any detrimental effects on material properties. In fact, as noted in Reference (1), the heating combined with the resultant plastic flow can result in slightly improved notch toughness and yield strength. Even heating substantially in excess of Reference (3) guidelines would not be expected to significantly degrade properties. Subcritical temperatures (below approximately 1340°F) would be expected to alter microstructure and therefore properties, only if those temperatures were reached and held for long periods of time (one or more hours). This circumstance is well outside the scope of heat straightening operations used by Leckenby. If the lower critical temperature was exceeded, partial transformation to austenite would occur. Upon cooling, the microstructure would be restored to essentially its original condition prior to heat straightening. In this case, the possibility of improved properties due to grain refinement does exist.

The probability of formation of microstructures which would produce cracking or low toughness (e.g., high carbon martensite) is insignificant. The hardenability of carbon manganese steels is low compared with the high yield strength materials and the thermal cycle produced by flame straightening is less detrimental than that produced by welding.

It is, therefore, concluded that heat straightening as applied by Leckenby did not degrade the material properties, and as such the process did not affect the quality of the SSW to any significant extent.

No further review or action is planned for this concern item.

References:

(1) Article, "Primary Concepts for Flame Bending", by R.E. Holt, AWS Welding Journal, June, 1971

(2) Memo WNP2WBG-215-F-80-1452, Task Force Trip Report, Item 4, dated 5/7/80

(3) AWS Structural Welding Code AWS D1.1-72

CONCERN NO. 16

The 215 Contractor (WBG) quality review of the Leckenby documentation did not include verification that all required UT examinations were performed, as required by specification and a Leckenby procedure.

BACKGROUND

The 215 Contract, Section 5B, paragraph 5.4 required ultrasonic testing (UT) of electroslag welded tee-joints in the SSW for lamellar tearing. The UT sampling requirements included six weld joints for every 16-25 electroslag welds. If no indications of lamellar tearing were observed after 24 ultrasonic examinations, the UT requirement was reduced to examination of two tee-joints for each additional 100 electroslag welds performed. There are 1273 electroslag welds in the SSW. This translates to 48 required ultrasonic examinations of welded tee-joints assuming all 1273 are tee-joints, which is not the case but conservative, and knowing that no lamellar tearing was found.

The welded tee-joints were to be examined by straight beam UT per ASTM A435-74. The Leckenby lamellar tearing UT examinations, however, were performed prior to this contract modification requirement. This UT was primarily performed due to concern for lamellar tearing at tee-joints where buttering, an original preventive measure, had not been used. The UT was performed per Leckenby Quality Control Procedure (QCP) - 8.0. The defect repair criteria in QCP-8.0 is substantially more stringent than the specification and ASTM A435 three-inch-diameter circle criteria. QCP-8.0 defect acceptance criteria states:

- o No cracks, lack of fusion, or incomplete penetration are allowed, and

- o No linear type discontinuities are allowed if the signal amplitude exceeds the reference level and the discontinuities have lengths which exceed:

  1/4 inch for T (a) up to 3/4 inch, 1/3T for T from 3/4 to 2¼ inch, and 3/4 inch for T over 2¼ inch.

(a) T is the thickness of the thinner portion.

CONCERN RESOLUTION

Leckenby performed 129 straight beam ultrasonic examinations for lamellar tearing, 81 for electroslag welded tee-joints and 48 for flux core arc welds. They performed 60 angle beam examinations for lamellar tearing at joints with geometry or access not compatible with straight beam examination, two for electroslag tee-joints, 58 for other processes. No lamellar tearing was observed or recorded. The Leckenby UT exceeded the 215 Contract requirements.

Implications for defects as a result of improperly performed UT by Mr. E.B. Hamilton are discussed in Concern No. 4.

No further action is required for this concern.

CONCERN NO. 17

1. Leckenby used liquid penetrant (LP) testing to examine SSW structures at Leckenby shops. Leckenby representatives reported that there was no approved LP procedure at the time the inspections were performed.

2. The procedure submitted by Leckenby which provides for weld sequence control (entitled: "Sacrificial Shield Wall Assembly Procedure") has no procedure number, no revision number, no date of preparation, and no evidence of ever having been approved. The American Welding Society (AWS) Structural Welding Code, D1.1-72, paragraph 3.4.3, requires the following:

Paragraph 3.4.3: The Contractor shall develop welding sequences which, in conjunction with the overall fabrication methods, will produce members and structures meeting the quality requirements specified. These sequences and any revisions necessary in the course of the work shall be sent for information and comment to the Engineer.

BACKGROUND

1. The 215 Contract contained no specific requirements for surface examination, dye penetrant or magnetic particle inspection.

The Leckenby Shop Quality Assurance and Quality Control Manual, dated October 28, 1975, has in Section 10 of the QC portion a procedure for liquid penetrant inspection.

The Structural Welding Code, AWS D1.1-72 (applicable to the SSW fabrication) in paragraph 3.7.2.4 states:

> Ascertain the extent of the crack by use of acid etching, magnetic particle inspection, or other equally positive means; remove the crack and sound metal 2" beyond each end of the crack, and reweld.

The liquid penetrant examinations were primarily performed for information after removal of material defects by grinding and/or air arc gouging. The related defects in the SSW were as follows:

o Surface laminations	7
o Edge lamination	1
o Blow-outs from burning	6
o Gouges from burning	3
o Material surface cracks	4 (a)
o Incomplete stud welds	2
o Material flaws	2
o Slag	2

(a) One report may be associated with cold lap rather than surface cracks.

There were no requirements for liquid penetrant examination other than providing a positive means to define the extent of cracks, of which four of the above are in this category. Also, the defects were identified visually; therefore, there was no requirement for PT after repair.

2. The following outline summarizes the procedures which have been submitted by Leckenby and/or referenced in this concern:

   The procedure entitled "Fabrication and Erection Procedure For The Sacrificial Shield Wall (SSW)", No. LEFP-1, new issue, dated April 10, 1975 was submitted by Leckenby to cover shop and field fabrication and erection of the sacrificial shield wall; however, this procedure does not address the area of welding sequence to control distortion and maintain dimensional stability. This procedure was "approved as noted" at the "new" issue and was returned to Leckenby for revision. This procedure underwent five additional review and revision cycles before receiving final approval on November 17, 1976.

   A five-page document entitled "Welding Sequence S.S.W.", dated October 29, 1975 was submitted by Leckenby to cover several specific welding sequence items. This document has no procedure number and no revision number and is essentially incomplete in that it only addresses a few specific items with respect to distortion control and dimensional stability. Item 4, page 3 of this document states: "additional information to follow on the other built-up columns and members"; however, no further information has been received to date and Leckenby states no additional related documents exist.

   The procedure entitled "Sacrificial Shield Wall Assembly Procedure", referenced in the concern above has never been received from Leckenby. (Note: Telecon inquiries to Leckenby about a procedure with this title indicate that this title is incorrect).

CONCERN RESOLUTION

1. Based on discussion with Leckenby, the liquid penetrant (dye penetrant) examinations were performed per Section 10 of the shop QC manual. The liquid penetrant examinations were performed in 1976, after Leckenby approval of the procedure.

   For information relative to defect implications from improperly performed dye penetrant examinations, refer to Concern No. 4.

   No futher action is necessary for this concern.

2. In spite of the fact that Leckenby failed to prepare a complete and detailed welding sequence procedure, the sacrificial shield wall was fabricated and erected with a minimum of distortion and with reasonably good dimensional stability. This fact alone indicates that Leckenby had implemented a reasonable welding sequence and distortion control during the fabrication and erection of the sacrificial shield wall.

The as-built dimensions of the sacrificial shield wall at elevation 541'-5" with respect to circularity and vertical plumb have been evaluated by Burns and Roe and have been found to be acceptable. Although it was necessary to install shim plates between rings 3 and 4 in order to maintain vertical plumb due to variations in vertical dimensions, it is believed that these variations are the result of tolerance stack-up and not due to weld sequencing.

The lack of a welding sequence procedure also implies the possibility of having high reaction stresses in the SSW (residual stresses due to member rigidity during welding rather than localized welding stresses). However, the fact that no cracks were found during the Burns and Roe visual inspection or during the UT performed for the Task Force, and post-fabrication weld cracks identified at the site were few (9 known, 7 other cracks of unknown location), provides confidence that a problem with high reaction stresses does not exist.

In view of the above, it is concluded that the lack of a formal, detailed welding sequence procedure was not a significant factor in the final outcome of the fabrication and erection of the sacrificial shield wall and that direction was implemented which enabled Leckenby to meet dimensional tolerances. Based upon this information, no further action is deemed necessary for this concern.

CONCERN NO. 18

Leckenby, as SSW fabricator, hired a consultant to determine the cause of an unusual crack in the SSW. Burns and Roe rejected the consultant's determination. According to Leckenby, their consultant's opinion was misunderstood by Burns and Roe. Burns and Roe has not had an opportunity to review the consultant's last letter (dated June 21, 1977).

BACKGROUND

During initial installation of radial beams at elevation 541', a crack was discovered in the SSW at the point of attachment. Leckenby, through their consultant, proposed a cause for the cracking to the Supply System and Burns and Roe. Burns and Roe reviewed and disagreed with the consultant's proposal. A response was forwarded to Leckenby at that time.

Subsequently, the NRC was informed of the existence of a second letter from the consultant to Leckenby, in which the consultant clarified his initial position.

The NRC questions whether Burns and Roe received, reviewed and responded to the letter.

CONCERN RESOLUTION

Burns and Roe has reviewed the June 21, 1977 letter and considers the amplifying remarks by Leckenby's consultant to be unpersuasive.

In brief, he proposed that the SSW cracked by a 5-step process because of the design.

Burns and Roe felt that cracking was caused by the welding method and the fabricating sequence selected by Leckenby. The welding conditions presented unusually severe restraint which resulted in cracking. Figure 18.1 illustrates these conditions. The radial beam consisted of two 2½" thick steel "cheek" plates rigidly welded to opposite sides of the web of a massive W14 beam, a 426 pound per foot wide flange column section. The attachment to the SSW was made with two electroslag tee welds between the cheek plates and the SSW.

The second of these two welds was deposited directly against an electroslag butt weld within the SSW which joined a 1½" thick "skin" plate to a 3" thick skin plate.

The thermal and weld-shrinkage effects were compounded by the use of a single steel bar which served as a common dam between the two tee welds. Thus, the weld shrinkage strains of the two large tee welds could act additively on the SSW. Moreover, when the second tee weld was deposited directly against the butt weld in the SSW, the severe thermal effects and deep penetration characteristic of the electroslag welding process developed transient high tensile strains on the inside surface, towards the concrete, which when added to the high residual tensile strains from the original electroslag butt welding exceeded the yield strength. Within such a plastic field, normally innocuous discontinuities may initiate fracture.

Burns and Roe believes the crack initiated under these conditions, and that the crack propagated into both skin plates when they cooled to the ambient winter temperatures. Then, in the zone where the lateral shrinkage forces of the three electroslag welds were additive, the crack branched and turned roughly parallel to the welds forming a figure "3".

Indeed, a sample cut from the point of branching revealed that the branching occurred at the edge of the heat-affected zone where the combined lateral shrinkage forces would be expected to be high; and, that the crack path was predominately transgranular with plastic deformation, indicative of stresses well in excess of the yield point and of ductile overload fracture.

The correctness of the conclusion that the SSW cracked because of the way the radial beam was welded to it and the incorrectness of the proposal of Leckenby's consultant that it cracked because of the design, were proven by disassembling the radial beams and rewelding them to the SSW correctly. This work was accomplished without a recurrence of the cracking and without the other dire effects such as a steam explosion and blowing of molten metal predicted by Leckenby's consultant.

TASK FORCE ASSESSMENT

In addition to the consultant's report discussed above, additional reports by Peloux and Conrads, commissioned by Bovee-Crail/GERI, have been reviewed (reference attachments to WBGBR-215-77-235).

The original debate between Burns and Roe and the Leckenby consultant, Holt, centered on the source of stress promoting the crack. Holt felt that expansion of the concrete, resulting indirectly from preheating/welding, provided the stresses. Burns and Roe's position was that the source of stress was residual welding stresses produced by welding with an incorrect sequence.

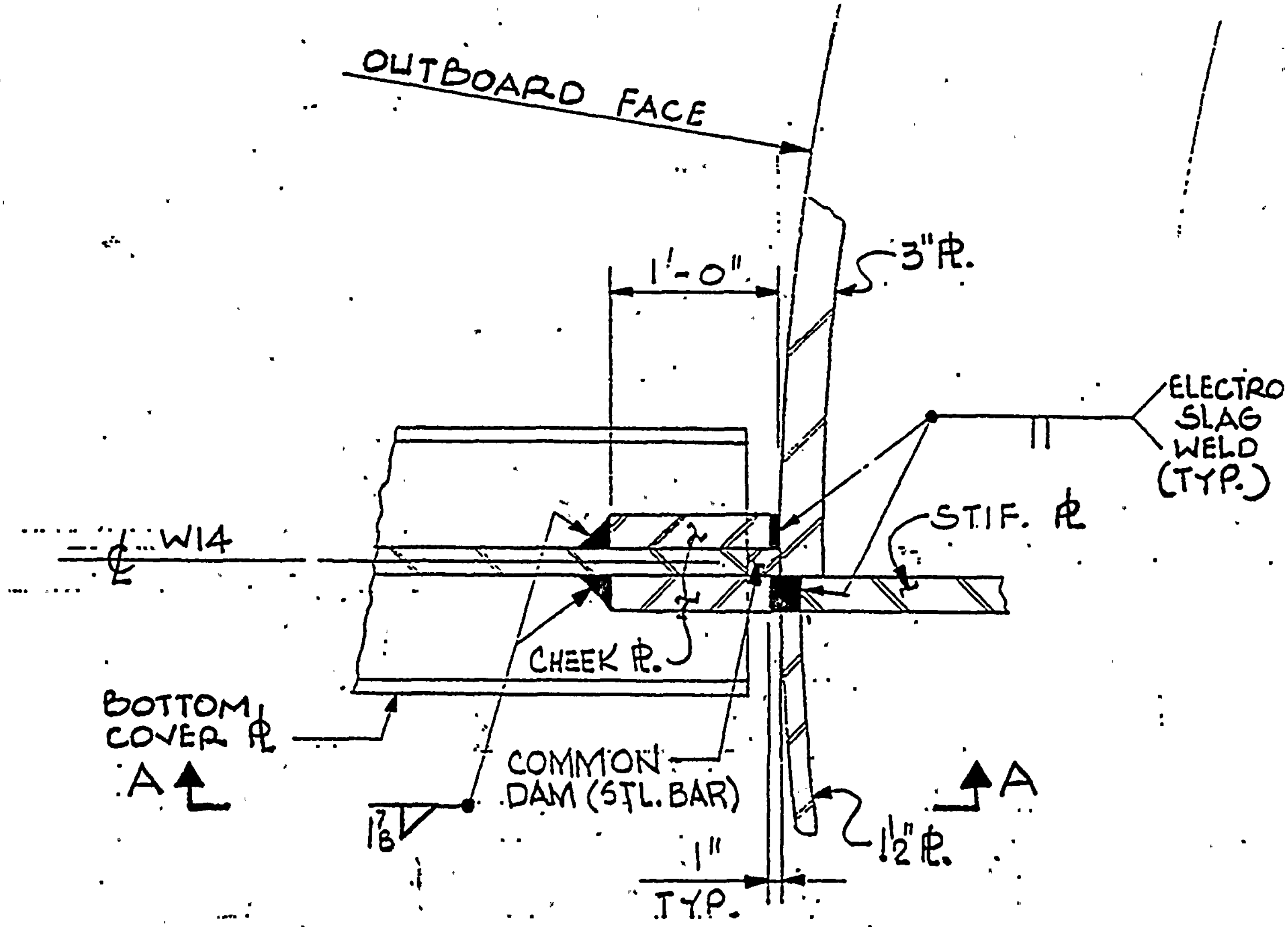
The report by Conrad also attributes the failure to residual welding stresses and poor sequence, but added that the design of the connection was also a contributory factor.

All the subject welds made using the electroslag process and the original sequence (eight) were examined by UT and repaired or reworked as necessary. Those which were reworked, and all subsequent joints, were made using the SMAW process, with a different sequence. In addition all welds were examined by UT and accepted.

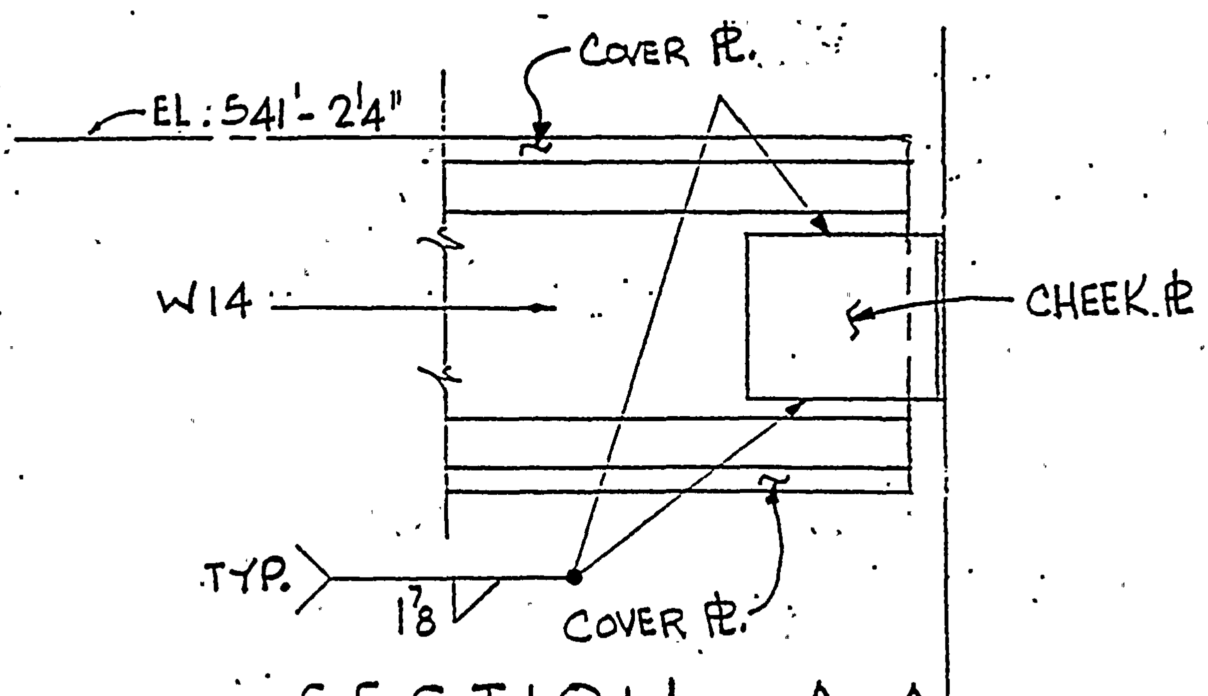
Thus, the cracking problem was identified and eliminated. The debate over the original cause is only significant if the conclusions would have affected the corrective action taken or would cast doubt on the adequacy of the joint for service.

The Burns and Roe repair action was formulated based upon the assumption that process/sequence was the main contributor. The success of the repair supports their assumption. If the source of stress were concrete expansion, then additional problems might have been expected to occur as all welds are preheated continuously. Similarly, if the weld connection design were a dominant factor, it would be expected that further problems might have occurred, which was not the case.

It is the Supply System's opinion that the design of this connection is such that careful procedures are required to successfully make the joint and that the primary problem was the combination of process and sequence used. No further action is required on this concern.



PLAN - TYP. BEAM CONN. @ SAC. SHIELD WALL
FOR W14 x 426 WITH COVER PLATES T. & B.



SECTION A-A

Figure 18.1

CONCERN NO. 19

The presence of free water was identified in the SSW structure. NRC Region V previously understood that the existence of free water in the SSW was one isolated case. However, a review of Contract 215 Inspection Reports (IR's) shows seven cases where evidence existed of free water or moisture emanating from the SSW. The water could have had a detrimental effect on welding if it was present in the weld preparation during welding.

BACKGROUND

Burns and Roe has conducted a review of all IR's written on the SSW and determined that there are only five documenting free water, which may have implications for the associated weld quality.

IR 2525 (Two locations)	NCR 4043
IR 3069	NCR 4561
IR 1703	NCR 5141
IR 1464 (Two locations)	No NCR
IR 2915	NCR 4463

CONCERN RESOLUTION

The seven documented cases of water leaking from the SSW all occur at deficient welds. The subject welds have all been repaired and magnetic particle examinations of the repaired areas have been made. The subject welds are now acceptable and no further "leaks" have been detected.

Six of the welds involved were made prior to placing concrete in the enclosed compartment. Therefore, water was not present at the backside of the joint during welding, and the question of its effect on the weld is moot. The remaining weld (IR 3069) was made between a 2" thick "window" plate and an internal diaphragm plate immediately after concrete was placed in the compartment, bounded by azimuths 15^{o} and 30^{o} and elevation 541'-5" and 544'-8". This compartment had been left open to facilitate other welding. This compartment was subsequently filled with concrete using the window plate opening for access.

The joint configurations for the window plate welds were designed to seal the concrete out from the back of the weld joint prior to welding. However, when repairs were conducted on the window plate weld, it was determined that water possibly could have been present, due to the weld preparation. Such a weld could not be performed with water present. Without doubt, the area of the joint was dried out prior to welding. However, all window plate welds have subsequently been inspected and any deficient welds have been documented and repaired.

The conclusion is that no water was present behind the subject welds during installation.

The source of any free water observed on the SSW prior to review of the IR's was the concrete behind the skin plates. It would only be speculation to make a statement on how water found its way through the deficient welds.

The main point to be made is that the inspection program located such defects, the defects were repaired and any other suspect areas of the same type were investigated. No further action is necessary.

CONCERN NO. 20

Burns and Roe Drawing S-802, Note 3, refers to the Burns and Roe specification for post-weld heat treatment (PWHT) requirements for the stabilizer truss assemblies. The specification does not appear to specifically address PWHT of stabilizers. It is, therefore, unclear whether or not Burns and Roe intended to require PWHT. Stabilizer truss material is A514. SSW material at the stabilizer truss attachment weld is A588. Containment vessel material at the stabilizer truss pin location is SA537.

BACKGROUND

Burns and Roe Drawing S-802, Note 3, reads as follows:

> "Note 3: For welding and heat treatment requirements for stabilizer truss, see specs."

The note does not specifically address PWHT requirements, as it refers to welding and heat treatment. Heat treatment may apply to one or more of three phases; preheat, interpass temperature, and post-weld heat treatment requirements. Each phase is accomplished as required.

Paragraph 3.6, Post-Weld Heat Treatment from specification section 17D of the 215 Contract states: "Post-weld heat treatment shall be performed in accordance with the applicable specification requirements and/or manufacturer recommendations."

Paragraph 3.9, Stress Relief Heat Treatment, from the 1972 and the 1975 editions of the AWS Structural Welding Code refers to footnote No. 12, which states:

> "Stress relieving of weldments of quenched and tempered steel is not generally required. Stress relieving may be necessary for those applications where weldments must retain dimensional stability during machining or where stress corrosion may be involved, neither condition being unique to weldments of quenched and tempered steel. However, the results of notch toughness tests have shown that post weld heat treatment may actually impair weld metal and heat-affected zone toughness and intergranular cracking may sometimes occur in the grain-coarsened region of the weld heat-affected zone."

A change was made to the above footnote in the 1979 edition of the AWS Structural Welding Code. This change appears in footnote No. 9 of paragraph 4.4; Stress Relief Heat Treatment, which states:

"Stress relieving weldments of A514, A517 and A709 Grades 100 and 100W steels is not generally recommended. Stress relieving may be necessary for those applications where weldments must retain dimensional stability during machining or where stress corrosion may be involved, neither condition being unique to weldments involving A514, A517 and A709 Grades 100 and 100W steel. However, the results of notch toughness tests have shown that post-weld heat treatment may actually impair weld metal and heat-affected zone toughness, and intergranular cracking may sometimes occur in the grain-coarsened region of that heat-affected zone."

CONCERN RESOLUTION

The question as to whether post-weld heat treatment of the stabilizer truss assemblies was required has been thoroughly reviewed with Burns and Roe and they have confirmed that the stabilizer truss assemblies were not to be post-weld heat treated.

Post-weld heat treatment is performed on welded assemblies for the following basic reasons;

- o To relieve stresses in the weldment base metal and weld metal,
- o To improve the dimensional stability in the weldment, and
- o To improve the machineability of the weldment.

In the case of the stabilizer truss assemblies, none of the above items were significant factors; therefore, there was no reason to apply post-weld heat treatment to the stabilizer truss assemblies. In addition, the drawing reference was to heat treatment in general, not to post-weld heat treatment specifically, and as indicated post-weld heat treatment may degrade A514 steel toughness properties and promote cracking.

No further action is necessary for this concern.

CONCERN NO. 22

Based on implications from previously identified Leckenby documentation irregularities, a review was performed of Leckenby welder qualification records to determine if the welders were properly qualified and if the testing was properly documented.

BACKGROUND

The welder qualification record review was performed by Burns and Roe and the Supply System and consisted of the shop and field qualification records submitted by Leckenby. The qualification records were evaluated for completeness, correctness and testing requirements as required by the AWS D1.1 Code and the Design Specification.

A total of 32 welder's qualifications were submitted for field work and 38 welder's qualifications were submitted for shop fabrication.

The welder qualification records exhibited varied deficiencies that were considered to render some qualifications invalid and deficiencies that were generic documentation problems that required clarification.

Qualifications considered invalid involved qualification records for three welders without test results, two welder's coupons incorrectly tested by UT, ten welder's records which did not identify the type of bend test and one welder for which another company's qualification record was used without the Engineers' approval. The deficiencies were evaluated recognizing that evidence does exist that the welders performed a qualification test and that because the record or manner of qualification was in error does not conclude the welder does not have the ability to produce sound welds. Some of these welder qualifications were found not to have been applied for SSW usage. Leckenby has been requested to provide the missing information from their files where possible.

Qualifications which contain generic documentation problems include items of missing or incorrect information such as: omission of contractor name, record title, certification statement, identification of weld backing, vertical progression direction, uninitialled changes, the number of electroslag wires; shielding gas designation, welder symbol, bevel angle, or qualifying code; one symbol assigned to two welders; conflicting procedure and process numbers; and typographical errors. These deficiencies do not apply to all the qualification records, but are provided as a summary of generic problems which include single or multiple items unique to an individual record. These generic documentation problems are considered as not invalidating a welder's performance capabilities as demonstrated by qualification even though some items violate the specific requirements of the AWS D1.1 Code. These qualifications are considered adequate to provide evidence of qualification to fulfill the intent of the Code to determine a welder's ability to produce sound welds. However, Leckenby has also been requested to update and clarify these welder qualification records.

In addition to review of qualification records it was determined that some welders were identified to have welded on the SSW for which no qualification records were on file and it is assumed that they had not performed a qualification test. When considering welder qualifications, the purpose of the test, to determine a welder's ability to produce sound welds, must be in mind as the test is not meant to serve as a training operation but a verification of his previous training and existing ability. Most welders possess the ability to produce sound welds and when performing a qualification test for each contractor which employs him, he is verifying his ability. If a welder did not possess an ability to produce sound welds due to inexperience or lack of training, his welds would clearly evidence it by exhibiting defects of non-fusion, slag entrapment, porosity and surface appearances with uneven and rolled beads, excessive arc strikes and weld spatter.

In an effort to determine if the lack of qualification was a significant factor in a welder's ability to produce acceptable welds, a study was conducted to examine the weld reject history for those welders that were definitely known to lack the proper qualification credentials to ascertain the quality of the welds they produced. The lack of proper qualification credentials includes invalid qualifications defined above, and no evidence of qualification tests being performed. These cases are subsequently termed as "unqualified" welders in the balance of this concern.

In order to attain a high level of confidence in this study, the scope was confined to those welds which were part of the Burns and Roe visual inspection and for which recent MT and UT was performed.

CONCERN RESOLUTION

A total of thirteen (13) "unqualified" welders (both shop and field welders) comprised the complement of welders for the assessment associated with the Burns and Roe inspection. These welders collectively produced four hundred (400) welds of which only twelve (12) contained rejectable defects, for a defect percentage of three (3) percent. All of these welds were made using several different welding processes as tabulated below:

Process	No. Welds	No. Defects
SMAW	157	2
FCAW - Self Shielded	63	0
FCAW - Gas Shielded	173	9
ESW	7	1

These results indicate that when considering only visual inspection in this case, the lack of proper qualification credentials by these welders was not a significant factor in the welder's ability to produce acceptable welds. (It should be noted that for all of the welds made on the SSW, with most of them being made by welders whose qualifications meet the intent of the AWS D1.1 Code, the defect percentage was 7.6 percent.)

Comparison of welds performed by welders with invalid qualifications and those with minor deficiencies (termed qualified below) in their qualifications to recently performed MT and UT, however, presents a different conclusion. Specifically,

- % weld rejects by UT by welders unqualified in one or more process - 21%,
- % weld rejects by UT by qualified welders - 9.5%,
- % weld rejects by MT and UT by welders unqualified in one or more process - 17%,
- % weld rejects by MT and UT by qualified welders - 7.7%,
- % weld rejects by UT by welders unqualified by process - 33% and,[a]
- % weld rejects by MT and UT by welders unqualified by process - 25%.[a]

(a) Sampling only included welds for which the welder was unqualified in that process.

Based on the unqualified welder NDE sample sizes, 29 UT and 7 MT, the statistical results above may be prejudiced.

The deficiencies noted for invalid welder qualifications in the fourth paragraph of BACKGROUND for this concern are not necessarily indicative of the capability of a welder to produce sound welds.

Potential defects associated with improper welder qualifications were evaluated to be few in number and structurally acceptable based on the recent visual inspections and nondestructive examinations (refer to subsection III.C of this report) and the structural assessment in subsection III.D which envelops known and postulated defects.

CONCERN NO. 23

Based on implications from previously identified Leckenby documentation irregularities, a review was performed of Leckenby welding procedures to determine if adequate welding procedure specifications were used and if those used were properly qualified to provide representation of the SSW welds.

BACKGROUND

The welding procedure review was performed by Burns and Roe and the Supply System. The welding procedures were evaluated for completeness, correctness and qualification requirements per AWS D1.1-Rev. 1-73 and the Design Specification. The review included 26 shielded metal arc welding (SMAW) procedures, 23 flux cored arc welding (FCAW) procedures and 25 electroslag welding (ESW) procedures. The welding procedures involve the welding of A588 and A36 base material and combinations thereof with E7018 electrode and A36 material with E7028 electrodes with the SMAW process. E70T-G without external shielding gas was limited to A36 material and E70T-1 with external shielding gas was used for both A588 and A36 material and combinations thereof for use with the FCAW process. The welding of A588 and A36 material and combinations thereof with the ESW process used EM12K wire with Linde 124 consumable guide tubes and flux. Due to the use of only EM12K wire for the ESW process the number of applicable ESW procedures was reduced from 25 to 12 as the other ESW procedures were for EL12 and EH14 wire.

The welding procedures exhibited AWS D1.1 and Design Specification deficiencies. The Design Specification deficiencies are identified as such, but actually resulted in AWS D1.1 deficiencies by exempting the prequalified status of the A588 base material. The Design Specification requirement to qualify the welding of A588 material in accordance with AWS D1.1 resulted in qualifications that were incomplete and inadequate for the support of the welding procedure. This deficiency is attributed to an incorrect interpretation of the Design Specification to qualify low alloy materials in accordance with ASME Section IX. Since A588 is considered a low alloy steel, the contractor used Section IX for the qualifications which resulted in cases of incomplete representation for positions, joint design, groove welds and fillet welds when applied to AWS D1.1. Welding procedure deficiencies identified were evaluated in an attempt to assess the impact they may have on the welded integrity of the SSW.

CONCERN RESOLUTION (by Process)

SMAW

Fourteen of the 26 SMAW procedures were found acceptable or accepted as-is. The procedures accepted as-is involved joint designations of the 1974 AWS D1.1 Code. However, the joint details conform to the 1973 revision of AWS D1.1 and is, therefore, not considered to have any weld impact or engineering significance. The balance of the procedures contained AWS D1.1 and Design Specification deficiencies.

The AWS D1.1 deficiencies resulted from the provision of horizontal instead of overhead position for joint design TC-U4a with a 30° bevel angle and 3/8" root opening for both E7018 and E7028 electrodes. By AWS classification the E7028 is a flat groove and horizontal fillet electrode and the E7018 is an all position electrode. If the E7028 was used for horizontal groove welds using this joint design, it would be expected to produce more defects than the E7018. However, due to the joint design specified it is possible because of electrode manipulation problems that intermittent inclusions and lack of fusion could occur with both electrodes. These defects would be considered to be limited to the first part of the joint on the bevel edge as accessibility would increase as deposited thickness increased. The extent of possible defects would be dependent upon the individual welder's skill and attending circumstances. It is estimated that the depth of possible inclusions or lack of fusion would be 3/16" maximum per weld bead. The evaluation and effect these possible defects may have on the load bearing capacity or potential for fracture of the SSW are enveloped by the structural assessment in subsection III.D of this report.

The Design Specification deficiencies resulted because of the specification requirement that exempted the A588 material from a prequalified status. The welding procedures would be acceptable under a prequalified status of AWS D1.1 except for the same joint designation and welding position problems previously discussed. The A588 material procedure qualifications were performed in accordance with ASME Section IX and as allowed by Section IX a groove weld on the flat position was used to support the procedures. When these procedure qualifications are applied to AWS D1.1, it results in unqualified procedures. The major resulting deficiencies were no fillet weld qualification, the vertical, horizontal and overhead positions not qualified, omission of travel speed and pass numbers, amperage range unqualified, and bevel angles less than 35° unqualified. In addition, the tensile dimensions were incorrectly machined. The omission of fillet weld testing is not considered significant as the fillet weld macro-etch is defined to determine soundness which is the same AWS defined purpose of bend tests. The groove weld test with bends and tensiles would be considered adequate representation. The weld positions, travel speed, pass numbers and amperage range must all be considered in conjunction. The objective is the determination of the effect of the heat input on notch toughness and tensile strength of the weld. The travel speed having the most effect on heat input is controlled to a low level by the restriction for essentially stringer beads with a maximum weave width of 3 times the electrode core diameter. In addition, the amperage ranges given are reasonable for the positions and electrode sizes specified. It is therefore considered that the heat input was not varied enough to degradate the weld properties. The bevel angle deficiency is not considered significant as the joint designs used are as allowed by AWS D1.1 and weld soundness would become a factor of the welders' abilities. The procedure qualification tensile specimens were machined to a width of 1.5" nominal instead of 1" nominal as required by the coupon thickness. This is not considered a significant item as the weld tensile properties have been adequately represented.

FCAW

Eighteen of the 23 FCAW procedures were found acceptable or accepted as-is. The procedures accepted as-is involved joint designation of the 1974 AWS D1.1 Code. However, the joint details conform to the 1973 revision of AWS D1.1 and is, therefore, not considered to have any weld impact or engineering significance. The balance of the procedures contained Design Specification deficiencies.

The Design Specification deficiencies resulted because of the specification requirement that exempted the A588 material from a prequalified status. The welding procedures would be acceptable under a prequalified status of AWS D1.1 except for omission of a specific travel speed range. The travel speed is indirectly specified and limited by the requirement for a stringer bead technique when possible and a torch oscillation or weave not to exceed 1/4". Therefore, this is not considered a significant item. The A588 material procedure qualifications were performed in accordance with ASME Section IX and as allowed by Section IX a groove weld in the flat position was used to support the procedures. When these procedure qualifications are applied to AWS D1.1, it results in unqualified procedures. The major resulting deficiencies were the vertical, horizontal and overhead positions not qualified, amperage range unqualified, voltage range unqualified, bevel angles less than 35^{0} unqualified, and tensile dimensions incorrectly machined. The E70T-1 electrode wire used is primarily intended for flat and horizontal position welding, but out of position welding with electrode wire diameters less than 3/32" are possible if used on the lower end of the manufacturer's recommended amperage range. The amperage and voltage ranges specified are in accordance with the manufacturer's recommendations which complies with AWS D1.1 under a prequalified status. However, the higher end of the amperage range if used in out of position welding as allowed could be expected to cause loss of puddle control. This could result in overlapped beads, inclusions, porosity and non-fusion. The extent of possible defects would be dependent upon the individual welder's skill and attending circumstances. It is estimated that the width or depth of possible defects would be 3/8" maximum per weld bead. The evaluation and effect these possible defects may have on the load bearing capacity or potential for fracture of the SSW are enveloped by the structural assessment in subsection III.D of this report. The weld position, travel speed, amperage range and voltage range must be considered with regard to applied heat input and the effect on notch toughness and tensile strength of the weld. The travel speed was controlled to a degree by the procedure requirement for basically stringer beads and in conjunction with a need to operate at a relatively low amperage for puddle control. The resulting heat input would be controlled to a reasonable level. It is, therefore, considered that the heat input was not varied enough to degradate the weld properties. The bevel angle deficiency is not considered significant as the joint designs used are as allowed by AWS D1.1 and weld soundness would become a factor of welders' abilities. The procedure qualification tensile specimens were machined to a width of 1.5" nominal instead of 1" nominal as required by the coupon thickness. This is not considered a significant item as the weld tensile properties have been adequately represented.

ESW

All the ESW procedures used for the SSW welding were considered to contain AWS D1.1 deficiencies. The major concern is no qualification records and therefore no mechanical or weld metal tension tests for the use of EM12K (Linde 29) bare electrodes with A588 base material which would verify that the weld would produce a yield strength of 50,000 psi minimum. Other concerns involve provisions in the welding procedures that are not fully qualified by mechanical or soundness tests.

The full thickness range specified in some procedures is not qualified by bend and tension tests. The mechanical and chemical properties of an electroslag weld depends upon the type and thickness of base material, the welding consumables composition, and the welding parameters. Therefore, a change in base metal thickness affects the welding parameters and dilution rate which will affect the weld form factor and chemistry which may alter the mechanical properties. The AWS D1.1 Code recognizes the effect of base material thickness by limiting the qualified thickness to 0.5T to 1.1T times the test thickness. The approach used by Leckenby on the qualifications to accommodate a change in base metal thickness by performing a supplementary coupon of different thickness and nondestructively examining for acceptance is incorrect and does not evaluate the change in mechanical properties involved with a thickness change.

The full amperage range of some procedures are not qualified. AWS D1.1 allows a change in welding amperage of 20%. Some procedures exceeded the qualified amperage by 1%. With the use of a 1/8" diameter electrode over 400 amps, as is the cases involved, an increase in the amperage increases the deposition rate and also decreases the weld form factor which results in a lower resistance to cracking and weld centerline inclusions or lack of fusion due to the dendritic grains meeting at an obtuse included angle. The weld form factor is the ratio of the weld pool width to its maximum depth. An increase or decrease in the amperage is not detrimental providing the welding voltage is correspondingly adjusted so that proper fusion and a high form factor is maintained. Amperage and voltage combinations that result in a low form factor could result in crack-like defects through the weld.

Changes in joint root openings are not qualified in some procedures. AWS D1.1 allows a change of 1/4" in the root opening from that qualified. A change beyond the 1/4" requires a supplementary test with the new root opening to be qualified by nondestructive examination. The purpose of the supplementary nondestructive examination is to determine if a sound weld is achieved with a given procedure when the root opening is increased or decreased. An increase in the root opening increases the form factor which raises the resistance to cracking. However, a large increase in the root opening in conjunction with similar parameters may result in a lack of fusion or slag entrapment along the side wall. These defects could be intermittent or continuous with weld length and typically shallow to 1/2" in the through-thickness dimension.

Changes made to design of molding shoes from fusing to non-fusing are not qualified in some procedures. The types of molding shoes involved are copper both sides, copper one side and fusing steel backing the other side, and fusing steel backing both sides. A change in the type or design of molding shoes from that in the qualification requires supplementary testing with nondestructive examination to determine if the change in the molding shoe with a given procedure will produce a sound weld. A procedure with parameters adequate with steel backing may produce non-fusion at the corner edge when used with copper backing if the voltage is not increased enough to increase the depth of fusion to overcome the chilling effect of the copper backing. A change from copper backing to steel backing may result in non-fusion or slag entrapment at the corner edge if the flux burden and resultant slag depth is excessive. These types of corner edge defects could range in depth from a slight undercut appearance to possibly 1/2".

Due to the extent of the ESW procedure deficiencies, instructions were issued to the 215 Contractor to have qualification tests performed for the parameters specified in the ESW procedures. It must be noted that the potential ESW procedure related defects postulated above were not found in the SSW welds by recent UT examinations (refer to subsection III.C of the report). With respect to the EM12K electrode and A588 base material qualification, strength property concerns do not exist. The design load calculations of subsection III.B resulted in maximum design stresses for the SSW being less than 18,000 psi.

PROCESS SUMMARY

The main concern for Leckenby welding procedures are the deficiencies associated with the ESW process. The deficiencies identified for the SMAW and FCAW processes are not considered to have significant impact as discussed above. The postulated defects are believed to be few in number as the recent MT and UT examinations of welds (refer to subsection III.C of the report) did not disclose defects as proposed. Based on the Task Force investigation, it is concluded that due to the examinations performed and the large design margins available, the existing welds in the SSW are acceptable without concern for structural integrity due to welding procedure deficiencies.

CONCERN NO. 24

Based on SSW Certified Material Test Report (CMTR) discrepancies noted by the 215 Contractor (WBG), the Supply System and Burns and Roe, concern arose with respect to the completeness and correctness of these documents.

BACKGROUND

A review of all available SSW CMTRs in conjunction with the SSW material traceability logs and other documentation identified 26 missing CMTRs. Five of these CMTRs have been located by Leckenby and transmitted to WBG. Additionally, numerous deficiencies have been identified in the CMTRs submitted by Leckenby.

CONCERN RESOLUTION

Eighteen of the missing CMTR numbers were determined to be associated with non-existent certifications. The numbers were originated from observation of missing CMTRs from the CMTR consecutive number list, e.g., 1, 2, 3, 5, 6, etc., (4 not included). The missing CMTR numbers are not associated with material in the SSW.

The remaining three CMTRs are missing and Leckenby is currently reviewing their records for these documents. One of these CMTRs, No. 196, is associated with pipe whip support girder material, not the SSW. No. 245, is associated with plate material used to bolt SSW ring segments together prior to welding (after welding, these plates serve no necessary structural function). As such, these 2 missing CMTRs do not structurally affect the SSW. The third missing CMTR is associated with an electrode used in the SSW. SMAW welds made using the subject electrode have been tested using a Clandon metascope. This instrument has established that no chromium exists in the welds, and as such, it is believed that the deposited weld filler metal is E70XX series, since no E60XX series electrode was selected for use in the SSW. It is believed with reasonable confidence that the missing CMTR is for E7018 electrode. Leckenby is currently pursuing the missing documentation with the electrode supplier. The heat number is known, 630R.

When/if the 3 missing CMTRs are found, they will be submitted to WBG for the standard review and documentation program.

The disposition of deficiencies identified in the available CMTRs will not affect the conclusion of the SSW structural assessment. This statement is based on the following:

- Nine deficiencies are associated with accessible bolts, washers, and cotter pins in the SSW penetration door assemblies,
- Eight deficiencies are associated with accessible bolts, washers, nuts and shim material for the attachment of pipe whip restraints to the SSW, and
- One of the deficiencies is associated with accessible cotter pins in the stabilizer truss assemblies.

Resolution of these deficiencies, e.g., replacement, can occur by the normal engineering disposition process and not change the structural conclusions in this report.

- Six deficiencies are associated with bolts used to connect ring segments in the SSW prior to welding. Subsequent to welding the ring segments together, the bolts serve no structural design function.

- Three deficiencies are associated with weld filler metal for which recently transmitted CMTRs appear to resolve the missing or erroneous information.

- One CMTR is missing for backing bar material used with A588 base material. Review indicates that the backing bar material is A36 or A588. Either of these materials are acceptable. In addition, the backing bar is not part of the design weld strength.

- One heat of A36 plate material was recorded to have a yield strength of 35,500 psi. The minimum yield strength for A36 material should have been 36,000 psi. Based on the design stresses in subsection III.B, this heat of A36 has been evaluated to have no structural significance for the SSW.

The above deficiencies will be resolved by the normal engineering dispositon process.

CONCERN NO. 25

Based on a Quality Assurance review by the 215 Contractor of Leckenby documentation, it was determined that two weld maps of the SSW had not been submitted.

BACKGROUND

Review of the Leckenby weld maps by the 215 Contractor identified that weld maps WF-205 and WF-253 had not been submitted. The 215 Contractor requested from Leckenby an index of the weld maps and the associated revision data to assure an accurate weld map list was available for further documentation reviews.

CONCERN RESOLUTION

Weld map WF-205 illustrates door stop weldents. NCR 5009 was issued on this missing weld map.

Corrective action for NCR 5009 requires the six related door stops to be removed from the SSW and reattached per the 215 Contractor's Work Procedure 84.

Weld map WF-253 was transmitted by Leckenby to the 215 Contractor and has been informally submitted to the Task Force. The drawing pertains to pipe whip support girders. Weld map WF-253 will be reviewed by the normal Quality Assurance and engineering process. No further action is necessary for this concern.

CONCERN NO. 26

Based on defects identified in the SSW by the 215 Contractor, general concern arose with respect to the SSW weld quality. One action item that resulted was a review of Leckenby documentation to ascertain from a design standpoint the completeness and correctness of the SSW welding.

BACKGROUND

The documentation review was performed by Burns and Roe and consisted of 166 Leckenby weld maps. All weld maps were reviewed to confirm that structural members included on Burns and Roe engineering drawings were included on Leckenby weld maps. Additionally, 20 of the weld maps were further reviewed to check that each Leckenby weld description was correct when compared to the appropriate Burns and Roe weld design drawing.

CONCERN RESOLUTION

All structural members and their associated welds were documented on the Leckenby weld maps. Six engineering related concerns were identified and dispositioned as follows:

- Four Leckenby weld details did not duplicate the preparation associated with the weld procedures. Investigation of these welds found negligible effect on the structural integrity of the connections. Two welds indicated no root opening, rather than a 1/4 inch or 3/8 inch root. A review of the original associated design margin indicated no structural concern. The other two welds had an angle that did not match the weld procedure. Either weld angle developed the full strength of the member and therefore did not effect the connection.

- The remaining two weld details did not match the Burns and Roe engineering drawings. These welds were not structural welds, but seal and reinforcing fillet welds. These welds were not included in the design of member connections and therefore have no effect on the SSW integrity.

Based on the small number of engineering related deficiencies identified in this review (six in approximately 1300 welds), and the fact that no structural concerns were identified, no further action is planned for this concern.

CONCERN NO. 27

Lamellar Tearing - Implications For The SSW Structural Evaluation

NRC Noncompliance Status Report 038-(80-06) (6) (5/20/80) identifies a concern over the potential for failure of SSW attachment welds caused by operational or welding stresses and low short transverse ductility of the A36 material.

The response to this concern has been expanded to cover the potential for lamellar tearing in the SSW as a whole, and the potential for failure in service caused by lamellar tears, laminations or low short transverse ductility.

I. BACKGROUND

Lamellar tearing (LT) is a form of cracking which can occur when plate or forging steels are strained transverse to the primary rolling or forging planes. The most frequent form of LT occurs during welding and is caused by residual stresses (or strains). It is also possible that lamellar tears could be initiated by applied loads, though only one instance was found in the literature.

Many types of material and weld joint designs are potentially susceptible to tearing. However, only in relatively few instances is tearing observed. Furthermore, a recent survey (Reference 1) has shown that only one instance of service failure can be attributed to the presence of a lamellar tear. However, when LT is encountered during fabrication it is usually repaired; often at substantial cost. Also, it is prudent to take precautions against LT during the design and fabrication of structures and pressure vessels.

It is usually difficult to specifically define a set of conditions which will result in (or conversely eliminate) LT.

The factors promoting LT are known in qualitative terms. However, the absolute values required to give LT and the interactions between variables are not well understood.

It is within this context that a concern has been raised over the possibility of lamellar tearing in the sacrificial shield wall (SSW).

This concern is addressed as follows:

A. The potential for LT in the SSW structure has been considered in terms of:

- o Material,
- o Joint design,
- o Erection sequence, and
- o Welding process.

B. The measures taken during design and fabrication to prevent LT have been assessed.

C. The inspection methods used to detect LT during and after fabrication have been identified and the results reviewed.

D. The potential for LT during the welding of attachments to the SSW has been addressed.

E. The effect of possible LT's on the performance of the SSW have been evaluated.

F. Conclusions as to the overall implications of this concern on SSW integrity have been made.

In addition, two related concerns have been addressed. These are the effect of plate laminations and low short transverse ductility on structural performance.

II. DEFINITIONS

LAMELLAR TEARING has been defined above.

LAMINATIONS are planar plate or forging defects which lie parallel to the primary rolling or forging plane of the material. They result from the rolling out of ingot defects. Laminations resulting from blowholes, blisters, exogenous inclusions, piping, etc., are macroscopic discontinuities. Smaller laminations, or laminar inclusions, result from the rolling of indigenous inclusions--sulphides or oxides of silicates. Lamellar tearing may, or may not, be associated with laminations.

SHORT TRANSVERSE DUCTILITY (STD) is a condition where the ductility at failure measured transverse to the rolling plane is low. Again this may or may not be associated with laminations, However, it does indicate a susceptibility to LT. The degree of susceptibility being inversely proportional to the ductility. An STD value less than ten percent indicates high susceptibility to LT.

III. DISCUSSION

A. Potential for LT in the SSW

The SSW is fabricated from ASTM A36 rolled sections and plate and ASTM A588 plate. Thicknesses are up to three inches with most material 1½ to 2½ inches thick. Susceptible weld joint designs include fillet welded T-joints, butt welded T-joints, and corner joints. The welding processes used were shielded metal arc, flux cored and electroslag.

No supplementary controls on plate chemistry were specified and the sulphur levels in the A36 range up to 0.045 wt%. Also, no volumetric examination was specified.

Thus, there is some potential for LT of T-and corner joints within the SSW. However, there have been no reported cases of LT associated with electroslag welds (Reference 2).

Some of the more susceptible joints are identified in Attachment 1 (drawing details). Some of the SSW joint details were changed to minimize LT. These changes are discussed further in the next section.

Given some susceptibility to LT produced by the joint type and the material, the level of risk is influenced by the weld sequence. The sequence used on the SSW was not very detailed (Attachment 2). However, from the general erection sequence we do know the order in which the structure was put together.

Each ring was assembled separately and then the complete wall put together in the field. The potential for tearing of a given joint will depend on the erection sequence. Thus, the first welds attaching the columns to the base plates, or ring members will be relatively unrestrained. However, closing connections between beams and columns or between the columns and the top ring member could be more highly restrained.

Given the difficulty in predicting go-no/go conditions for LT (refer to I of this concern) and the lack of specific information on the erection sequence, it is difficult after the fact to judge whether LT would or would not have occurred in a given joint.

B. Precautions Taken During Design, Fabrication and Erection

During the design of the weld details for the SSW a number of changes were made to minimize the potential for lamellar tearing (see Attachment 3). These changes related primarily to the fabrication of the built-up columns and beams.

In most instances the joint designs used were of the type recommended to minimize tearing in that the bevel was placed on the susceptible member in a corner joint. One exception is member 4 where the bevel is completely on the intersecting member.

However, in all of the box sections the joint design is such that any tearing would propagate to the end of the plate with a high probability that it would be detected visually.

Member 9 is a built-up beam and the design required that the flange faces be grooved and buttered to prevent tearing under the flange/web welds.

Thus, it is concluded that there is no reason to suspect a major problem with LT in the built-up beams and columns.

However, in assembling the wall, the ring beams and columns are joined by welding. Also, there are numerous internal stiffeners welded into columns and also spanning column to column.

Amongst this set of weld details there are many with a susceptibility to LT (see Attachment 1). No precautions were apparently taken to prevent LT in these joints.

C. Inspections to Detect LT

1. During Fabrication

The 215 Contract (Section 5B, paragraph 5.4) required ultrasonic testing (UT) of electroslag welded joints in the SSW for lamellar tearing. The joints were to be examined by straight beam UT per ASTM A435-74.

The Leckenby lamellar tearing UT examinations, however, were performed prior to this contract modification requirement. This UT was primarily performed due to concern for lamellar tearing at tee-joints where buttering, an original preventive measure, had not been used. The UT was performed per Leckenby Quality Control Procedure (QCP)-8.0. The defect repair criteria in QCP-8.0 is substantially more stringent than the specification and ASTM A435 three-inch-diameter circle criteria. QCP-8.0 defect acceptance criteria states:

- No cracks, lack of fusion, or incomplete penetration are allowed, and
- No linear type discontinuities are allowed if the signal amplitude exceeds the reference level and the discontinuities have lengths which exceed

  1/4 inch for T (a) and up to 3/4 inch, 1/3T for T from 3/4 to 2¼ inch, and 3/4 inch for T over 2¼ inch.

(a) T is the thickness of the thinner portion.

Leckenby performed 129 straight beam UT examinations for LT. Of these, eighty-one were on ESW and forty-eight on FCAW. Also, two angle beam examinations were performed on ESW and fifty-eight on other processes. The number of lamellar tearing UT examinations performed by Leckenby exceeded the specification requirements. No lamellar tearing was found.

This sample consisted of about six percent of ESW (83 of 1273) and about 1.5% of all welds on the SSW. Considering that many of the weld joints are not susceptible to lamellar tearing, the sample percentage of susceptible welds will be much higher.

2. UT Examinations Performed for the Task Force

All SSW exterior, accessible electroslag welds have been UT'd. As a part of this examination the base plate six inches on either side of the weld was scanned for laminations or lamellar tears. A total of seventy-three welds were examined. Of these twenty-seven were potentially susceptible to LT (Type A in Figure III.C.1); thirty-four were not susceptible (Type B); the details of twelve are not readily available.

None of the welds were rejectable for LT.

In only one instance was a lamination detected in the material adjacent to the weld.

In addition, seven double bevel, full penetration, T welds made using the flux cored arc process were examined by UT. The weld detail is shown in Figure 27.1 of this concern. No laminations or LT was detected.

3. Ultrasonic Examination Performed as a Result of Cracks Associated With the Radial Beam to SSW Connection

All radial beam to SSW welds were inspected and repaired after discovery of a cracking problem associated with the original attachment electroslag welds.

At the time of discovery of the crack eight welds had been made. All were UT'd and repaired as necessary. In addition, all other attachment areas were UT'd before attachment of the remaining beams. An area eight inches to all sides of the connection region was included.

The areas were then buttered and MT'd. After completion of the beam/SSW connection the welds were again UT'd. This inspection was performed after seventy-two hours had elapsed from completion of the weld.

In all these inspections no evidence of lamellar tearing was found.

4. Conclusions Related to Inspections

A significant number of volumetric examinations of welds susceptible to lamellar tearing have been made during and subsequent to fabrication of the SSW. These include welds attaching members to the outside of the SSW. No evidence of LT was detected.

D. Potential for LT Occurring During Welding of Pipe Whip Restraints, and Other Attachments, to the SSW

The welding attachments to the SSW since 1977 have been to the controlled procedures of Work Procedure-84.

Prior to attachment the area of the SSW is examined by MT. The complete attachment area is then buttered and re-examined.

All welds are made using an approved sequence.

All welding is performed at controlled preheat. Intermediate passes are peened and MT examination performed on the root pass and at completion. Welding heat input is also controlled.

Initial experience with the repair and subsequent installation of the radial beam to SSW connection welds gave confidence that even under restrained conditions these procedures were adequate to prevent LT. This confidence resulted from extensive UT of the attachment areas before and after welding (see previous section of this concern).

It is concluded that adequate precautions to minimize LT under attachments have been taken.

E. Influence of LT, Laminations and Low Through Thickness Ductility on Joint Performance

1. Laminations or Lamellar Tears

Laminations and lamellar tears will have a similar effect on joint performance.

It is worth reemphasizing at the outset that only one instance of service failure from LT or a lamination has been reported.

There has been little work done on the effect of this type of discontinuity on joint performance. However, the effect of LT/laminations on structural integrity can be addressed in the same manner as for other cracklike defects provided the reduced through-thickness properties of the material are considered (Reference 3).

Though the Charpy impact energy and fracture toughness of the material in the short transverse direction is lower than in the longitudinal/transverse directions, the nil-ductility transition temperature (NDT) is not increased significantly. The main difference is in the upper shelf energy. Thus, at a significant margin above the NDT the fracture mechanism in the short transverse direction is low energy ductile tearing. Provided the structure operates at an adequate margin above the NDT, unstable fracture by cleavage under elastic loading will not occur. Plastic strains and displacements will be required to cause fracture.

Under these circumstances the controlling failure mechanism is probably plastic collapse. Unpublished experimental work by the Welding Institute supports these conclusions. Their findings are summarized in Figure 27.2. The joint types used in the testing are shown in Figure 27.3.

The tests were performed on a material which had a short transverse Charpy impact energy of 15 ft. lbs. At the test temperature some cleavage was observed, but failure was predicted by plastic collapse analysis.

The two lines shown on Figure 27.2 represent failure predictions based upon such analyses. Three expressions were used:

$$\sigma_{arm} = \sigma_y \left(1-\frac{2a}{D}\right) \quad - 27.1$$

$$\sigma_{arm} = \sigma_y \left(1-{}^{2a}/_{W}\right) \quad - 27.2$$

$$\sigma_{arm} = \sigma_{Flow} \left(1-{}^{2a}/_{D}\right) \quad - 27.3$$

Where: σ_y is the yield stress,

$\sigma_{Flow} = \dfrac{\sigma_y + \sigma_u}{2}$, and

σ_u = ultimate tensile stress.

Refer to Figure 27.3 for other parameter definitions.

Equation 27.3 accurately predicts failure for configuration (B), (Figure 27.3), but is very conservative for configuration (A) where the width of the weld across the toes exceeds the thickness of the branch member.

Thus, it is considered that the influence of any laminations or lamellar tears are covered by the fracture and plastic collapse assessment presented in this report.

In addition, McDonald has derived an elastic-plastic fracture model to predict the effect of laminations on joint performance (Reference 4).

McDonald's data for A36 and A588 shows that even with large laminations considerable plastic deflection is required to produce failure. In addition, in spite of the very large laminations, the residual strength of the joints was substantial and in excess of half the nominal yield, even with laminations several inches wide. Thus, with normal levels of elastic design stress, the potential for failure is low. This data also tends to support the Welding Institute findings.

The use of buttering on the outside of the SSW will also reduce the potential for failure from laminations or LT. The buttering distributes the applied strains over a much larger area of the base material, effectively the dimension W (Figure 27.3) is increased. Thus, the potential for failure for buttered joints will be even less than that for conventional joints.

2. Low Short Transverse Ductility

Low short transverse ductility promotes susceptibility to lamellar tearing. From 0 to 10% there is a potential for LT in lightly restrained structures, from 10 to 15% in moderately restrained structures and from 15 to 20% in highly restrained structures (Reference 2).

Low values (as low as 0 percent) have been reported from transverse tensile specimens. However, these results are pessimistic in that only a small area is sampled and the presence of inclusions or small laminations can cause failure at low strains.

Under extreme circumstances it could be visualized that service loads could cause a laminar failure in a steel which had low short transverse reduction in area. However, in the SSW service stresses in the susceptible areas are well below yield and thus plastic straining of the base material does not occur. Under these circumstances it is difficult to envisage the formation of lamellar tears. Tearing during welding occurs after significant plastic strains which are of the order of a magnitude higher than the elastic design strains. Even if a laminar tear were to initiate, further plastic strain would be required to cause failure as discussed in III.E.1 of this concern, with a significant additional margin against joint failure. Similarly, the use of buttering reduces this risk for the SSW attachments.

3. Conclusions with Respect to Effect of Laminations, LT or Low STD

It is concluded that the potential for failure initiating from LT, lamination or low transverse ductility is low. This is based upon:

- The low incidence of reported failures,
- Experimental data showing the need for high strains/deflections to promote failure from large laminations,
- Even with susceptible materials some plastic strain is needed to promote tearing and the tear must be propagated to cause joint failure. Thus, for elastically stressed joints there is little potential for failure caused by LT, laminations or low transverse ductility.
- The use of buttering reduces the potential for failure from laminations, lamellar tears or low short transverse ductility.

IV. CONCLUSIONS

- o There are a number of weld joint details in the SSW which are potentially susceptible to LT.

- o Inspections performed during and after fabrication indicate that there was no generic problems with LT in the SSW.

- o The potential for joint failure caused by LT, laminations or low short transverse ductility is low under elastic design stresses.

- o The use of buttering before making attachment welds to the SSW makes potential for LT under these welds very low.

- o The use of buttering reduces the potential for joint failure from laminations, LT or low ductility in the through-thickness direction.

- o The implications of LT, laminations or low short transverse ductility for SSW integrity is discussed further in the main body of this report. The conclusion is that there is no significant concern. This is based on the low probability of failure by elastic fracture and the multiple parallel load paths which preclude plastic collapse.

- o The overall conclusion is that there is reasonable assurance that failure of the SSW resulting from laminations, LT or low short transverse ductility will not occur.

References

1. NUREG-0577 (Comment issue)

2. Lamellar Tearing In Welded Steel Fabrication, The Welding Institute, 1972.

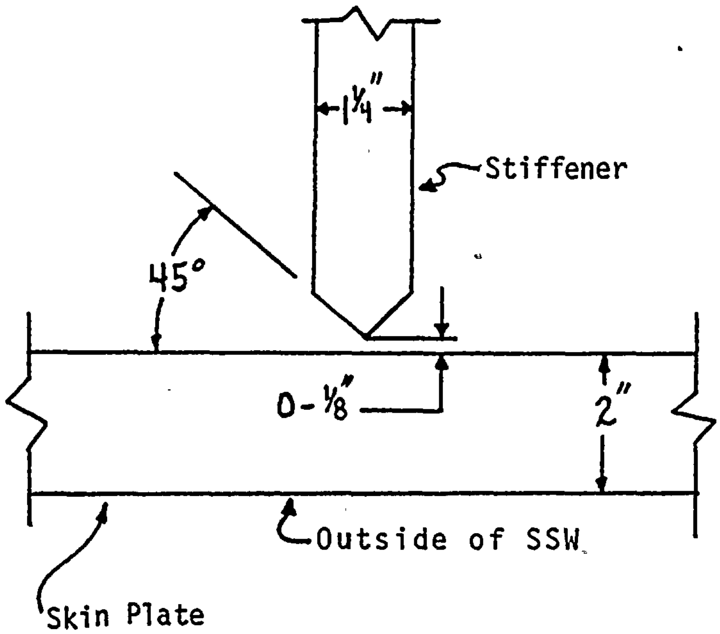
3. A.A. Willoughby, United Kingdom Welding Institute, private communication.

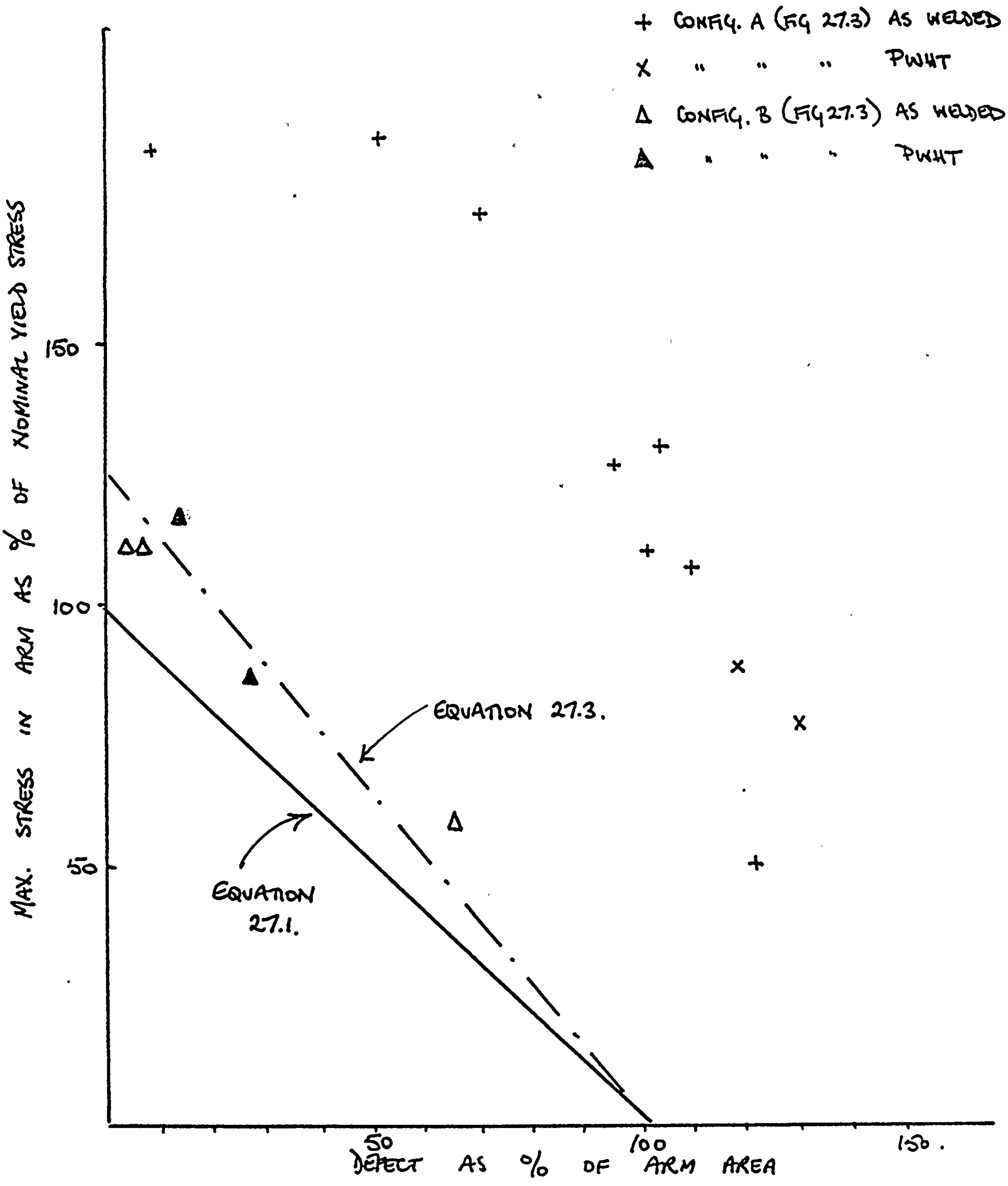
4. B.D. McDonald "Effect of Laminations on Moment Connection Capacity." ASCE Journal of the Structural Division.

FIGURE 27.1

LAMELLAR TEARING UT

FCAW TEE-JOINTS





<u>FIG. 27.2.</u> RESULTS OF TENSILE TESTS ON THE NEW CONFIGURATIONS SHOWN IN FIG. 27.3. (REF. 3.)

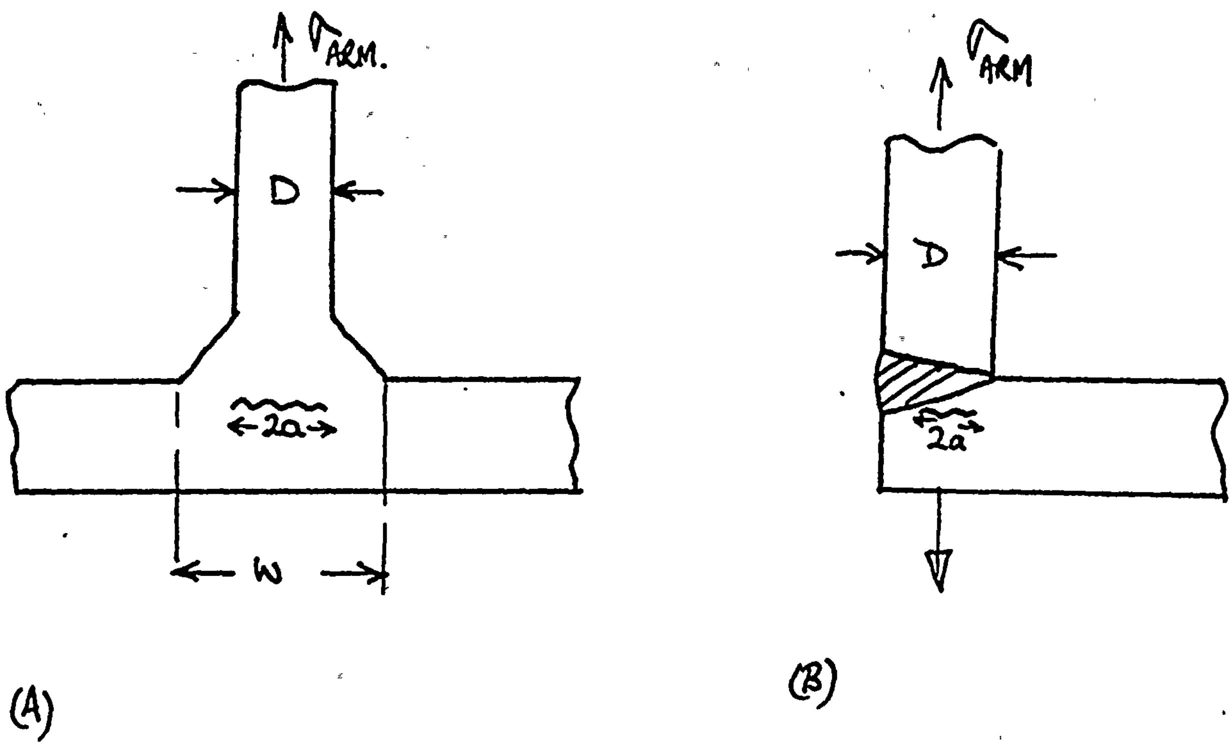


FIG. 27.3. JOINT CONFIGURATIONS USED TO GENERATE DATA SHOWN IN FIG 27.2.

Concern No. 27

Attachment 1

Typical details showing attachment of pipe whip restraint support steel to the SSW.

NOTE: Details xeroxed from Leckenby drawings:

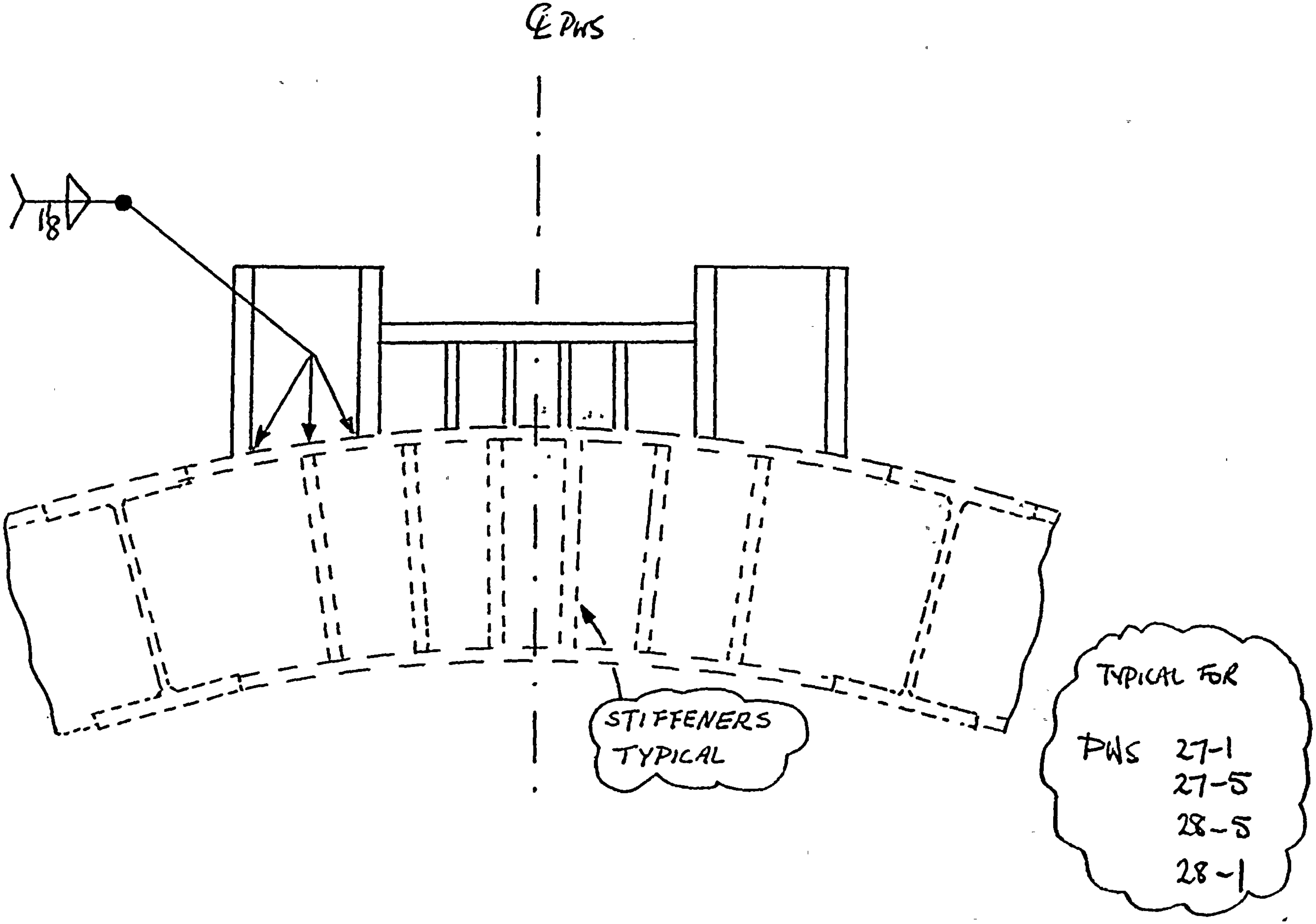
F272 Alt. 5

F273 Alt. 1

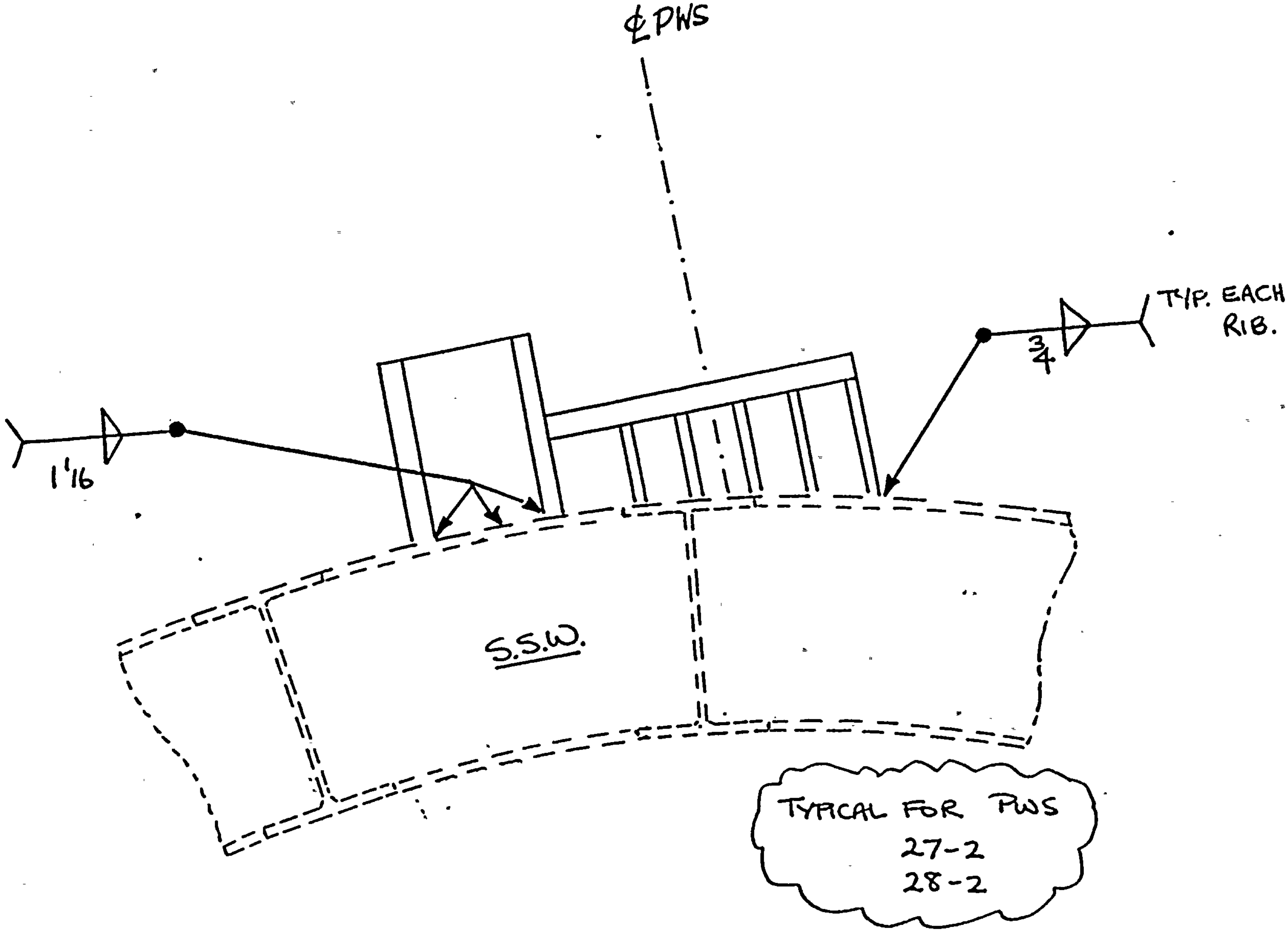
F274 Alt. 2

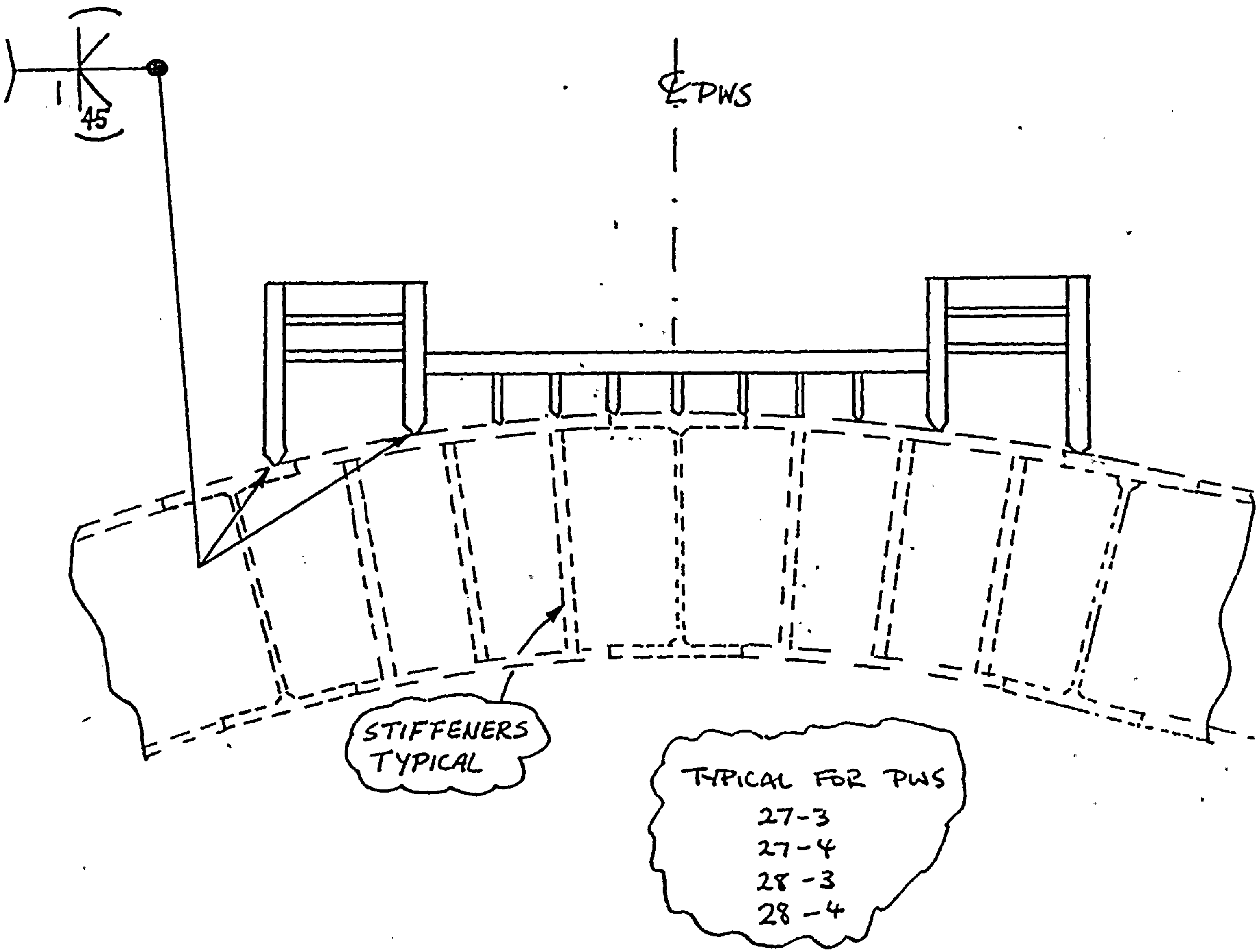
F275 Alt. 3

Typical stiffeners added.

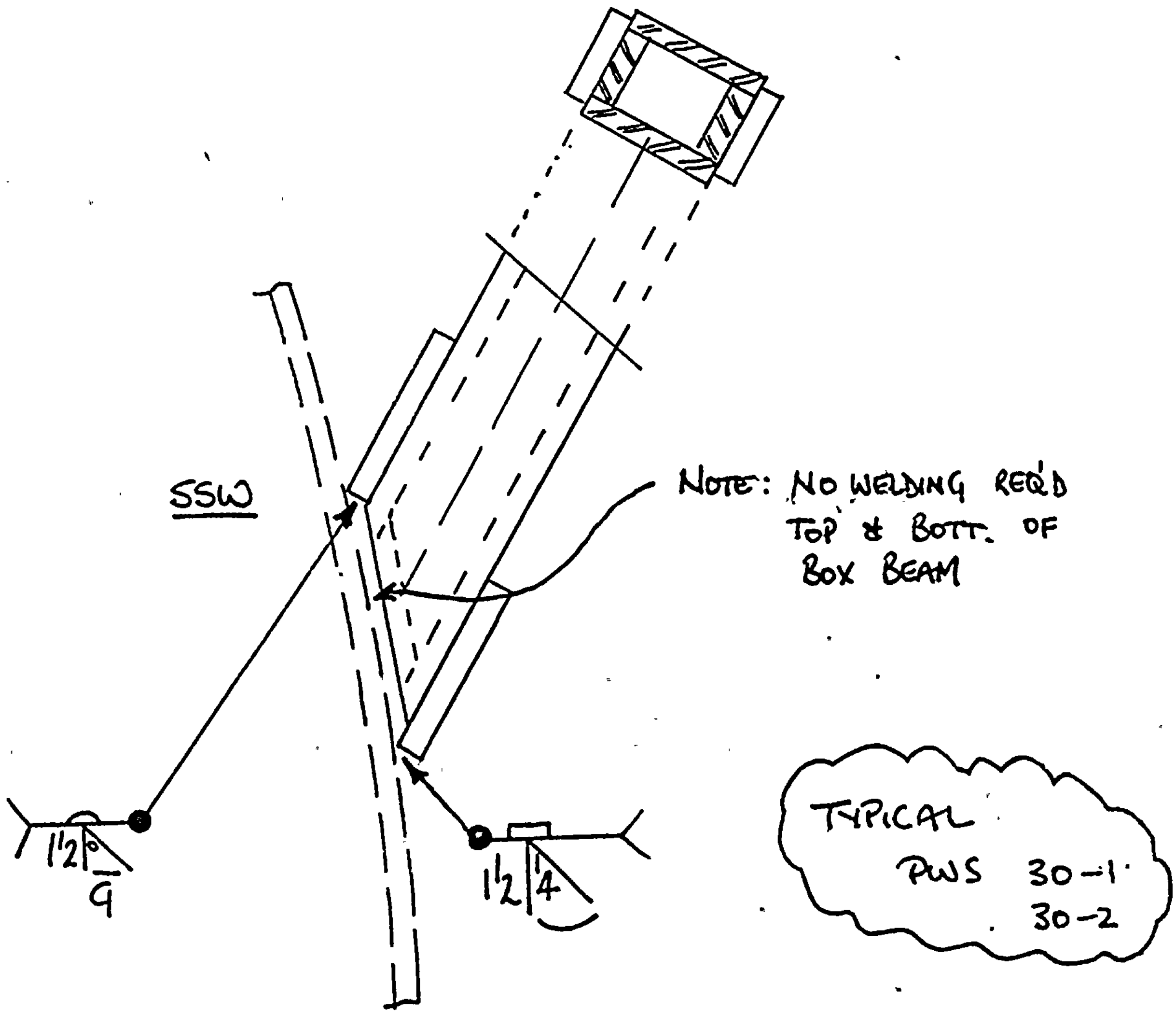


℄ PWS
1/8
STIFFENERS
TYPICAL
TYPICAL FOR
PWS 27-1
27-5
28-5
28-1


℄ PWS
TYP. EACH RIB.
3/4
1 1/16
S.S.W.
TYPICAL FOR PWS
27-2
28-2



45
℄ PWS
STIFFENERS TYPICAL
TYPICAL FOR PWS
27-3
27-4
28-3
28-4


SSW
NOTE: NO WELDING REQ'D TOP & BOTT. OF BOX BEAM
1½ 9
1½ 4
TYPICAL PWS 30-1 30-2

Concern No. 27

Attachment 2

SSW Welding Sequence Document (5 Sheets)

ATTACHMENT 2 2745 11th Ave. S.W., MAin 4-2377, Seattle, Wash. 98134 12-12

FROM THE DESK OF John Bowman DATE October 29, 1975

B. Mahoney, C. Montgomery, R. Holt, File 5757

TO: P. Moore, H. Wilson, G. Kopp, R. Gorman, B. Pittsenbarger, W. Vogl, C. Ahl

SUBJECT: Welding Sequence S.S.W.

10 102

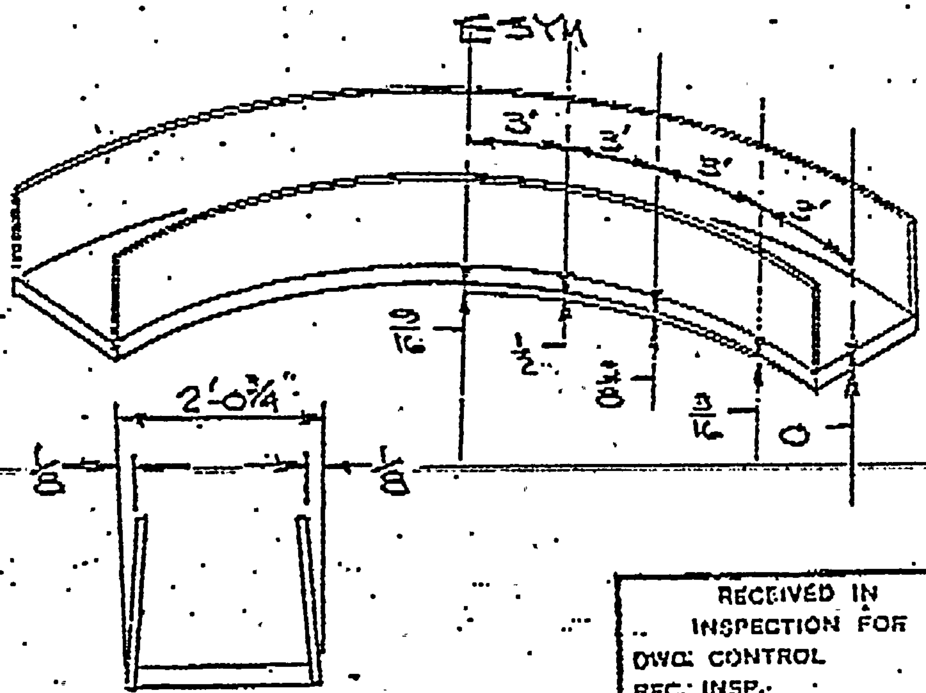
The following is a list of items that Professor Holt has recommended for fabrication of the SSW.

1. The base plate should be cut to a larger radius as the welding of the columns will cause it to shrink about .001"/1" of circumference. This is equal to 1.05 inches on the circumference or about 3/8" on the diameter. I assume that as the bearing plate has an equal amount of welding that the same shrinkage value would hold true for it.

   The drawings will not show this increase in diameter but the cutting diagrams will be revised to reflect it.

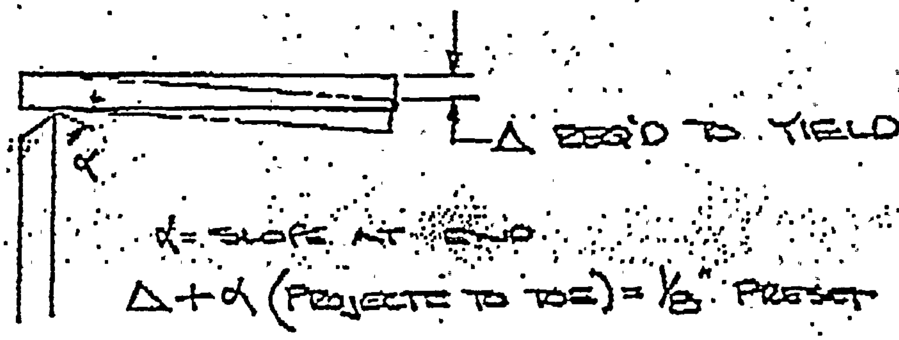
2. Ringbeam (2)

   The 3/4" base plate should be precambered 9/16" as shown below and the toe ends of the 1 1/4 plates should be preset 1/8" as shown.



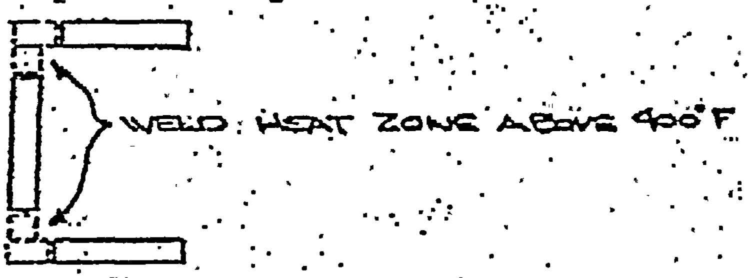
ATTN: MERL PARISH

The calculation for finding the required toe offset is as follows.



The calculation for the precamber in the 3/4" plate is based on a surface tension of 6000 PSI in the plate.

When calculating the moment of inertia for this section, the material in the weld area above 400° F is not used as it is in the plastic range.



3. Built-up Member (10)

In this type of column the N.A. is found and the welding is sequenced by using the moment arm from the weld to the N.A. to offset opposite welds.

On this member the first layer is made on the outside and then two layers on the inside, finish outside, finish inside.

This ring should be back stepped and the welding should be away from any diaphragms toward the center.

4. Additional information to follow on the other built-up columns and members.

5. Questions to be answered on the 2nd Ring Assembly.

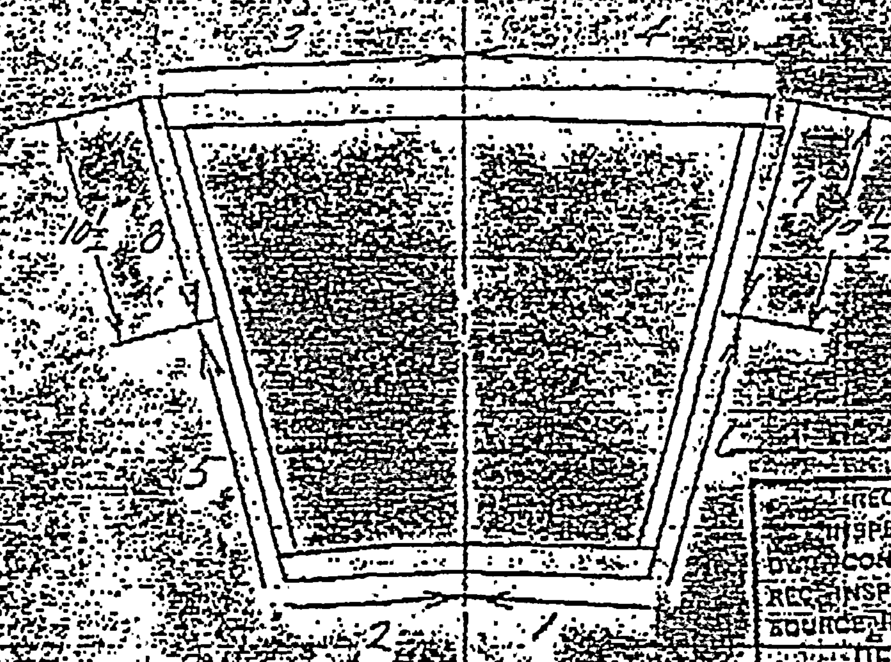
   a. Do we cut the Ring Beam to a longer diameter?

   b. Do we adjust the location of the anchor bolts to allow for this shrinkage of the base and bearing plates? I feel the template should be made to match the as built condition- the shear lugs and slots?

   c. Do we shim out the vertical column indexes on the assembly jig to match the 3/16" increase in the base plate radius?

6. Use sequences shown below for welding columns to base plates.

Built-Up Member (10) [illegible]



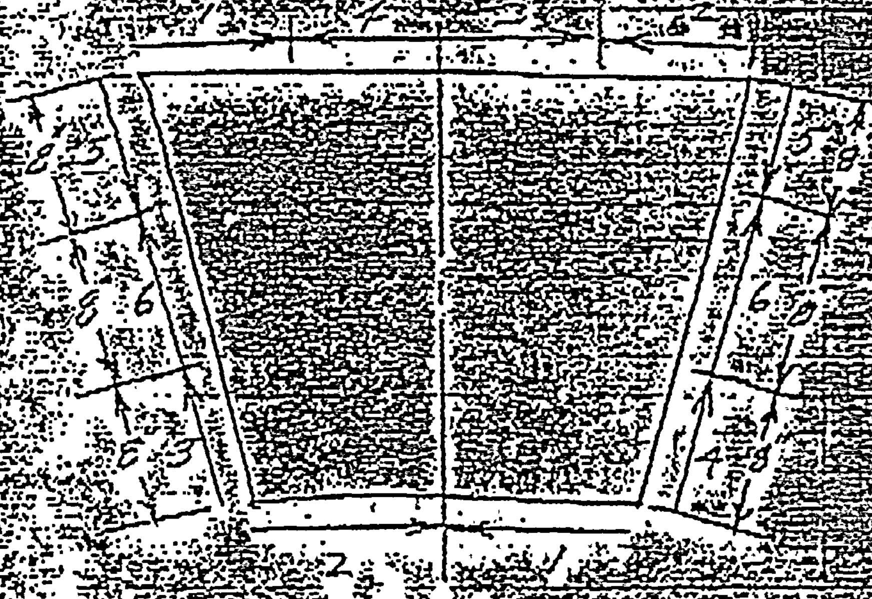
All Layers with F-CAW

Peen each layer

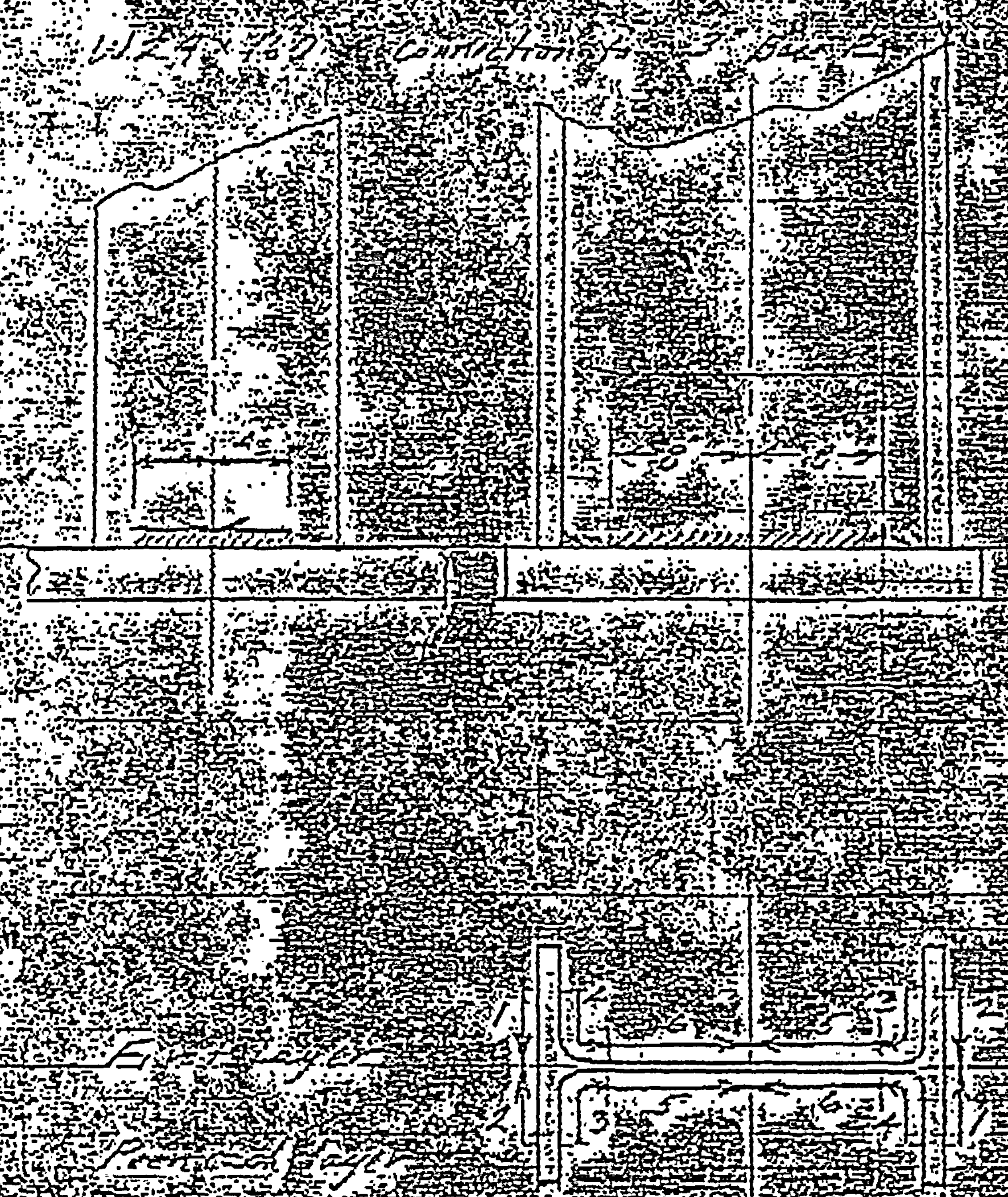
The last layer to be [illegible]

not against base metal

RECEIVED [illegible]
INSPECTION [illegible]
QUALITY CONTROL
REC. INSP. X
SOURCE INSP.
[illegible]
FOR REVIEW
INFO. ONLY
ANSWER REQ'D
QC RECORDS
[illegible]



All layers with SMA



Place all layers with fill above grille

The first layer to be between weld beads — not against base metal

Concern No. 27

Attachment 3

Revised SSW Weld Joints to

Prevent Lamellar Tearing (14 Sheets)

Leckenby

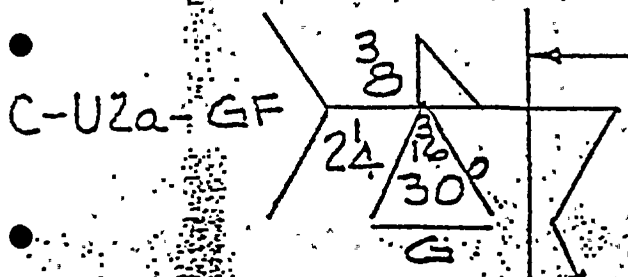
C.E.M. DATE .... ITEM BUILT-UP MEMBER (1)

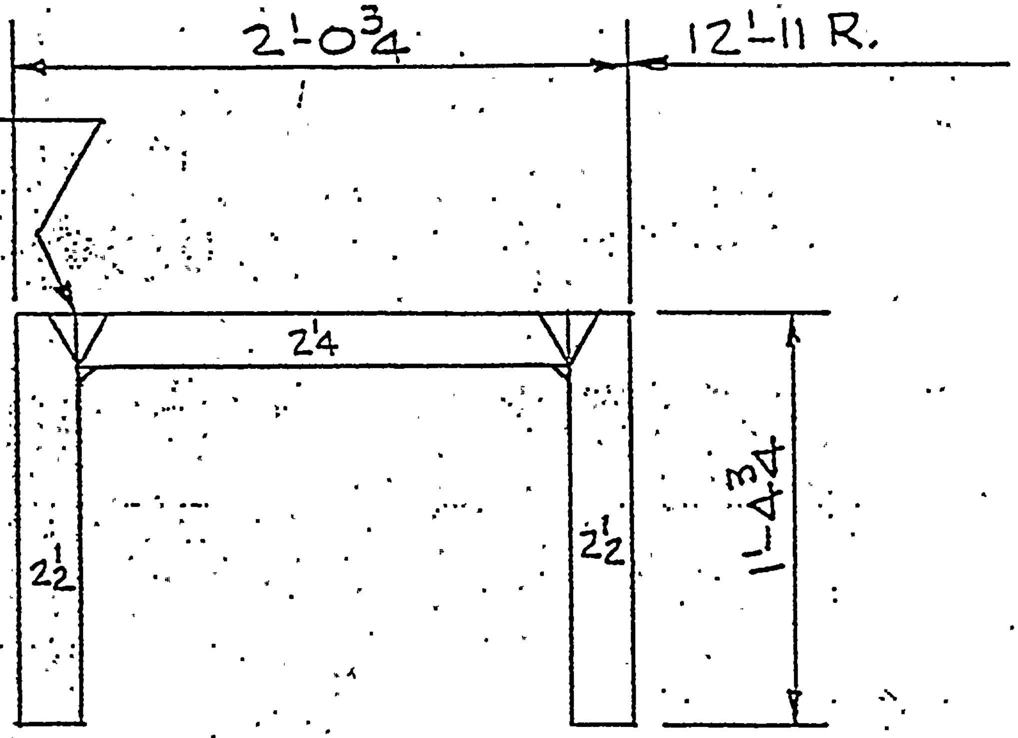
DATE .... JOB SAC WALL

LOCATION ....

SHEET NO. (1) ... OF ...

LECKENBY JOB NO. 5756 △1





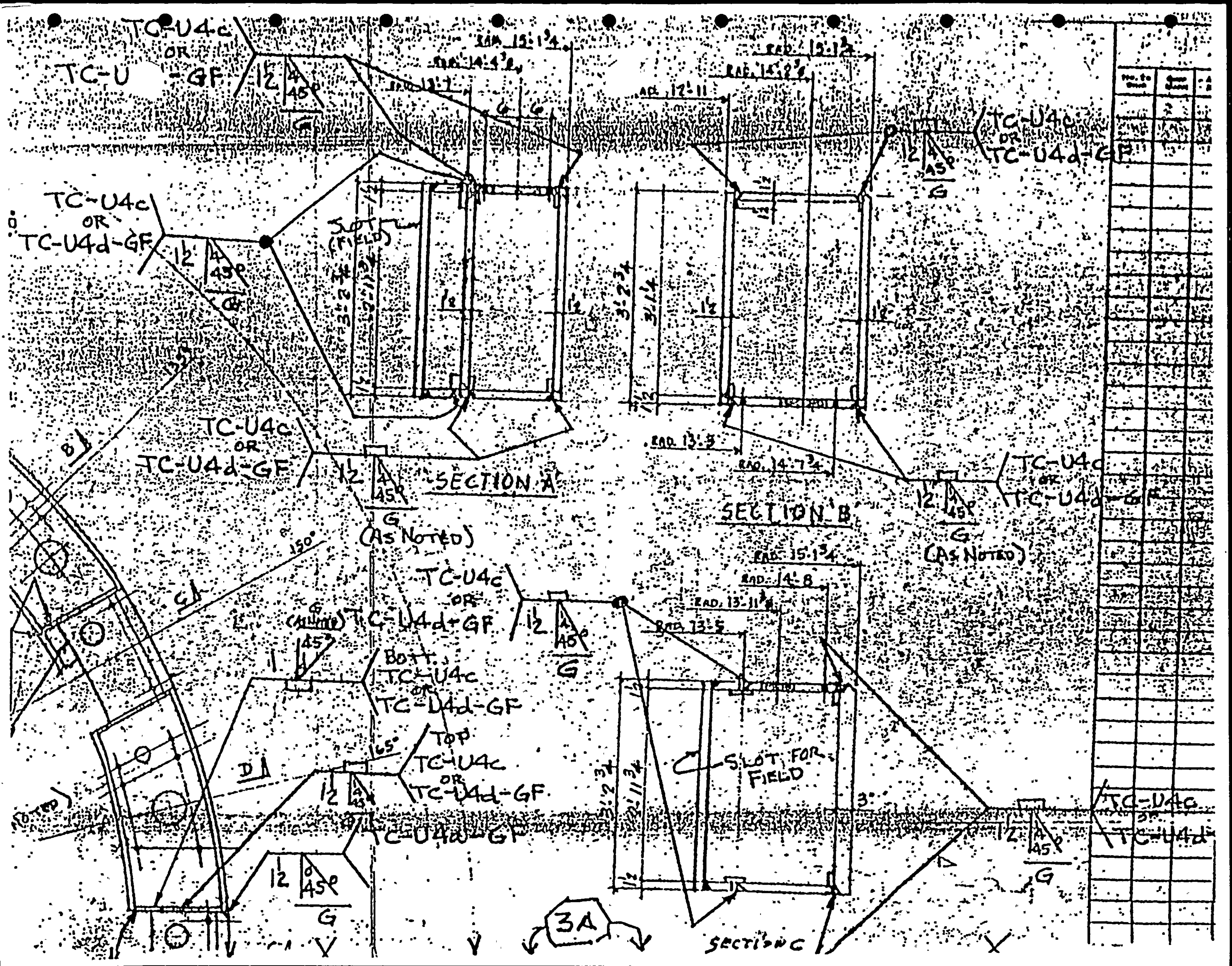
RADIAL BEAM
A588 STL.
ONE COMPLETE RING REQ'D.
REF. DWG. 5783

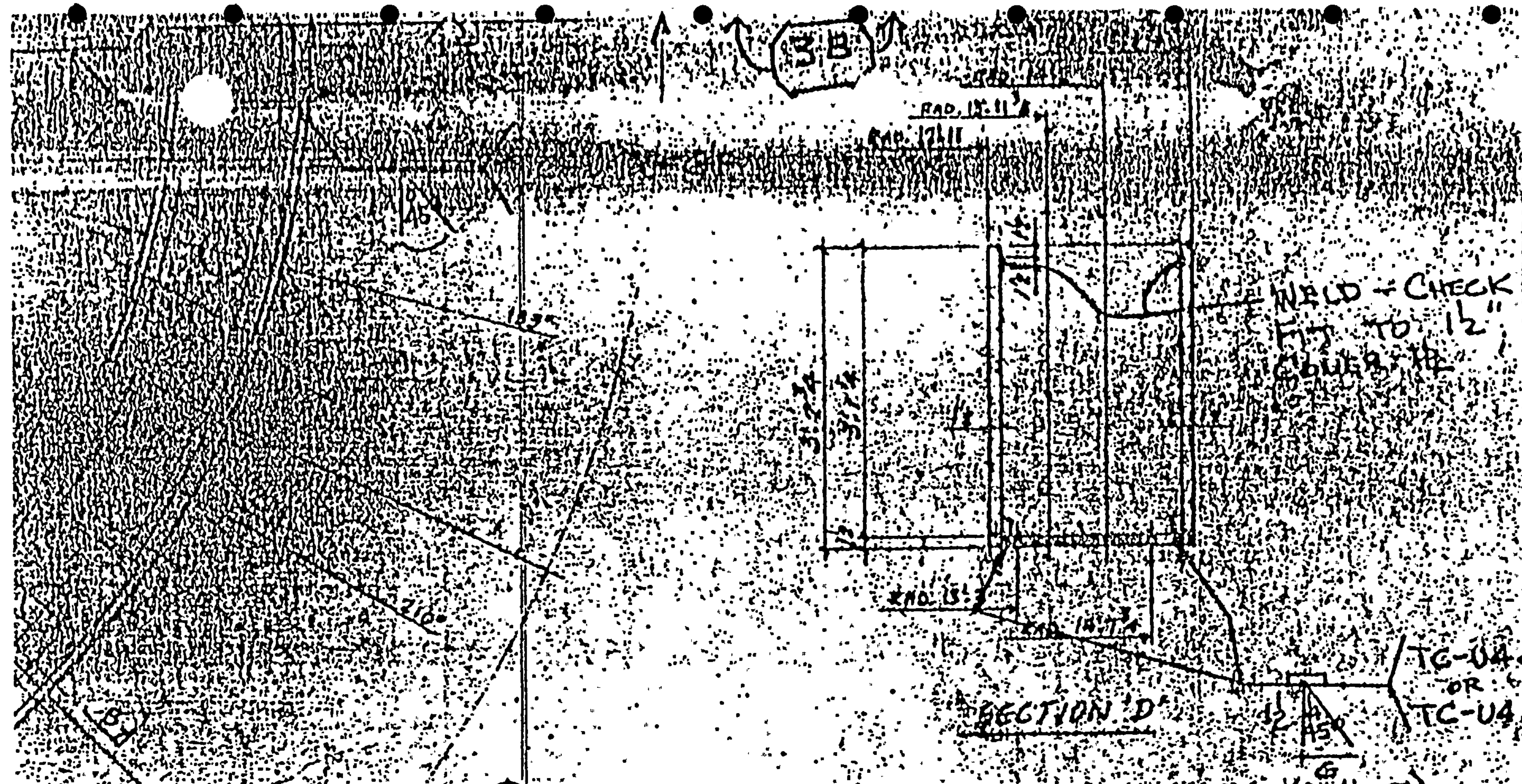
NOTE: GOUGE ROOT TO SOUND METAL PRIOR TO WELDING FILLET.

TO MARK SYVERSON 201-265-9500 (EXT. 327)
B.R WINTERS AVE. ORADELL N.J.
~~FROM HANFORD #2 (MATT GIANNINI)~~
SHEETS # (1) (3A)-(3B) (7) (10) (9) (11) (12) (14)
(TOTAL NINE (9) SHEETS)

△1 REVISED WELD & PREPARATION. ADDED NOTE.
C.E.M. - 7/21/75

ATTACHMENT 3


TC-U4c
OR
TC-U4d-GF
SECTION A
SECTION B
(AS NOTED)
SLOT (FIELD)
Bott.
TC-U4c
OR
TC-U4d-GF
TOP
TC-U4c
OR
TC-U4d-GF
SLOT FOR FIELD
SECTION C
3A



① WELD ALL BACK-UP BARS.

② BOTTOM ℄ TO BE CONTINUOUS W/ NOTCHES AS REQ'D FOR CHANGES IN OUTBOARD ℄ THICKNESSES & SLOTS @ INBOARD FACE.

ING BEAM ③

CERT. WELDERS	
SUP. REQ'D.	
END & EDGE DIST	
OPEN HOLES	
WELDS	
PAINT	
DEL. PROMISE	

LE(

2745 11TH AVE.

ITEM

Leckenby

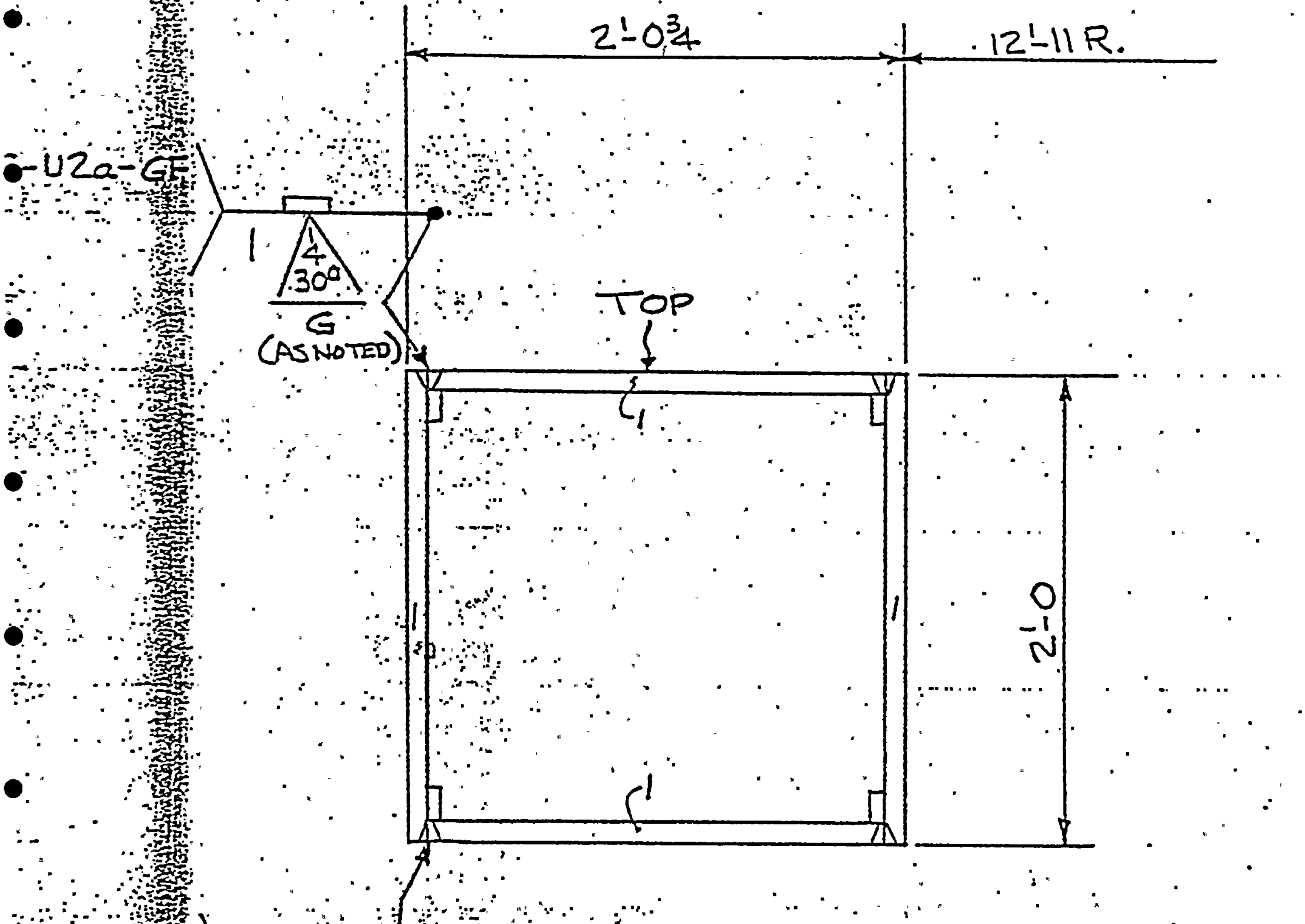
C.E.M. DATE ITEM BUILT-UP MEMBER ⟨7⟩

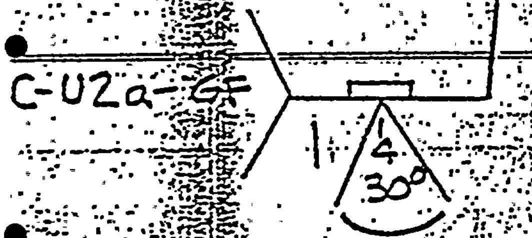
CHK. DATE JOB SAC WALL

TR. LOCATION

SHEET NO. ⟨7⟩ OF

JOB NO. 5756 ⚠1





RADIAL BOX BEAM
A36 STL.
6 REQ'D. - 4@ 7'± & 2@ 4'±
REF. DWG. S783 & S788

⚠1 REVISED WELDING - ALL JOINTS IDENTICAL W/ADDITION OF BACKING BAR TO BOTT. JOINTS.
C.E.M. - 7/21/75

LECKENBY COMPONENTS

BY C.E.M. DATE ______ ITEM BUILT-UP MEMBER (9)

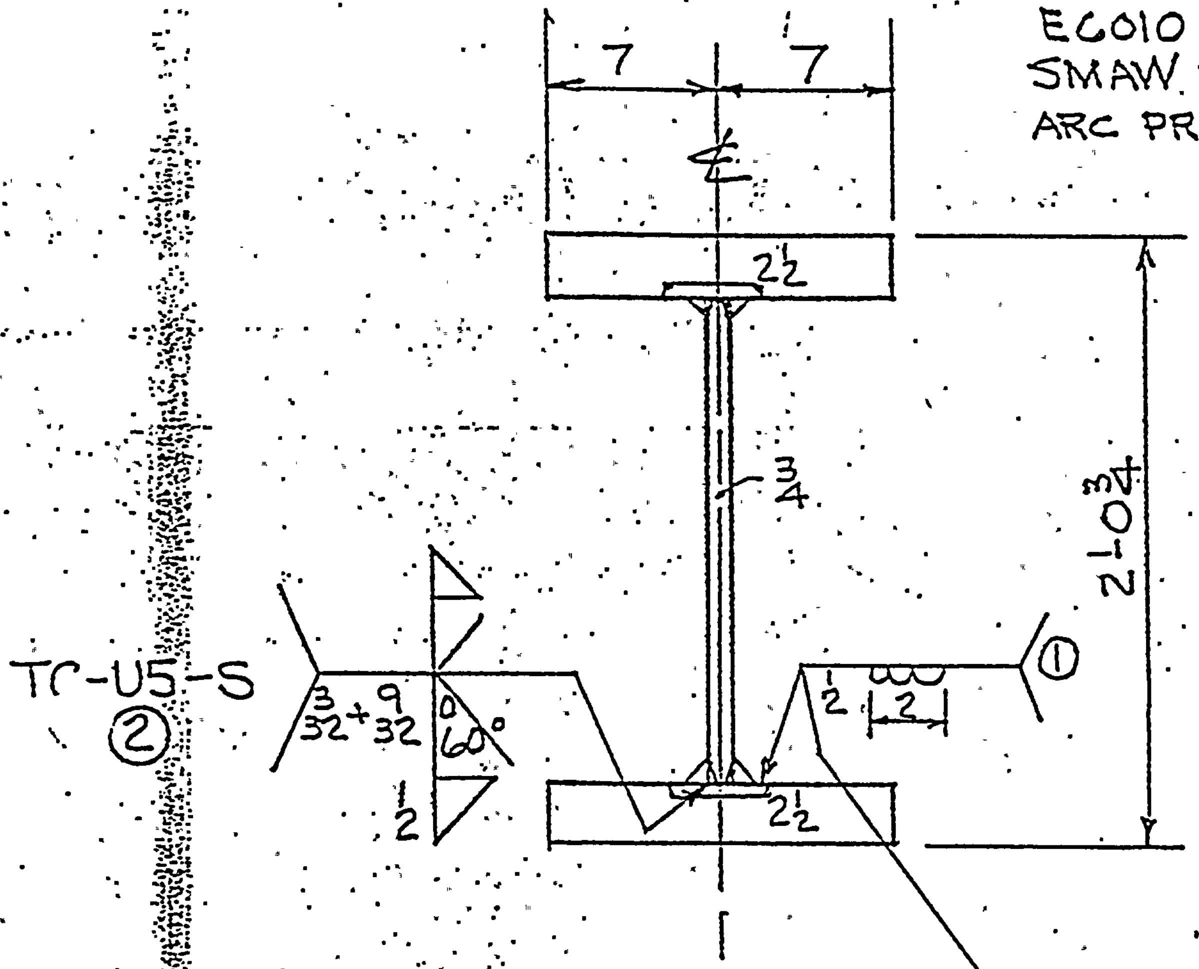
CHKD. BY ______ DATE ______ JOB SAC WALL

CUST. ______ LOCATION ______

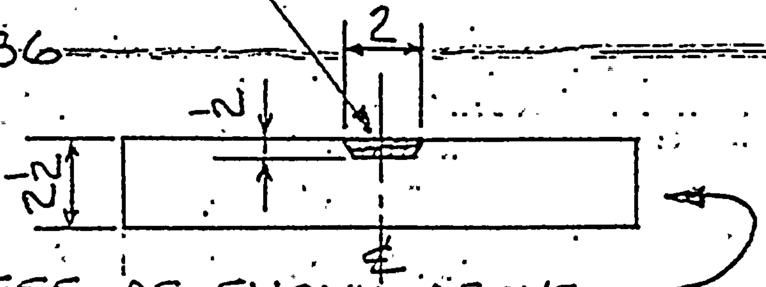
SHEET NO. 9 OF ______

LECKENBY JOB NO. 5756 △1

△1 IN NOTES, CHANGED GOUGE TO MILL, ELECTRODES E6010 TO 860-L60 & SMAW TO SUBMERGED ARC PROCESS.
C.E.M. - 7/21/75



COLUMN
A36 STL.
10 REQ'D @ 10'-9±
REF. DWG. S783 & S786



(1) MILL OUT ½" × 2" SLOT & FILL WITH 860-L60 IN TWO (2) LAYERS BY SUBMERGED ARC PROCESS AS SHOWN ABOVE.

(2) AFTER COMPLETING PREPARATION AND WELDING OF FLANGES AS NOTED IN (1), FINISH TEE CONNECTIONS AS NOTED ON DETAIL.

Lockheed

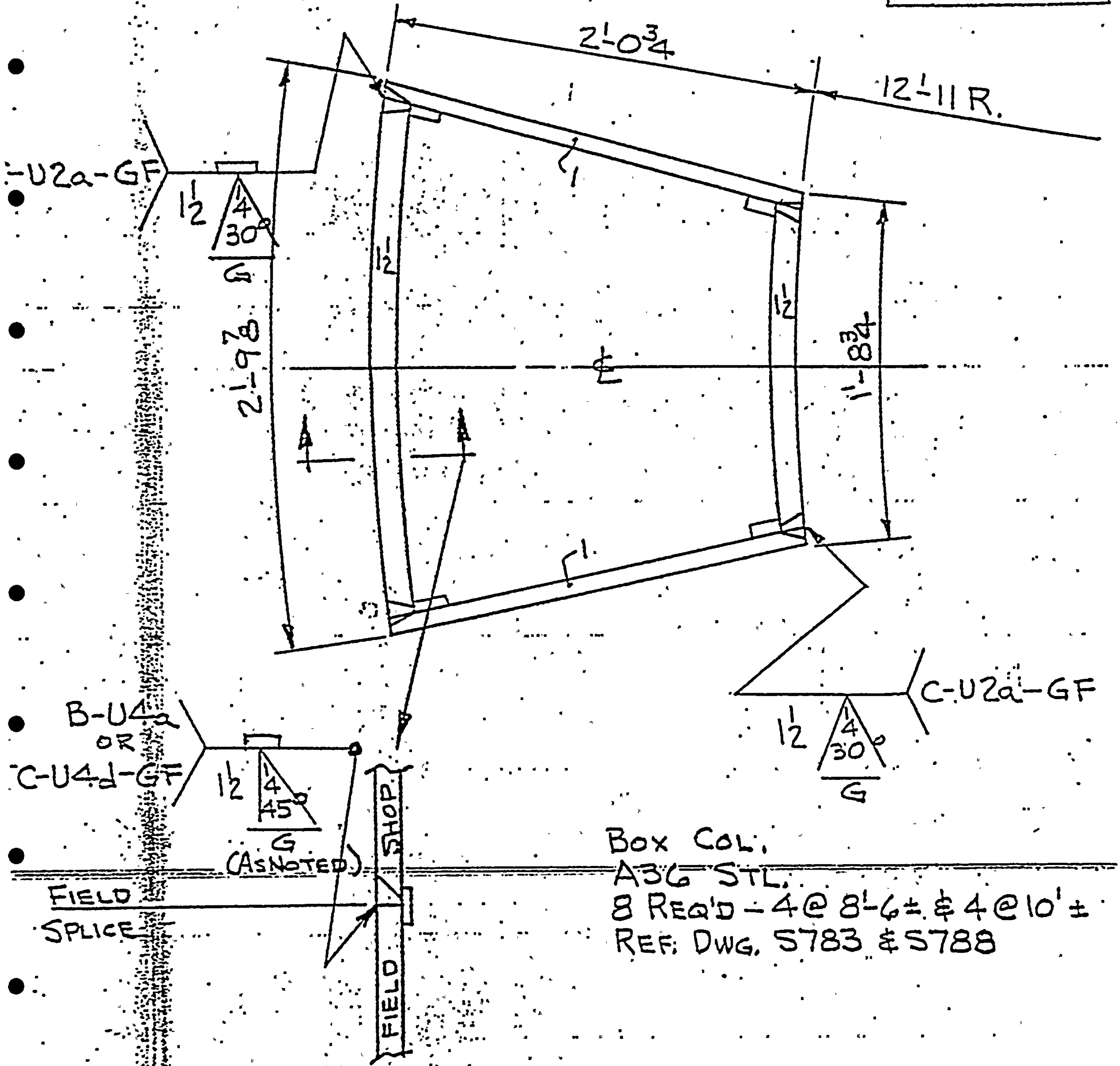
C.E.M. DATE ITEM BUILT-UP MEMBER (10)

CKD. BY DATE JOB SAC WALL

LOCATION

SHEET NO. (10) OF

5756 △1



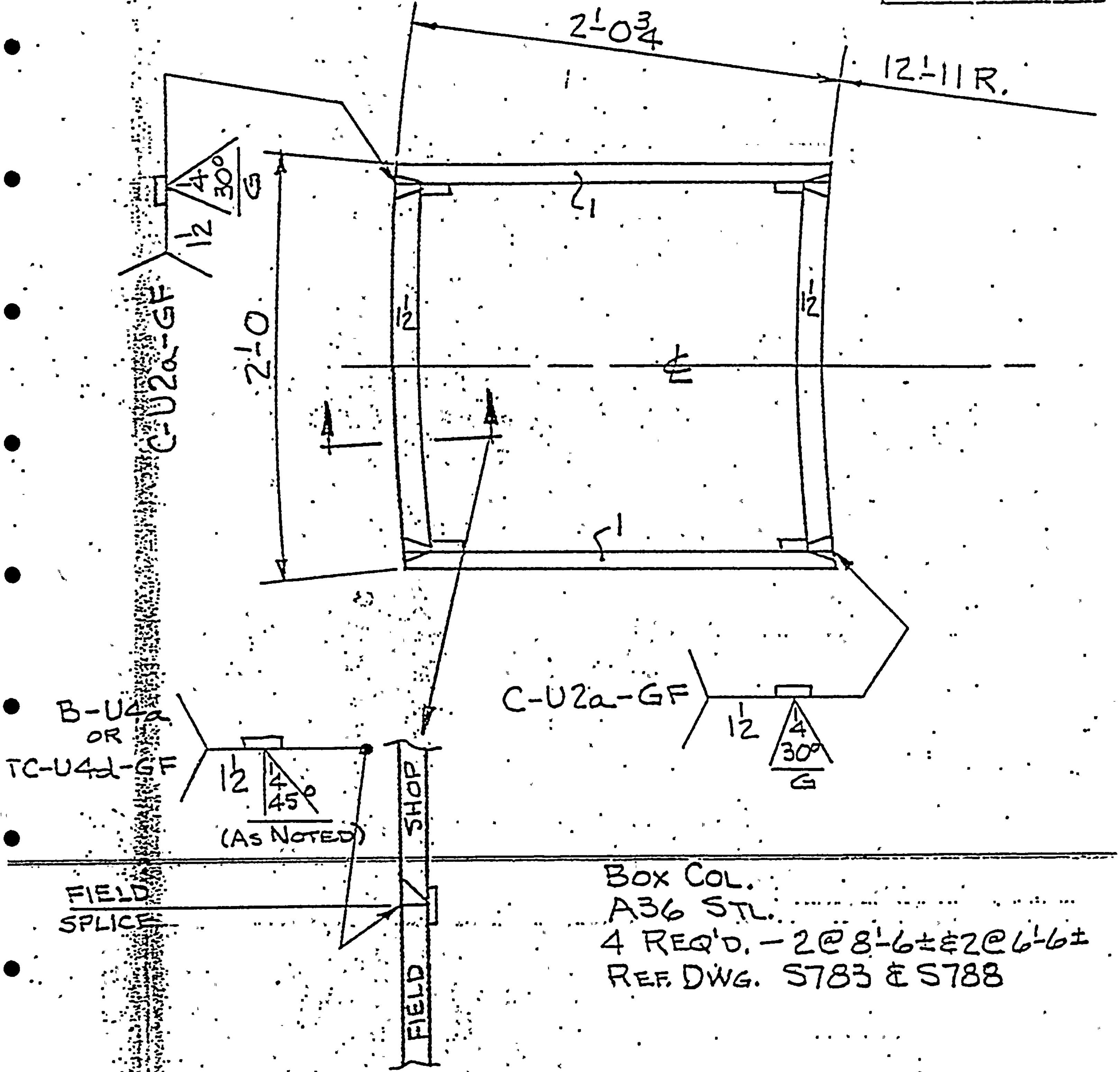
BOX COL.
A36 STL.
8 REQ'D - 4 @ 8'-6± & 4 @ 10'±
REF. DWG. 5783 & 5788

△1 REVISED WELD & PREPARATION. C.E.M. - 7/21/75

Leckenby

C.E.M. DATE ITEM BUILT-UP MEMBER (11) COLUMNS
DATE JOB SAC WALL
LOCATION

SHEET NO. (11) OF
5756 △1



BOX COL.
A36 STL.
4 REQ'D. – 2@8'-6± & 2@6'-6±
REF. DWG. S783 & S788

△1 REVISED WELD & PREPARATION.
C.E.M. – 7/21/75

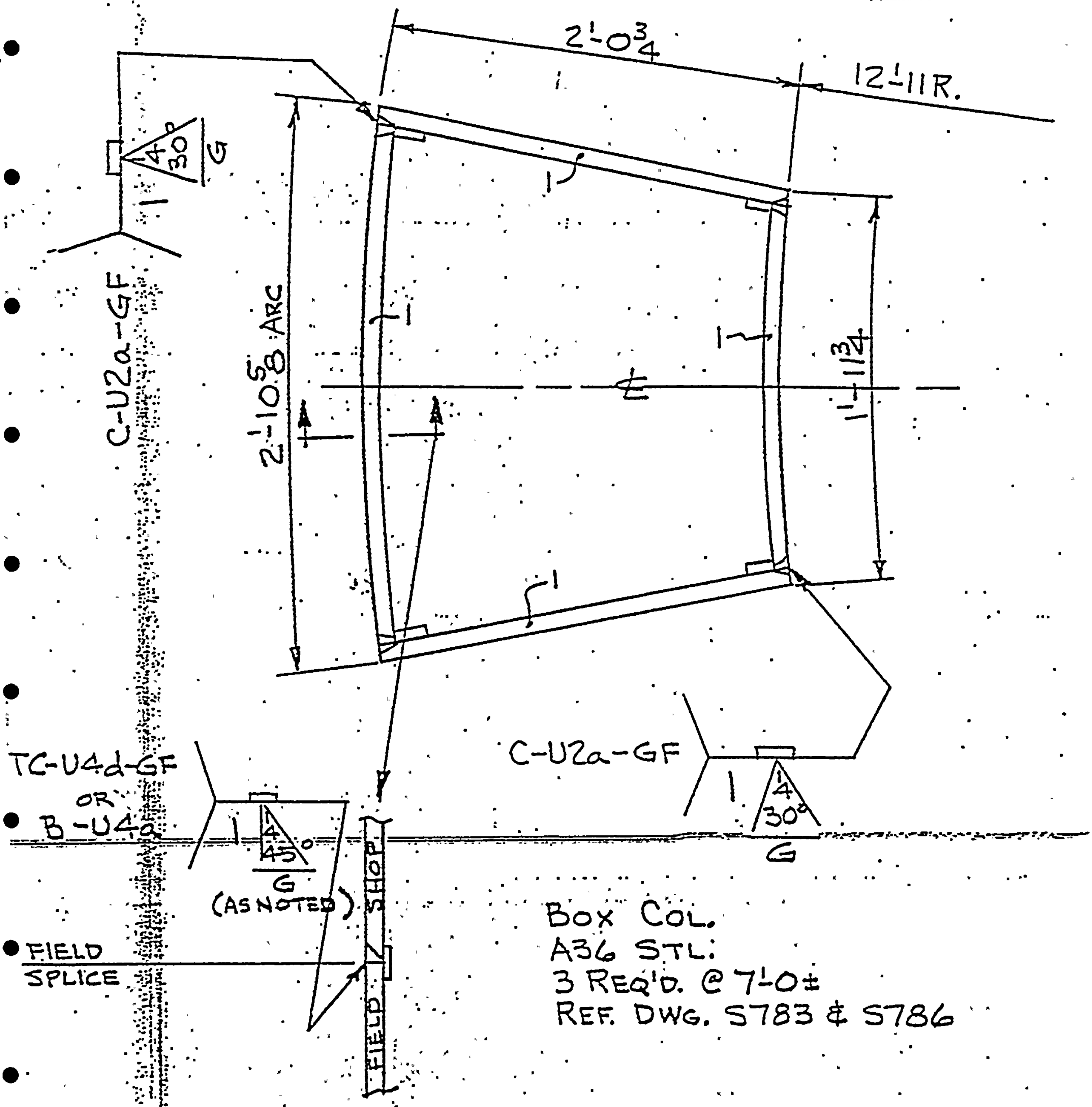
C.E.M. .... DATE .... ITEM BUILT-UP MEMBER (12)

.... DATE .... JOB SAC WALL

.... LOCATION ....

SHEET NO. (12) OF ....

5756 △1



BOX COL.
A36 STL.
3 REQ'D. @ 7'-0±
REF. DWG. S783 & S786

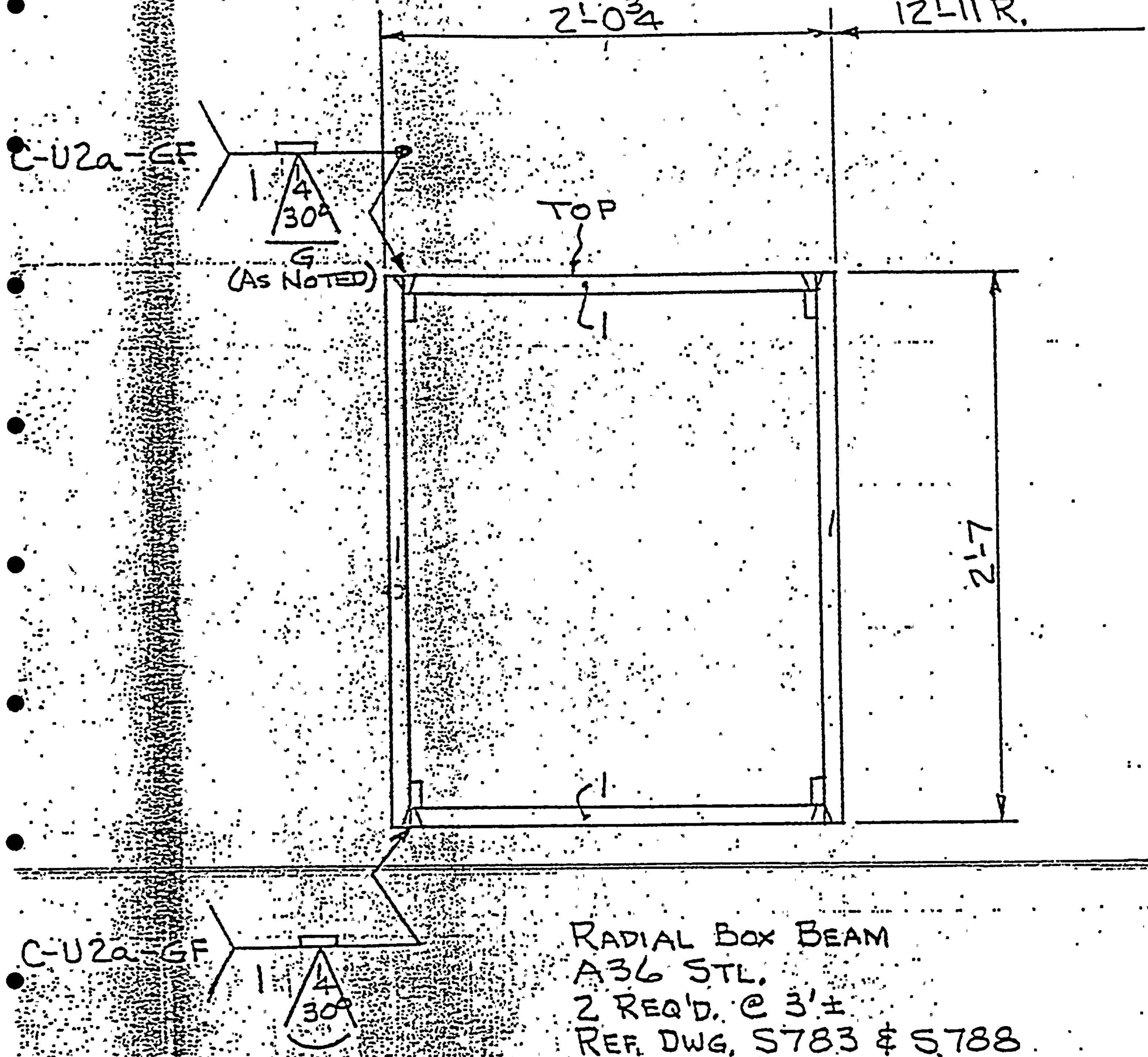
△1 REVISED WELD &
PREPARATION.
C.E.M.-7/21/75

Leckenby

C.E.M. DATE .... ITEM BUILT-UP MEMBER (14)
.... DATE .... JOB SAC WALL
.... LOCATION ....

SHEET NO. (14) OF ....

5756 △1



RADIAL BOX BEAM
A36 STL.
2 REQ'D. @ 3'±
REF. DWG. S783 & S788

△1 REVISED WELDING. ALL JOINTS IDENTICAL W/ ADDITION OF BACKING BAR TO BOTT. JOINTS.
C.E.M.-7/21/75

Leckenby

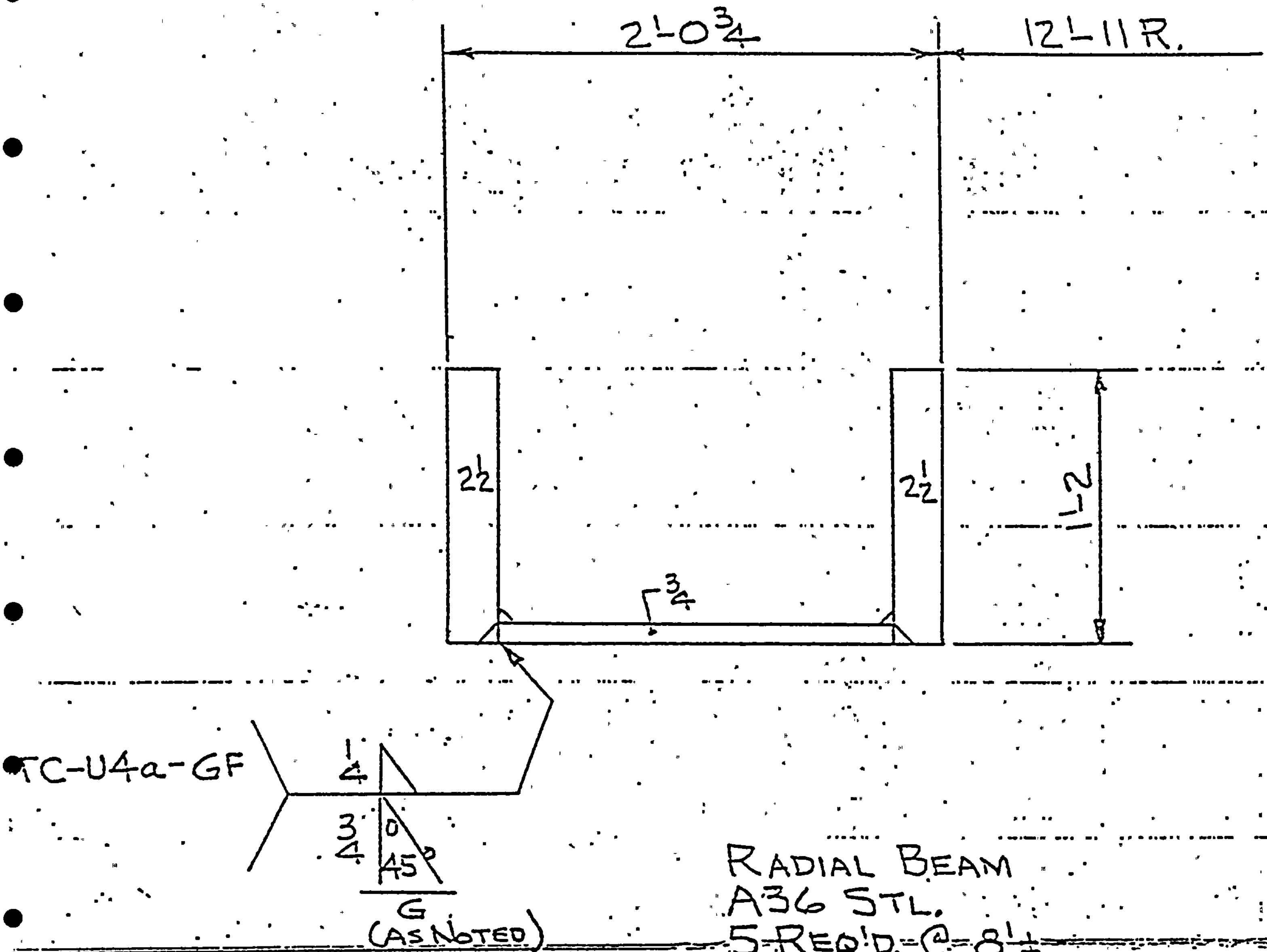
BY C.E.M. DATE ITEM BUILT-UP MEMBER (8) O.K.

CHKD. BY DATE JOB SAC WALL

CONTR. LOCATION

SHEET NO. (8) OF

LECKENBY JOB NO. 5756 (1)



RADIAL BEAM
A36 STL.
5 REQ'D. @ 8'-1"
REF. DWG. S783

NOTE: GOUGE ROOT TO SOUND METAL PRIOR TO WELDING FILLET.

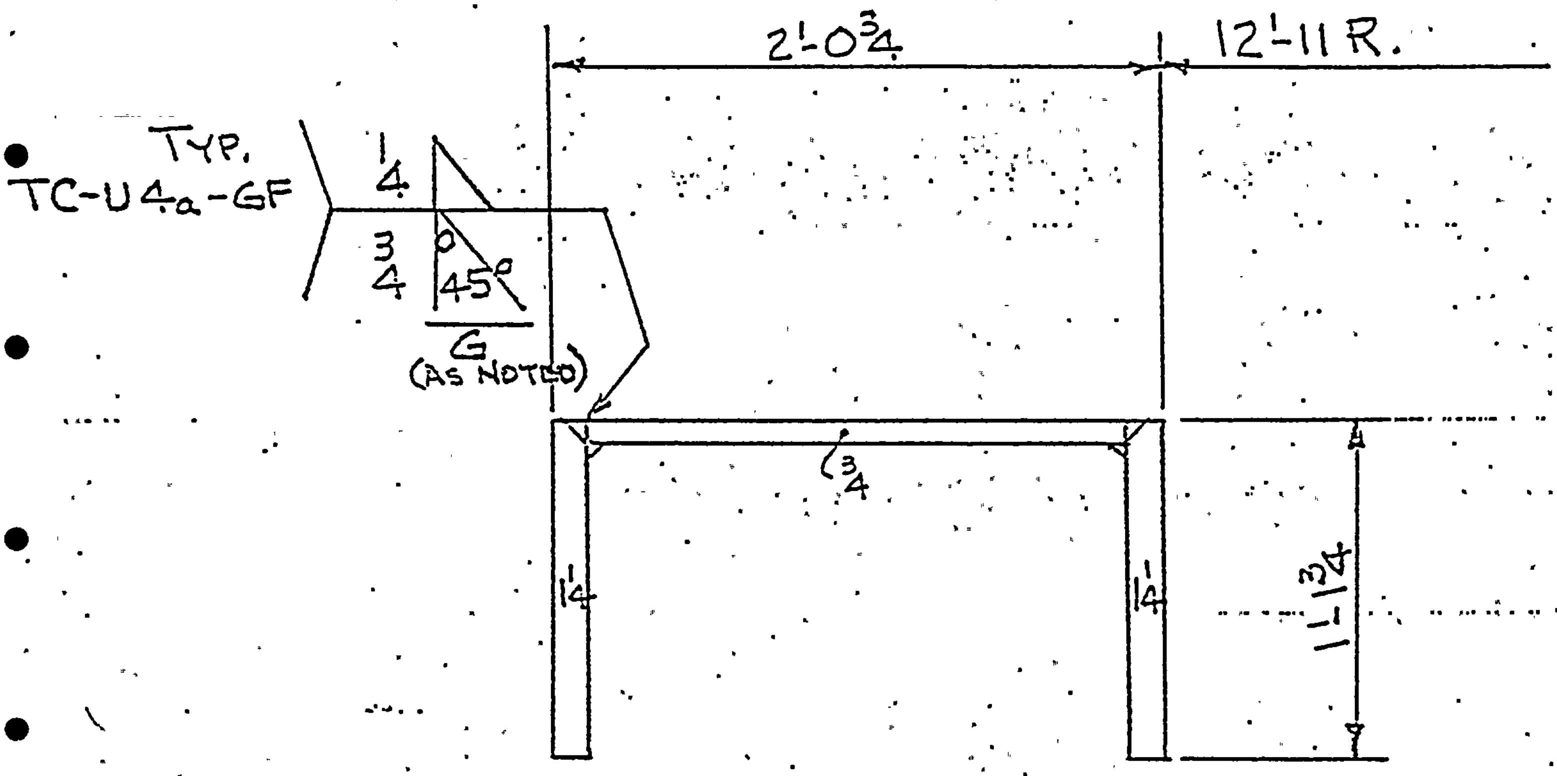
(1) CHG'D. FILLET SIZE FROM ½ TO ¼. ADDED NOTE.
PER APPROVAL OF RFI 215-77.
C.E.M. - 7/21/75

Leckenby

BY C.E.M. DATE ITEM BUILT-UP MEMBER (2) JOB SAC WALL LOCATION

SHEET NO. (2) OF

LECKENBY JOB NO. 5756 △1



RADIAL BEAM

A36 STL.

4 COMPLETE RINGS REQ'D.

+ 15 SEGMENTS 8' ± LONG.

REF. DWG. 5783.

NOTE: GOUGE ROOT TO SOUND METAL PRIOR TO WELDING FILLET.

△1 CHG'D. FILLET SIZE FROM 3/8 TO 1/4. ADDED NOTE.

PER APPROVAL OF RFI 215-77

C.E.M. - 7/21/75

Leckenby

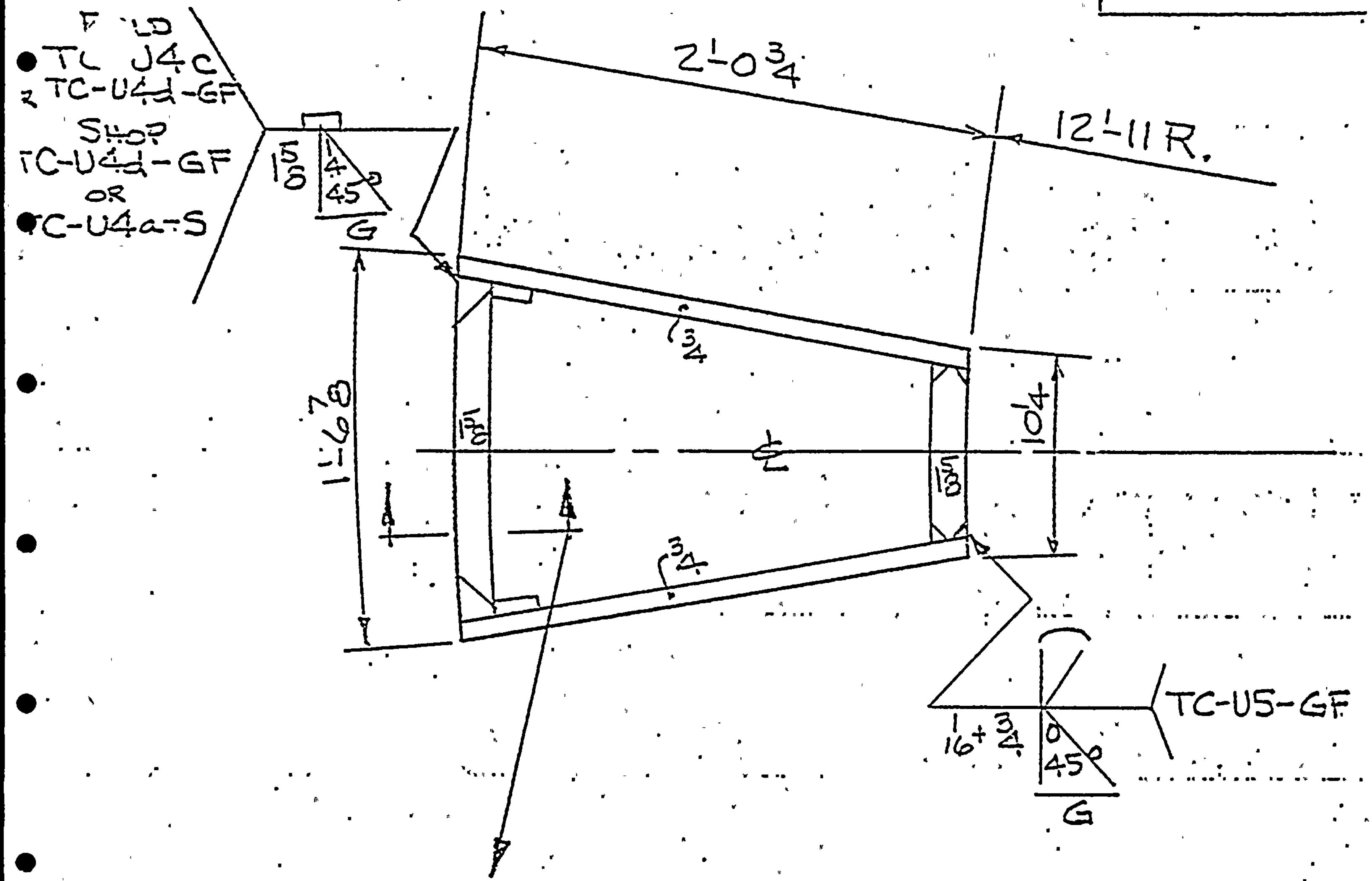
BY C.E.M. DATE ITEM BUILT-UP MEMBER (4) O.K.

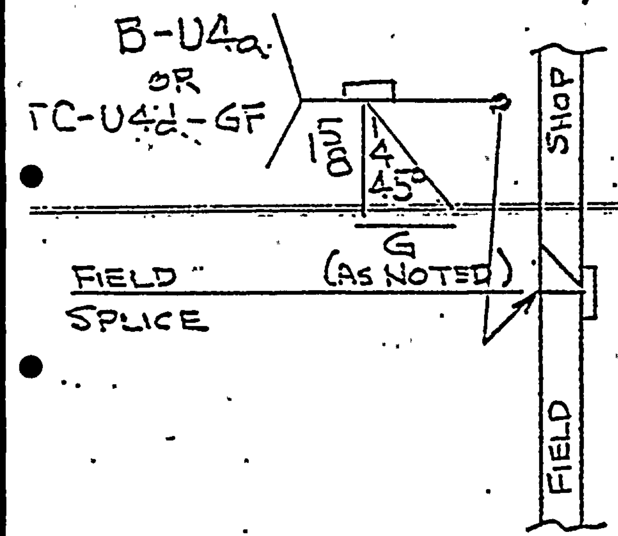
CHKD. BY DATE JOB SAC WALL

CONTR. LOCATION

SHEET NO. (4) OF

LECKENBY JOB NO. 5756 (1)





Box Col.
A36 STL.
2 REQ'D @ 10'-10 ±
REF. DWG. 5783

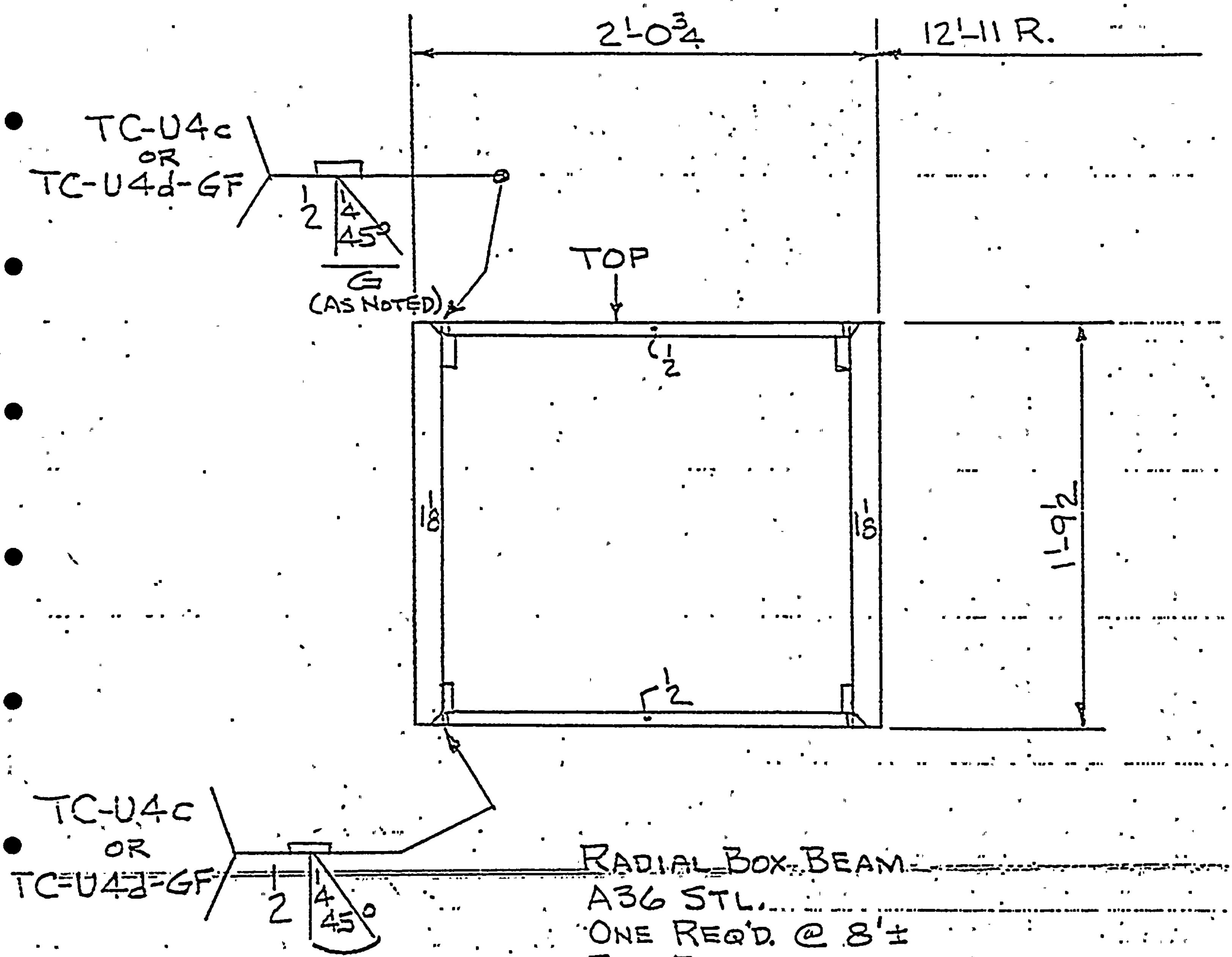
(1) ALL DETAILS APPROVED BY RFI 215-77.
C.E.M. - 8/21/75

LECKENBY

o.k.

BY C.E.M. DATE .... ITEM BUILT-UP MEMBER ⟨5⟩
CHKD. BY .... DATE .... JOB SAC WALL
CONTR. .... LOCATION ....

SHEET NO. ⟨5⟩ OF ....
LECKENBY JOB NO. 5756 △1



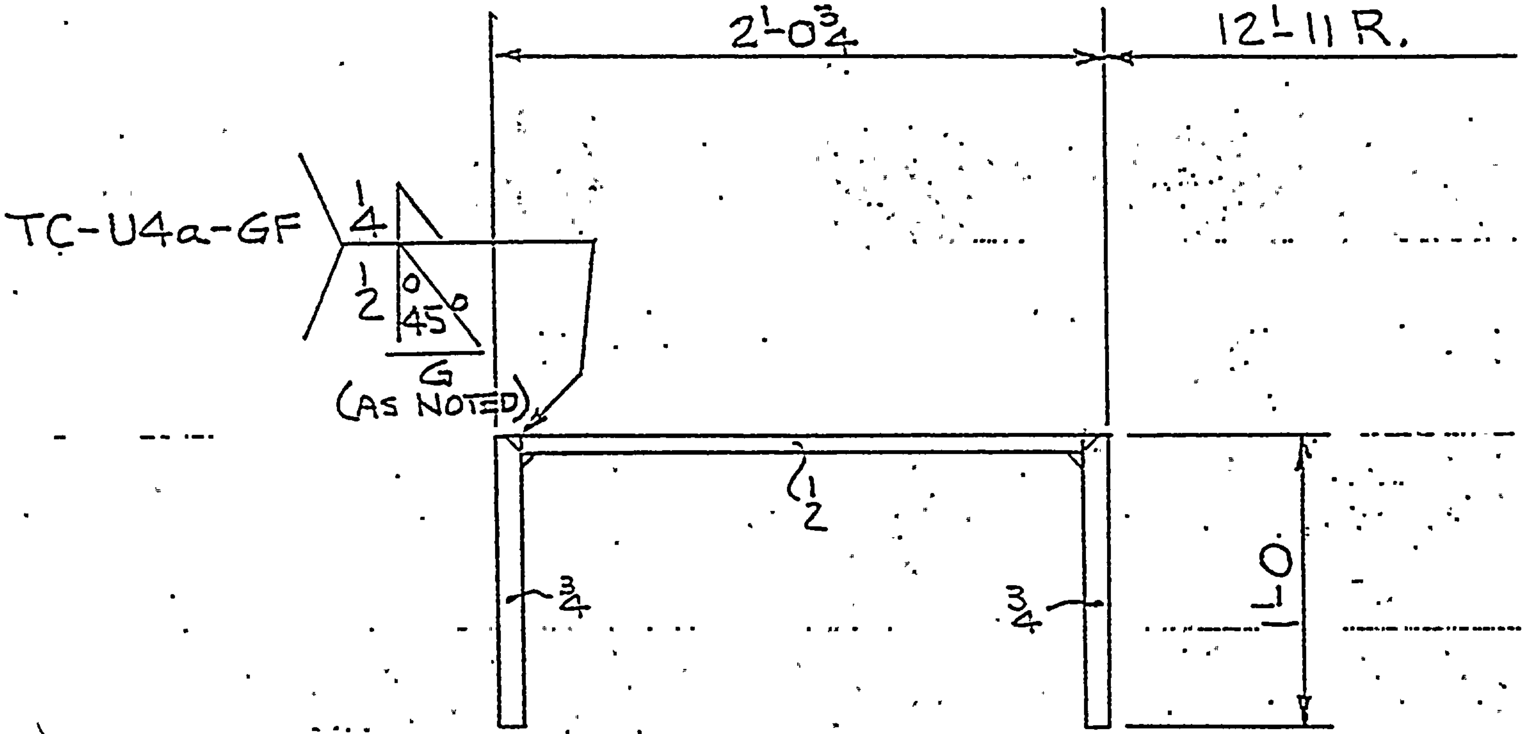
RADIAL BOX BEAM
A36 STL.
ONE REQ'D. @ 8'±
REF. DWG. S783

△1 CHG'D. WELD OF ALL CORNERS TO SAME AS TOP W/ADDITION OF BACKING BAR TO BOTT. JOINTS.
C.E.M. - 7/21/75

Leckenby

BY C.E.M. DATE .... ITEM BUILT-UP MEMBER (6)
CHKD. BY .... DATE .... JOB SAC WALL
CONTR. .... LOCATION ....

SHEET NO. (6) OF ....
LECKENBY JOB NO. 5756 ⚠1



RADIAL BEAM
A36 STL.
17 REQ'D. @ 8' ±
REF. DWG. S783

NOTE: GOUGE ROOT TO SOUND METAL PRIOR TO WELDING FILLET.

⚠1 CHG'D. FILLET SIZE FROM 3/8 TO 1/4. ADDED NOTE,
PER APPROVAL OF RFI 215-77.
C.E.M. - 7/21/75

CONCERN NO. 28

It was noted during review of defect related documentation that four repairs of cracks in SSW shop welds did not comply with AWS D1.1 requirements.

BACKGROUND

During reviews of Leckenby documentation by NRC Region V, it was discovered that several crack repairs did not include the proper inspections and excavation criteria. This documentation was associated with the SSW and the pipe whip support girders.

Additionally, during review by the Task Force, four such repairs associated specifically with the SSW were identified, two of which had been previously identified by the NRC.

CONCERN RESOLUTION

The AWS Code requires a positive means to ascertain the extent of cracks in weld or base material prior to weld repair. No dye penetrant or magnetic particle examinations were performed during three crack repairs on the SSW to our knowledge. However, the repair instructions did state to air arc out the defect to sound metal. Additionally, the AWS Code requires removal of the crack and sound metal to 2 inches beyond each end of the crack prior to repair. Confirmation of such removal is not available for four known SSW crack repairs, the above three included. Two of these weld repair areas are accessible. Recent UT performed on the accessible areas found no defects or indications. Potential defects remaining in the SSW associated with the other crack repair areas as a result of not complying with these AWS Code requirements are enveloped in the bounding defect assessment in subsection III.D.

No further action is necessary for this concern.

APPENDIX B

SSW Load Analysis Refinements

This appendix contains an explanation of the refinements in loads and analysis techniques made subsequent to the submittal of Reference III.B.1.

Tech. Memo. No. 1185	-	Refinements in Annulus Pressurization Analysis for a Postulated Feedwater Line Break
Tech. Memo. No. 1187	-	Simplified Dynamic Model Used for Structural Assessment of the SSW
Tech. Memo. No. 1188	-	Finite Element Seismic Analysis of the Reactor Building
Tech. Memo. No. 1190	-	Pipe Break Loading on SSW

TECHNICAL MEMORANDUM

DATE 7/8/80

TO R. E. Snaith

FROM P. A. Bickel

SUBJECT W. O. 2808
Washington Public Power Supply System
WPPSS Nuclear Project No. 2
Refinements in Annulus Pressurization Analysis for a Postulated Feedwater Line Break
Technical Memorandum No. 1185

COPIES TO:

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FJPatti
KRonis/MRamchandani
EFerrari
GHarper
MParise
TTHsu
PABickel
TM File
pf
db

REFERENCES:

1) Burns and Roe Calculation 5.07.04.10, Feedwater Blowdown for Annulus Pressurization

2) Burns and Roe Calculation 5.06.30.2, SSW Pressure Analysis from Feedwater Blowdown, RELAP 3 Input

3) RELAP 4/MOD 5--A Computer Program for Transient Thermal-Hydraulic Analysis of Nuclear Reactors and Related Systems, ANCR-NUREG-1335, September 1976

4) WPPSS-74-2-R2-B, Sacrificial Shield Wall Design Supplemental Information

5) GEBR-2-75-765, dated April 15, 1975

The purpose of this Technical Memorandum is to discuss the refinements in annulus pressurization analysis which have resulted in a reduction in annulus pressurization load for a postulated feedwater line break. The basic refinement which has been made is a reanalysis of the feedwater blowdown mass and energy data which is required for the annulus pressurization analysis. The revised feedwater blowdown calculation is Reference 1 and the subsequent annulus pressurization calculation is Reference 2. The physical model of the annulus is unchanged and needs no discussion. The postulated feedwater line break is an instantaneous double-ended guillotine pipe rupture of the 12 inch main feedwater line at one of the six nozzles to the reactor pressure vessel. A brief review will be made of the two methods of calculating the feedwater blowdown data, followed by a comparison of the blowdown data results. Annulus pressurization results will also be compared.

Revised Blowdown Data

The revised feedwater blowdown data for the current assessment of the sacrificial shield wall (SSW) annulus pressurization are from Reference 1. In Reference 1, a comprehensive model was developed for the entire condensate/feedwater system from the condenser to the reactor vessel. This model in conjunction with the RELAP 4/MOD 5 computer program (Reference 3) was used to calculate the transient mass and energy blowdown data.

Original Blowdown Data

The SSW design of Reference 4 is based in part on the original feedwater blowdown data of Reference 5. The analysis of Reference 5 was a hand calculation based on the physical properties of the blowdown fluid and the applicable break areas of the feedwater line. The break areas chosen were conservative and resulted in high mass and energy blowdown data.

Blowdown Data Comparison

Figures 1 and 2 compare the revised and the original feedwater blowdown data. Figure 1 is a comparison of mass flow rates and Figure 2 is a comparison of energy rates. The significant portion of the transient is before 0.100 second and during this part the revised mass flow rate is 30% of the original mass flow rate and the revised energy rate is 25% of the original energy rate.

Comparison of Annulus Pressurization Results

Figure 3 is the node model for the sacrificial shield wall annulus for the feedwater line break. Typically data for nodes near the break (1, 2, 3, 6, 7 and 11) are shown to illustrate the annulus pressurization results.

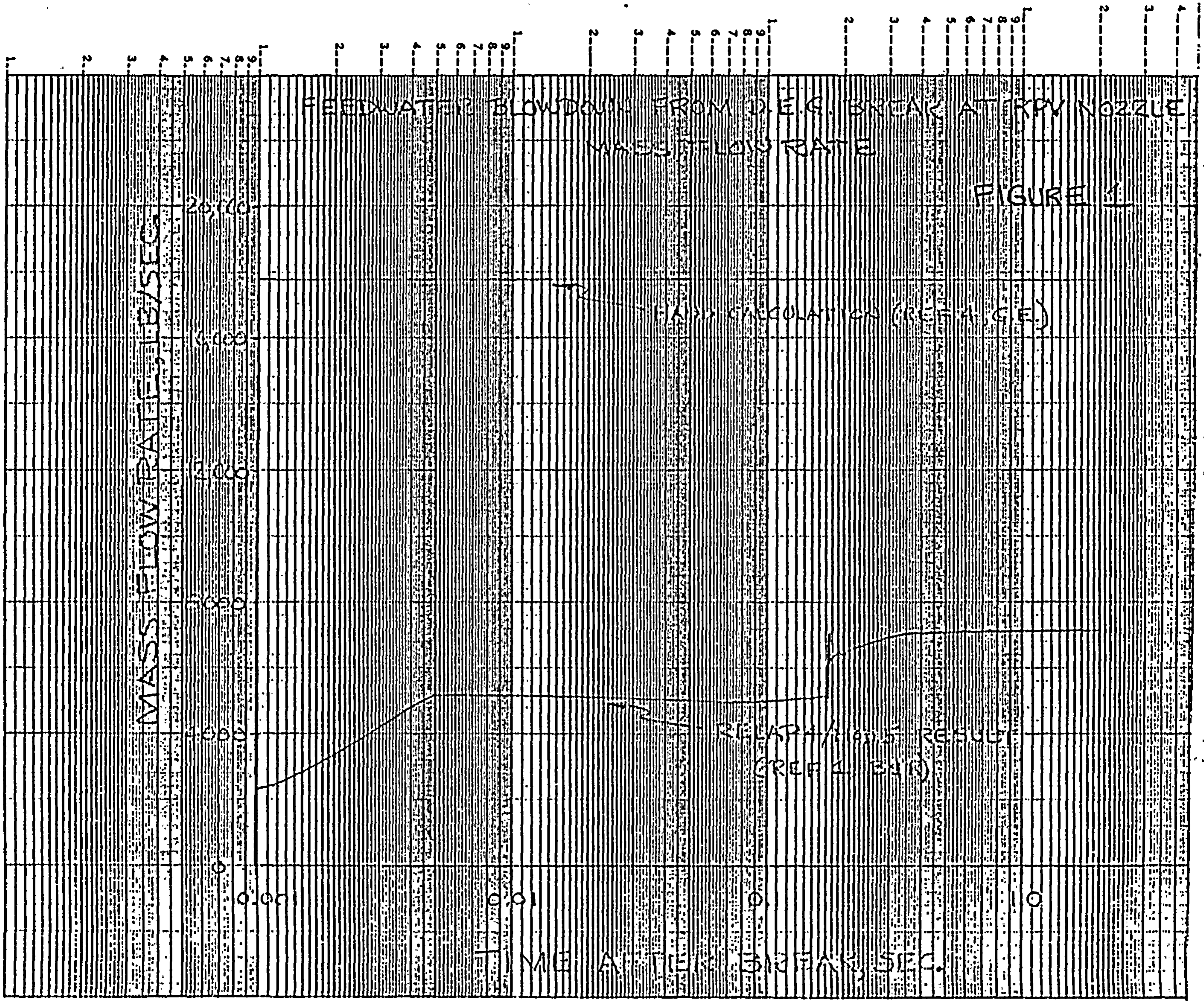
In Figures 4 through 9 the annulus pressurization data are compared for the original blowdown (dashed curve, Reference 4) and the revised blowdown (solid circle curve, Reference 2). In general, the peak differential pressure reduction approaches a factor of three for the higher pressure nodes (1 and 2) and is about a factor of two for the lower pressure nodes (3, 6, 7 and 11).

Prepared by: *Paul A. Bickel*
P. A. Bickel

Approved by: *T. T. Hsu*
T. T. Hsu

TTH/PAB/pn
Attachments

K+E SEMI-LOGARITHMIC 5 CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.
46 6212



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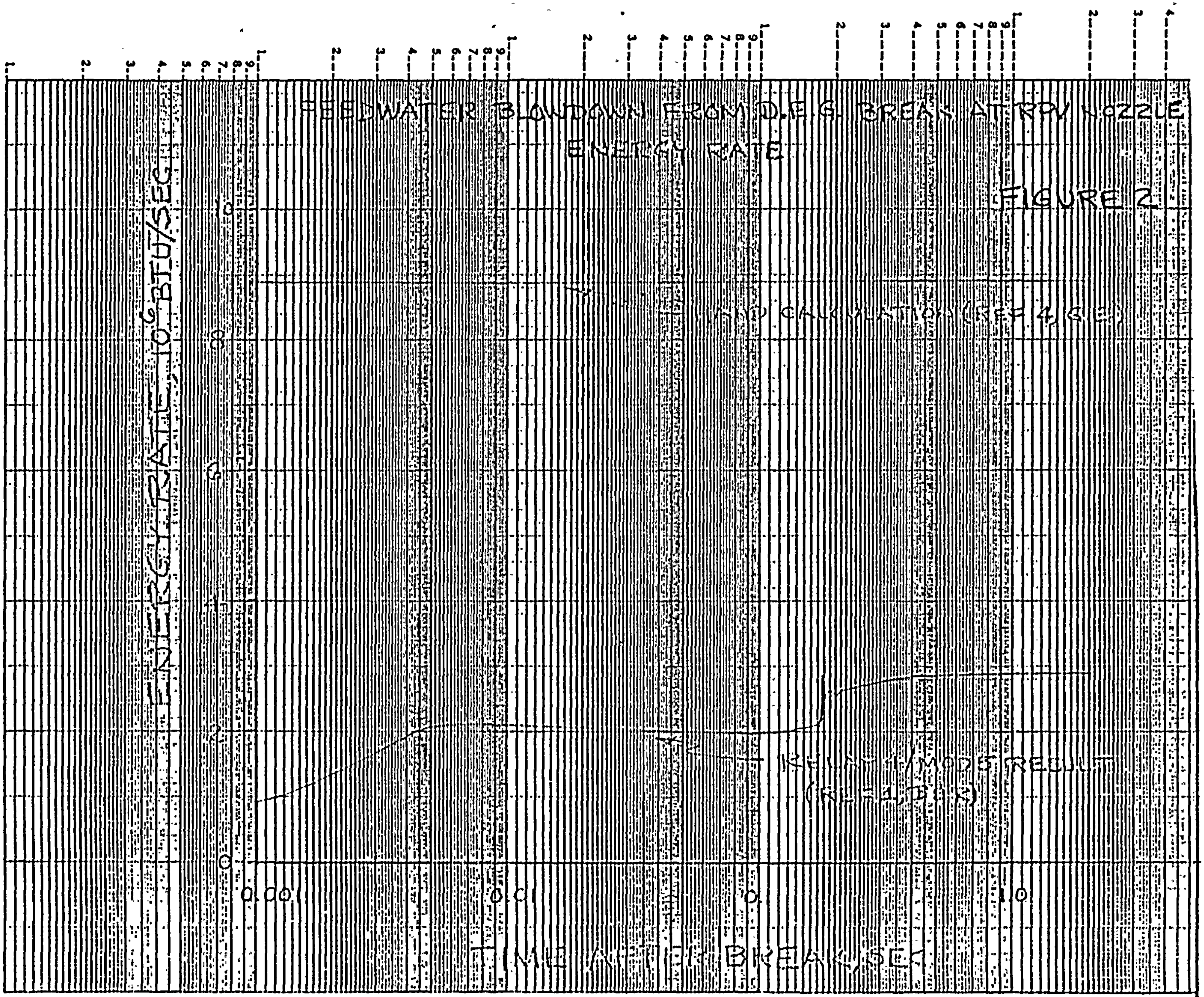
FEEDWATER BLOWDOWN FROM D.E.G. BREAK AT RPV NOZZLE
ENERGY RATE
FIGURE 2
ENERGY RATE, 10^6 BTU/SEC
HAND CALCULATION
0.001
0.01
0.1
1.0
10
TIME AFTER BREAK, SEC

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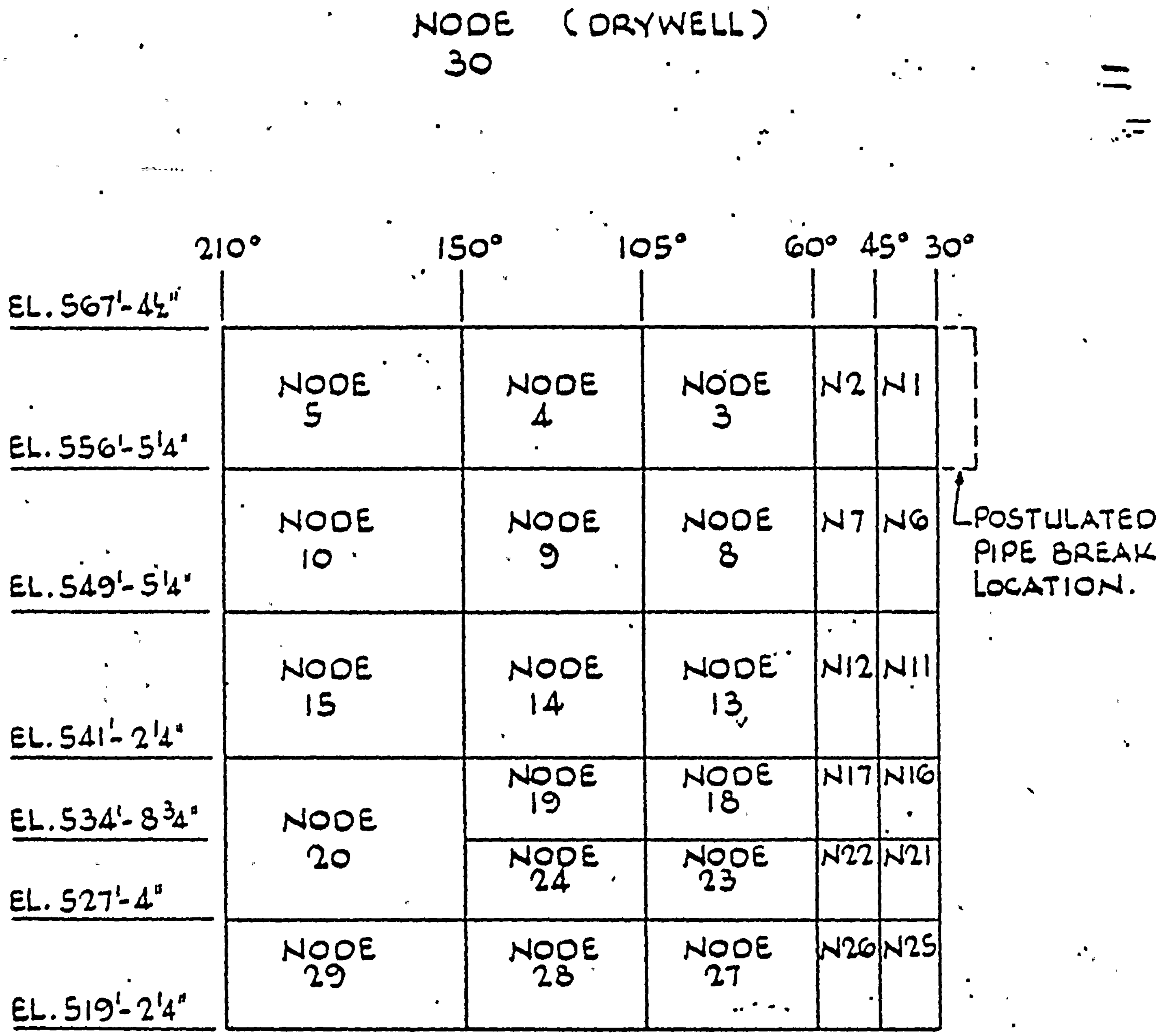
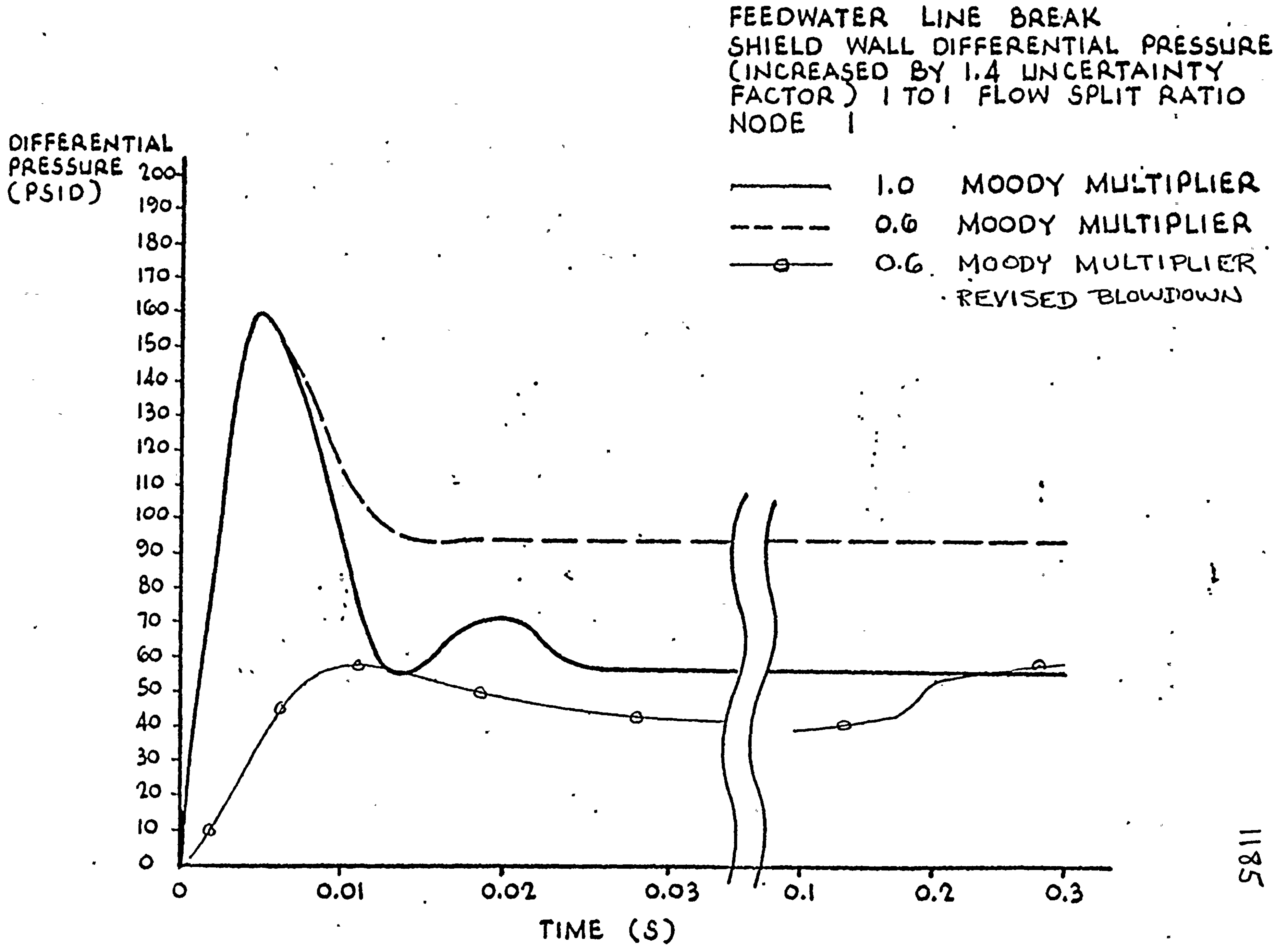


180° FLAT DEVELOPMENT OF SHIELD WALL ANNULUS

WASHINGTON PUBLIC POWER SUPPLY SYSTEM NUCLEAR PROJECT NO. 2	NODE MODEL - FEEDWATER LINE BREAK	FIGURE 3



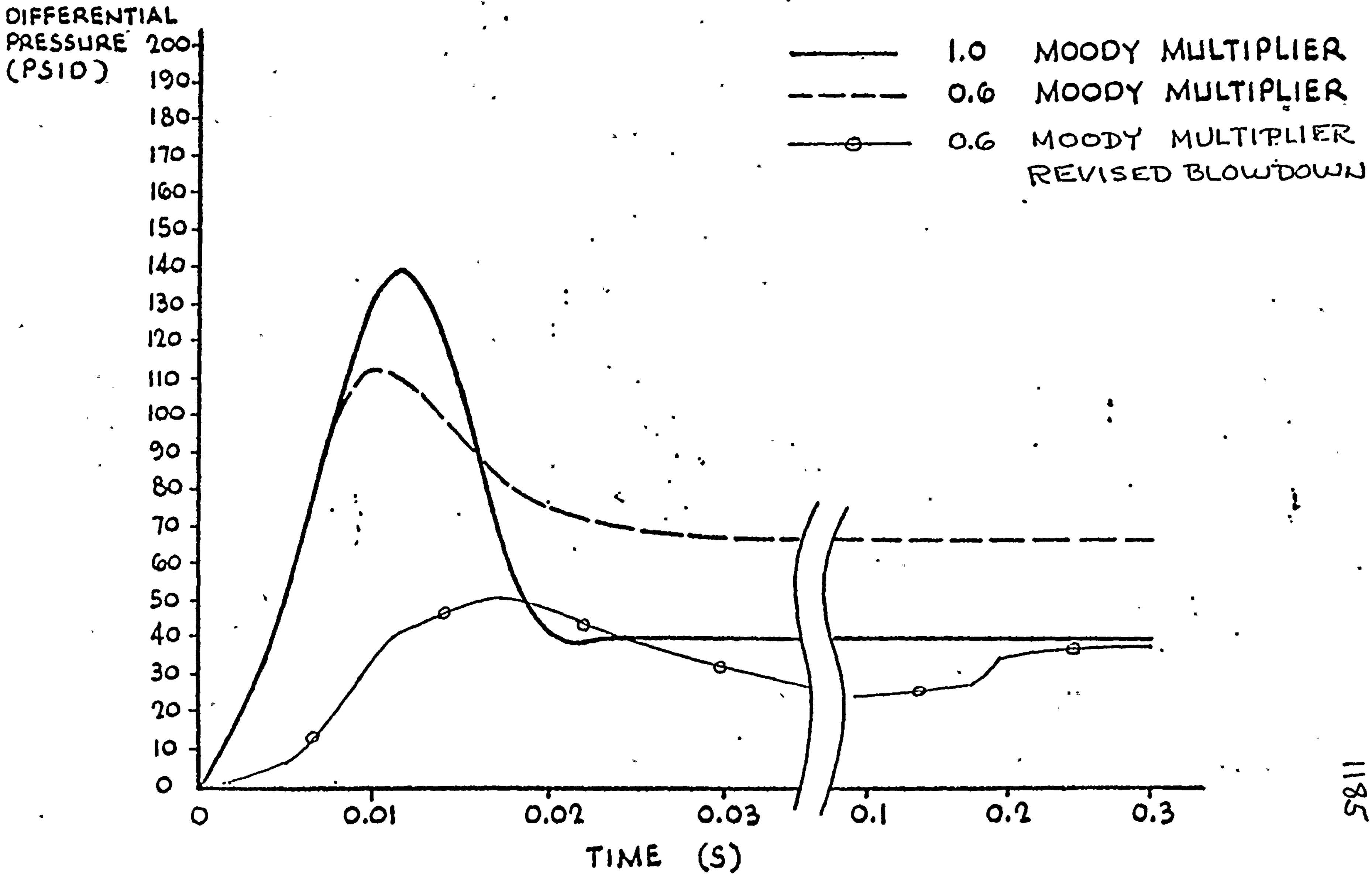
WASHINGTON PUBLIC POWER SUPPLY SYSTEM
NUCLEAR PROJECT NO. 2

FEEDWATER LINE BREAK
NODE 1

FIGURE 4

1185

FEEDWATER LINE BREAK
SHIELD WALL DIFFERENTIAL PRESSURE (INCREASED BY 1.4 UNCERTAINTY FACTOR) 1 TO 1 FLOW SPLIT RATIO
NODE 2



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WASHINGTON PUBLIC POWER SUPPLY SYSTEM
NUCLEAR PROJECT NO. 2

FEEDWATER LINE BREAK
NODE 2

FIGURE 5

WASHINGTON PUBLIC POWER SUPPLY SYSTEM
NUCLEAR PROJECT NO. 2

FEEDWATER LINE BREAK
NODE 3

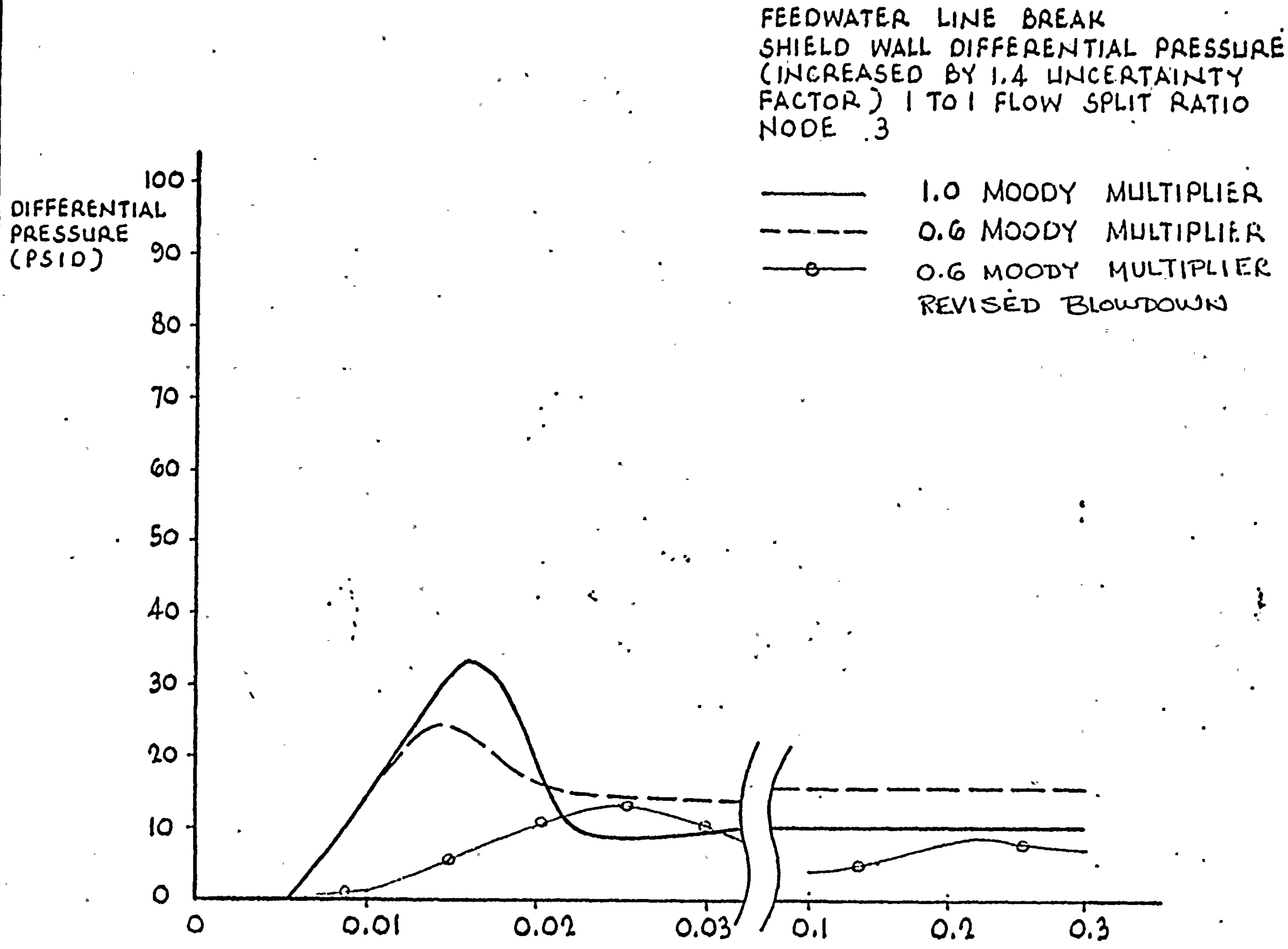

FIGURE 6

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WASHINGTON PUBLIC POWER SUPPLY SYSTEM
NUCLEAR PROJECT NO. 2

FEEDWATER LINE BREAK
NODE 6

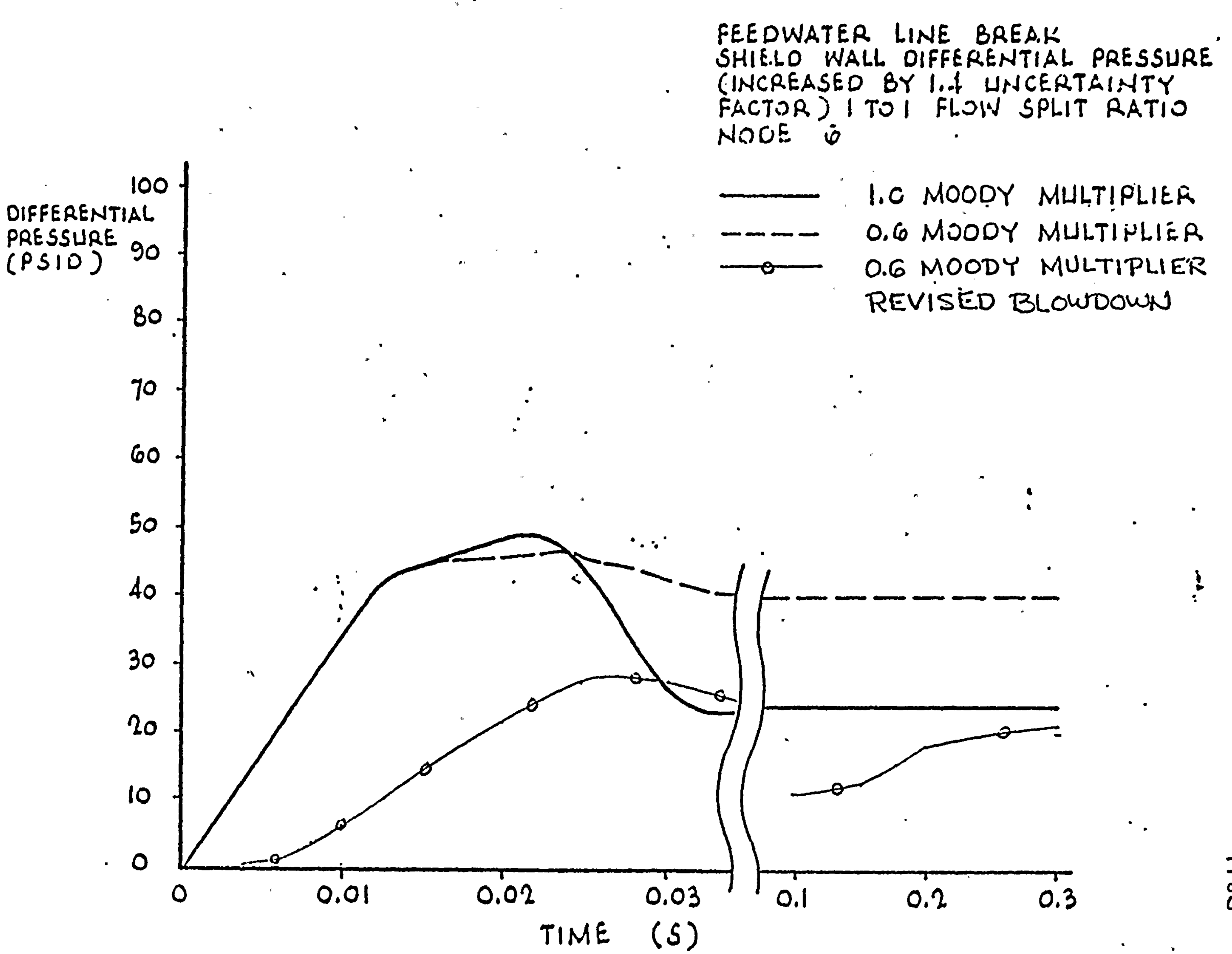


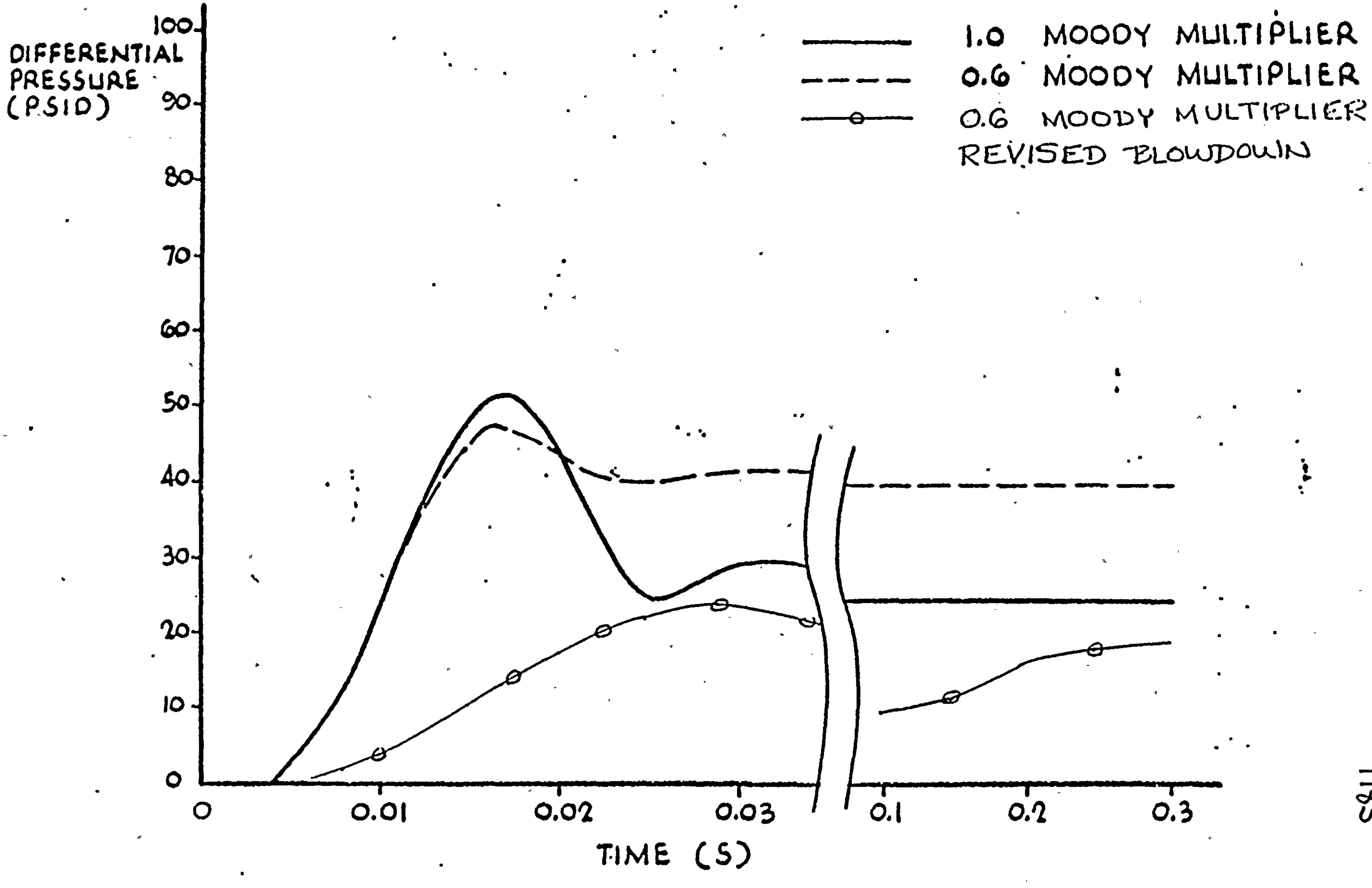
FIGURE 7

WASHINGTON PUBLIC POWER SUPPLY SYSTEM
NUCLEAR PROJECT NO. 2

FEEDWATER LINE BREAK
NODE 7

FIGURE 8

FEEDWATER LINE BREAK
SHIELD WALL DIFFERENTIAL PRESSURE
(INCREASED BY 1.4 UNCERTAINTY
FACTOR) 1 TO 1 FLOW SPLIT RATIO
NODE 7



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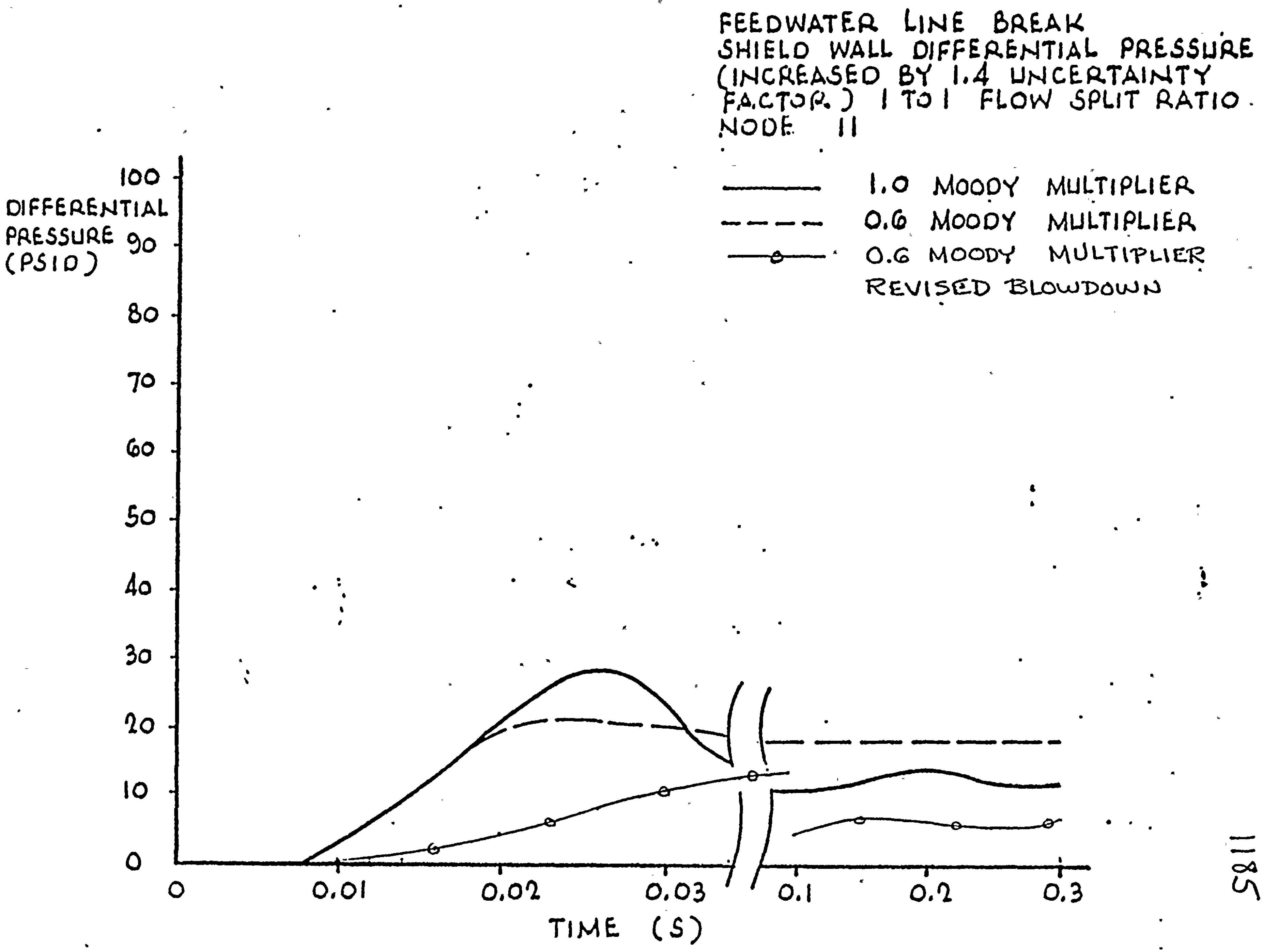
WASHINGTON PUBLIC POWER SUPPLY SYSTEM
NUCLEAR PROJECT NO. 2

FEEDWATER LINE BREAK
NODE 11

FIGURE 9



1185

TECHNICAL MEMORANDUM

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JBraverman
DBagchi
pf
db
TM file

DATE 7/17/80

TO R. E. Snaith

FROM J. O'Donnell/J. Braverman

SUBJECT W.O. 2808
Washington Public Power Supply System
WPPSS Nuclear Project No. 2
Simplified Dynamic Model Used for Structural Assessment of the Sacrificial Shield Wall
Technical Memorandum No. 1187

Reference:
1. Burns and Roe letter, BRGE-2-78-009, 1/19/78
2. GE letter, GEBR-2-79-1447, dated 9/7/79

The present base line design of the sacrificial shield wall (sac wall) is based on equivalent static analyses for dynamic loadings. In order to approximate what conservatisms exist in the equivalent static method of analysis, a simplified dynamic model was developed to assist in the structural reassessment of the sac wall. This simplified dynamic model provides a more realistic response of the sac wall to the dynamic loadings it is subjected to. Following this investigation, which utilizes the simplified dynamic model, a more refined and accurate model will be developed.

This technical memorandum provides a description of the simplified dynamic model and the method of analysis used in reassessing the structural adequacy of the sac wall.

A finite element mathematical model of the entire reactor building and supporting soil was used to perform the dynamic analysis. The various structural elements (basemat, exterior walls, containment, pedestal, sac wall, and RPV) were represented by axisymmetric conical shell elements which have non-axisymmetric loading capability. Structural elements such as the columns, stabilizer truss, bellows, and shear lugs were modeled using springs. In the sacrificial shield wall region where the annulus pressurization loads are applied and where a more accurate representation is required, the node locations are more closely spaced. The mathematical model of the reactor building and internals is illustrated in figure 1.

The commercially available computer program ANSYS, Rev. 2 was used to calculate the structural response of the reactor building and internals due to the annulus pressurization loads. The capability of ANSYS to perform a reduced linear transient dynamic analysis was used to obtain displacement time histories at essential degrees of freedom. This is done by solving the equations of motion by direct integration.

For the recirculation line break, the following loads have been considered:

1. pressure - as defined in reference 1
2. pipe restraint - as defined in reference 2
3. jet reaction - as defined in reference 2
4. jet impingement - as defined in reference 2

These loads are shown pictorially on the attached figure 2. They are applied to the sac wall and reactor pressure vessel using time dependent concentrated forces at applicable nodes and distributed circumferentially by a Fourier series.

Since the sac wall was modeled using axisymmetric thin shell elements, the calculated displacements are representative of the overall dynamic displacements. Inherent in this assumption is that displacements at openings would not be significantly higher than the overall displacements calculated from the simplified dynamic model.

The displacements obtained from the simplified dynamic model were then used as input into a more refined, three dimensional model of the sac wall. This model is used to calculate the stresses since it is more representative of the real sac wall structure. It contains the actual properties of the individual elements (vertical columns, circumferential beams, and cover plates) and also models the sac wall openings.

Prepared by ______________
J. Braverman

Reviewed by ______________
P. Hsueh

Approved by ______________
J. O'Donnell

JB/gb

REACTOR BLDG FINITE ELEMENT MODEL

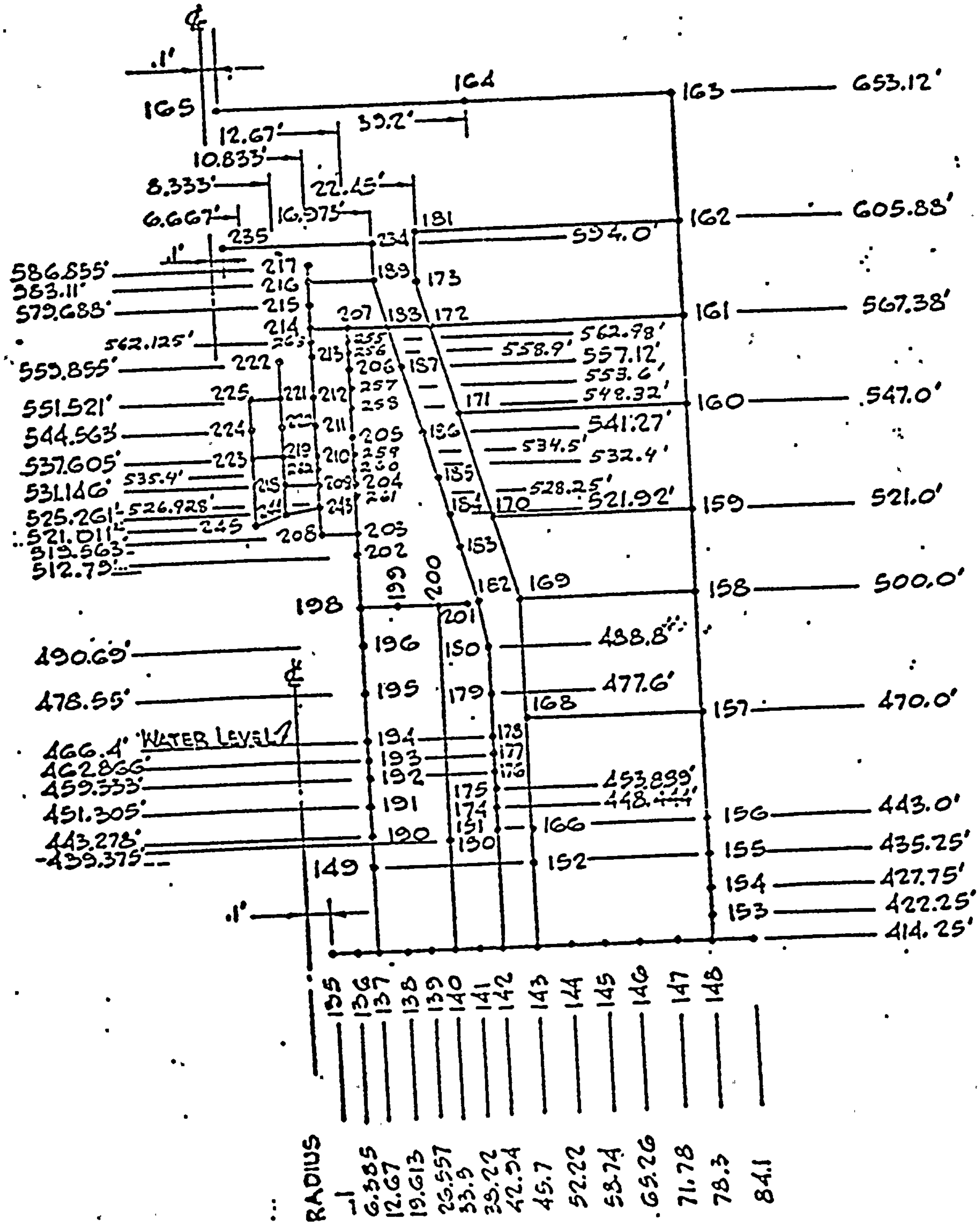

FIGURE 1

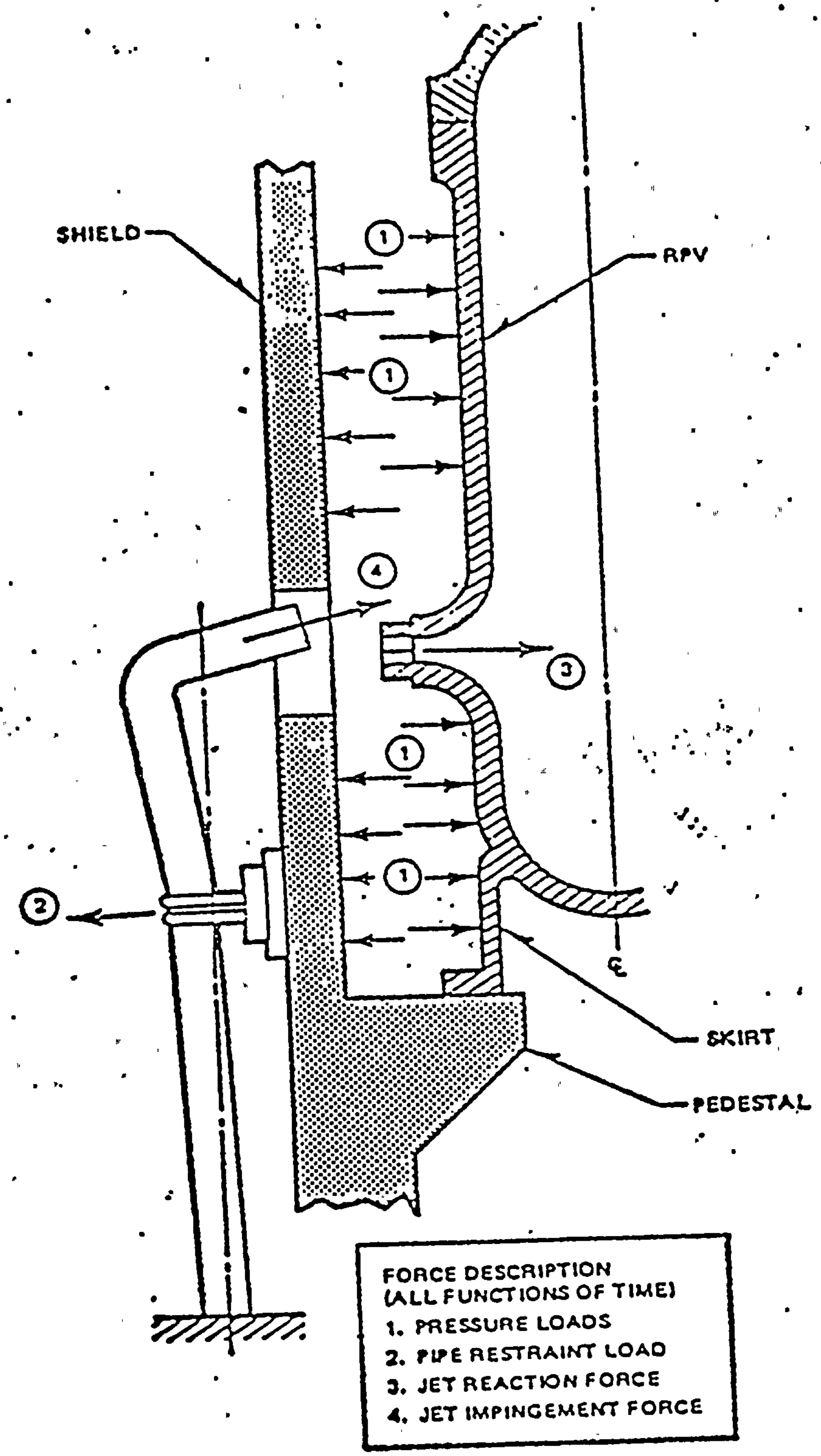
SHIELD
RPV
1
2
3
4
SKIRT
PEDESTAL
℄
FORCE DESCRIPTION
(ALL FUNCTIONS OF TIME)
1. PRESSURE LOADS
2. PIPE RESTRAINT LOAD
3. JET REACTION FORCE
4. JET IMPINGEMENT FORCE

FIGURE 2

MEMORANDUM

BURNS and ROE, Inc.

DATE 7/18/80

TO R. E. Snaith

FROM M. Ettouney

SUBJECT W. O. 2808
Washinton Public Power Supply System
WPPSS Nuclear Project No. 2
Finite Element Seismic Analysis
of the Reactor Building
Technical Memorandum No. 1188

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I. Objects of Analysis

The finite element seismic analysis was conducted to establish a more realistic response of the WNP-2 reactor building to the design earthquakes specified for the site. The analysis utilizes finite element techniques in obtaining the dynamic interaction effects between the structures and the soil in accordance with the provision of the Standard Review Plan 3.7.2. Design response spectra are generated as a result of the analysis.

II. Conclusions

The major findings of the study were:

A. A new set of design response spectra at all the mass points of the reactor building mathematical model and for all the degrees of freedom were generated, both for SSE and OBE with maximum horizontal and vertical ground acceleration of 0.250 g and 0.125 g, repectively. In general, the new response spectra were found to be less than previously generated using a lumped mass spring approach.

B. For the soil-structure system analyzed it was found that it is more conservative to specify the control motion at the elevation of the base of the reactor building rather than at the finished grade level. The final analysis was based on specifying the free field control motion to be applied at the elevation of the reactor building mat.

III Discussion

A. General

The total soil-structure system was modeled and analyzed in one step. A finite element approach was used in this step. The design motion was deconvoluted to the base rock in the free field, then the structural response to this deconvoluted motion is evaluated. This analysis was performed in the frequency domain. The Reg. Guide 1.60 ground motion was used as input to this study.

B. Programs

1. The first step in the seismic analysis was to analyze the dynamic soil-structure system. The FLUSH program was used for this purpose. The FLUSH program was a plane strain finite elements program, which also has one-dimensional beam elements. The main features of the FLUSH program are:

   - It incorporates the Lysmer semi-infinite boundaries thus being able to account for the radiation damping in an inexpensive way.

   - It can account for the soil nonlinearities by an interative scheme.

   - It accounts in an approximate way for the three-dimensional soil behavior.

The output of the program (accelerations of the different mass points of the structure) could be used directly in the design. However, due to the fact that the structural model in the soil-structure model is not detailed enough, an extra step in the analysis was performed.

B. Programs (Con't)

2. The next step in the analysis was to build a detailed three-dimensional mathematical model of the reactor building. The input to this model were the resultant acceleration time histories at the base of the structure (soil-structure interface) of the simplified soil-structure model analyzed as described before. The program NASTRAN was used in this step. The advantages of performing this step are:

- Analysis of the reactor building in more detail is possible.
- It accounts for the coupling of the six different directions (three translations and three rotations).
- Better modeling of the water masses is obtained which the FLUSH program cannot handle.

The output from NASTRAN were acceleration time histories of the different structural mass point associated with the six dynamic degrees of freedom.

C. <u>Generation of Response Spectra</u>

The last step was to generation design response spectra from acceleration time histories. The generation of the response spectra was based on solving the dynamic equation of a damped single degree of freedom system.

Prepared by M. M. Ettouney
M. M. Ettouney

Approved by J. O'Donnell
J. O'Donnell

ME/has

TECHNICAL MEMORANDUM

DATE 7/23/80

TO R. E. Snaith

FROM R. K. Dubey

SUBJECT W. O. 2808
Washington Public Power Supply System
WPPSS Nuclear Project No. 2
Pipe Break Loading on Sacrificial Shield Wall
Technical Memorandum No. 1190

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EWagner db
EFerrari SF-2
HTuthill TM File
GHarper

Reference: 1. Memo to M. Fialkow from R. K. Dubey dated 4/15/80, "Pipe Break Loading on Sacrificial Shield Wall"
2. B&R Report No. WPPSS-74-2-R1, Rev. 2 dated January '76, "Protection Against Pipe Breaks Inside Containment"

Purpose

The purpose of this technical memorandum is to document the basis for refinements in pipe break reaction loads which have been used in the reevaluation of the sacrificial shield wall.

Background

Pipe break reaction loadings used in the original design of sacrificial shield wall (SSW) were based on approximate locations of pipe whip supports and conservative gaps between pipe and pipe whip supports.

Current Loading

The current loadings used in the reevaluation of SSW design, have been determined using final locations of pipe whip supports and more realistic gaps between pipe and pipe whip supports (reference 1).

Dynamic Analysis

An analysis has been performed for each postulated pipe break. An energy balance model has been used in the analysis. Kinetic energy generated during the first quarter cycle movement of the ruptured pipe is imparted to the piping/ restraint system through impact, and is converted into equivalent strain energy.

July 23, 1980

Simplified dynamic analyses as described in reference 2 have been performed to obtain pipe break loadings. The entire structure including pipe, support linkage, restraint beams and major structure to foundations absorbs energy by elastic, elasto-platic, or plastic deformation. The maximum deformation of the restraint member has been limited by limiting the ductility ratio μ, the ratio of the maximum deflection (Ym) to the elastic deflection (Ye). The maximum permissible ductility ratio is limited to 50% of μ_c, the ductility ratio that corresponds to collapse.

Time history of unbalanced forces on the ruptured pipe has been simplified to a suddenly applied, constantly maintained force. Dynamic loading on the pipe whip restraint is assumed to be a suddenly applied constantly maintained force described above, in conjunction with a kinetic energy of impact.

Prepared by R.K. Dubey
R. K. Dubey

Approved by M. Ramchandani
M. Ramchandani

RKD/gb

ATTACHMENT 1

L D Report

LD 22526
June 1980

AN EXAMINATION OF THE STRUCTURAL INTEGRITY OF THE SACRIFICIAL SHIELD WALL OF THE WPPSS NUCLEAR PROJECT NO 2

INTERIM REPORT

FOR: WASHINGTON PUBLIC POWER SUPPLY SYSTEM (WPPSS)

BY : A A Willougby

THE WELDING INSTITUTE

L D Report

LD 22526
June 1980

AN EXAMINATION OF THE STRUCTURAL INTEGRITY OF THE SACRIFICIAL SHIELD WALL OF THE WPPSS NUCLEAR PROJECT NO 2

INTERIM REPORT

FOR: WASHINGTON PUBLIC POWER SUPPLY SYSTEM (WPPSS)

BY : A A Willougby

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Abington Hall, Abington, Cambridge. CB1 6AL

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CONTENTS

AN EXAMINATION OF THE STRUCTURAL INTEGRITY OF THE SACRIFICIAL SHIELD WALL OF THE WPPSS NUCLEAR PROJECT No 2

Interim Report

By: A A Willoughby

1. INTRODUCTION

The sacrificial shield wall (SSW) at WPPSS Nuclear Project No. 2 (WNP-2) is a cylindrical wall surrounding the pressure vessel. It consists of a framework fabricated by welding plate and rolled members into box sections, with the outside covered with skin plates, and the inside filled with concrete to provide a radiation field (Figs. 1(a) and 1(b)). Steels used were A36 and A588 in 1" - 3" thickness. Whilst it may be assumed that the concrete would contribute to the structural strength of the wall, no credit is taken for this in the analysis to be presented. Welding processes used in fabricating the wall include shielded metal arc (SMA), flux-cored arc (FCA) and electroslag (ES). During normal service the design stress is small but in certain circumstances (for instances, a loss of coolant accident coupled with seismic loading) the nominal design stress would reach approximately the minimum yield stress of the base material. Most of the 13,000 welds, which are not stress relieved, are now inaccessible, but the survey of the visible ones has revealed many instances of welding defects which exceed AWS D1.1 visual acceptance criteria. In addition, during fabrication, the contractor who made the SSW had a significant problem with the quality of electroslag and flux-cored arc welds, and magnetic particle inspection of areas of the outside of the SSW by another contractor has revealed a number of cases of cracks and linear defects. Because of these concerns, an assessment of the structural integrity of the SSW has now been called for.

2. GENERAL APPROACHES TO FRACTURE ASSESSMENT

Failure of the structure may occur by either of two mechanisms:

i) Plastic collapse
ii) Fracture

2.1. Plastic Collapse

Plastic collapse occurs when the net section is insufficient to support the load on it. This could be a problem where extended defects result in a significant reduction in net sectional area. Consideration of this possibility involves the assessment of the the likely maximum size of defects at the various levels of section size and nominal stress present in the structure (residual stresses, which are self-balancing and are relieved by plastic flow, do not affect the tendency towards plastic collapse). If plastic collapse cannot be ruled out in certain details, the effect of loss of load-bearing capacity in these details must be examined.

2.2. Fracture

Fracture in the structure requires the operation of two mechanisms:

i) Initiation
ii) Propogation

In order for the structure to fail, both stages must take place. An assessment of structural integrity in a welded structure can therefore be based on either

a) The likelihood that fracture will not initiate from pre-existing defects, or
b) The likelihood that an initiated fracture will not propagate a significant distance but will arrest in the material.

The application of these two approaches will now be considered further.

2.2.1. Initiation

From a knowledge of fracture toughness and stress level, the maximum tolerable defect size and shape may be calculated by means of fracture mechanics. The fracture toughness should be obtained for all materials employed (parent materials, weld metals and heat affected zones (HAZs)). In structural steels, the measurement of "valid" K_{Ic} or K_{Id} values requires very large specimens, and so yielding fracture mechanics parameters, such as COD, are more readily obtained. Alternatively, a lower bound value of K_{Id} may be estimated via correlations with other parameters.[1] The stress level employed in the analysis is the nominal applied stress with allowances made for stress concentration and residual stresses. In the COD approach, the toughness, stress and maximum allowable defect size are connected by means of the COD design curve.[2] The maximum allowable defect size calculated by this means is not the critical value for fracture initiation, but incorporates a safety factor of the order of two or three.

2.2.2. Arrest of a propagating crack

The philosophy behind the crack arrest approach is to assume that cracks can initiate at defects, at locally embrittled regions and at regions of high local stress and to demonstrate that fracture will be arrested by the surrounding material. The details of the initiating defect and its immediate environment need not be considered. The simplest approach is based on the drop weight test (DWT) test of Pellini[3] which is semi-empirical but is well supported by available data. From a knowledge of the nil-ductility transition temperature (NDT), crack arrest can be assumed at a temperature of NDT + x, where x depends on nominal stress level, section thickness and size of initial defect. For initial defects of comparable or smaller size than the plate thickness, and for nominal stresses of around yield, the crack arrest temperature will be taken as:

NOMINAL STRESS/YIELD STRESS	0.25	0.5	1.0
Crack arrest temperature (1" thickness) °F	NDT+10	NDT+30	NDT+60
Crack arrest temperature (3" thickness) °F	NDT+40	NDT+60	NDT+90

with intermediate thicknesses in proportion. These temperatures are obtained from Pellini's Fracture Analysis Diagram[3] (FAD) for 1" thick material, and by applying a recommended 30°F temperature shift to allow for the extra constraint in 3" thick material. This may be an overestimate at low stresses. The whole approach is considered to be conservative if defects are not extremely large, although it is not known what the precise margins of safety are.

In applying this approach, all possible crack propagation paths must be considered. This includes fracture in parent materials, weld metals, and, possibly, in HAZs.

3. METHODOLOGY TO BE APPLIED TO THE ASSESSMENT OF STRUCTURAL INTEGRITY IN THE SSW

3.1. Plastic Collapse Assessment

The possibility of plastic collapse will be assessed in terms of the nominal design stresses, the likely defect sizes and the estimated flow stresses of the materials (based on generic data). Where this possibility is found to exist, the effect of redundancy of structural members and the nature of the applied loading system (which will be principally displacement controlled due to the effects of load distribution into the framed structure and to the restraint of the concrete in-filling) will be considered.

3.2. Crack Arrest Approach

The crack arrest philosophy will next be applied since details regarding the defects, such as severity and local embrittlement, need not be considered. The crack arrest temperature, as defined in Section 2.2.2, will be estimated for all materials where cracks might propagate - i.e. A36 and A588 plates and sections, all weld metals and possibly the HAZs. Specific data in terms of NDT temperatures on the materials of the SSW are not available, and so estimates will be based on generic data where possible, on a worst case basis to give conservative predictions. Use may also be made of conservative Charpy energy/NDT correlations, where applicable.

Several reasons may be envisaged which prevent the assurance of structural integrity by means of the crack arrest approach:

(a) The available generic data on NDT temperatures may be indadequate,
(b) The upper bound NDT temperatures estimated may be too high to guarantee crack arrest at the service temperatures.

In the first case, steps should be taken to acquire more data, by means of laboratory tests on procedure qualification weldments or on material cut from the SSW. In the second case, consideration should first be given to raising the service temperature above the crack arrest temperature. If it is not possible to raise the temperature sufficiently, then those regions and materials which are below the crack arrest temperature will be identified and assessed in terms of the maximum allowable defect sizes for crack initiation, as detailed below.

3.3. Prevention of Fracture Initiation

For those regions where crack arrest cannot be assured, as identified in Section 3.2, the maximum allowable defect sizes to ensure that fracture initiation will not occur will be determined.

The first approach will be via the reference K_{IR} curve[1], which is a standard K_{Id} versus temperature curve for all materials of yield strength below 50ksi, referenced to the NDT temperature. There exist some doubts, however, concerning the applicability of the K_{IR} curve in all cases. Pellini[4] suggests that it is excessively conservative for low strength materials such as A36, and its use for higher strength materials such as the weldments in the SSW has not been established. Depending on the margin of safety, it may be necessary to conduct laboratory tests in a few specific cases. In this case, fast strain rates will be used because the pipe whip loads following a loss-of-coolant accident (LOCA) will be dynamic in nature. Linear elastic fracture mechanics (LEFM) tests could be employed, but the thickness of material involved would almost certainly mean that these tests would be invalid, in which case dynamic COD tests on specimens of full section thickness will be used. The material for the tests could be either cut out of the SSW or simulated in the laboratory, using the same welding conditions as those used in the wall.

From the value of the dynamic fracture toughness, however estimated, the maximum allowable defect sizes will be calculated.

These must be compared with the actual defect sizes in the regions established to be at risk, and so non-destructive examination should be carried out on all accessible details in order to allow an estimate of defect population to be made. From this, the probability of fracture in the details at risk may be calculated.

4. DATA APPLICABLE TO THE SSW

4.1. Stress Levels and Distribution

It is understood that, during normal operation, the nominal design stress on the SSW is small, consisting principally of the deadweight of the structure and attached pipework. If one of the high energy lines were to rupture, however, the resulting movement of the pipe ends would apply large dynamic loads to the SSW, via the pipe whip restraints. Alternatively, the rapid release of steam into the annulus gap between the SSW and the reactor pressure vessel as a result of a coolant pipe break within the annulus would induce radial stresses. For pipe failures in this region the radial loading would be additive to the pipe whip loading. The main causes of stressing may thus be summarised as follows:-

(1) Deadweight loading.
(2) Seismic loading.
(3) Pipe-whip following a LOCA.
(4) Annular pressure following a LOCA.

It must be emphasised that the probability of these loads being applied simultaneously is extremely remote, requiring as it does a combination of a pipe break inside the annulus and an earthquake. Nevertheless, the structure was designed with this contingency in mind, and the architect engineer, Burns & Roe, Inc., estimate that the maximum nominal stresses could reach yield in certain regions of the SSW.

The rate of application of the load for the various categories outlined above is different: the first is static, the second of slow to intermediate rate, and the last two are dynamic in nature. Calculations by Burns & Roe indicate that the annulus pressurisation load reaches a maximum (of 92.4psig) within approximately 0.005 seconds of a LOCA and then decays to approximately 40psig in 0.01 seconds. In the absence of further data it will be assumed that the pipe whip loads are applied at a similar rate, and that the combination of pipe whip and annulus pressurisation causes loads approaching yield stress magnitude to be attained in the 0.005 seconds. The nominal strain rate is then approximately 0.5 in/in/sec. This figure is intended to be a guide only: part of the loading is static or relatively slow, thus reducing the strain rate, whereas the rate at stress concentrations and discontinuities could be much higher.

A finite element analysis has been carried out by Burns & Roe, and the calculated stress distribution under the worst combination of loading is approximately depicted in Fig. 2. The most highly stressed regions are in the top ring and in the second ring up from the base. The fourth ring up is mostly stressed to less than half the allowable design stress. It is understood that these calculations of stressing are conservative in nature, and that Burns & Roe are currently re-analysing the situation in an attempt to define the stresses more precisely.

4.2. Materials

The majority of the structure is fabricated from A36, as-rolled. Plates of ¾" - 3" thickness and rolled sections of up to 1" flange thickness were used. A588 plate, Grades B and H, were used for the uppermost ring, in 2¼" and 2½" thickness. Welding processes were of three main types - shielded metal arc, flux-cored metal arc and electroslag. The electrode type, manufacturers designation, and the specified minimum tensile properties for all the materials are given in Table 1. In the case of the electroslag weldments, no tensile properties were specified, so for the welds in A36 the results of the weld procedure test are given. For those in A588, the scatter bands for the similar weldments reported elsewhere[10] are taken as giving a good indication of tensile properties.

4.3. Inspection and Defect Details

Three different inspections were carried out on various weldments:

(1) Leckenby, the contractor, visually inspected all welds and repaired as necessary. Defects were found in 37% of the electroslag welds. Some ultrasonic inspection was also carried out to detect lamellar tears associated with the electroslag T welds.

(2) Magnetic particle inspection was carried out independently by the mechanical installation contractor in all areas where attachments were to be made to the SSW. A total of 74 defects were detected and repaired. This number is small compared to the total number of welds inspected (700).

(3) After fabrication, Burns & Roe carried out visual inspection on accessible welds and found a large number of defects, mainly attributable to bad workmanship. Some accessible welds were omitted in error and it is understood that these will be inspected and the defect analysis updated accordingly.

The various defect types, with the largest size reported, are given in Table 2. There are three main areas of concern:-

Firstly, the high reject rate on the electroslag welds indicated that there was a problem with the process used. The major defects were from lack of fusion (39" was the longest reported). These usually break the surface in electroslag weldments, so it is probable that where removable copper shoes were used, all these defects were found and repaired. However, a small number of welds (approximately 100) were made with permanent steel shoes, and in these cases, it is probable that lack of fusion defects would remain undetected.

Secondly, the original visual inspection of all weldments performed by Leckenby was shown to be inadequate by the later examinations on accessible welds, and so it is highly likely that the inaccessible welds contain similar workmanship defects.

Thirdly, the magnetic particle inspection on accessible welds revealed a number of linear and crack-like indications. This inspection was carried out prior to grinding, and therefore any small discontinuities would be detected, giving a pessimistic indication of the weld quality. Nevertheless, it is possible that crack-like or linear defects exist elsewhere in the structure, in the welds which were not inspected magnetically.

The potential failure mode (plastic collapse or fracture) as a result of the defect is also indicated in Table 2. In general, plastic collapse must be considered as a possibility for any defect which causes a significant reduction in load bearing area (hence only the larger defects are important), whereas fracture could initiate from any defect which is sufficiently sharp to give a significant stress concentration (for instance, lack of fusion defects and cracks) or which embrittles the material (as with arc strikes). Defects such as excess metal will not increase the propensity to collapse or fracture. Since a crack arrest approach will first be considered, the tendency of small defects to cause fracture initiation is unimportant, and therefore the dimensions of defects need only be taken into account in terms of their ability to cause plastic collapse of the structure. Referring to Table 2, the defect types which cause the greatest reduction in load bearing area are lack of fusion, underfill and undersized fillet.

The lack of fusion defects in the electroslag welds which were made with removable shoes were all ground out and repaired. Unfortunately, only one inspection report gave the depth of excavation required, which was approximately ½". European experience suggests that lack of fusion defects in electroslag welds, which occur at the edge of the weld pool, are seldom this large, even in a 3" thick weld. It has been suggested[21], that the welding parameters were incorrect - the root gap was too large, and the guide tubes were too far from the backing shoes. On the other hand, lack of fusion defects were thought[21] to be less prevalent in welds made with permanent steel backing shoes, due to the lower rate of heat removal. These conclusions must be regarded as somewhat speculative. Nevertheless, it is considered unlikely that lack of fusion defects of depth greater than ½" would exist in the small number of welds made with permanent steel shoes.

It is understood that the fillet welds where extensive lack of fusion had been reported by the Burns & Roe inspection were re-examined, and that the indications were found to be caused by inter-run crevices, sharp re-entrant angles between weld bead and base metal due to a highly convex weld profile, or in one case by a mechanical gouge. The greatest loss of section caused by any of these was found to be only 3/32", in a 5/8" fillet.

WPPSS have analysed the data from the Burns & Roe inspection reports in terms of defect length per unit area of wall and per unit length of weld. From a sample of about 200' of weld, both fillet and butt, lack of fusion defects were found in 2%, underfill in 6% and undersized fillet in 1%, of total weld length (all in fillet welds). These figures suggest that the proportion of welds with large defects is small.

Other possible defect types, which were not reported, include hydrogen cracks, lamellar tears and lack of penetration. Hydrogen cracks, if present, are found in the weld metal and HAZs, particularly at the toes of weld beads where stress concentrations may occur. They generally break the surface but may not be detected by magnetic particle inspection unless the area is ground locally. Because they tend to be sharp and discontinuous, they tend to cause brittle fracture rather than plastic collapse (which requires large reductions in net sectional area).

Lamellar tears often initiate at hydrogen induced cracks and propagate parallel to the rolling plane in the base metal and HAZ. They occur while the weld is cooling down, and are encouraged by poor short transverse ductility and joint configurations which give rise to welding stresses acting perpendicular to the plate surface, for instance cruciform and T-butt joints. The risk of tearing increases with increasing restraint. If the tears break the surface they are frequently detected visually, but this is not always possible because they may be entirely buried. In this case they can be detected by ultrasonic examination. Since lamellar tears are crack-like and may be large, they could conceivably cause failure by either a collapse or a fracture mechanism. In practice, however, service failures occurring as a result of lamellar tearing are extremely rare. The possibility of such failures occurring in the SSW will be examined in Section 5.1.

Lack of penetration defects, if present, are not normally sharp, and so would tend to promote failure by plastic collapse rather than by brittle fracture. This possibility is also considered later.

4.4. Plastic Collapse Data

For the evaluation of the risk of failure by plastic collapse, the data required are the defect sizes, the nominal stress levels and the minimum stresses to cause plastic flow in the net sections. Specific information on defect sizes for certain types is limited, as shown in the previous section. Concerning the nominal stresses, as a first approximation, it will be assumed that these reach the nominal yield stresses of the base metals. The flow stresses of the various materials, σ_{flow}, will be taken as the average of the minimum yield and tensile stresses, i.e.

$$\sigma_{flow} = \frac{\sigma_Y + \sigma_u}{2} \qquad \ldots (1)$$

where σ_Y and σ_u are the yield and ultimate tensile stresses respectively. The effect of dynamic loading will also be considered, since the loads following a LOCA are dynamic in nature and these materials will be fairly sensitive to strain rate. It is suggested in Reference 5 that an increase in σ_{flow} of approximately 65% would be appropriate for strain rates in the range 10 - 1,000 in/in/sec. The strain rates in the SSW are likely to be smaller than this, except possibly in the region of severe stress concentrations (see Section 4.1). For a strain rate of 0.5 in/in/sec, available experimental data,[22-23] suggest that for low strength structural steels the likely elevation in flow stress would be approximately 30 - 50%. Therefore a lower bound estimate of 30% will be taken as the elevation of flow stress for the likely strain rates in the SSW following a LOCA.

4.5. Crack Arrest Data

The initial approach to the assessment of structural integrity will consider the likelihood that brittle fractures, once initiated, will arrest rapidly. This requires the nil-ductility transition temperature to be estimated for all materials in which extensive brittle fractures could conceivably run.

4.5.1. NDT temperatures from available data.

The NDT temperatures from data available in the literature are summarised in Table 3, column (a).

A considerable volume of data was found for A36 plate. The maximum value reported was +40°F. Reference 6 quotes 52 measurements (although some of these may refer to rolled sections). These had an average NDT temperature of +25°F, with a standard deviation of 11°F. Data from the North Anna investigation were also included, where the A36 plate was found to exhibit worse than average Charpy impact energies[7]. Kuang[8] reports NDT temperatures in the range +20 - +40°F for 2" thick plates and 5 different heats of steel. It is, therefore, concluded that the highest probable NDT temperature for A36 plate is +40°F.

One factor which adds some uncertainty is that the skin plates were cold bent to a radius of about 12', resulting in a plastic strain in the outer fibres of about 0.7% for 2½" thick plates. Prestrain is known to have a deleterious influence on tearing resistance, but there is some uncertainty as to its effect on cleavage fracture toughness. Work on precracked COD specimens at the Welding Institute, where the material was given a 1% plastic strain locally around the crack tip, has indicated that the resulting reduction in toughness decreases to an insignificant amount as the level of toughness diminishes (at toughnesses corresponding to that at the NDT temperature). These results are supported by the work of Jones and Turner[25] on mild steel, where even comparatively large prestrains were found to have negligible effect on the stress for crack arrest in notched tensile specimens where failure occurred by a cleavage mechanism. The tentative conclusion is that the small plastic strains produced in the skin plates and other members will cause a negligble reduction in NDT temperature, especially when compared to the variability in published data for these materials.

Data on A36 rolled section are less numerous (although some may be included in Reference 6). The highest value obtained,[4,9] however, was +54°F. Dolby[9] reported values of +41°F to +54°F for 3" thick flanges of A36 beams which supported a platform at WNP-2. The beams used in the SSW are of smaller section, and therefore an NDT temperature of +54°F will be taken as the maximum probable value.

Limited information was found for A588, and that only on Grade A plate.[10,12] The NCHRP Report[10] gave NDT temperatures for 1" and 4" thick plate from the same heat as +40 and +60°F respectively (the plate was stated as being of Grade B composition, but it in fact corresponded to Grade A). US Steel[12] have measured NDT temperatures in the range 0 - +60°F for 1" thick plate, and +10 - +80°F for 1 - 2" thickness. The mean of all these data (13 plates) was +51°F, with a standard deviation of 21°F. The maximum upper bound NDT temperature for Grade A plate is therefore estimated as +80°F. The impact properties are probably influenced more by rolling conditions than by composition[12] but nevertheless, it is doubtful if these values can be assumed for the Grade B and H plates used in the SSW.

There were few NDT data found for the weld metals. Masubuchi et al[13] found that NDT temperatures for all C-Mn electrodes fell within the range -5 - +40°F, and for E7016 type electrodes within 0 - +20°F. This result may be taken as a good indication for the LH70 electrode (conforming to E7018). The only difference is in the iron powder added to the E7018, which may slightly reduce the toughness because of the larger bead size. For the electroslag weldments, no information was found for the exact combination of weld metal, flux and plate (the parent plate composition will have a large effect on the composition of the weld metal due to the extensive melting which occurs during the process).[14] Australian data[6] give NDT temperatures in the range -30 - +60°F for unspecified electroslag weldments, and values of 0 and +10°F were found[10] for welds in A588A made with an EM13K-EW wire (Hobart 25P) and Hobart PF201 flux. This wire is very similar in composition to the Linde 29 used here, and it has been suggested[15] that the Linde 124 flux tends to give improved Charpy impact properties compared to PF201 flux. Even so the data cannot be considered to be conclusive since only two heats of steel were used, and a similar but not identical wire/flux combination. The welding conditions were also different, in terms of preheat, shoe type, guide tube and heat input.

4.5.2. NDT temperatures estimated from Charpy energy.

Several correlations have been attempted between NDT and Charpy energy, 3,4,10,16,17,18. It appears that the absorbed energy at the NDT temperature varies quite markedly with material. For instance, Harsem and Wintermark[16] found C_v energies at the NDT temperature of between 22 and 93ft.lbs (average 41ft.lbs) for longitudinal Charpys of fine grained C-Mn steel. This is in agreement with Pellini[3] where high energies are reported for these improved steels, as compared to the much lower values for "ship fracture" steels similar to the ones of interest here. The available data for steels similar to A36 and A588 are summarised in Table 4. For A36 plate, the NDT temperature would appear to correlate with a Charpy energy of 10 - 30ft.lbs. The correlation energy for ES weld metals and HAZs is lower, in the range 6 - 23ft.lbs.

The main area where NDT temperature data are scarce but C_v data are available is in the SMA and FCA weld metals. No direct data correlating the two were found. However, the NDT temperatures for all low hydrogen multi-run welds were observed to be within the range -76 - +20°F

(Table 3 column (a)), so if the individual welds used here show good Charpy impact properties, it is reasonable to conclude that there NDT temperatures will lie within this band.

Therefore in order to estimate the NDT temperatures for the other weld metals it will be assumed that these are given by the temperatures at which Charpy impact energy of 50ft.lbs is obtained. Despite the absence of direct correlations for these materials, it is felt that this will give conservative estimates of the NDT temperatures. In his commentary on the AASHTO Bridge Codes, Hartbower[19] recommends that minimum Charpy impact values be specified at the lowest anticipated service temperature, while Hurlick in the same document advises testing 20 - 40°F below this temperature. This is in contrast to the AASHTO requirements of testing at 70°F above, and it is aimed at ensuring arrest of a fast moving crack which initiates at an embrittled region. The situation is thus very similar to that envisaged in the SSW, but even the most stringent recommendation in Ref. 19, of achieving 20ft.lbs at 20 - 40° below the service temperature is much less conservative than the criterion adopted here - namely, 50ft.lbs at 60 - 90°F below service temperature (depending on thickness, at yield stress levels). Therefore, a considerable degree of confidence is felt in the overall safety of the approach proposed here.

Charpy impact energies were obtained from the electrode manufacturers and from weld metal qualifications (in both cases on weldments made to AWS A5.1/A5.20 specifications), from Welding Institute data on actual weldments, and in the case of the Chemetron IIIAC electrode on a weld made for procedure qualification. The results are given in Figs. 3, 4 and 5. For the LH70 electrode (Fig. 3), the Welding Institute data is considered to be the most representative since it refers to actual weldments. Welds were made in the vertical up position, which would give worst values of toughness. Also shown is the scatter band for welds made with several electrodes corresponding to E7018 specification. Taking the LH70 data on welds, 50ft.lbs was absorbed at -12°F. It can therefore be concluded that the NDT temperature for LH70 weld metal lies below 0°F.

Figure 4 shows the C_V/T transition for the Lincoln NR203M electrode. Results were obtained from a variety of sources. Taking the bottom of the scatter band (data from Ref. 20) gives 50ft.lbs at approximately +40°F. Therefore it will be assumed that the NDT temperature is at +40°F or below.

For the Chemetron IIIAC welds, a considerable number of results were available from AWS A5.20 test specimens (Fig. 5). Some procedure qualification tests had also been carried out at 0°F, and these fall close to the bottom of the scatter band for the manufacturer's data. The lower bound of these data would then seem a reasonable estimate of true impact energies above 0°F. At +32°F, the AWS A5.20 welds gave a minimum of 51ft.lbs and so this temperature will be taken as a conservative estimate of NDT temperature.

The estimated NDT temperatures, derived from Charpy data, for these weld

metals are given in Table 3 column (b). Because of the lack of specific data on NDT temperature/Charpy correlations for these materials, the estimates cannot be verified conclusively, but are nevertheless felt to be conservative.

No consideration has so far been given to the welds made with the E7028 electrode (Lincoln LH3800). There was originally some doubt as to whether this had been employed on the SSW, but it now appears that it was used fairly extensively. Figure 6 shows, from the small amount of Charpy data obtained, that its impact properties are inferior to those of the other weld metals. It is not possible to estimate an NDT temperature with any confidence, on the basis of these results. It is understood that WPPSS are in the process of measuring the NDT temperature on a simulated weld made with LH3800.

Culp[14] has published a lot of data on the Charpy properties of electroslag weldments in A36 and A588, using four electrodes. The type most relevant to the present case are welds in A36 and A588 Grade A plate, using Hobart 25P wire and Hobart PF201 flux (a similar combination to the Linde 29/Linde 124 used in the SSW). At +20°F, this weld metal gave a C_v impact energy of 30 - 60ft.lbs (depending on specimen location) for both base metals. Using the correlation between NDT temperature and Charpy energy from Ref. 10 (see Table 4), this would suggest that the NDT temperatures of the weld are well below +20°F, a conclusion supported by the data in Ref. 10 for welds of similar composition in A588. Once again, however, caution must be exercised when drawing these conclusions, due to differences in base metal composition and in welding parameters.

4.5.3. Discussion of NDT temperatures.

The assumed NDT temperatures for the materials in the SSW are given in Table 3 column (c). The maximum values are estimated with confidence for A36 plate and rolled section (from available data), and for the LH70, IIIAC and NR203M weld metals (from Charpy impact data). The materials where insufficient data were found were the A588 plates (Grades B and H) and the electroslag and LH3800 weld metals. For the A588 plates, the NDT temperatures found all referred to Grade A material, although there is no reason to assume that the value of +80°F will be exceeded in Grades B and H. For the electroslag weldments, the NCHRP Report[10] indicates that the NDT temperatures are comparable to, or better than, those of the parent plates, for A588 welded with a similar electrode to that used on the SSW. However, no information was found for the combination of A36 and EM12K electrode used, and very little for LH3800 weld metal. It is understood that steps are being taken to measure NDT temperatures on samples of A588 plate cut from the SSW, and on simulated weldments using EM12K (electroslag) and LH3800 (SMAW) electrodes.

No consideration so far has been given to the possibility of fast fracture occurring in the HAZs. This is discounted in the case of the SMA and FCA weldments, because the HAZs will be narrow and do not lie in a plain perpendicular to the plate surface, due to the geometry of the weld preparation. Brittle fractures normally travel on planes perpendicular to the plate surfaces, and so could not run down the HAZs. Also, shrinkage of the weld during cooling will induce tensile residual stresses of near yield magnitude running the length of the weld and extending a short distance into the plate. These stresses would tend to direct a running crack out into the plate.

The same arguments concerning residual stress and plane of fracture can be applied to the HAZ; in electroslag weldments. In the latter case, the weld preparation is normal to the plate surface, but because of local melting the fusion boundary is curved, concave to the weld. Heat affected zones on ES weldments can be fairly wide, but Culp[14] points out that most of this has much improved impact properties and it is only the narrow region (1 - 2mm wide) next to the fusion boundary which undergoes grain coarsening. In any case, the Charpy energy absorbed was found to be greater in this region, due to its find secondary structure, than in the base metal. This phenomenon may be expected to vary with other factors such as heat input and steel type, but it is supported for the specific type of steel under consideration by the results of Ref. 10, where the HAZs in A36 and A588 plates had lower NDT temperatures than the base metals, unless these were already very low. For these reasons, an extensive brittle fracture running exclusively along the HAZs is not considered to be a serious possibility, in either the shielded metal arc, flux-cored arc or electroslag weldments.

5. EVALUATION OF STRUCTURAL INTEGRITY

5.1. Plastic Collapse

It will be assumed that plastic collapse occurs when the net section stress reaches the flow stress (as defined in Equation (1)). For a long surface breaking defect of depth, a, in a member of thickness, t, the critical flaw depth to thickness ratio, a/t is given by the expressions (see Appendix):-

$$\frac{a}{t} = 1 - \frac{1.02\sigma_Y}{\sigma_{flow}} \quad \text{simple tension} \qquad \ldots (2)$$

$$\frac{a}{t} = 1 - \sqrt{\frac{0.75\sigma_Y}{\sigma_{flow}}} \quad \text{pure bending} \qquad \ldots (3)$$

assuming that the nominal stress reaches the minimum specified yield stress (σ_Y). The critical values of a/t are given in Table 5, for two levels of flow stress:

(1) Assuming static tensile properties

(2) Assuming dynamic loading conditions and an elevation in σ_{flow} of 30%.

At the critical combination of loading conditions, as described in Section 4.1, the majority of the loading will be dynamic in nature, especially in the region of pipe whip restraints. The initial strain rate during a LOCA was estimated to be 0.5in/in/sec, giving a likely elevation of 30% in flow stress. Table 5 shows that this assumption significantly increases the critical defect sizes for plastic collapse.

Under statically applied loads, the most critical regions for plastic collapse are the A588 plate and ES weldments when loaded in tension with critical defect depth to thickness ratios of 0.15 and 0.12 respectively. The first category would embrace HAZ defects such as hydrogen cracks, if it is assumed that the flow stress equals that of the parent plate. However, these cracks do not usually extend down the length of the HAZ, but are intermittent in nature, and so greater depths could be tolerated without collapse occurring. Defects in the electroslag weld metals in A588 are particularly critical, because of the low value of flow stress assumed. It was in these weldments that numerous lack of fusion defects had been reported, the majority of unspecified depth. These were all repaired, but some doubt exists as to the state of the ES welds made with permanent fused shoes, where visual inspection was not possible. However, it is argued in Section 4.3 that these are likely to be shallow (less than ½" deep), so the critical defect depth should not be exceeded except for the welds of smaller section thickness. The probability and consequences of collapse at such defects is considered below.

The loading for the majority of SMA and FCA fillet welds is likely to be a combination of tension and bending, although in fact the mode does not make a great difference to the defect tolerance. The critical depth ratios are 0.24 (tension) and 0.38 (bending), for static and dynamic conditions respectively, in A588 weldments. Judging from the defect reports, there is a slight possibility that defects of one quarter the section thickness might exist - for instance, the worst case of underfill reported was of length 24" and depth 3/16" in one leg of a 3/8" fillet weld.

No instances of lamellar tearing were reported, although it is possible that lamellar tears could exist either as surface breaking or buried flaws. However, service failures resulting from lamellar tearing are extremely rare. Recent work at the Welding Institute has shown that failure in the laboratory may be assessed in terms of the same two criteria as for other defects - namely, brittle fracture and plastic collapse. The risk of collapse is dependent on the loss of cross sectional area caused by the tears, assuming that the through thickness stress in a plate at a weld is transmitted over a distance equal to the width of the connecting arm, D, (see Fig. 7). A simple analysis showed that, for large defects, failure could be predicted conservatively if the maximum stress in the arm is :

$$\sigma_{max} = \sigma_Y(1 - \frac{2a}{D}) \quad \ldots (4)$$

where 2a is the maximum defect width. In fact no reduction in load

bearing capacity was observed until the defect area exceeded 30% of the arm area. Similar findings were reported by MacDonald[24] for the case of a beam or tab welded end-on to a column containing extensive laminations. No reduction in strength was observed for laminations which had defect area/load area ratios of approximately 0.25 for A36 and 0.15 for A588. These defect area ratios agree well with the predictions for static loading given in Table 5 of 0.23 and 0.15 respectively, even though the geometry of the laminations with respect to the weld is not the same in the two cases. Table 5 was evaluated on the basis of flow stresses applicable to the longitudinal direction in rolled plate. The agreement with Ref. 24 would suggest that this assumption is realistic, despite the fact that the flow stress in the short transverse direction is likely to be lower. Compensation for this fact is probably caused by the conservatism of the plastic collapse analysis as discussed later. Slightly larger critical flaw sizes are predicted in Table 5 in the presence of bending stresses. These are calculated assuming surface breaking flaws, and will be conservative estimates if the flaws are buried.

The same predictions of allowable defect size apply to lack of penetration defects, if these are present. Since none were reported in the visual inspection, any defects of this type are likely to be buried (for instance, at the root of double V butt welds). Assuming reasonable joint design and preparation, they are likely to be small and should therefore not pose a threat to the integrity of the structure.

The predicted flaw sizes are relatively large for all other details (of the order of one quarter of the thickness, even for static loads), and it is unlikely that there would be many extended defects of this depth in the SSW. Nevertheless, since the majority of the welds are now inaccessible, it cannot be proven that the critical defect size for plastic collapse will not occur somewhere in the structure. However, there are several points which suggest that the analysis is very pessimistic:-

(1) The effect of dynamic loading. Table 5 shows that, assuming an elevation in flow stress of 30%, the defect tolerance of the most critical members is increased by a factor of two or three.

(2) It has been assumed that the nominal stresses reach yield, whereas current work by Burns & Roe is indicating that in many regions of the SSW, the stresses are considerably lower.

(3) The analysis itself is known to be very pessimistic. Even a simple tension specimen fails at its ultimate tensile strength (by definition) rather than at the estimated "flow" stress, and the effect of increased triaxiality will be to raise the ultimate tensile stress (UTS) further towards the true fracture stress. Better estimates of the flow stress would be the UTS or the average of the yield and the true failure stresses in tension. The former estimate would increase the assumed flow stress by about 20% for the weld metals. The exception to this argument is the case of collapse from lamellar tears, where the use of the UTS measured in a longitudinal direction

would be an overestimate compared to its true value in the through thickness direction. If the flow stress in the longitudinal direction is to be applied to collapse in the through thickness direction, Welding Institute work and Ref. 24, discussed above, would suggest that the usual estimates of flow stress (Equation (1)) would not be unduly conservative.

(4) The vast majority of welds in the SSW will be limited in the strain they can undergo, because of the redundancy inherent in a system with multiple load paths, and because of the large mass of concrete which would provide some restraint. While it is probable that any region with critical defects will reach yield on the net section, in order to reach the flow stress (however defined) considerable plastic deformation will need to take place. This could only be possible if all the members in parallel had defects of the critical dimension. This is extremely unlikely because, although many welds probably contain defects, it is only the large, extended ones which are critical, and the chances of these existing in all parallel welds is very remote. As discussed in Section 4.3, of the sample of welds examined visually, only 2% of the total length contained lack of fusion defects (and most of these were found to be interrun crevices), 6% had underfill and 1% an undersized fillet.

This last argument, concerning structural redundancy and strain limitation on the welds, does not apply to certain details. The pipe whip restraints are attached to skin plates, which are welded to the framework of the SSW. On the application of pipe whip loads, the skin plate welds would not have these limitations, and collapse could occur at any large defects present. These welds should be inspected to ensure that they do not contain defects of size greater than those given in Table 5 (see Section 8.1), and that they satisfy dimensional requirements.

It is therefore concluded that there is a possible risk of plastic collapse occurring in the welds of the skin plates which support the pipe whip restraints, but that the risk elsewhere in the SSW is negligble.

5.2. Crack Arrest

The criterion for crack arrest is that all materials should operate at a temperature of NDT + x, where x depends on stress level, defect size and section size. For stresses of yield point magnitude and defects of a size comparable to, or smaller than, the section thickness, x varies between 60 and 90°F for 1" and 3" thickness respectively (see Section 2.2.2).

Using the estimated NDT temperatures, crack arrest temperatures at yield stress levels have been calculated and are given in Table 6. Because of the uncertainty in NDT temperatures for certain materials (A588, and LH3800 and electroslag weld metals) the crack arrest temperature is only tentative. It may be seen however, that for materials where the NDT temperatures were estimated with confidence, the maximum crack arrest temperature is +130°F (for 3" thick A36 plate and NR203M weld metal at stresses of yield magnitude). As discussed in Section

4.5.3, the possibility of crack propagation occurring in the HAZs was dismissed.

The estimated crack arrest temperature for the A588 steels (165°F) is based on data from a different grade of material and is uncertain. No estimate could be made for LH3800 weld metal, and laboratory tests should be carried out in order to acquire data. The crack arrest temperatures for the electroslag weld metals are low in comparison to those of the parent plates, but they are subject to uncertainty because the data found were not completely relevant to the materials and welding parameters used in the SSW.

This analysis indicates, therefore, that the minimum operating temperature to ensure crack arrest in A36 plate and the SMA and FCA weldments (except those made with the LH3800 rod) is +130°F at nominal stresses of yield magnitude. Firm conclusions on desired minimum operating temperature could not be drawn in the case of A588 and the LH3800 and electroslag weld metals, but the indications are that the A588 could be limiting, with a crack arrest temperature of 165°F. Steps should therefore be taken to acquire more data on these materials, by testing simulated or actual welds and samples of A588 cut from the SSW.

It is possible that the stresses on the SSW have been overestimated: Burns & Roe are attempting to refine the calculations and the initial indications are that in some areas the stresses may be as low as 20% of yield. If this is the case, or if the loadings can be reduced further by a change in operating conditions, the criteria for crack arrest of NDT + (60 - 90°F) can be relaxed accordingly, allowing lower operating temperatures.

6. FRACTURE INITIATION

It is not intended to calculate initial defect sizes for crack initiation at present, because it would be pointless to do so until more crack arrest data have been acquired for those materials where such information is inadequate. When the maximum crack arrest temperatures for all materials have been established, consideration should first be given to raising the service temperature of the SSW to the maximum crack arrest temperature. Only if this is not feasible will crack initiation arguments be considered.

7. CONCLUSIONS

1. During a critical incident, there is a small risk of plastic collapse in the skin plate welds which indirectly support the pipe whip restraints.

2. The risk of plastic collapse occurring elsewhere in the SSW is remote.

3. Crack arrest temperatures were estimated with confidence for A36, and for welds made with LH70, NR203M and IIIAC electrodes. The maximum value for these materials was 130°F at nominal stresses of yield magnitude.

4. Crack arrest temperatures could not be estimated reliably for the A588 plates, or the LH3800 weld metal and for electroslag welds.

5. Extensive crack propagation in heat affected zones is considered to be highly unlikely.

8. RECOMMENDATIONS

1. All exterior skin plate welds which indirectly support the pipe whip restraints should be inspected and repaired as necessary. Table 5 gives the allowable defect depths, assuming nominal stresses of yield. These depths should be taken as the maximum depths for extended surface or buried flaws, or the maximum lengths for through thickness flaws, as a fraction of weld thickness or length respectively. For intermediate cases (ie. short, deep flaws) the figures in Table 5 should be taken as giving the allowable loss of cross sectional area. It is recommended that for these critical areas the figures appropriate to static loading, and the worst value for either tension or bending, be used as a basis for acceptability. Nevertheless, there will be some margin of conservatism as a result of the dynamic nature of the pipe whip loads.

   Inspection should consist of two stages:-

   (1) Visual inspection to ensure that all welds meet the dimensional requirements stipulated in the design drawings.

   (2) Ultrasonic inspection to detect the presence of surface breaking buried flaws which exceed the critical sizes given in Table 5, for static loading.

   Further recommendations on the testing procedures can be supplied when details concerning the skin plate welds are known. These recommendations only apply to failure by plastic collapse. Fracture must also be considered, as below.

2. The feasibility of raising the temperature of the SSW to 130°F should be examined. Lower operating temperatures may be considered if loads can be reduced.

3. Drop weight tests to determine NDT temperatures should be carried out on A588 plates, Grades B and H, on weldments made with LH3800 electrodes, and on electroslag weld metals in A36 and A588 plates. Where possible, weldments should be simulated using the same conditions and materials as used on the SSW.

4. If the crack arrest temperatures determined from the laboratory tests are higher than +130°F, the feasibility of raising the service temperature of the SSW to the maximum value should be considered. The probability of load reductions should also be explored. If neither is adequate, critical defect sizes for crack initiation for all materials where the crack arrest temperature exceeds the service temperature should be considered and compared with the likely defect population.

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TABLE 1. Details of the steels used in the SSW

(a) Parent Plates

STEEL GRADE	THICKNESS	YIELD STRESS[1] σ_Y ksi	TENSILE STRENGTH[1] σ_u ksi
A36	$\frac{3}{4}$" - 3"	36	58
A588 Grade B	up to $2\frac{1}{2}$"	50	70
A588 Grade H	up to $2\frac{1}{2}$"	50	70

(b) Weld Metals

PROCESS TYPE ELECTRODE	ELECTRODE SPECIFICATION	MANUFACTURER'S DESIGNATION	BASE METALS IN JOINT	σ_Y[1] ksi	σ_u[1] ksi
SMAW[4]	E 7018	Lincoln Jet LH 70	A36/A36 A36/A588	60	72
SMAW[4]	E 7028	Lincoln Jet LH 3800	A36/A36	60	72
FCAW[5]	E 70T-G	Lincoln NR 203M	A36/A36 A36/A588	62	70
FCAW[5]	E 70T-I	Chemetron III AC	A36/A588	60	72
ESW[6]	EM 12K	Linde 29/ Linde 124 flux	A36/A36 A36/A588 A588/A588	42.9[2] – 46–61[3]	70.1[2] – 69–87[3]

[1]Minimum specified values, unless otherwise stated
[2]Actual values from procedure qualification
[3]Scatter band from Ref. 10
[4]Shielded metal arc weld
[5]Flux cored arc weld
[6]Electroslag weld

TABLE 2. Summary of worst case defects in weldments, as given in the inspection reports.

REGION	DEFECT TYPE	LARGEST REPORTED LENGTH x WIDTH x DEPTH ins	POTENTIAL FAILURE MODE
Parent material	Arc strike	3/8 x 3/8 x 1/32	F[2]
Fusion boundary	Lack of fusion	42 x 0[1] x 0[1] (FCAW/SMAW)	P[3], F
		39 x 0 x 0 (ESW)	P, F
Weld metal	"Crack"	13 x 0 x 0	P, F
	Undercut	3/8 x 3/16 x 1/8	P, (F)[4]
	Undersized fillet	9 x 0 x 3/8	P
	Overlap	3 x 0 x 1/8	F
	Underfill	24 x 0 x 3/16	P
	Overfill	72 x 0 x 1/4	-
	Porosity	2 x 1/2 (bounding area)	(P)
	Crater	1 x 1/2 x 3/8	(P)
	Unequal leg	0	
	Convex fillet	48 x 0 x 1/8	-

[1]0 signifies that the dimension is unknown or not reported.
[2]F = Fracture
[3]P = Plastic Collapse
[4]()= signifies lower probability

Defects which were not reported, but which may conceivably be present, include toe-breaking defects (e.g. lamellar tears, hydrogen cracks), lack of penetration, slag inclusions and internal porosity.

TABLE 3. Summary of estimated NDT temperatures.

MATERIAL	a) NDT range from published data °F	Ref	b) NDT from C_v correlation °F	Ref	c) Assumed Maximum NDT °F
A36 plate	-20 to +40	4, 6, 8, 10, 11			+40
A36 rolled section	+41 to +54	4, 9			+54
A588 (Grade A)	+10 to +80	10, 12			+80?
LH70 WM)	0 to +20 (all E7016)	13	-12	*	-12
LH70 WM) NR203M WM)	-76 to + 14 All multi-run, low hydrogen electrodes		+40	*	+40
IIIAC WM)		6	+32	*	+32
LH3800 WM)			-		-
A36 ES WM	-40 to 0	10)	<+20	10,12	+20?
	-30 to +60	6)			
A588 ES WM	0 to +10	10)			
	-30 to +60	6)			
A36 ES HAZ	-40 to 0	10			
A588 ES HAZ	0 to +10	10			

* See text

? signifies insufficient data

TABLE 4. Charpy energy at NDT - reported data for materials similar to A36 and A588

Material	C_V energy at NDT (ft.lbs)	Reference
A36 plate	25 - 30	)
ES Weld metal in A36	6 - 21	)10
ES HAZ in A36	14 - 23	)
A588A plate	28 - 33	)
ES weld metal in A588A	9 - 15	)10
ES HAZ in A588A	8 - 14	)
Low strength C-Mn steels similar to A36	10 - 20	3
A36	15 - 20	4
Hot rolled ABS-C (similar to A36)	17 - 26	17
Normalized A302-B (similar to A36)	22 - 44	17

TABLE 5. Critical flaw depth to thickness ratios for plastic collapse assuming long surface breaking defects.

Material	Design Stress σ_1 ksi	Static Loading σ_{flow} ksi	Static a/t Tension	Static a/t Bending	Dynamic Loading σ_{flow} ksi	Dynamic a/t Tension	Dynamic a/t Bending
A36	36	47	0.23	0.24	61	0.41	0.37
A588	50	60	0.15	0.21	78	0.36	0.35
E7018/A36	36	66	0.45	0.36	86	0.58	0.47
E7028/A36	36	66	0.45	0.36	86	0.58	0.47
E70T-G/A36	36	66	0.45	0.36	86	0.58	0.47
E70T-I/A36	36	66	0.45	0.36	86	0.58	0.47
EM12K/A36	36	56.5[1]	0.36	0.31	73	0.51	0.43
E7018/A588	50	66	0.24	0.25	86	0.42	0.38
E7028/A588	50	66	0.24	0.25	86	0.42	0.38
E79T-G/A588	50	66	0.24	0.25	86	0.42	0.38
E70T-I/A588	50	66	0.24	0.25	86	0.42	0.38
EM12K/A588	50	58-[2] 74	0.12- 0.32	0.20- 0.29	75- 96	0.34 0.48	0.34 0.41
E7018/A36/A588	50	66	0.24	0.25	86	0.42	0.38
E70T-I/A36/A588	50	66	0.24	0.25	80	0.42	0.38
EM12K/A36/A588	36[4]	56.5[3]	0.36	0.31	73	0.51	0.43

[1] From procedure qualification
[2] Scatter of data from Ref. 10
[3] Value for EM12K/A36 assumed
[4] Design stress for A36 assumed

TABLE 6. Estimated crack arrest temperatures at maximum design stresses.

MATERIAL	MAXIMUM THICKNESS ins	ESTIMATED NDT °F	CRACK ARREST TEMPERATURE °F
A36 plate	3	+40	130
A36 rolled section	1	+54	114
A588 Grade B	2½	+80?	163?
A588 Grade H	2½	+80?	163?
LH70 WM	3	-12	+78
LH3800 WM	3	-	-
NR203M WM	3	+40	130
IIIAC WM	3	+32	122
EM12K/A36 WM	3	+20?	110?
EM12K/A588 WM	2½	+20?	110?

? Signifies insufficient data

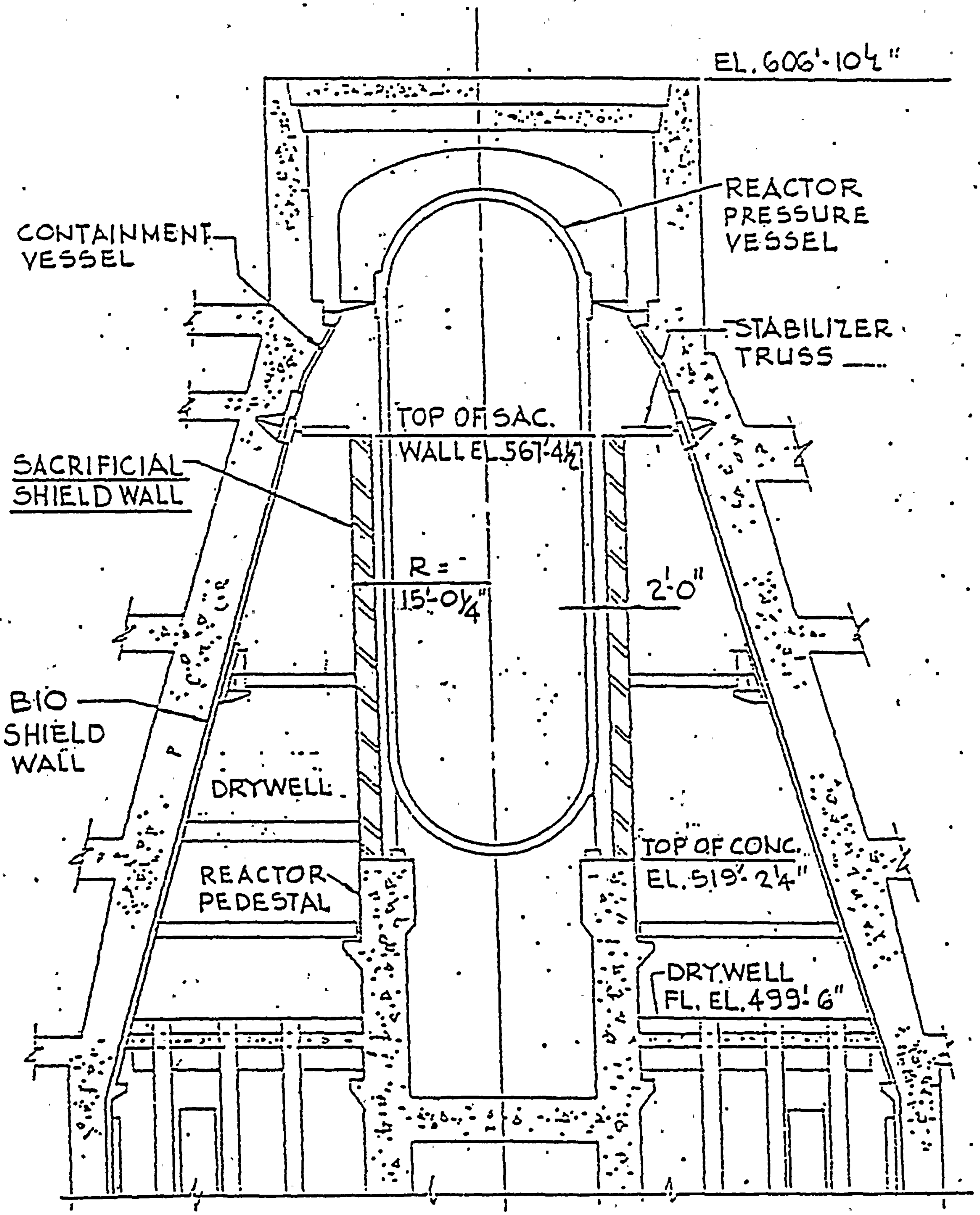


Fig. 1(a) REACTOR BUILDING DRY WELL

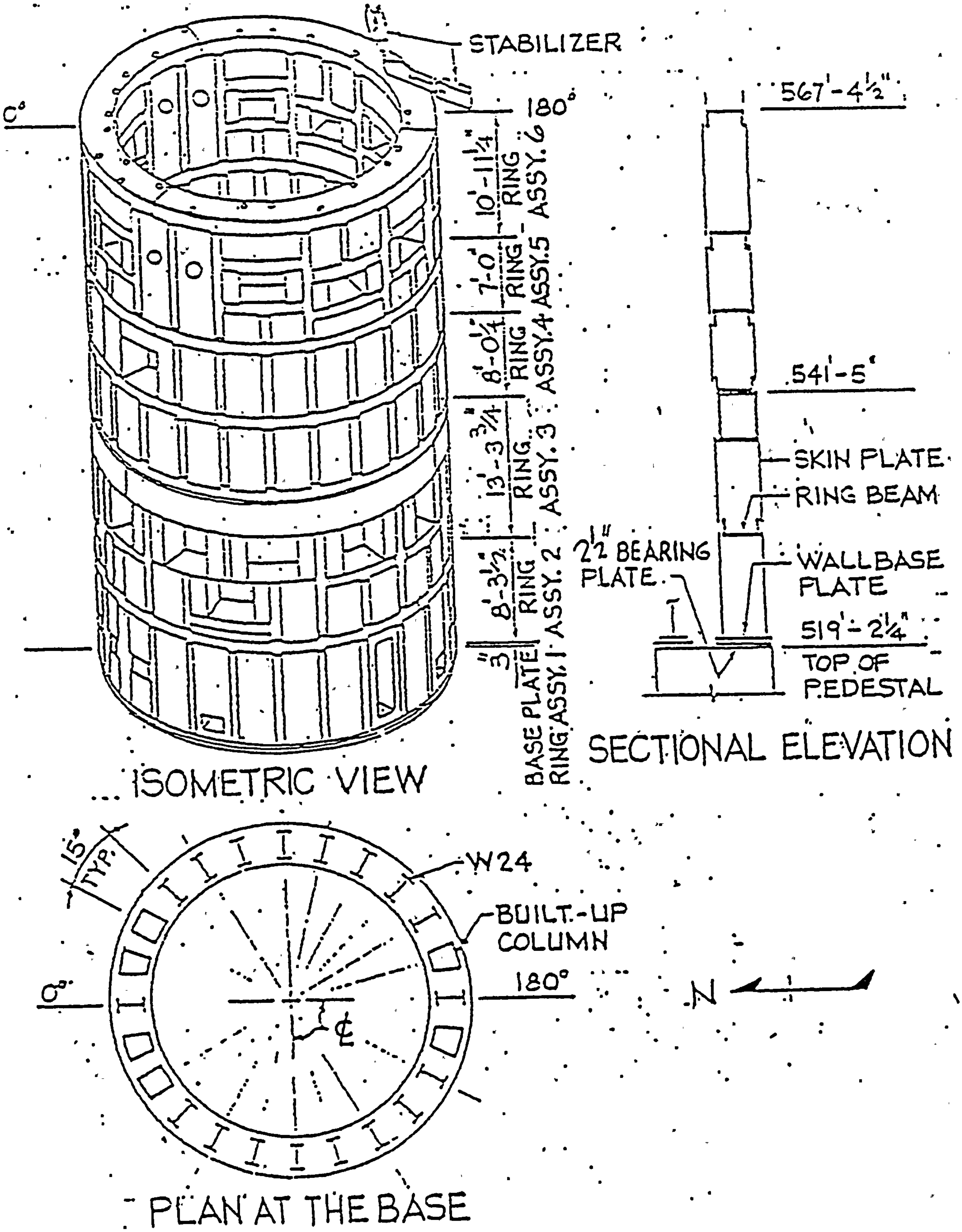


Fig. 1(b) SACRIFICIAL SHIELD WALL

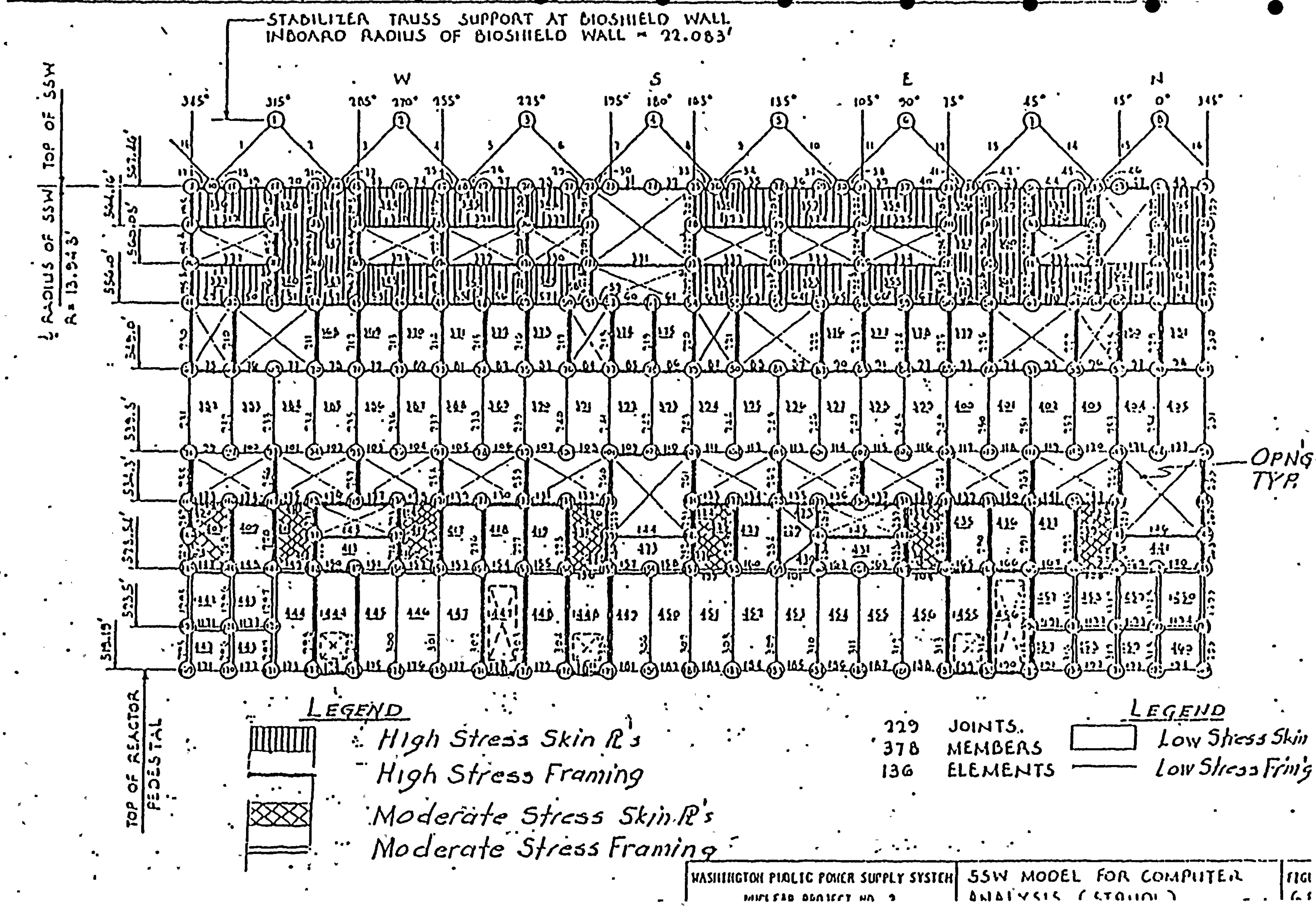


Fig. 2. FINITE ELEMENT STRESS ANALYSIS OF SSW.

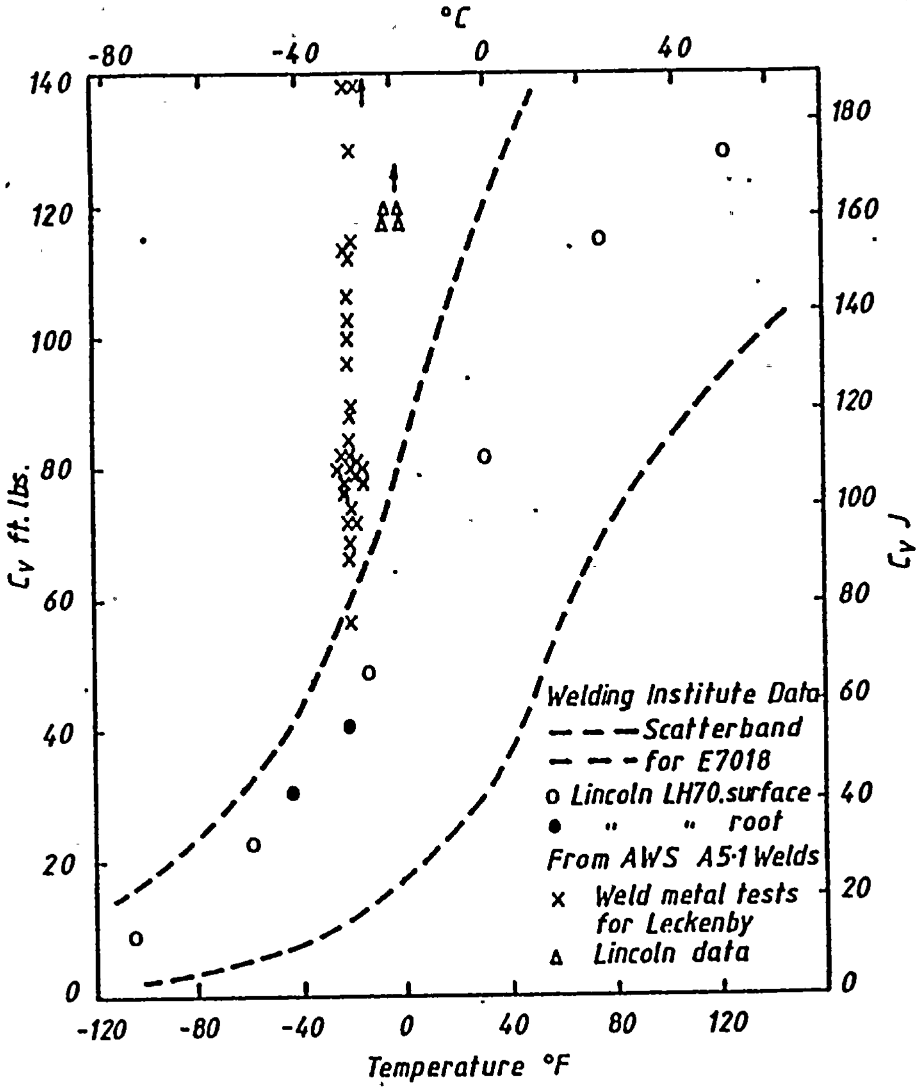


Fig.3. Charpy impact data for LH70 weld metal.

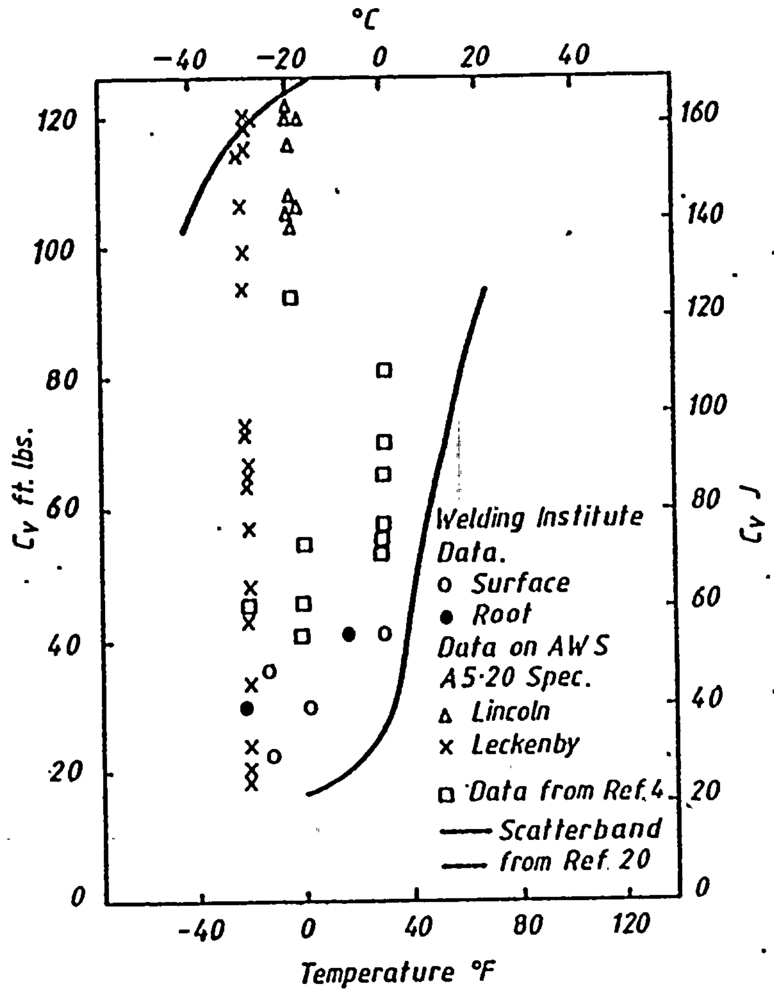


Fig.4. Charpy impact data for NR203M weld metal.

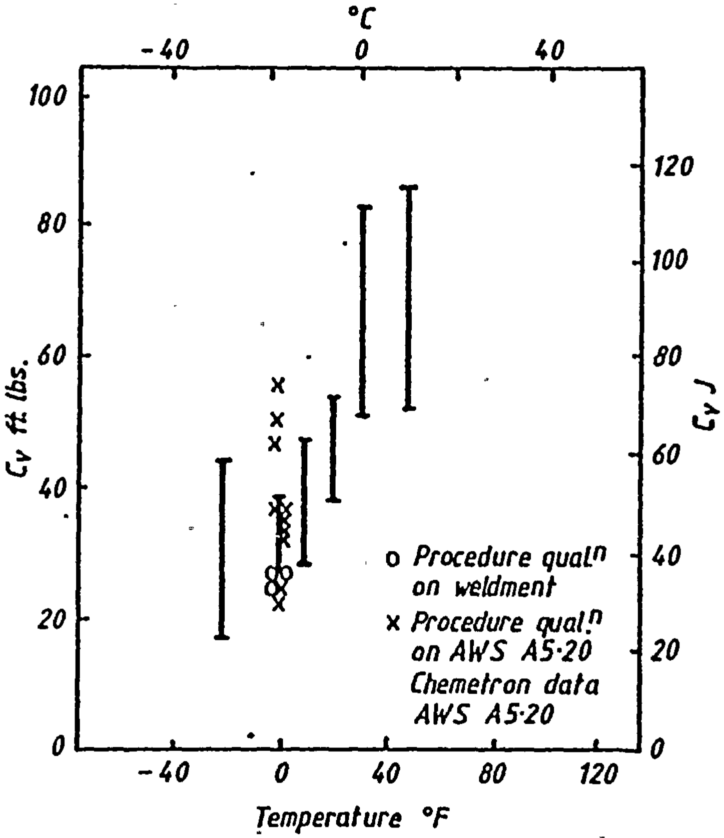


Fig.5. Charpy impact data for Chemetron 111AC weld metal.

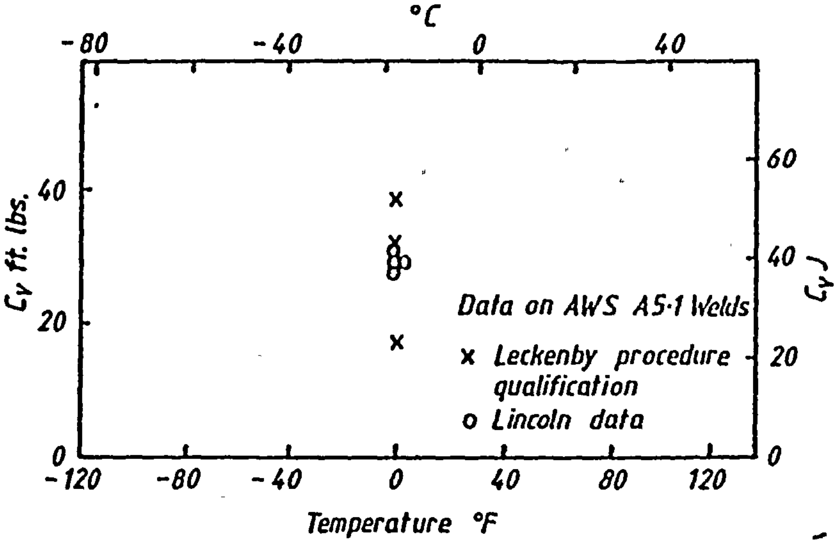


Fig.6. Charpy impact values for LH3800 weld metal.

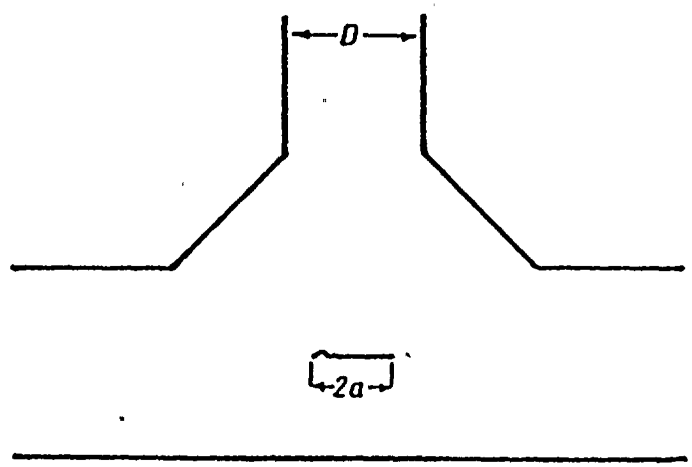


Fig.7. Lamellar tearing beneath fillet weld.

CALCULATION OF CRITICAL DEFECT SIZES FOR PLASTIC COLLAPSE

The SSW is designed according to the elastic working stress method of the AISC Code, Part I, 1969. This gives allowable stresses in tension and bending as follows:

Allowable tensile stress = $0.6\ \sigma_Y$
Allowable outer fibre bending stress = $0.66\ \sigma_Y$ (compact members)

Under certain unusual circumstances, such as earthquake loading, a load factor of 1.7 on allowable stress is applied by Burns & Roe, with NRC approval, i.e.

Maximum tensile stress = $1.02\ \sigma_Y$
Maximum outer fibre bending stress = $1.12\ \sigma_Y$

(a) Tension

Considering a member of thickness, t, containing a surface defect of depth, a, and equating the design load on the gross section to the load for plastic collapse gives:-

$$t \cdot \sigma_1 = a(t - a) \cdot \sigma_{flow}$$

where σ_1 is the nominal design stress.

$$\text{Hence } \frac{a}{t} = 1 - \frac{1.02\sigma_Y}{\sigma_{flow}} \qquad - (2)$$

with $\sigma_1 = 1.02\sigma_Y$ - - - - -

(b) Pure bending

For an outer fibre stress equal to σ_1, the bending moment on a solid rectangular beam is

$$M_b = \frac{1}{6}\sigma_1 \cdot t^2$$

The collapse moment, for a surface defect of depth, a, is

$$M_c = \frac{1}{4}\sigma_{flow}\ (t - a)^2$$

Hence the initial defect depth is given by

$$\frac{1}{6}\sigma_1 t^2 = \frac{1}{4}\sigma_{flow}\ (t - a)^2$$

$$\frac{a}{t} = 1 - \sqrt{\frac{2}{3}\frac{\sigma_1}{\sigma_{flow}}} \qquad - (3)$$

with $\sigma_1 = 1.12\ \sigma_Y$

ATTACHMENT 2

Scope Of Task Force Review

I. Sacrificial Shield Wall Quality Assurance (QA) Review Scope

The QA SSW documentation review consisted of:

- o Location and identification of all non-destructive examination (NDE) reports,
- o Identification of all inspectors that performed visual, surface or volumetric examinations,
- o Location of all fabrication, weld and material defect identification reports, e.g., Leckenby Incomplete/Rejection Tags and Leckenby (Field) Inspection Reports,
- o Review of Leckenby inspector qualifications,
- o Review of the 215 Contract related Leckenby shop and field QA manuals,
- o Identification and review of Leckenby NDE procedures,
- o Identification and review of Leckenby welder qualifications,
- o Review of appropriate Leckenby documentation for photocopied signatures or records falsification,
- o Review of welder and inspector qualifications against NDE and defect identification reports to establish physical versus paper-work credibility,
- o Review of Leckenby inspector performance to determine correlations, if any, between inspectors and reported defects or defect types,
- o Review of Leckenby welder performance to determine correlations, if any, between welders and reported defects or defect types,
- o Review of the material traceability system,
- o Review of Leckenby weld maps for structural, welding and documentation irregularities,
- o Review of material test reports for completeness and accuracy, and
- o Review of the appropriate sections of the 215 Contract to identify additional areas requiring investigation.

II. Sacrificial Shield Wall Engineering Review Scope

The SSW engineering review consisted of:

- o Performance of additional visual, surface and volumetric examination on the SSW,
- o Review of all NDE reports for defect classification, description, severity, trends and implications,
- o Review of all material and weld defect identification reports for classification, description, severity, trends and implications,
- o Review of documentation for welding process defect trends and implications,
- o Review of welding procedures for improper qualification and implications for physical impact (providing direction for requalification where prudent),
- o Assessment of weld map recorded discrepancies and weld defects for structural and welding significance,
- o Review of defect distribution,
- o Review of weld filler metal control,
- o Review of cold forming and heat straightening processes used during fabrication and assessment of their technical significance/implications,
- o Review of material properties including assessment of nil-ductility transition temperatures (providing direction for additional testing where prudent),
- o Assessment of the nonconformances in material test reports for SSW structural implications,
- o Review of welding defects with respect to cause, e.g., process, position, procedure, or welder technique,
- o Review of the fabrication and erection methods for potential effect on stresses and distortion,
- o Review and reassessment of SSW design loads (including an update to current codes and models) to assist in the evaluation of known and potential defects, and
- o Review of the as-built structural integrity of the SSW taking into account the potential for failure by brittle fracture or plastic collapse.

D. Burns w/a
DC Timmins w/a
SSW File w/a
DB/lb
SF (2)
PF

THIS LETTER (DOES) (DOES NOT) ESTABLISH A NEW COMMITMENT.

WPPSS CORRESPONDENCE NO. ____________

ATTACHMENT 3

July 15, 1980
G02-80-152

A. A. Willoughby
The Welding Institute
Research Laboratory
Abington Hall
Abington
Cambridge CBI 6AL
United Kingdom

Subject: WI REPORT LD 22526

Dear Tony:

Enclosed are the Supply System's comments on your interim SSW Report.

If the new information presented changes the general conclusions in the report or if you disagree with any of the statements, please let me know as soon as possible by Telex or telephone.

Otherwise, I don't think there is any need to respond formally at this stage. We plan to complete the open items with respect to stress analysis and material testing and send you that data. At that time we will request a final report to close out the task provided that additional fracture mechanics analysis is not required. The enclosed comments can then be incorporated or resolved as appropriate.

We plan to present our report to the NRC in the near future. The Welding Institute report will be incorporated as an attachment to that report. We do not see any need for a representative of the Institute at this preliminary meeting. However, such a need could develop as the NRC reviews the report.

Thank you for the letter on lamellar tearing and laminations. The data and comments were very useful and certainly support our earlier position that the effect of lamellar tears/laminations is better analyzed by plastic collapse rather than L.E.F.M. Any comments on the letter will be sent under separate cover. Again, we can incorporate the findings in a final SSW report.

Sincerely,

D. Burns

D. Burns
Lead Materials/Welding Engineer

DB/rmm
Attachment
cc: WNP-2 Files

FILE COPY

AUTHOR:	D. Burns D. Burns 7/15/80		FOR SIGNATURE OF:	D. Burns	
SECTION					
FOR APPROVAL OF	DC Timmins				
APPROVED	DC Timmins				

ATTACHMENT

Comments on Welding Institute Report LD 22526 (June 1980)

Section		Comments
1.	Line 5:	"shield" for "field"
	General:	Since our letter of 4/12/80 the Supply System has directed the UT examination of electroslag, flux cored arc (FCAW) and snielded metal arc (SMAW) welds and MT of FCAW and SMAW welds. These inspections identified a possible generic problem with incomplete root penetration of the FCAW and SMAW welds. Further details of these inspections are given in our comments to Section 4.3 of LD 22526.
2.2	Line 3:	"propagation" for "propogation"
3.2	Line 13:	typo - "inadequate"
4.1	Line 6:	"Additionally" for "Alternatively". A given break could cause both annulus pressurization and pipe whip reaction loads.
	Paras. 1&3	The pipe breaks which produce annulus pressurization are within the SSW penetration cavity <u>not</u> within the annulus. The only weld within the annulus is the nozzle to vessel weld and break is not assumed at this weld. The safe end to nozzle weld lies within the SSW penetration.
	General:	Burns and Roe have completed their preliminary analysis of the reduced loads and resultant SSW stresses. The results of this analysis can be summarized as follows:

1. Normal Load Conditions

   Stress levels less than or equal to 25% of allowable (allowable is about 2/3 of yield)

2. Normal + Seismic

   Stress levels less than 37% of acceptable (acceptable is, in this case, about 2/3 of yield).

3. Accident Conditions

   Stress levels are less than 50% of acceptable (acceptable for this load combination is approximately yield).

   The analysis for the accident condition is a dynamic analysis using a simplified SSW model. Burns and Roe are now doing a dynamic analysis with a three dimensional finite element model to confirm this data.

Section		Comments
4.2	General:	Further review revealed the use of one heat and thickness of ASTM A588 grade A plate for stiffeners in the top ring (ring 6). Charpy impact data on the mill cert shows a Charpy energy of above 100 ft. lbs. at +40°F (all three specimens). We have concluded that this material will not be limiting in terms of its NDT temperature. Electroslag welding procedures for ASTM A588 are being qualified. Tensile tests and drop weight NDT measurements will be made on the test welds.
4.3.(1)	Line 3:	The defect rate for electroslag welds has been revised to 30.5% following re-analysis of the data.
4.3.(2)	Line 5:	726 areas were MT'd. Note the inspections were of 726 <u>areas</u> not 726 welds. Some areas may have contained more than one weld; some may have contained no welds.
4.3.(3)	General:	All accessible welds have now been examined.
4.3.	Page 7: Para. 3.	Substitute "excavated" for "ground out". Usual method for removal was air-arc gouging.
	General:	Does the Welding Institute have any data on the probability of occurrence of corner lack of fusion defects in ESW welds made with steel backing shoes?
	General:	The SSW Task Force has directed additional inspections of accessible welds. The findings are summarized below:

1. UT of ESW Joints

   - 73 welds were examined per AWS D1.1
   - 1 contained a rejectable reflector. The design drawings indicate this is in a permanent backing shoe.
   - 3 contained questionable reflectors. Location indicated backside geometry.
   - Both L-wave and 70° angle inspection used.

2. UT of FCAW Joints

   - 9 Joints examined:

     7 double bevel, full penetration T-welds.
     2 single bevel full penetration corner welds.

   - 6 of 7 T-welds had incomplete root penetration along length of weld with 5/32 (max) dimension through thickness

- o Both single bevel corner welds also showed incomplete penetration (IP).
- o Beam path measurements indicate the defects are IP and not lamellar tears or underbead cracks.

3. UT of SMAW Welds

- o 6 SMAW single bevel, full penetration welds examined per AWS D1.1
- o 2 acceptable
  1 rejected - incomplete penetration
  3 acceptable indications characterized as incomplete penetration.

4. MT Inspections

- o 18 SMAW fillet welds and 5 FCAW fillet welds examined.
- o No cracks or lack of fusion.

4.3. General: <u>Underfill/Undersize Fillets</u>:

The Burns and Roe inspection data has been reviewed to clarify the terminology. The term underfill is now used only for butt welds. Only one case was observed (dimensions 4x0x1/8). Undersize fillet now includes both local and general undersized areas.

Burns and Roe examined 1170 welds from a total of 12842. Of these 74 were undersized fillets (6.3%). Of the 74 we have analyzed size data on 66. Of the 66, 10.6% had effective reductions in load bearing cross-section of 50% or more. (50% is lowest critical FCAW size for plastic collapse at design stress of 1/2 yield) thus, 0.67% of welds examined exceed this size.

However, population of welds examined is biased as proportion of <u>accessible</u> welds which are fillets, is greater than proportion in SSW as whole. Primary structural welds are mainly full penetration butt welds with low probability of underfill defects.

4.5.1 Para. 3 Line 16 — Typo. "negligible". Substitute "increase" for "reduction".

Section	Comments
4.5.1 Para 3.	We plan to measure the effect of cold bending on the NDT of A36 plate.
4.5.3 Para. 1	See comment on 4.2 for proposed testing of ESW welds.

Tests on E7028 are complete. Results are:

	NDT
Root	+30°F
Upper Part of Weld	0°F

Tests performed per WI recommendations. However, root crack occurred during welding which required repair.

Removal of ASTM A588 from wall is held up by strike.

5.1. Plastic Collapse At Attachments — Review of PWS attachments revealed two general types:

1. Large restraints attached to many members (see figure 1)
2. Small restraints attached to limited number of members (figure 2).

We are assuming that our general plastic collapse argument is still valid for type 1.

For type 2; we have reviewed the B&R visual inspection data and performed sample MT and UT of welds in SSW which take loads from the PWR. No defects other than the IP discussed in the comments to 4.3. were detected.

We have concluded that there is no reasonable risk of collapse at these attachment areas.

Burns and Roe indicate that the SSW is generally redundant in that complete members can be removed at critical locations without exceeding the acceptable stress levels. This does not apply to members directly under PWR's.

5.2. General: In view of the reduced stresses we have concluded that arrest is provided at 100°F, for all materials except A588, subject to confirmation of maximum NDT for ESW joints.

Table 2 — An up date of Table 2 is attached.

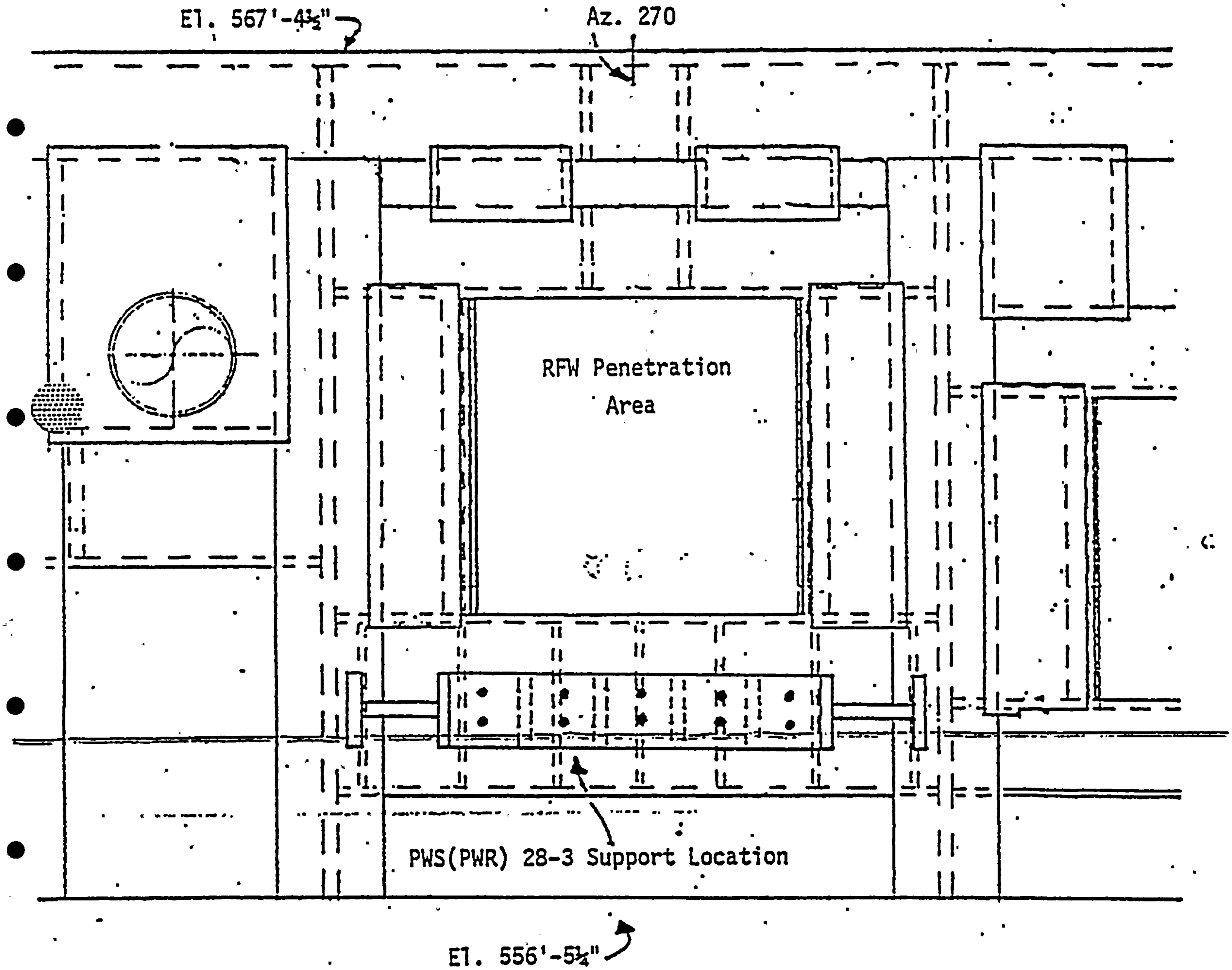
Table 5. — "E70T-G" for "E79T-G".

A modification to Table 5 for applied stresses of 1/2 yield is attached.

Section	Comments
Figure 5	Symbol missing on Chemetron data. Data from A5.20 is material qualification not procedure qualification.
Appendix A (a)	First equation should read: $t \cdot \sigma_1 = (t-a) \cdot \sigma_{flow}$.
4.3.(2) Line 3:	84 defects were detected, not 74.

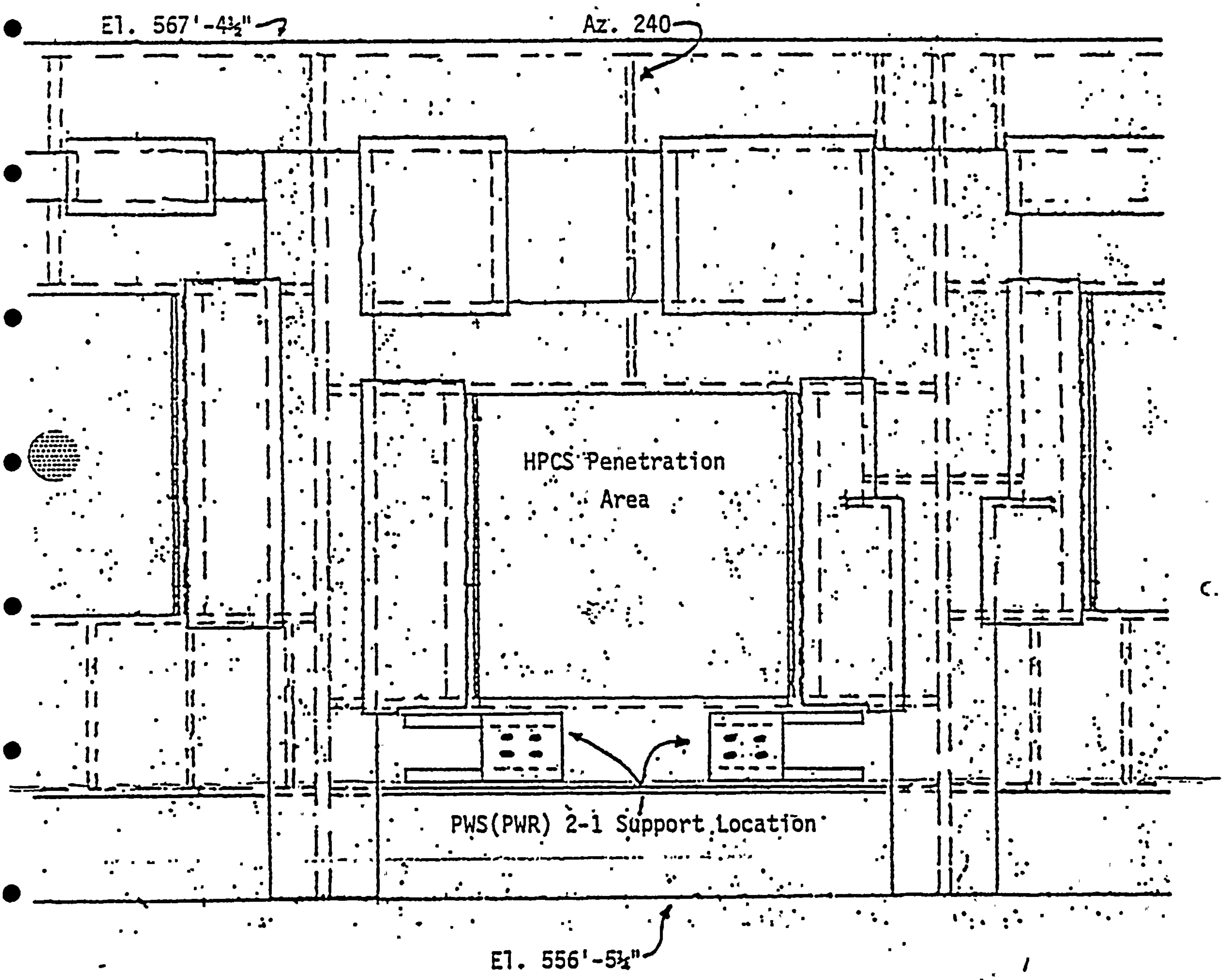
FIGURE

1



El. 567'-4½"
Az. 270
RFW Penetration Area
PWS(PWR) 28-3 Support Location
El. 556'-5¼"

FIGURE
2.



El. 567'-4½"
Az. 240
HPCS Penetration
Area
PWS(PWR) 2-1 Support Location
El. 556'-5½"

TABLE V.2

CRITICAL FLAW DEPTH TO THICKNESS RATIOS FOR PLASTIC COLLAPSE ASSUMING LONG SURFACE BREAKING DEFECTS

Material	Design Stress	Static Loading σ Flow	Static Loading a/t Tension	Static Loading a/t Bending	Dynamic Loading σ Flow	Dynamic Loading a/t Tension	Dynamic Loading a/t Bending
A36	18	47	0.62	0.50	77	0.77	0.61
A588	25	60	0.58	0.48	99	0.75	0.59
E7018/A36	18	66	0.73	0.58	109	0.84	0.67
E7028/A36	18	66	0.73	0.58	109	0.84	0.67
E70T-G/A36	18	66	0.73	0.58	109	0.84	0.67
E70T-1/A36	18	66	0.73	0.58	109	0.84	0.67
EM12K/A36	18	56.5	0.68	0.54	93	0.81	0.64
E7018/A588	25	66	0.62	0.50	109	0.77	0.61
E7028/A588	25	66	0.62	0.50	109	0.77	0.61
E70T-G/A588	25	66	0.62	0.50	109	0.77	0.61
E70T-1/A588	25	66	0.62	0.50	109	0.77	0.61
EM12K/A588	25	58-74	0.57-0.66	0.47-0.53	96-122	0.74-0.80	0.59-0.63
A7018/A36/A588	25	66	0.62	0.50	109	0.77	0.61
~~E70T-1/A36/A588~~	~~25~~	~~66~~	~~0.62~~	~~0.50~~	~~109~~	~~0.77~~	~~0.61~~
EM12K/A36/A588	18	56.5	0.68	0.54	93	0.81	0.64

a - flaw depth
t - material thickness

TABLE V.5

SUMMARY OF WORST CASE DEFECTS IN WELDMENTS

Region	Defect Type	Largest Reported Length x Width x Depth (a) Inches	Potential Failure Mode
Parent Plate	Arc Strike	3/8 x 3/8 x 1/32	F
	Lamellar Tears	None	P, (F)
Heat Affected Zone	H-cracking	None	F, (P)
	Liquation Cracks	None	F
Fusion Boundary	Lack of Fusion	8 x 0 x 0 (b) 39 x 0 x 0 (ESW) (f)	P, F
Weld Metal	Crack	13 x 0 x 1/8 (c)	P, F
	Undercut	8 x 0 x 3/32 24 x 0 x 0 (ESW)	P, (F)
	Undersized Fillet	26 x 0 x 1/4 (d)	P
	Overlap	3 x 0 x 1/8	F
	Underfill	4 x 0 x 1/8 24 x 0 x 0 (ESW)	P
	Excess Reinforcement	72 x 0 x 1/4	--
	Porosity	8 x 0 (boundary area) 19 x 1 (boundary area, ESW)	(P)
	Crater Fill	1 x 1/2 x 3/8	(P)
	Incomplete Penetration	48 x 1/8 (e) x 5/32 (subsurface)	P, F
	Slag Inclusions	1½ x 0 x 0	F

F = Fracture, P = Plastic collapse, ( ) - signifies lower probability

(a) Depth in the thru-thickness direction.

(b) 0 - signifies dimension unknown.

(c) One 2½ inch long crack extended through the 1¼ inch thick electroslag weld. No other such occurrences have been identified in the documentation.

(d) Worst case based upon percentage reduction in area from original weld size.

(e) Estimated from fit-up requirement.

(f) AVAILABLE ~~DATA~~ INFORMATION FROM INDUSTRY SOURCES INDICATES A MAXIMUM DEPTH FOR THIS TYPE OF CORNER LACK OF FUSION OF 1/2".

ATTACHMENT 4

Concern No.1 Additional Information

This attachment provides additional information on the proposed partial penetration groove weld at elevation 541'-5". The information provided herein is briefly discussed below.

- The Project Engineering Directives (PED) which provide the instructions for the qualification, joint preparation, inspection, shim gap shielding repair, and welding of the partial penetration weld are enclosed.

  PED-215-CS-2741
  PED-215-W-2749
  PED-215-W-3775 (a)
  PED-215-W-3776 (b)
  PED-215-W-3830
  PED-215-M-2746
  PED-215-M-3320
  PED-215-M-3604

  (a) This PED supersedes PED-215-W-2742 which was previously submitted to the NRC on this issue.

  (b) This PED supersedes PED-215-W-1604 which was previously submitted to the NRC on this issue.

  One additional change to the above welding (W) PEDs will be issued in a PED addendum. The change provides for buttering the bottom face of the joint after the MT inspection.

- The Welding Procedure Specification, WPS No. 26, for the partial penetration weld is enclosed.

- A sketch (Sketch-1) illustrating details of the existing area to be affected by the partial penetration weld is enclosed.

- A section titled "Partial Penetration Weld Structural Considerations" is enclosed. Within that section, additional information listed below is attached.

  Burns and Roe Technical Memorandum No. 1173

  Burns and Roe Calculation No. 6.19.37

  Discussion titled "Analysis and Design of Sacrificial Shield Wall"

  Leckenby drawing F124

BURNS AND ROE, INC. WPPSS NUCLEAR PROJECT NO. 2	PROJECT ENGINEERING DIRECTIVE	CODE: 2 1	PROJECT ENGINEERING DIRECTIVE: 215-CS-2741
		DATE: 03/13/80	PRIORITY: II

REASON FOR P. E. D.:

SLOT WELDS REQUIRED PER DETAIL D-2038 (S782) MADE TO TOP OF SHIMS AND DO NOT CONNECT RING 3 (BEAM TYPE ③) AND RING 4 (BEAM TYPE ②) AS REQUIRED.

INFORMATION COPIES: N/A

SHEET 1 OF 6

REFERENCES	
SUBJECT	SAC. SHIELD WALL WELDS
LOCATION	EL. 541-5 ALL AROUND
ENG. SYSTEM	N/A
S/U SYSTEM	
QUALITY CLASS	I

ORIGINATING DOCUMENTS: NCR 215-5688

DESCRIPTION OF WORK:

REPLACE SLOT WELDS WITH A PARTIAL PENETRATION WELD BETWEEN THE UPPER AND LOWER RINGS AS DETAILED ON SHEETS 3 THRU 5 OF THIS P.E.D.

WELD PREPARATION SHALL BE AS DIRECTED ON P.E.D. 215-W-2742.

WELD QUALIFICATION SHALL BE AS DIRECTED ON P.E.D. 215-W-2749.

REPAIR OF GAPS AT SHIMS (NCR 215-4884) SHALL BE AS DIRECTED ON PED 215-M-2746.

WELD SHALL BE MADE AS DIRECTED ON P.E.D. 215-W-1604.

NOTES

1. THIS PED REVISES DIRECTION PREVIOUSLY PROVIDED BY THE FOLLOWING PED(s): N/A
2. THIS PED VOIDS DIRECTION PREVIOUSLY PROVIDED BY THE FOLLOWING PED(s): N/A
3. THIS PED WORK SHOULD BE COORDINATED WITH KNOWN OTHER WORK UNDER THE FOLLOWING PED'S: 215-W-1604, 215-W-2742, 215-W-2749, 215-M-2746
4. THIS PED DEPENDS ON THE PRIOR INSTALLATION OF THE FOLLOWING PED'S: N/A

REVISE:

NONE ___
DRAWINGS X
SPECIFICATION ___

APPROVALS:

[signature] DISCIPLINE ENGINEER	3/24/80 DATE
[signature] LEAD DISCIPLINE ENGINEER	3.24.80 DATE
[signature] for A. James S/U LIAISON ENGINEER	4.11.80 DATE
[signature] RESIDENT PROJECT ENGINEER	4.11.80 DATE

PROJECT ENGINEERING DIRECTIVE			CODE	PROJECT ENGINEERING DIRECTIVE
WNP-2	BURNS & ROE, INC.	PAGE 2 OF 6	2 1	215-CS-2741

REFERENCE DRAWINGS

REVISE	DRAWING NO.	SHEET NO.	SUFFIX	REV.
Y	5782	-	-	12
Y	5835	-	-	06
Y	5838	-	-	01
N	5783	-	-	11
N	5337	-	-	05

REFERENCE DRAWINGS

REVISE	DRAWING NO.	SHEET NO.	SUFFIX	REV.

REFERENCE SPEC. PARAGRAPHS

REVISE	SECTION	PARAGRAPH	PAGE	REV.

WJ 5-13-86

REF. DOC; PCN — NCR 215-5688

WPPSS NUCLEAR PROJECT NO. 2

BURNS AND ROE, INC.

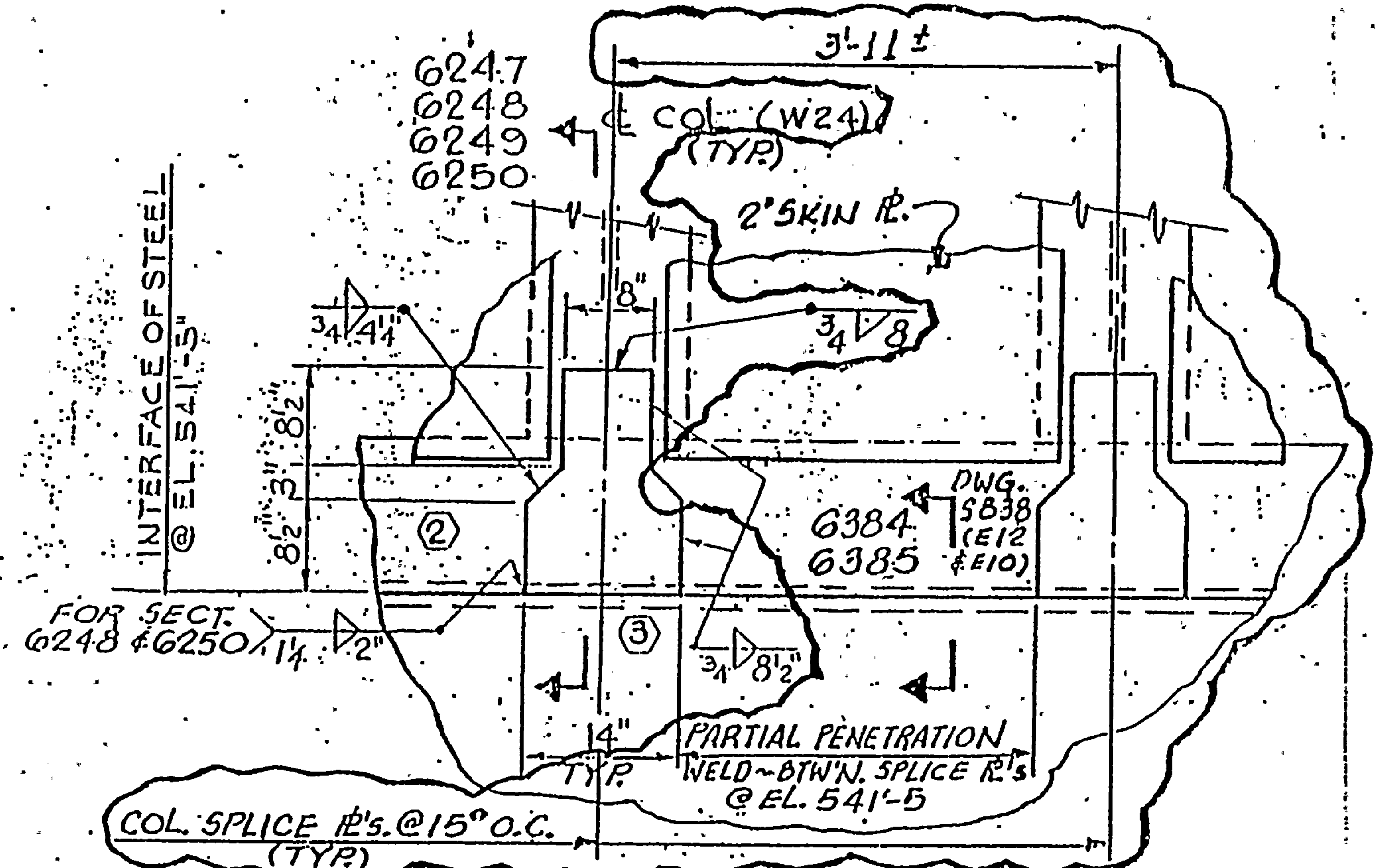
REF. SPEC. SECTION: — PAGE: — PARA: —

REF. DWG. 5655 REV. 5 DWG. ZONE D14

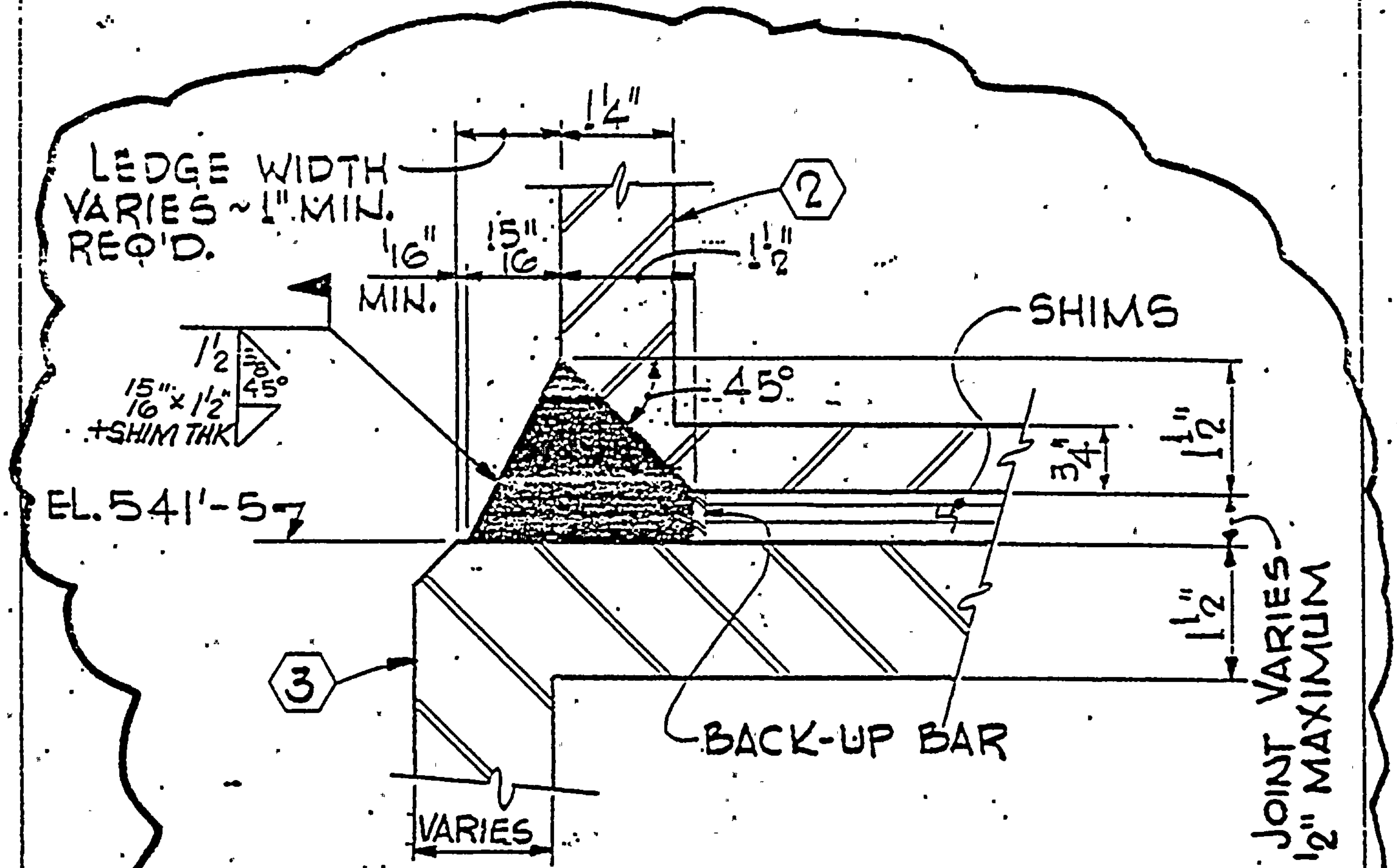
RED 215-C5-2741 [5 of 6?]

SCALE N.T.S.

TITLE: REACTOR BUILDING SAC SHIELD WALL SHT 8



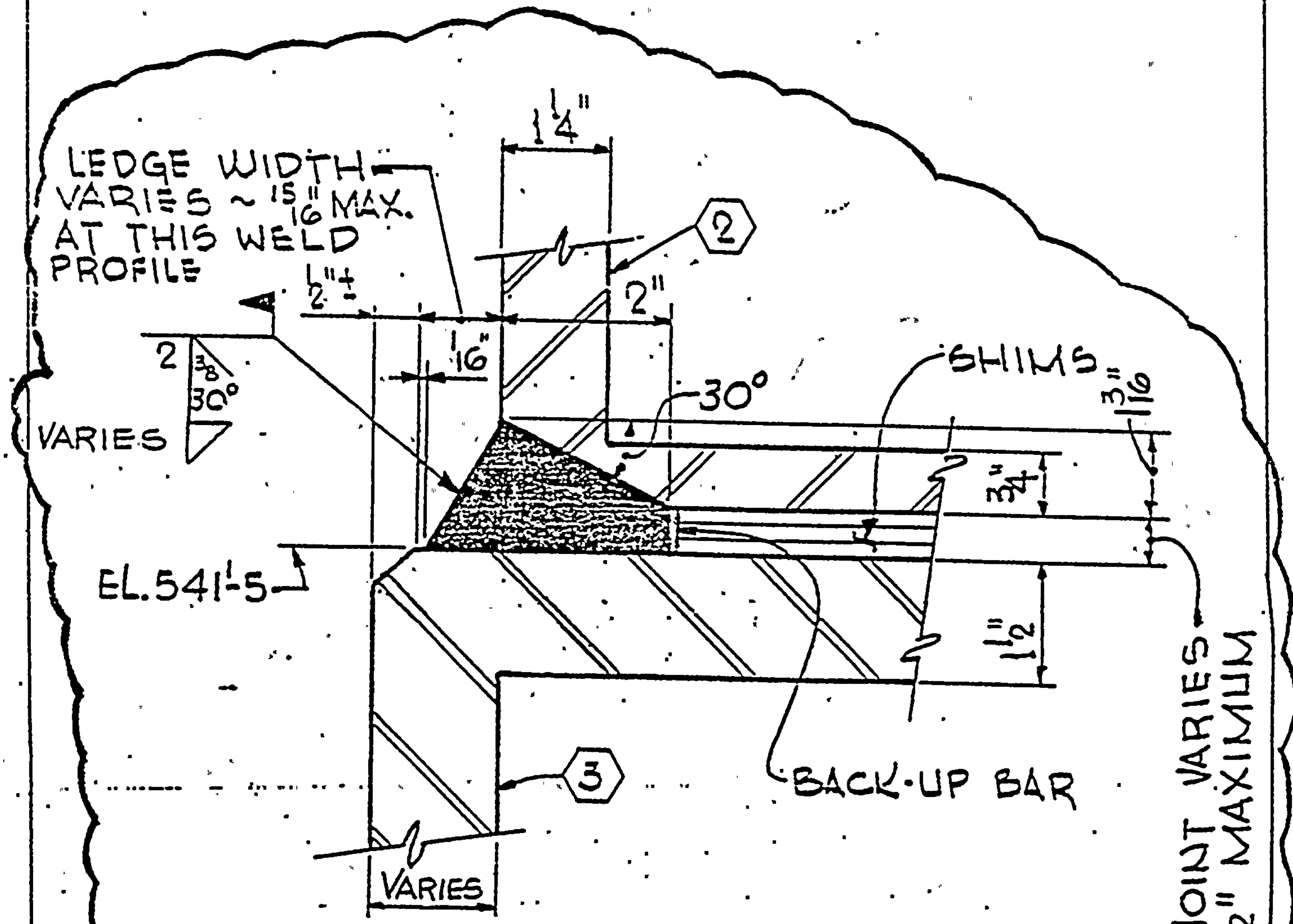
TYP. EXTERIOR SPLICE PL. @ COLUMNS



SECTION 6384-6384

TYPICAL WELD PROFILE WHERE LEDGE IS A MINIMUM OF 1" WIDE.

REF. DOC.: PCN ~~REF~~ NCR 215-5688	WPPSS NUCLEAR PROJECT NO. 2
REF SPEC. SECTION: PAGE: PARA:	BURNS AND ROE, INC.
REF. DWG. 5838 REV. 1 · DWG. ZONE: E12	PED 215-CS-2741 SH 4 OF 6
SCALE N.T.S. DRAWN BY KERNER DATE [illegible] CHKD BY [illegible] DATE [illegible]	TITLE: REACTOR BUILDING SAC. SHIELD WALL SHT.11



SECTION 6385-6385

TYPICAL WELD PROFILE WHERE LEDGE IS LESS THAN 1" WIDE

REF. DOC.: PCN —— RF: NCR 215-5688		WPPSS NUCLEAR PROJECT NO. 2	
REF. SPEC. SECTION: —— PAGE: —— PARA:		BURNS AND ROE, INC.	
REF. DWG. S838 REV. 1	DWG. ZONE E10	PED 215-CS-2741	SHT 5 OF 6
SCALE: N.T.S.	DRAWN BY KERKER DATE 5/10/82; CHKD BY [illegible] DATE 5/12/82; APPVD [illegible] DATE 5/24	TITLE: REACTOR BLDG. SAC. SHIELD WALL SHT. 11	

WPPSS NUCLEAR PROJECT NO. 2

BURNS AND ROE, INC.

REF. DOC. PCN: NCR 215-5688

REF. SPEC. SECTION: PAGE: PARA:

REF. DWG.: S782 Rev 12 DWG. ZONE: D5

SCALE: N.T.S.

TITLE: Reactor Building Sac Shield

BURNS AND ROE, INC. WPPSS NUCLEAR PROJECT NO. 2	PROJECT ENGINEERING DIRECTIVE	CODE 21	PROJECT ENGINEERING DIRECTIVE: 215-W-2749
		DATE	03/14/80 — PRIORITY I

SHEET 1 OF 1

REASON FOR P. E. D.:

This PED is to allow the contractor to prepare for welding to be done by Dual Shield FCAW Process.

INFORMATION COPIES

REFERENCES	
SUBJECT	Dual Shield FCAW Qualification
LOCATION	El. 541'-5"
ENG. SYSTEM	N/A
S/U SYSTEM	N/A
QUALITY CLASS	I
ORIGINATING DOCUMENTS	NCR-215-5688

DESCRIPTION OF WORK:

Contractor shall obtain machinery, welding wire and test materials to qualify a procedure and personnel, suitable to perform necessary capacity of welding to be done on the Sac. Wall.

Contractor shall coordinate all operations with Burns and Roe Welding Engineer in contractors establishment for qualifying procedures and personnel, to inable this program to be expedited.

The procedure and personnel shall be qualified in the horizontal position. The test plate for qualifying the procedure and personnel shall be in accordance with AWS D1.1 and Spec. 215-17D. A 2'x 2' mock-up of the plate thickness (as close as possible), and joint design shall be welded by each welder prior to welding on the Sac. Wall.

Type of Machinery Required

12
Manufacturer: Airco Flux Core Welding Machines

John Brosnann
(415) 658-5010

Type of Filler Metal Required

25 lb. spools
(1500 lbs)
(Dia. .045)
Dual Shield
(E-70T-1)

Manufacturer:
Chemetrom Welding Supply
(206) 682-2880

Gas - Argon - CO_2
98-2%

NOTES

1. THIS PED REVISES DIRECTION PREVIOUSLY PROVIDED BY THE FOLLOWING PED(s): N/A
2. THIS PED VOIDS DIRECTION PREVIOUSLY PROVIDED BY THE FOLLOWING PED(s): N/A
3. THIS PED WORK SHOULD BE COORDINATED WITH KNOWN OTHER WORK UNDER THE FOLLOWING PED'S. N/A
4. THIS PED DEPENDS ON THE PRIOR INSTALLATION OF THE FOLLOWING PED'S N/A

REVISE:

NONE
DRAWINGS N/A
SPECIFICATION

APPROVALS:

Signature	Title	Date
[signature]	DISCIPLINE ENGINEER	3-24-80
[signature]	LEAD DISCIPLINE ENGINEER	3-25-80
[signature]	S/U LIAISON ENGINEER	3/25/80
[signature]	RESIDENT PROJECT ENGINEER	3-25-80

REV 1 BR 803-2

BURNS AND ROE, INC. WPPSS NUCLEAR PROJECT NO. 2	PROJECT ENGINEERING DIRECTIVE	CODE: 2 1 (1 2) — PROJECT ENGINEERING DIRECTIVE: 215 – W – 3775 (3–15) DATE: 07/08/80 (16–21) PRIORITY I

REASON FOR P. E. D.:

This PED is to revise PED 215-W-2742 for the preparation of the partial penetration weld joint to be used on the sac. wall at 541'-5" el.

The stop Work Order must be lifted before work is started.

INFORMATION COPIES ______

SHEET 1 OF 6

REFERENCES	
SUBJECT	Sac. Shield Wall Welds
LOCATION	541'-5" All A
ENG. SYSTEM	N/A
S/U SYSTEM	N/A
QUALITY CLASS	I

ORIGINATING DOCUMENTS NCR 215-05688

DESCRIPTION OF WORK:

Refer to pages 2 through 6 of this PED for direction of weld joint preparation as shown on attached details.

All documentation for this work shall be prepared in accordance with WP 84 Rev. 15 and approved procedures.

NOTES

1. THIS PED REVISES DIRECTION PREVIOUSLY PROVIDED BY THE FOLLOWING PED(s): 215-W-2742
2. THIS PED VOIDS DIRECTION PREVIOUSLY PROVIDED BY THE FOLLOWING PED(s): 215-W-2742
3. THIS PED WORK SHOULD BE COORDINATED WITH KNOWN OTHER WORK UNDER THE FOLLOWING PED'S: 215-W-2749, 215-CS-2741, 215-W-3776
4. THIS PED DEPENDS ON THE PRIOR INSTALLATION OF THE FOLLOWING PED'S: N/A

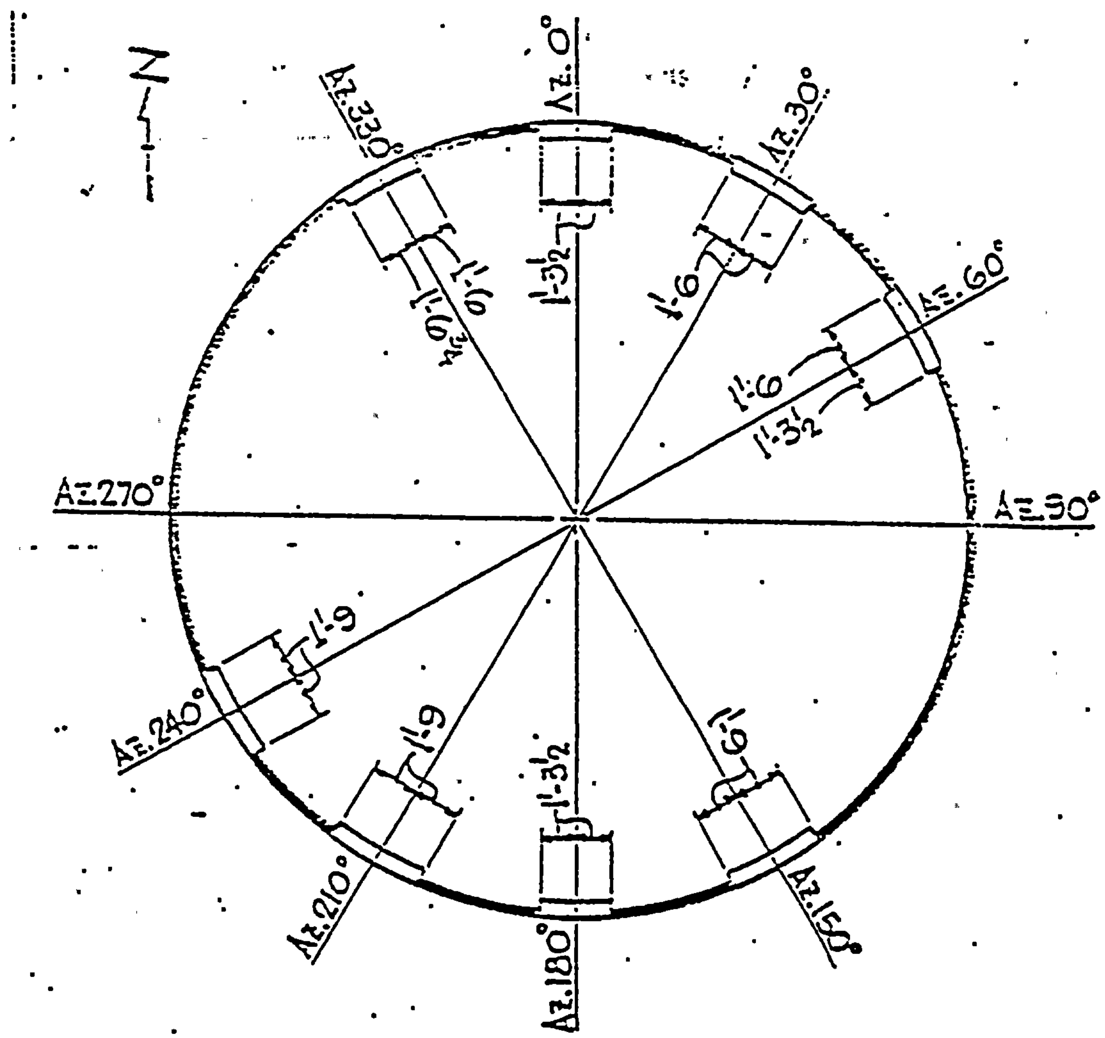
REVISE:

NONE ______ N/A
DRAWINGS ______
SPECIFICATION ______

APPROVALS:

Signature	Title	Date
M. Gallagher	DISCIPLINE ENGINEER	7-8-80
L. F. Akers	LEAD DISCIPLINE ENGINEER	7-8-80
[signature] for A. James	S/U LIAISON ENGINEER	7-8-80
[signature]	RESIDENT PROJECT ENGINEER	7-8-80

REV 1 BR 803-2



PLAN (T.O.S. EL. 541'-5)

SHADED AREAS INDICATE 1½" THK. SIDE PL. ON BUILT-UP MEMBER (3)

UNSHADED AREAS INDICATE 3" THK. SIDE PL. ON BUILT-UP MEMBER (3)

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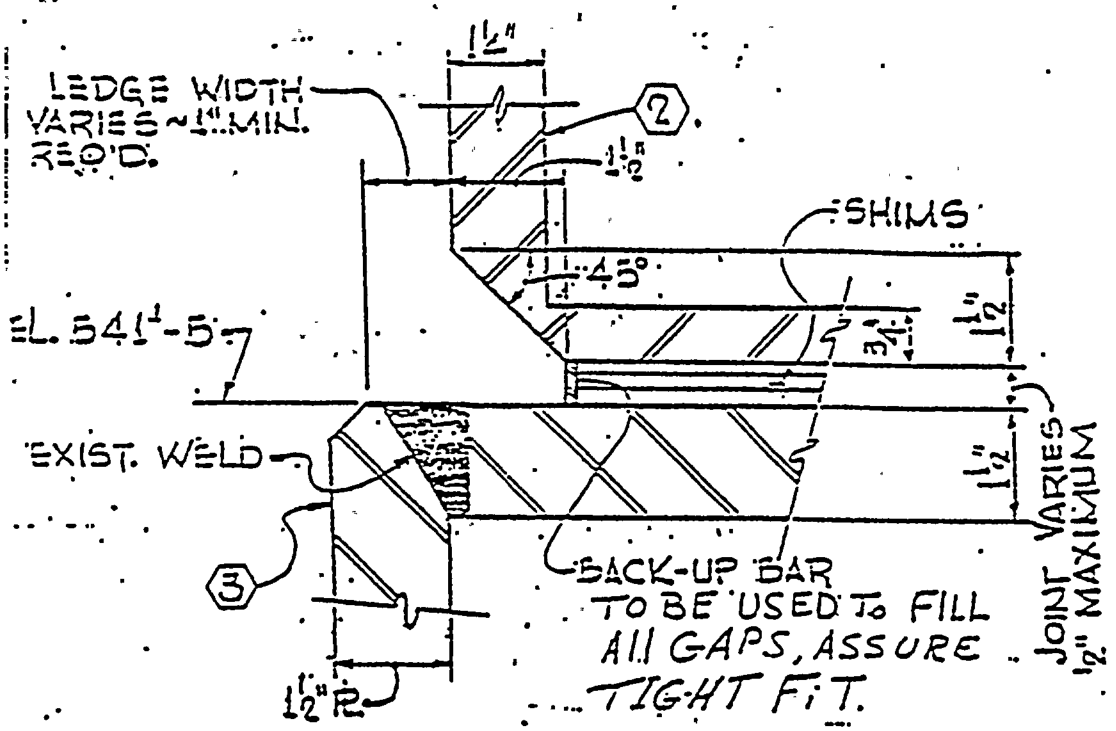
SCALE: NTS	DRAWN BY — DATE — CHKD BY [signature] DATE 7-1-90	APPV'D [signature] DATE	TITLE: PLAN OF BUILT-UP MEMBER (3)



TYPICAL WELD PREPARATION WHERE LEDGE IS A MINIMUM OF 1" WIDE & SIDE PL/BUILT-UP MEMBER (3) IS 1½"

NOTE:
1) Insure proper preheat of 200°F. ± 25°F. with 1½ hrs. soak time prior to air arc-gouging joint preparation.
2) Clean and grind after air arc-gouging to a visual acceptance per AWS D1.1 prior to welding.
3) Joint preparation shall have a minimum root gap of 3/8" with installation of backing where open root exist. Areas where insulation was pumped in shall be seal welded and not be considered. root pass of original weld. "This seal weld around backing may tend to leave gas pocket holes in seal weld, which shall be blended out and acceptable as is for appling root passes of original weld.
4) Existing column splice welds shall not be removed, only beveled to make joint preparation acceptable.

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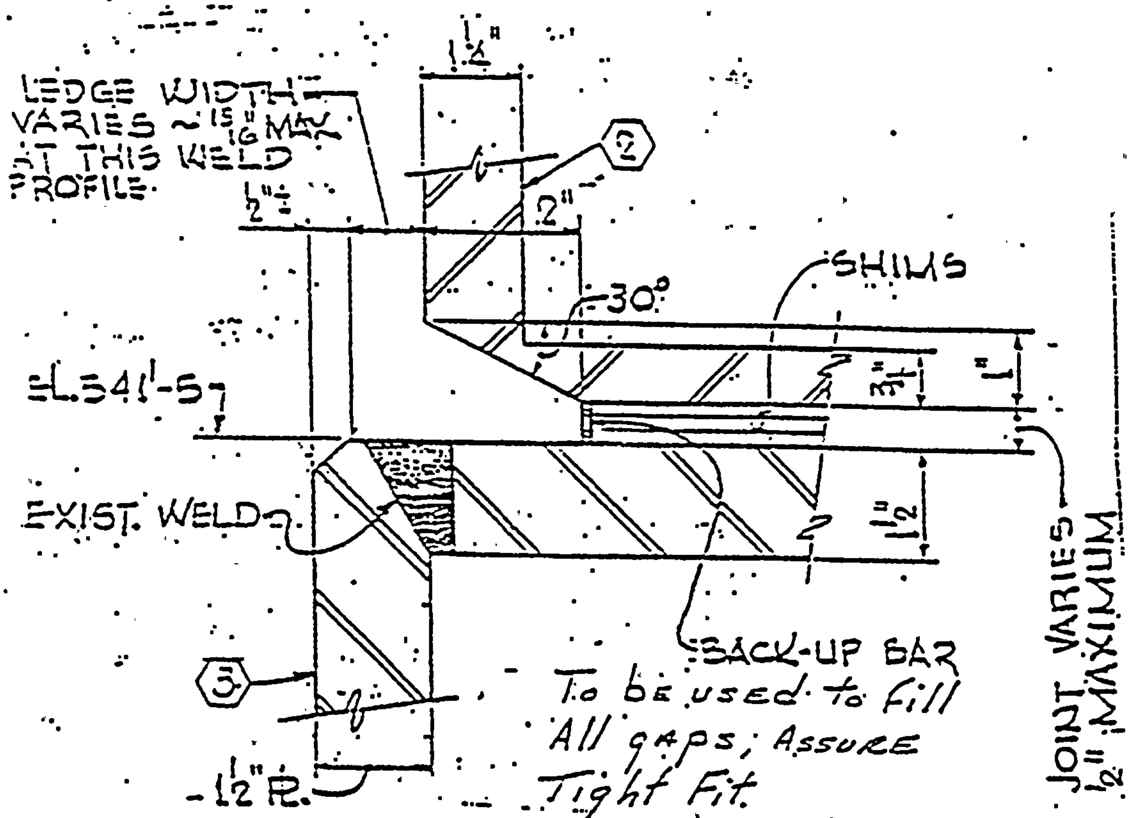
SCALE: NTS	DRAWN BY DATE: / CHKD BY [signature] DATE 9-8-88	APPVD [signature] DATE	TITLE: WELD PREPARATION



TYPICAL WELD PREPARATION WHERE LEDGE IS LESS THAN 1" WIDE & SIDE PL./BUILT-UP MEMBER ⑤ IS 1½"

NOTE:
1) Insure proper preheat of 200°F. ± 25°F. with 1½ hrs. soak time prior to air arc-gouging joint preparation.
2) Clean and grind after air arc-gouging to a visual acceptance per AWS D1.1 prior to welding.
3) Joint preparation shall have a minimum root gap of 3/8" with installation of backing where open root exist. Areas where insulation was pumped in shall be seal welded and not be considered root pass of original weld. This seal weld around backing may tend to leave gas pocket holes in seal weld which shall be blended out and acceptable as is for appling root passes of original weld.
4) Existing colmn splice welds shall not be removed, only beveled to make joint preparation acceptable.

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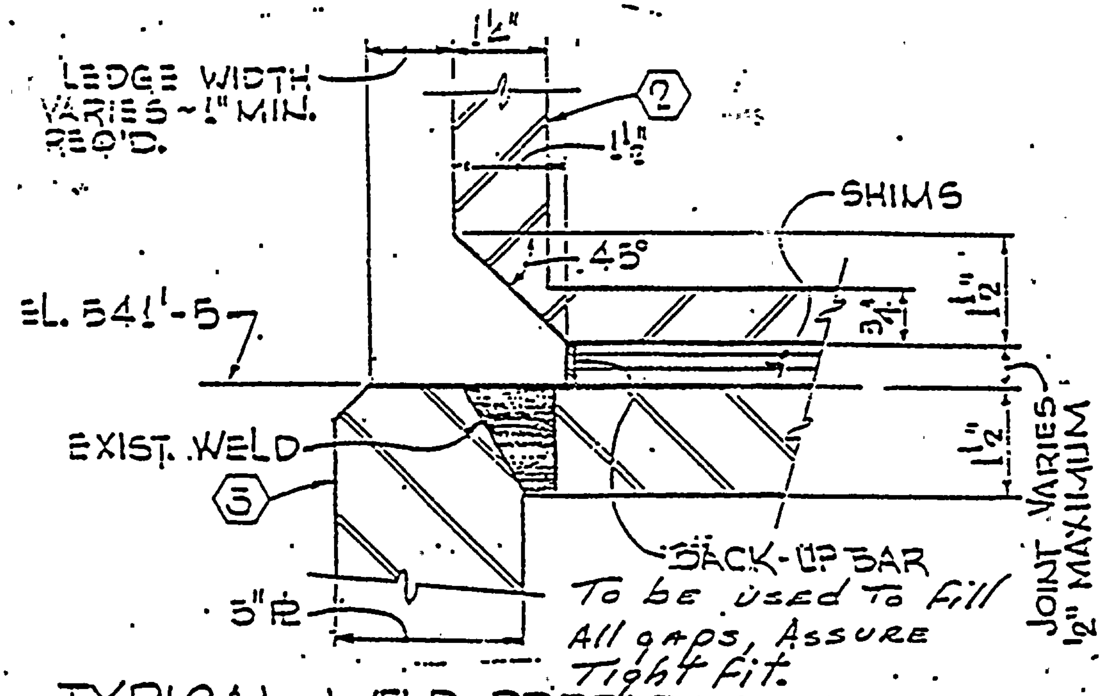
SCALE: NTS	DRAWN BY — DATE — CHKD BY [signature] DATE 7-8-88	APPV [signature] DATE	TITLE: WELD PREPARATION

REV. 1



TYPICAL WELD PREPARATION WHERE LEDGE IS A MINIMUM OF 1" WIDE & SIDE PL. / BUILT-UP MEMBER (3) IS 5"

NOTE:
1) Insure proper preheat of 200°F. ± 25°F. with 1¼ hrs. soak time prior to air arc-gouging joint preparation.
2) Clean and grind after air arc-gouging to a visual acceptance per AWS D1.1 prior to welding.
3) Joint preparation shall have a minimum root gap of 3/8" with installation of backing where open root exist. Areas where insulation was pumped in shall be seal welded and not be considered root pass of original weld. This seal weld around backing may tend to leave gas pocket holes in seal weld, which shall be blended out and acceptable as is for appling root passes of original weld.
4) Existing colmn splice welds shall not be removed, only beveled to make joint preparation acceptable.

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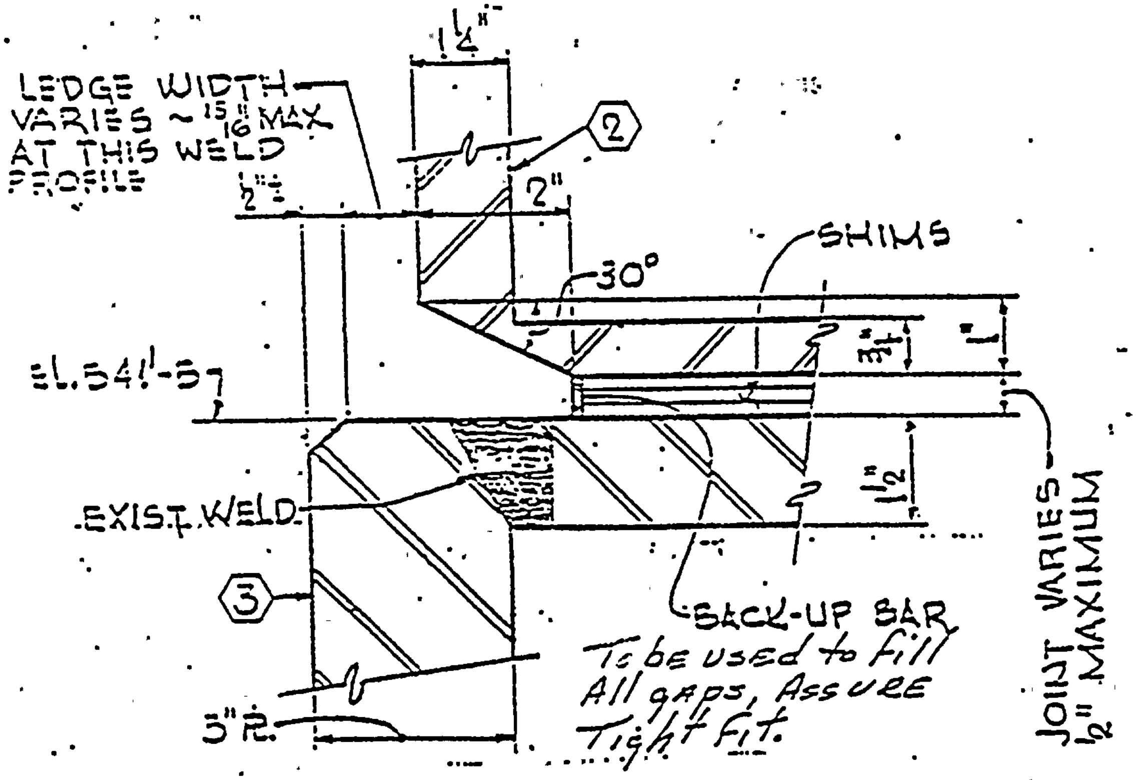
	CHKD BY ___ DATE ___ APPVD ___ DATE ___	



TYPICAL WELD PREPARATION WHERE LEDGE IS LESS THAN 1" WIDE & SIDE PL. / BUILT-UP MEMBER ③ IS 3"

NOTE:
1) Insure proper preheat of 200°F. ± 25°F. with 1½ hrs. soak time prior to air arc-gouging joint preparation.
2) Clean and grind after air arc-gouging to a visual acceptance per AWS D1.1 prior to welding.
3) Joint preparation shall have a minimum root gap of 3/8" with installation of backing where open root exist. Areas where insulation was pumped in shall be seal welded and not be considered root pass of original weld. This seal weld around backing may tend to leave gas pocket holes in seal weld, which shall be blended out and acceptable as is for appling root passes of original weld.
4) Existing colmn splice welds shall not be removed, only beveled to make joint preparation acceptable.

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SCALE: NTS	DRAWN BY DATE:		TITLE: WELD PREPARATION
	CHKD BY [signature] DATE 7-8-86	APPVD [signature] DATE	

BURNS AND ROE, INC. WPPSS NUCLEAR PROJECT NO. 2	PROJECT ENGINEERING DIRECTIVE	CODE 21	PROJECT ENGINEERING DIRECTIVE 215-W-3776 DATE 07/08/80	PRIORITY I

INFORMATION COPIES

SHEET 1 OF 15

REASON FOR P. E. D.:

This PED is to revise PED 215-W-1604 for Welding to replace the slot welds required per detail D 2038 (S782) made to top of shims and do not connect ring (Beam type 3) and ring 4 (Beam type 2) as required.

The stop Work Order must be lifted before work is started

REFERENCES	
SUBJECT	Sac. Shield Wall Welds
LOCATION	541'-5". All A
ENG. SYSTEM	N/A
S/U SYSTEM	N/A
QUALITY CLASS	I

ORIGINATING DOCUMENTS: NCR 215-05688

DESCRIPTION OF WORK:

Replace slot welds with a partial penetration weld between the upper and lower rings as shown on attached details with FCAW process being used for complete joint welding.

All welding is to be performed per direction of Burn & Roe Welding Engineers, Addenda System and this PED which includes a work procedure with peening, grinding, visual inspection, MT inspection and a sequence.

All documentation shall be prepared in accordance with WP 84 Rev. 15 and approved procedures.

NOTES

1. THIS PED REVISES DIRECTION PREVIOUSLY PROVIDED BY 215-W-1604 THE FOLLOWING PED(s):
2. THIS PED VOIDS DIRECTION PREVIOUSLY PROVIDED BY 215-W-1604 THE FOLLOWING PED(s):
3. THIS PED WORK SHOULD BE COORDINATED WITH KNOWN OTHER WORK UNDER THE FOLLOWING PED'S: 215-W-2749, 215-W-2741, 215-W-3775
4. THIS PED DEPENDS ON THE PRIOR INSTALLATION OF THE FOLLOWING PED'S: N/A

REVISE:

NONE N/A
DRAWINGS
SPECIFICATION

APPROVALS:

Signature	Title	Date
M. Goldman	DISCIPLINE ENGINEER	7-8-80
[signature]	LEAD DISCIPLINE ENGINEER	7-8-80
L. Bond for A. James	S/U LIAISON ENGINEER	7-8-80
J. J. Good	RESIDENT PROJECT ENGINEER	7-8-80

REPAIR PROCEDURE FOR NCR #05688 AT THE
541'-5" LEVEL IN REACTOR CONTAINMENT VESSEL

1) PROCEDURE

The purpose of this procedure is to establish the requirements for the structural steel repair welding inside the containment. Any deviation from the requirements of this procedure will require specific approval of the Burns and Roe Welding Engineer. Deviation approvals will be granted only after examination of the problem areas and a resolution given by Burns and Roe Welding Engineer by Addendum system.

Welding sequences shall be issued as attachments to this procedure. Any changes or additions to weld sequences or other special instructions shall require approval by the Burns and Roe Welding Engineer.

The Quality Control Manager shall be responsible for assuring compliance with these procedures.

2) DOCUMENTATION

Work packages shall be used for all structural steel work and shall be prepared in accordance with WP 84 Rev. 15 and approved procedures.

The Structural Steel Weld Record form shall be used for structural steel welding documentation.

Weld repairs, if required, shall be documented on the Structural Steel Weld Repair forms.

The loss of Preheat/Interruption of Weld Sequence form shall be used to document such occurences. If cracks are discovered, an Inspection Report will also be initiated. Upon completion of the form, a copy will also be immediately given to Burns and Roe Welding Engineer on duty for approval.

Preheat recorder charts shall be identified by weld, iso., or dwg. no., and transmitted, upon completion of work, to the Q.A. vault.

3) MATERIAL

Electrode Control shall be in accordance with the work procedure. Electrodes shall be purchased in hermetically sealed containers and shall be dried for at least one(1) hour at temperatures between 750°F. and 800°F. prior to issuance. Electrodes shall be maintained at a minimum temperature of 250°F. after the high temperature bake until withdrawn for use or temporary storage in portable ovens or a storage oven conveniently placed near the work area. Electrodes shall be removed from portable ovens one at a time and used immediately. Electrodes that have been or are wet shall be bent and discarded in an approved container. (Note: FCAW wire does not require pre-baking).

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3) cont'd FCAW wire shall be maintained in sealed containers until withdrawn for use in the field. Spools shall not be returned to ovens after each shift. A maximum effort shall be taken to keep wire spools covered and clean in dustproof wire feeders.

4) WELDER QUALIFICATIONS

All welders using this procedure shall be qualified to unlimited thickness and all positions in accordance with approved weld procedures and AWS D1.1.

Welders qualified by groove welds on 8" sched. 120 pipe or larger and on plates 1" or over are qualified for all thicknesses of structural steel

5) PROCEDURE

PREHEAT PROCEDURE AND REQUIREMENTS

The following material shall be on hand prior to preheat and welding operations:

a) Heating torches
b) Heating coils or blankets
c) Heat retaining blankets
d) Clips for holding coils, blankets, etc., in place.
e) Temperature control and recording equipment.

6) TORCH HEATING

1) Torches may be used for applications involving arc-air gouging, attaching strongbacks, heater blanket clips, tacking, backing bars, and minor repairs. Preheat shall be 200°F. ± 25°F. with a 15 minute soak time.

2) Heating torches may be used to locally preheat the structure and weld site in the areas to be tack welded.

3) Heating torches shall be used with a neutral flame.

4) When preheat is obtained through torch heating for other than temporary tack welds, Q.C. shall frequently monitor the site both prior to and during welding to assure that minimum preheat and maximum interpass temperature requirements are maintained.

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7) RESISTANCE HEATING

All areas to be preheated, except those specifically exempted by the Burns and Roe Welding Engineer, shall be preheated using electric heating elements. The precise locations of the heaters will be designated by the preheating contractor's welding engineer.

Strip chart records of weld joint preheat and cool down are required.

Only magnetic holders shall be used to hold heaters and blankets to the Sacrificial Wall and to structures on the 541' level.

The preheat and maximum interpass temperature shall be held from the center line of the joint outward to at least 3" on each side of the joint. More than 3" from the joint the temperature range may be less than the minimum specified but shall not be more than the maximum specified. Thermocouples shall be located no more than 3" from the weld center line and their placementrequires approval by the Burns and Roe Welding Engineers.

Inspectors shall check preheat with a contact pyrometer at fit-up before allowing welding to begin. During welding, inspection shall monitor minimum preheat and maximum interpass temperatures in the joint using a contact pyrometer.

After reaching preheat temperature, soak the joint at temperature for 1½ hours before beginning welding. Maintain the temperature range until all welding has been completed and then soak for another three (3) hours before starting cool-down.

Heat retaining blankets shall be used as necessary to control cool-down rate. The cool-down rate shall not exceed 50°F. per hour. Blankets may be removed when ambient temperature has been reached.

The heat retaining blankets, which must be maintained throughout preheat, all welding inspection, and cool-down, may be adjusted to permit welding. For instance, a heater and blanket may be placed directly over the joint for preheat and soak, then removed during welding.

When the preheat drops below the specified minimum, a Loss of Preheat form shall be prepared. The temperature shall be restored as soon as possible after the low temperature is detected.

8) TEMPERATURE REQUIREMENTS

The preheat requirement for local torch heating for attaching strongbacks, heater blanket clips, backing bars, and for tacking shall

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CHKD BY MJY DATE 4-1-80 APPVD L. [signature] DATE	Weld Work Procedure

be 150°F. to 200°F. for at least 2" in each direction from the weld site, with a 15 minute soak time at temperature prior to beginning work.

Welders and/or operators shall be provided temperature indicating crayons or contact pyrometers to assure that preheat requirements are being met.

9)

	PREHEAT	MAXIMUM INTERPASS TEMPERATURE
Welds to Sacrificial Shield Wall and within 24" of the Sacrificial Shield Wall.	200 ± 25°F.	250°F.

The minimum preheat and maximum interpass temperature for all welding shall be as noted above.

10) FIT-UP AND TACKING

The joint gap for structural and partial penetration welds shall not exceed 3/16" for material thicknesses less than 3". The joint gap shall not exceed 5/16" for material thicknesses 3" and above. Such joints shall incorporate adequate backing against which to weld.

The root opening for single bevel grooves against backing bars shall be as follows.

1/4" min. to 9/16" max. backing bar removed after welding.
3/8" min. to 9/16" max. backing bar left on.

Tack welds shall be subject to the same quality requirements as the final welds except that discontinuities such as undercut and unfilled craters need not be removed before the final arc weld.

Preheat is mandatory for single pass tack welds which are remelted and incorporated into continuous arc welds (final welds).

Tack welds must be large enough to prevent shifting or cracking during subsequent welding. They must be clean, contain no cracks, lack of fusion, or slag and should be designed to become part of the final weld.

Tack welds which are incorporated into the final welds shall be made with electrodes meeting the requirements of the final welds and shall be cleaned thoroughly.

WELDING

11) All welding shall be performed using approved welding procedure according to AWS D1.1 and Specification Section 2808-215-17D. A stringer bead technique shall be used to the greatest extent possible. In any case, the width of bead shall not exceed three (3) core diameters of the electrode (except for dual shield flux cored wire which shall not exceed 3/8" in width.

The minimum size of a root pass shall be sufficient to prevent cracking and the maximum thickness of layers subsequent to root pass shall be 1/8" for welds made in the flat position and 3/16" for welds made in any other position.

Each weld pass of deposited weld metal shall be thoroughly cleaned using slagging picks, wire brushes, or by grinding.

Any cracks, blow holes, or other defects that appear on the surface of weld beads shall be removed by chipping or grinding before the next covering weld bead is deposited.

All weld beads, except those in the root and final layers, shall be peened immediately after removal of slag. However, any visible defects such as porosity, cracks, or slag pockets must be removed by grinding prior to peening. Peening shall be done using an air hammer with a round nose tool of a minimum diameter of one quarter inch (¼"). Peening shall be done in a straight and continuous line. Care shall be exercised to prevent scaling or flaking of weld base metal from over-peening. Peening shall be used in all cases, except where specifically prohibited by a note on the weld sequence sheet. Air operated "needle" slagging guns shall not be used for peening purposes. Peen per sketch attached.

No downhill welding will be permitted.

Heat input range shall not exceed the following:

35kj/in. heat input shall be maximum for welding.

Buttering may be done horizontally, vertically (up), or any combination of the two. Buttering does not require peening.

All groove welds and all fillet welds against the Sac. Wall require that the Sac. Wall be buttered.

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Every effort should be made to provide continuous welding until the joint is complete. As a minimum, 3/4" throat thickness shall be obtained without an interruption. "Interruptions" shall be defined as welding which is discontinued for more than 1 hour but less than 2 hours. All "interruptions" shall be recorded. Any weld which is discontinued for more than 1 hour must be dispositioned and approved by the Burns & Roe Welding Engineer. Any weld which exceeds the 2 hour interruption limit shall require documentation on an IR/NCR if deemed necessary by the Burns & Roe Welding Engineer. For all interruptions, the following action shall be taken:

1) The last weld layer shall be peened before the weld is left.

2) The weld shall be covered with insulation blankets and the required preheat maintained. Q.C. shall verify this.

3) The weld shall be visual inspected prior to resuming welding. The visual inspection report noting the interruption shall be included in the work package. If a crack is discovered, an IR shall be prepared.

4) Each weld shall be peened and inspected, per attached sketch.

12) INSPECTION

Prior to any welding, the area to be welded shall be visual inspected in accordance with AWS D1.1, and after any arc-gouging, cutting or grinding. All welding shall be MT inspected at 100% completion at preheat temperature. All welding shall be MT inspected 72 hours after cool down.

When the finished weld will be inaccessible for the 72 hour magnetic particle inspection because another weld or member will have covered it, acceptance will be based on a hot MT made when the weld is complete and visual and 72 hour MT of any remaining exposed areas. This exception is only allowed when it eliminates heat cycling a weld zone, and it shall be approved by the Burns & Roe Welding Engineers.

B & R Welding Engineer shall evaluate all rejectable indications revealed by visual or MT inspection prior to any rework.

13) REPAIR SEQUENCE

Remove the indication revealed by visual inspection to sound metal beyond each end of the discontinuity by grinding or chipping. If the defect extends one half inch (½") arc-gouging may be used. The required preheat shall be specified. Arc-gouging is to be used sparingly to minimize the possibility of crack propagation.

Excavation shall be reinspected to assure that the defect has been removed.

Reweld excavated area following appropriate paragraphs in this procedure.

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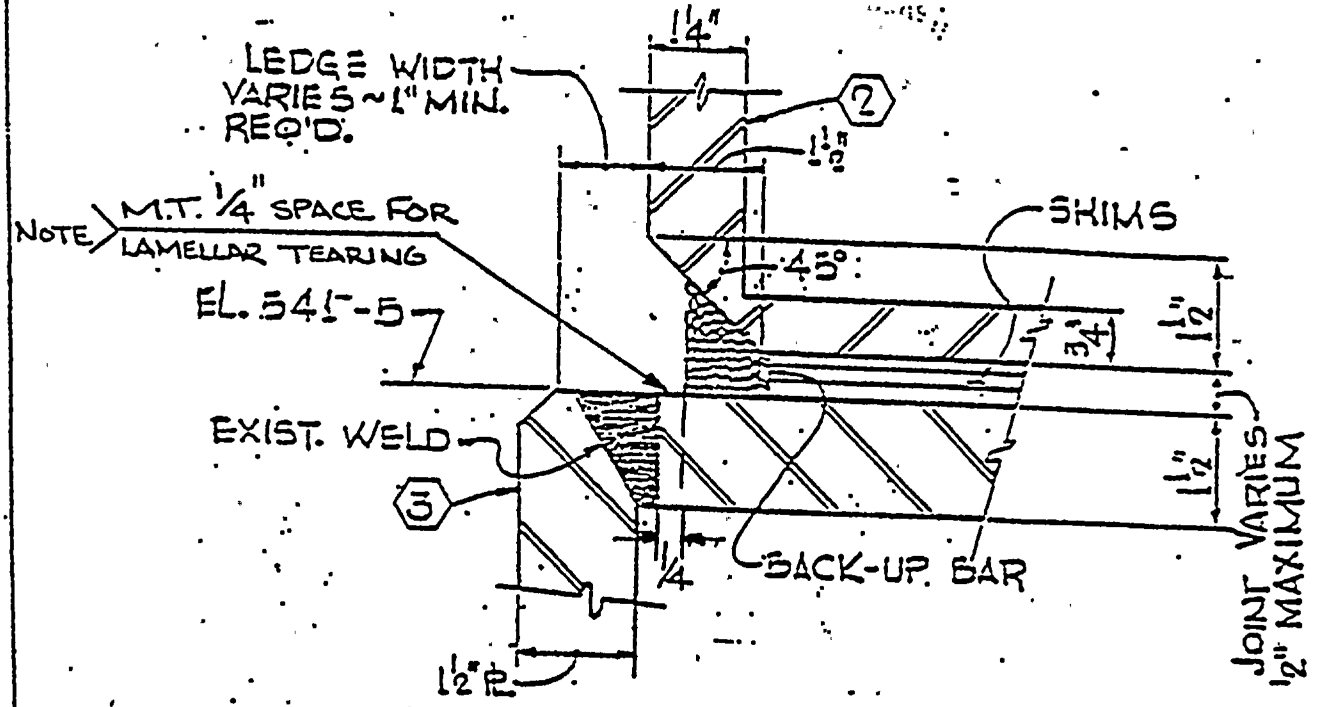

TYPICAL PHASE I WELD DEPOSIT WHERE LEDGE IS A MINIMUM OF 1" WIDE & SIDE PL. / BUILT-UP MEMBER (3) IS 1½".

1) After root passes have been applied all remaining passes shall be peened. *

2) Any indications that should be picked up by visual inspection shall be evaluated by B & R Welding Eng. prior to any rework.

3) M.P.T. final weld at preheat temp. and 72 hrs. after complete cool down.

*Except cover pass.

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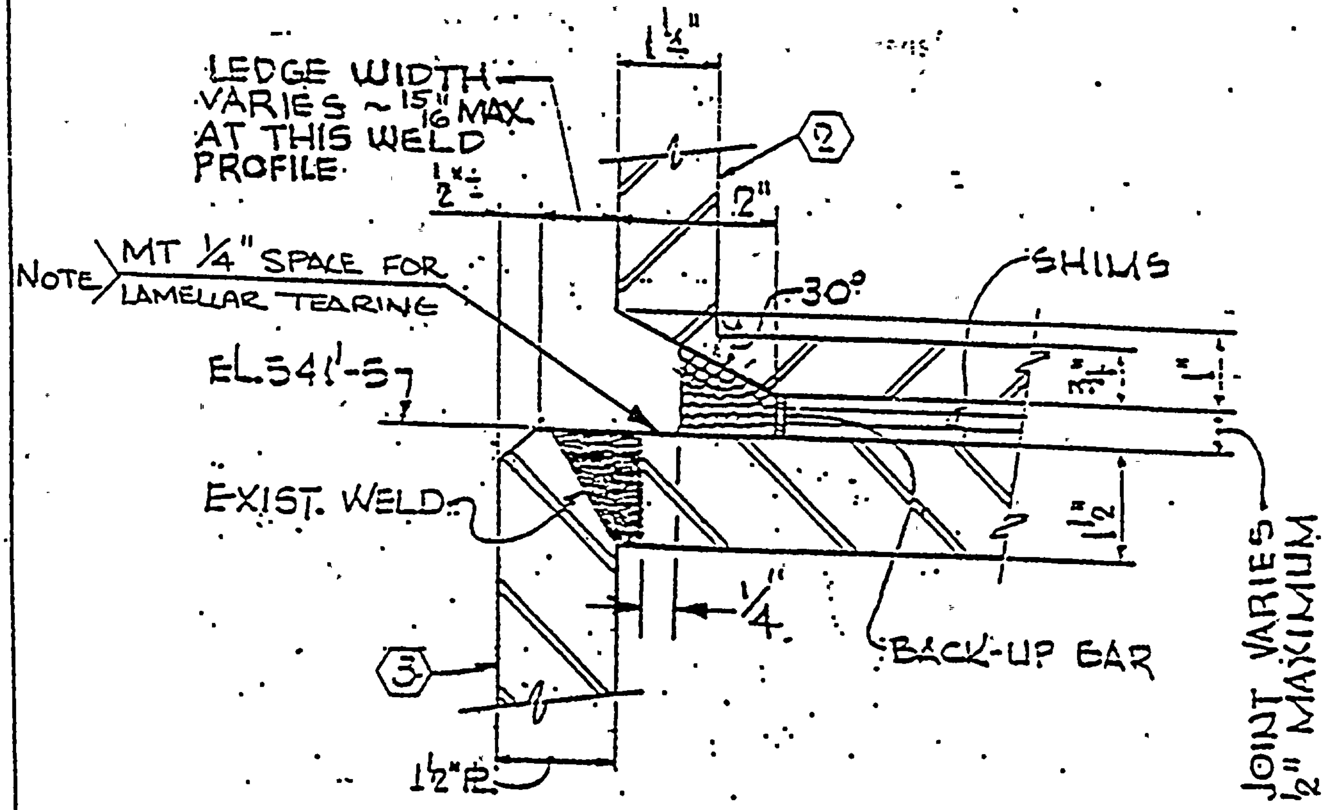

TYPICAL PHASE I WELD DEPOSIT WHERE LEDGE IS LESS THAN 1" WIDE & SIDE PL./BUILT-UP MEMBER ③ IS 1½"

1) After root passes have been applied all remaining passes shall be peened.*

2) Any indications that should be picked up by visual inspection shall be evaluated by B & R Welding Eng. prior to any rework.

3) M.P.T. final weld at preheat temp. and 72 hrs. after complete cool down.

*Except cover pass.

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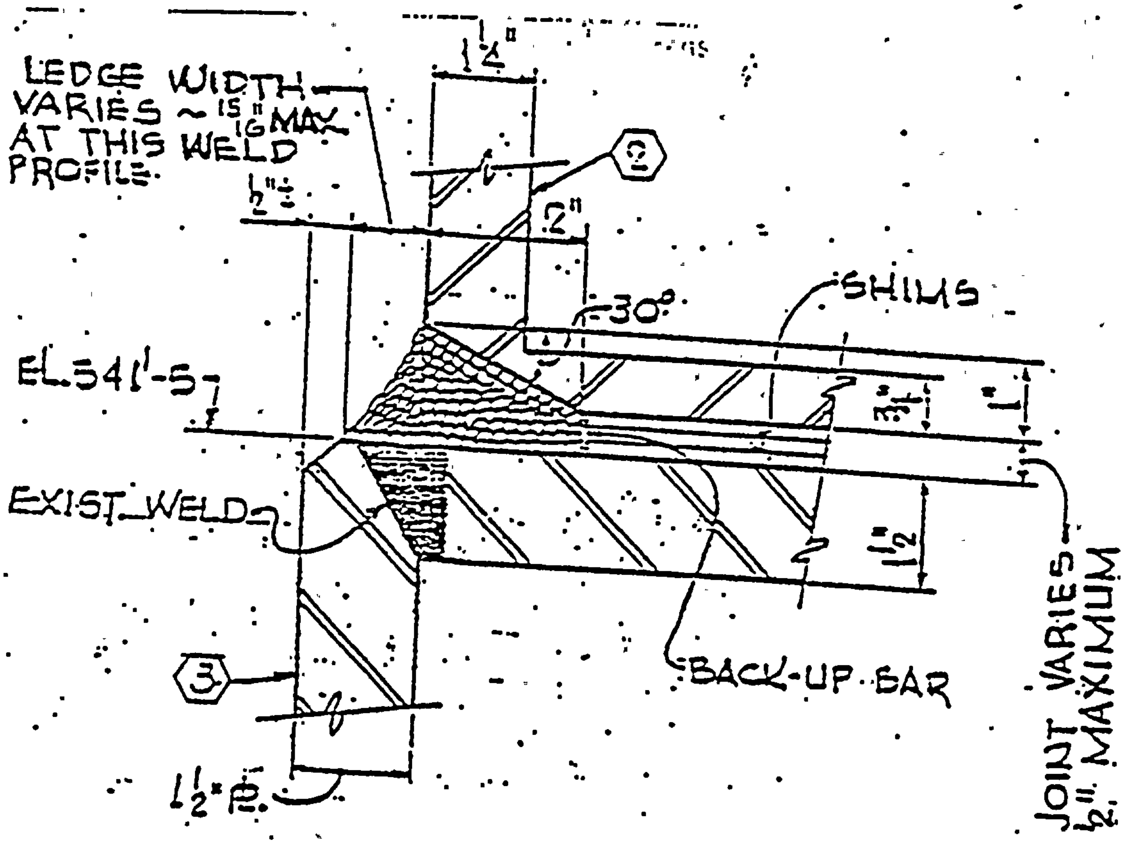
SCALE: NTS DRAWN BY DATE	—	TITLE:
CHKD BY [signature] DATE 7/8/80	APPV'D [signature] DATE	Weld Deposit Phase I

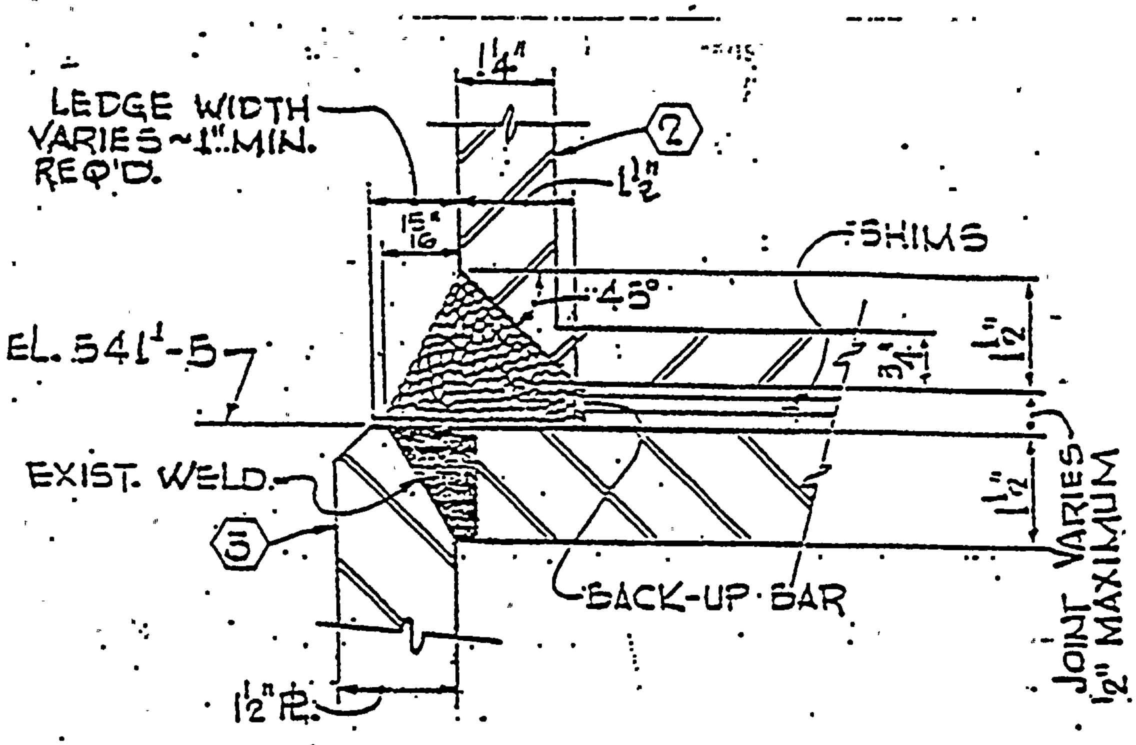


TYPICAL PHASE II WELD DEPOSIT WHERE LEDGE IS LESS THAN 1" WIDE & SIDE PL. / BUILT-UP MEMBER (3) IS 1 1/2"

1) After root passes have been applied all remaining passes shall be peened. *
2) M.P.T. final weld at preheat temp. and 72 hrs. after complete cool down.

*Except cover pass.

REF. DOC.: PCN ~~RFI~~ NCR 215-5688		WPPSS NUCLEAR PROJECT NO. 2
REF SPEC. SECTION: PAGE: PARA:		BURNS AND ROE, INC.
REF DWG.:	DWG. ZONE:	PED 215-W-3776 SHT. 10 OF 15
SCALE: NTS	DRAWN BY DATE / CHKD BY [signature] DATE [illegible] APPVD [signature] DATE	TITLE: Weld Deposit Phase II.

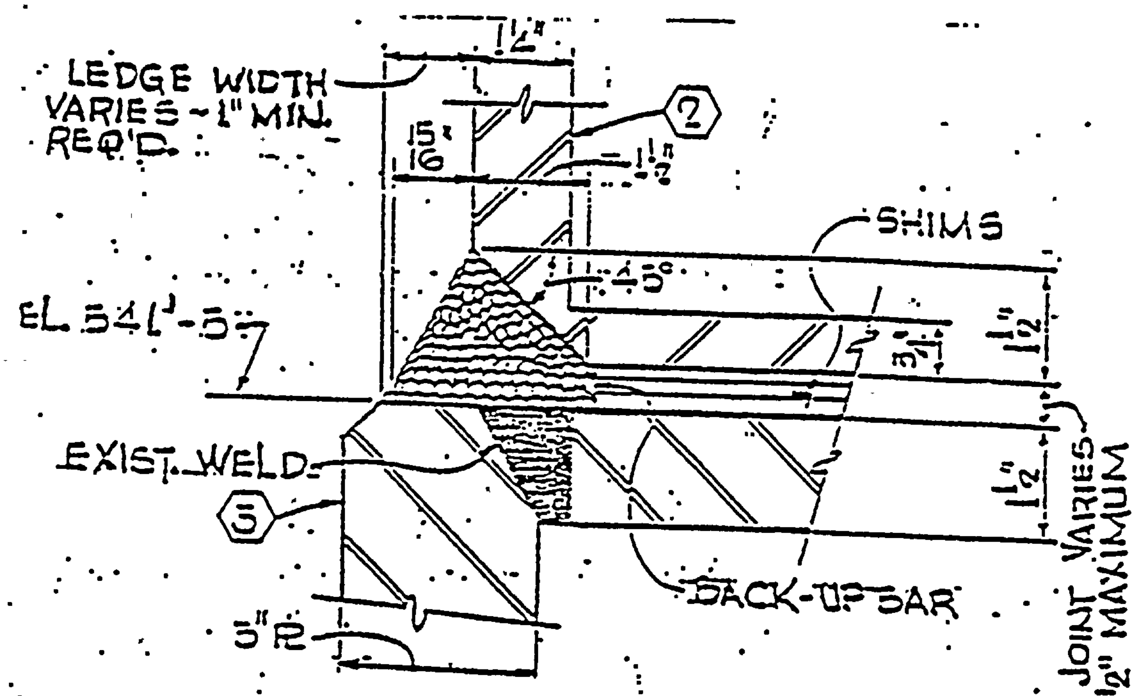


TYPICAL PHASE II WELD DEPOSIT WHERE LEDGE IS A MINIMUM OF 1" WIDE & SIDE PL./BUILT-UP MEMBER ⟨3⟩ IS 1½"

1) After root passes have been applied all remaining passes shall be peened. *
2) M.P.T. final weld at preheat temp. and 72 hrs. after complete cool down.

*Except cover pass.

REF. DOC.: PCN —— RFI NCR 215-5688		WPPSS NUCLEAR PROJECT NO. 2
REF SPEC. SECTION: —— PAGE: —— PARA. ——		BURNS AND ROE, INC.
REF DWG.: ——	DWG. ZONE ——	PED 215-W-3776 SHT. 11 OF 15
SCALE: NTS	DRAWN BY DATE	TITLE:
	CHKD BY [signature] DATE 7-8-88 APPV [signature] DATE	Weld Deposit Phase II

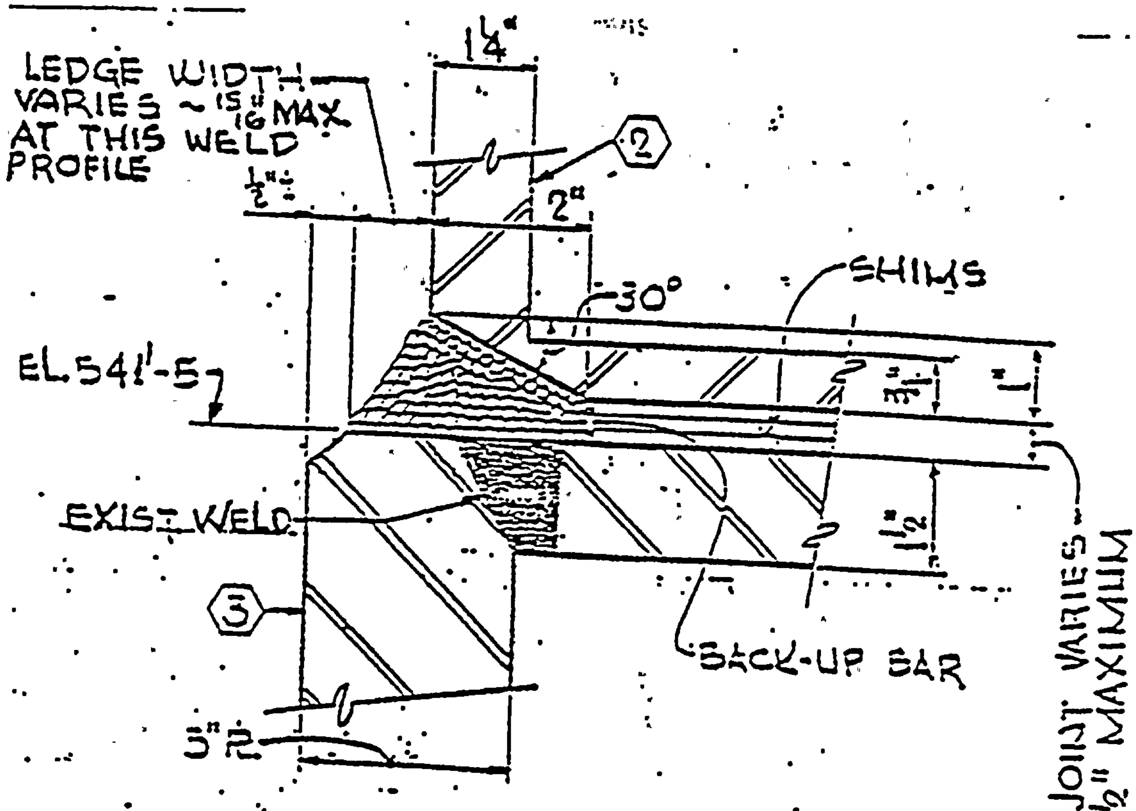


TYPICAL WELD DEPOSIT WHERE LEDGE IS A MINIMUM OF 1" WIDE & SIDE PL. / BUILT-UP MEMBER (5) IS 5"

1) After root passes have been applied all remaining passes shall be peened. *
2) M.P.T. final weld at preheat temp. and 72 hrs. after complete cool down.

*Except cover pass.

REF. DOC., PCN ——— RFI NCR 215-5688		WPPSS NUCLEAR PROJECT NO. 2	
REF SPEC. SECTION: ——— PAGE: ——— PARA. ———		BURNS AND ROE, INC.	
REF DWG. ———	DWG. ZONE ———	PED 215-W-3776	SHT. 12 OF 15
SCALE: NTS	DRAWN BY ... DATE / CHKD BY [signature] DATE	— / APPVD [signature] DATE	TITLE: Weld Deposit

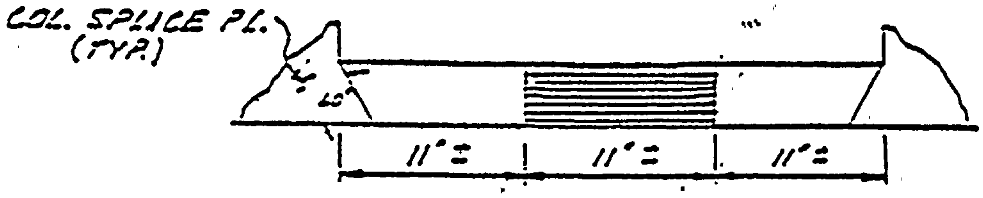


TYPICAL WELD DEPOSIT WHERE LEDGE IS LESS THAN 1" WIDE & SIDE PL / BUILT-UP MEMBER ③ IS 3"

1) After root passes have been applied all remaining passes shall be peened. *
2) M.P.T. final weld at preheat temp. and 72 hrs. after complete cool down.

*Except cover pass.

REF. DOC.: PCN ~~RFI~~ NCR 215-5688			WPPSS NUCLEAR PROJECT NO. 2
REF SPEC. SECTION: PAGE: PARA:			BURNS AND ROE, INC.
REF DWG.:		DWG. ZONE:	PED 215-W-3776 SHT. 13 OF 15
SCALE: NTS	DRAWN BY DATE: / CHKD BY [signature] DATE 7-8-80	APPVD [signature] DATE	TITLE: Weld Deposit



SECTION A-A

TYPICAL CASCADE WELD DETAIL

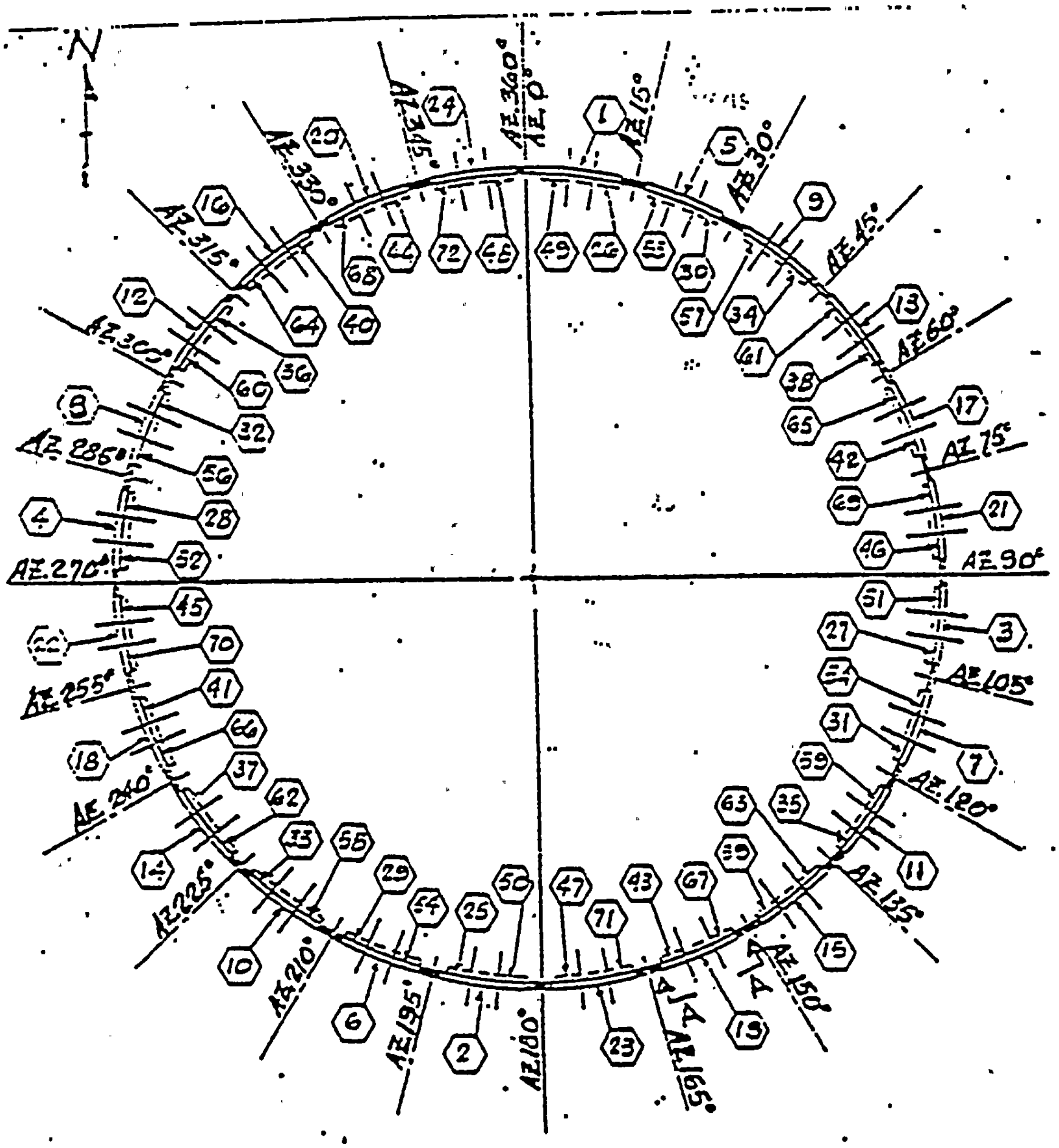
NOTES:

A) 4 -11" cascade area's shall be made first, to assure that there is no movement to the wall, also to establish the stability for the remaining welding.

B) All remaining welding may be completed in a different sequence if so designated by B & R Welding Engineer.

1) Four (4) welders to weld simultaneously throughout sequence.
2) First sequence to start at AZ. 7°-30'.
3) Second sequence to start at AZ 191°-30'.
4) Third sequence to start at AZ. 103°-30'.
5) No welder shall proceed ahead of any other welder in a sequence.
6) Each sequence number consists of approximately 11".

REF. DOC.. PCN ——— ~~RFI~~ NCR-215-5688			WPPSS NUCLEAR PROJECT NO. 2
REF SPEC. SECTION: ——— PAGE. ——— PARA: ———			BURNS AND ROE, INC.
REF DWG.: ———		DWG. ZONE: ———	PED 215-W-3776 SHT. 14 OF 15
SCALE:	DRAWN BY DATE		TITLE:
NTS	CHKD BY [signature] DATE 7-9-8?	APPVD [signature] DATE	Weld Deposit



PLAN ~ WELD SEQUENCE

⬡ INDICATES WELD SEQUENCE NUMBER

WORK THIS SHEET WITH SHEET 8 thru 15

REF. DOC.: PCN ——— ~~RFI~~ NCR 215-5688			WPPSS NUCLEAR PROJECT NO. 2
REF SPEC. SECTION: ——— PAGE: ——— PARA: ———			BURNS AND ROE, INC.
REF DWG.. ———		DWG. ZONE ———	PED 215-W-3776 SHT. 15 OF 15
SCALE: NTS	DRAWN BY ——— DATE		TITLE: Weld Sequence Plan
	CHKD BY [signature] DATE 7/1/88	APPVD [signature] DATE	

BURNS AND ROE, INC. WPPSS NUCLEAR PROJECT NO. 2	PROJECT ENGINEERING DIRECTIVE	CODE: 2 1 PROJECT ENGINEERING DIRECTIVE: 215-W-3830 DATE: 07/22/80 PRIORITY: I

REASON FOR P. E. D.:

This PED is to establish the inspection criteria for the partial penetration joint prior to welding on the Sac. Wall at the 541' El. between Ring 3 and 4.

INFORMATION COPIES ______

SHEET 1 OF ______

REFERENCES	
SUBJECT	Inspection Criteria
LOCATION	541' El. Drywell
ENG. SYSTEM	------
S/U SYSTEM	------
QUALITY CLASS	AWS D1.1 Class 1
ORIGINATING DOCUMENTS	NCR 215-5688

DESCRIPTION OF WORK: Mag. particle inspection of 2" partial penetration excavation joint.

1) Linear indications shall not be arbitrarily rejectable as a crack until excavation has been done for evaluation. All cracks shall be completely removed.

2) Inspection criteria for magnetic particle examination shall meet the requirements of AWS D1.1-74, para. 8.15 except for crack or laminations all other indications shall be excavated to a depth not to exceed 3/8" then sealed and welded out.

3) If a linear discontinuity is proven to be a lamination in the base plate material, the requirements of AWS D1.1-74, para. 3.2 shall apply, except that for discontinuities over 1 inch (25.4mm) in length with depth greater than 1 inch shall not be cause for rejection of the plate and weld repair shall be limited to 1 inch in depth of the plate from the prepared joint surface.

NOTES

1. THIS PED REVISES DIRECTION PREVIOUSLY PROVIDED BY THE FOLLOWING PED(s): ______
2. THIS PED VOIDS DIRECTION PREVIOUSLY PROVIDED BY THE FOLLOWING PED(s): ______
3. THIS PED WORK SHOULD BE COORDINATED WITH KNOWN OTHER WORK UNDER THE FOLLOWING PED'S: 215-W-2749, 215-W-3776, 215-W-3775
4. THIS PED DEPENDS ON THE PRIOR INSTALLATION OF THE FOLLOWING PED'S: ______

REVISE:

NONE N/A
DRAWINGS
SPECIFICATION

APPROVALS:

Signature	Title	Date
[signature]	DISCIPLINE ENGINEER	7-22-80
[signature]	LEAD DISCIPLINE ENGINEER	7/22/80
[signature]	S/U LIAISON ENGINEER	7/23/80
J. J. Good	RESIDENT PROJECT ENGINEER	7-23-80

REV 1 BR 803-2

BURNS AND ROE, INC. WPPSS NUCLEAR PROJECT NO. 2	PROJECT ENGINEERING DIRECTIVE	CODE: 2 1	PROJECT ENGINEERING DIRECTIVE: 2 1 5 - M - 2 7 4 6
		DATE: 0 4 / 0 4 / 8 0	PRIORITY: I

REASON FOR P. E. D.:

To direct contract 215 to repair the forty (40) gaps between shims located at the 541'-5" elevation on the sacrificial shield wall (SSW). This repair is necessary to restore the shielding adequacey of the SSW at this elevation.

INFORMATION COPIES: CS, W

SHEET 1 OF 6

REFERENCES	
SUBJECT	SSW Shim Gap Repair
LOCATION	541'-5" SSW: Containment
ENG. SYSTEM	N/A
S/U SYSTEM	N/A
QUALITY CLASS	I
ORIGINATING DOCUMENTS	SSW Task Force Action Plan Concern No. 2

DESCRIPTION OF WORK:

-Refer to sheets 2 through 6 of this PED-

NOTES

1. THIS PED REVISES DIRECTION PREVIOUSLY PROVIDED BY THE FOLLOWING PED(s): N/A
2. THIS PED VOIDS DIRECTION PREVIOUSLY PROVIDED BY THE FOLLOWING PED(s): N/A
3. THIS PED WORK SHOULD BE COORDINATED WITH KNOWN OTHER WORK UNDER THE FOLLOWING PEDS: PED-215-W-2749, PED-215-W-1604
4. THIS PED DEPENDS ON THE PRIOR INSTALLATION OF THE FOLLOWING PEDS: PED-215-W-2742

REVISE:

NONE X
DRAWINGS
SPECIFICATION

APPROVALS:

[signature] DISCIPLINE ENGINEER	4/4/80 DATE
[signature] LEAD DISCIPLINE ENGINEER	4/4/80 DATE
[signature] SUPERVISION ENGINEER	4-11-80 DATE
[signature] RESIDENT PROJECT ENGINEER	4-11-80 DATE

GENERAL DESCRIPTION

This PED directs contract 215 to repair the forty (40) gaps between shims that were identified and documented during the month of December 1979. The survey that was performed at that time was documented and this documentation package (because of its bulk) will be provided to you by the owner (Fred S. Weingard, Ext. 2876) under separate cover. The survey identifies each gap numerically (# 1-40) and gives the azimuth for the centerline of each gap and all measured parameters of the gap. Each gap shall be repaired by filling with an Owner approved shielding material (to be specified later in this PED). Due to the nature of this repair, and as the result of commitments to the NRC, prototype testing shall be implemented to develop a verified procedure for repair.

The scheduling of all repairs shall be controlled by Construction Management. This work shall be implemented after PED-215-W-2742 is implemented for the area of concern and before PED-215-W-1604 is implemented in the area of concern. Technical direction for this repair shall be controlled by B&R Engineering (Fred S. Weingard, Ext. 2876). All work to be done by contract 215, as directed by this PED, shall be done to Owner approved, Quality Class I, procedures and shall be implemented only with a B&R Engineering representative present at all times.

It should be noted that throughout the context of this PED, contract 215 is directed to procure the products and/or services of Brand Industrial Services, Inc. (BISCO). It is highly recommended that contract 215 work these requests through their BISCO sub-contractor on site. To assist in this effort, the following contacts are provided:

1. Mr. Mike Marsh, BISCO site contact.
2. Mr. Jim Sherwood, Director of Marketing, BISCO.
3. Mr. James Anderson, Technical Support, BISCO.
4. Mr. Clayton W. Brown, Vice President, BISCO.

DETAILED DESCRIPTION

I. Material Specification.

Contract 215 shall procure enough shielding material to fill all the gaps in the SSW and to perform prototype testing. The total amount of shielding material required is (with conservatism) approximately that amount of shielding material capable of filling 2.5 cubic feet of volume. All shielding material brought on site shall be stored in strict accordance with manufacturer's recommendations.

The shielding material to be used shall be BISCO product NS-1 (high density). NO SUBSTITUTE shall be acceptable! NS-1 (high density) is a combination of BISCO's NS-1 binder and lead filler

REF DOC PCN -NA-	RFI -NA-		WPPSS NUCLEAR PROJECT NO. 2
REF SPEC SECTION -NA-	PAGE -NA-	PARA -NA-	BURNS AND ROE, INC.
REF DWG -NA-	DWG ZONE -NA-		PED 215-M-2746 SH 2 OF 6
SCALE NONE	DRAWN BW DATE 4.4.80		TITLE [illegible]

(11% by volume). A silicon based compound may be added to the mixture to cause foaming in a controlled manner. Expansion due to foaming may not exceed 1%-2% by volume. The total density of the final "as-installed" product (after curing and foaming) must be greater than or equal to that density of ordinary concrete which is 2.4 grams/cc or 150 lbs/ft^3. Certification must be provided that the "as-installed" mixture meets the above criteria.

The radiation shielding properties of the "as-installed" material must meet or exceed the shielding properties of ordinary concrete. The above criteria shall be documented via experimental data or by analytical modeling and computer programming such as with the ANISN program or others. This documentation shall also be transmitted to the Owner for approval prior to procurement of the material. The "as-installed" product shall be capable of withstanding an integrated dose of 2.0 x 10^{10} rads over the 40 year life of the plant. All radiation test reports for the material shall be transmitted to the Owner with a list of the following properties provided giving data before exposure and after exposure (if available):

1. Density
2. Composition (chemicals by % weight)
3. % Lead fill (by volume)
4. Composite flame spread:
   (a) ASTM E-84
   (b) ASTM E-162
   (c) ASTM E-119
5. Tensile strength
6. Elongation
7. Durometer (hardness)
8. Halogen content

The aforementioned test reports and property data shall be transmitted to the Owner for approval prior to procurement of the shielding material.

The thermal stability of the "as-installed" material must also be certified for the following concerns:

1. Continuous ambient temperature of 270° F for 40 years
   and
2. Short term heat input due to welding that might bring the temperature close to 600° F.

Note that certification for concern # 1 (above) may be extrapolated from shorter term data.

The construction features of this shielding material shall be such that it may be injected into a shim gap as small as 1/16 inch by 1/16 inch by 24 inches and after foaming and curing, fill this gap completely. The flow characteristics, cohesion, adhesion, and

... the properties of this material shall be such that the aforementioned gap size (1/16 x 1/16 x 24) will be filled completely at an ambient temperature of no greater than 100° F. The expected temperature range during filling (or injection) and curing shall be between 50° F. and 100° F.

The construction features and concern number two (2) of the thermal features shall be verified during prototype testing. It is imperative that the shield material be procured and delivered to the site as soon as possible.

II. Prototype Testing

A. The Owner shall provide a test fixture for prototype testing of the construction features of the shielding material. This test fixture consists of two (2) 1/2" x 18" x 2'0 3/4" plates for which varying shim stock may be inserted between the plates to simulate gaps between shims at the 541' 5" elevation of the SSW. The plates are held together by heavy duty "C" type clamps. The simulated gap sizes shall vary between:

1. Height: 1/16" to 5/8"
2. Circumferential length: 1/16" to 9"
3. Radial depths = shim depth on either side of gap shall either be 2' 0 3/4" or 1'0".

Note that the 2' 0 3/4" radial depth shim prototype represents straight-thru gaps as depicted in the survey data. The 1'0" radial depth shim prototype represents gaps where the shims on either side of the gaps do not extend the full radial depth of the SSW wall as indicated by the hooked probes during the shim gap survey. In both cases it shall be assumed that there is no backing for the flow of the shielding material into the gap. The backing and methodology for inserting backing shall be determined during prototype testing. It is recommended that oil free, steel wool be used for backing the gap, however, other methods suggested by contract 215 or BISCO may be tried to determine feasibility. Any material inserted as a backing (or a dam) for the shielding must be approved by the Owner. The chemical analysis of the backing (or dam) shall be submitted to the Owner for approval.

Prototype testing shall be implemented in the following stages:

1. Write a 'prototype procedure' delineating steps and controls.
2. The procedure should closely follow these steps:
   a. insert backing
   b. apply (pour or pressurize or inject) shield material - method of application shall be determined by BISCO
   c. let cure (and/or foam) - foam control and cure time established by BISCO
   d. remove "C" clamps and disassemble test fixture
   e. observe gap for complete fill (Owner must be present)

3. The Owner's representative will then decide if the 'fill' is acceptable. If the 'fill' is not acceptable, the 'prototype procedure' shall be modified to correct deficiencies and the contractor shall proceed back to step #1 above. If the 'fill' is deemed acceptable by the Owner's representative the 'prototype procedure' shall be implemented several more times for varying gap sizes and parameters (as directed by the Owner's representative). In any case, where the Owner's representative deems the results unacceptable, the 'prototype procedure' shall be modified to correct deficiencies and the entire test program shall be reinstated from the start.

4. Upon final acceptance of the 'prototype procedure' by the Owner's representative, the prototype testing shall be deemed complete and acceptable and a final formalized procedure shall be submitted to the Owner for approval.

B. The test fixture for the weld qualification delineated in PED-215-W-2749 shall contain a gap. This gap shall be filled by contract 215 per the finalized approved procedure written in accordance with #4 above. Welding shall be performed per the direction given in PED-215-W-2749, however, after welding the test fixture shall be (destructively) cut to qualify the weld and the shield material with respect to heat input concerns during welding. If the shield material is not acceptable to Owner after welding, a new test fixture (with a gap) shall be constructed in accordance with the requirements of PED-215-W-2749. The shield material shall again be injected per the approved finalized procedure; however, space shall be left for installation of an Owner-approved thermal insulator. BISCO has recommended Babcock and Wilcox ceramic fiber product Roll Board which can be inserted between the installed shielding and the backing ring for the weld. The appropriate weld shall then be made and the test fixture shall be cut to qualify the weld and shielding material again. If the heat input from the weld results in damage to the shield material that is deemed unacceptable by the Owner's representative, then the shield material shall be deemed unacceptable and a new material shall be located by the Owner. If this situation arises, new direction will be issued to contract 215 at that time. If the shield material passes either the first or second weld qualification test, then the shielding material shall be deemed "Owner approved" with the final installation procedure being modified to include the addition of a thermal insulator, if required.

Prototype testing shall be implemented as soon as the shield material is delivered to the site.

III. Repair of Shim Gaps.

A. After PED-215-W-2742 is implemented in a particular area of concern (work zone) and at the direction of contract management (CM), contract 215 shall 'clean out' all gaps in the work zone specified by CM. In no case shall cleaning involve blowing air (or liquid) into the gap. All cleaning of gaps shall be accomplished by vacuum technique. It is recommended that BISCO direct the cleaning of the gaps so as to insure the proper cleanliness for the injection of the Bisco shield product into the gap.

As was noted previously, all gaps and their locations are identified in the survey documentation package to be provided to you under separate cover.

B. For the gaps (in the work zone) identified to be repaired, contract 215 shall post a man in the nearest SSW door opening so that he can observe with a flashlight the inner openings of the gaps (if they are 'straight thru' or 'point thru'). Leakage out of these inner openings during filling shall be reported to the Owner's representative immediately.

C. The gaps shall be filled with the shielding material per the approved, finalized procedure which was determined during prototype testing. The safety precautions, as recommended by the manufacturer, shall be strictly adhered to during the mixing and curing process.

D. The repair crew shall go on to a new work zone at the direction of CM and shall proceed with the repair of those gaps in the work zone.

E. A procedure incorporating steps A through D above shall be submitted to the Owner.

IV. Scheduling.

It is anticipated that the shield repairing of the gaps will start in early May 1980. Prototype testing may be started as soon as the shielding material arrives on site. The prototype testing must be completed and approved by Owner prior to implementing the actual repairs on the SSW.

BURNS AND ROE, INC. WPPSS NUCLEAR PROJECT NO. 2	PROJECT ENGINEERING DIRECTIVE	CODE: 2 1	PROJECT ENGINEERING DIRECTIVE: 215 - M - 3320	DATE: 05/06/80	PRIORITY: I - (Rush)

INFORMATION COPIES

SHEET 1 OF 3

REASON FOR P. E. D.:

1. To expedite the initiation of prototypotesting as delineated on sheets 4 and 5 of PED-215-M-2746.
2. To delineate a different prototype test fixture as prescribed on sheet 4 of PED 215-M-2746. This new fixture will allow for several (4) gaps to be tested at one time and therefore decrease the overall prototype testing time which is dependent on the shield material cure time (10 hrs.)

REFERENCES

SUBJECT	SSW shim gap prototype testing
LOCATION	off site
ENG. SYSTEM	N/A
S/U SYSTEM	I Procedures
QUALITY CLASS	
ORIGINATING DOCUMENTS	Verbal with Mike Brewer on 5/2/80

DESCRIPTION OF WORK:

1. (a) Sheet 3 of 6 of PED 215-M-2746 requires (in two places) the transmittal of documentation to the owner for approval prior to procurement of the shielding material. This requirement shall be implemented for the shielding material to be installed in the SSW and does not apply to shielding material required on site for prototype testing. The purpose of this PED is to clarify the intent of those statements so as to expedite the initiation of prototype testing.

   (b) In line with the above, Contract 215 is authorized to have the prototype testing shield material air-freighted to the site to reduce the delivery time.

2 (a) Revise sheet 4 of 6 of PED 215-M-2746 as per sheet 2 of 3 of this PED.

   (b) Refer to figure 1 on sheet 3 of 3 of this PED. This figure delineates the test fixture required to perform prototype testing as called out in Sheet 2 of 3 of this PED.

*** Note that two (2) test fixtures are required by this PED. ***

NOTES

1. THIS PED REVISES DIRECTION PREVIOUSLY PROVIDED BY THE FOLLOWING PED(s): Sht 4 of 215-M-2746
2. THIS PED VOIDS DIRECTION PREVIOUSLY PROVIDED BY THE FOLLOWING PED(s):
3. THIS PED WORK SHOULD BE COORDINATED WITH KNOWN 215-M-2746 OTHER 215 WORK UNDER THE FOLLOWING PED'S:
4. THIS PED DEPENDS ON THE PRIOR INSTALLATION OF THE FOLLOWING PED'S:

REVISE:
NONE X
DRAWINGS
SPECIFICATION

APPROVALS:

[signature] DISCIPLINE ENGINEER	5-6-80 DATE
[signature] LEAD DISCIPLINE ENGINEER	5-6-80 DATE
[signature] S/U LIAISON ENGINEER	5-6-80 DATE
[signature] RESIDENT PROJECT ENGINEER	5-6-80 DATE

mentioned gap size (1/16 x 1/16 x 24) will be filled completely at an ambient temperature of no greater than 100° F. The expected temperature range during filling (or injection) and curing shall be between [illegible] F. and 100° F.

The construction features and concern number two (2) of the thermal features shall be verified during prototype testing. It is imperative that the shield material be procured and delivered to the site as soon as possible.

II. Prototype Testing

A. The Owner shall provide two identical test fixtures for PED 215-M-3320 prototype testing of the construction features of the shielding material. Each test fixture shall be capable of simulating four (4) owner prescribed gaps.. The test fixture shall consist of two (2) plates for which varying shim stock may be inserted between the plates to simulate gaps between the shims at the 541'5" elevation of the SSW. The plates are held together by heavy duty "C" type clamps. The test fixture and all dimensions are delineated in figure 1 on sheet 3 of 3 of PED 215-M-3320. The gaps prescribed in this figure are indicative of those found per the survey. Each fixture (set of four gaps) shall fulfill the requirement for varying gap sizes as called out in step 3 on sheet 5 of 6.

In all cases it shall be assumed that there is no backing for the flow of the shielding material into the gap. The backing and methodology for inserting backing shall be determined during prototype testing. It is recommended that oil free, steel wool be used for backing the gap, however, other methods suggested by contract 215 or BISCO may be tried to determine feasibility. Any material inserted as a backing (or a dam) for the shielding must be approved by the Owner. The chemical analysis of the backing (or dam) shall be submitted to the Owner for approval.

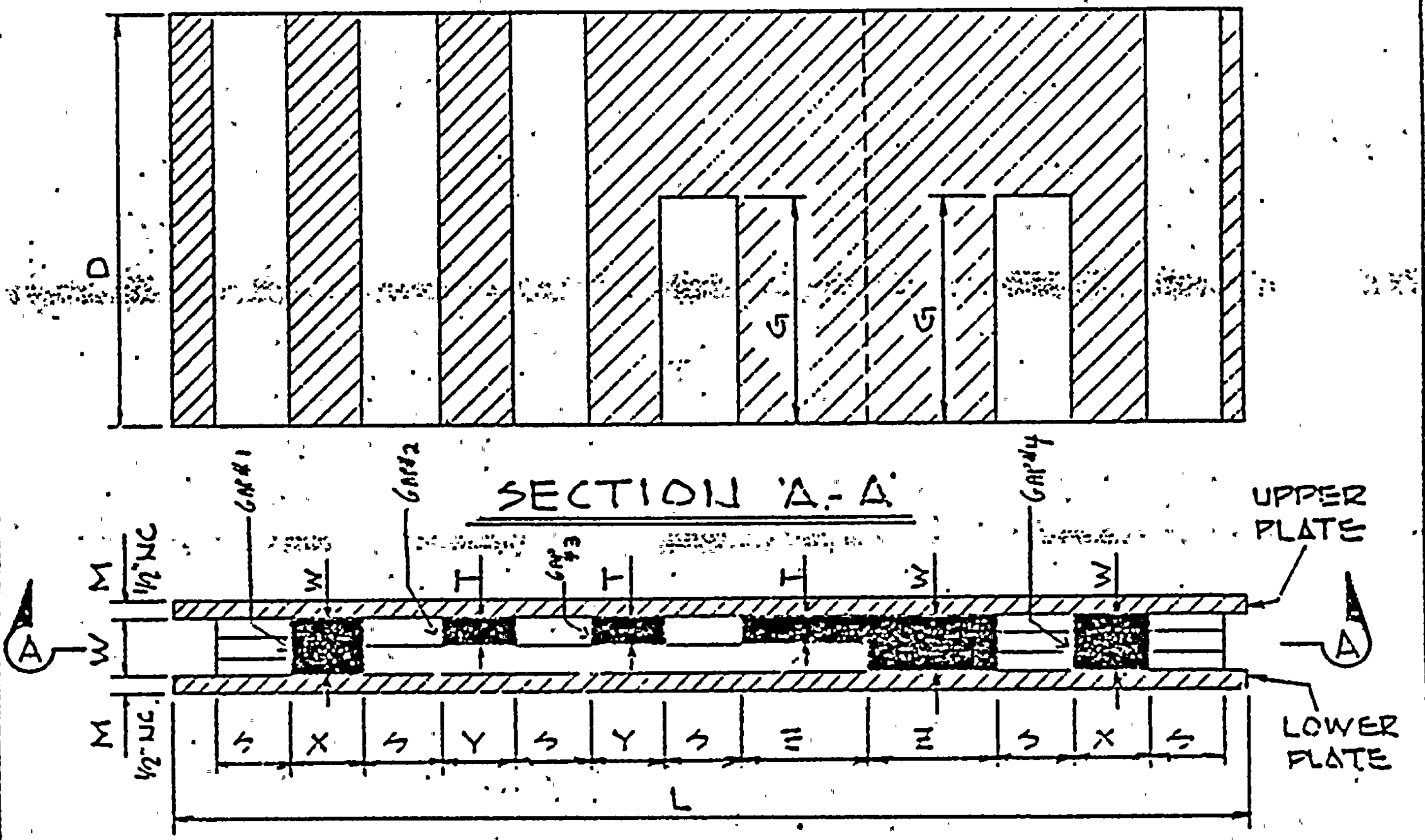
Prototype testing shall be implemented in the following stages:

1. Write a 'prototype procedure' delineating steps and controls.
2. The procedure should closely follow these steps:
   a. insert backing
   b. apply (pour or pressurize or inject) shield material - method of application shall be determined by BISCO
   c. let cure (and/or foam) - foam control and cure time established by BISCO
   d. remove "C" clamps and disassemble test fixture
   e. observe gap for complete fill (Owner must be present)

REF DOC PCN -NA-	RFI -NA-	WPPSS NUCLEAR PROJECT NO. 2
REF SPEC SECTION -NA- PAGE -NA- PARA -NA-		BURNS AND ROE, INC.
REF DWG -NA-	DWG ZONE	PED 215-M-[illegible] SHT [illegible] OF 6
SCALE NONE DRAWN BY JSW DATE [illegible] / CHKD BY [illegible] DATE [illegible]	APPVD JSW -NA-	TITLE SSW Shim Gap Repair

REF. DOC PCN		RFI		WPPSS NUCLEAR PROJECT NO. 2
REF SPEC. SECTION:		PAGE.	PARA:	BURNS AND ROE, INC.
REF DWG.		DWG. ZONE		PED 215-M- 3320 SHT 2 OF 3
SCALE. none	DRAWN BY JSW DATE 5-6-80			TITLE: Revise SSW Shim Gap Repair PED
	CHKD BY JSW DATE 5-6-80	APPVD JSW DATE 5-6-80		

DIM.	DESCRIP.	DIM.	TOL.
D	SAC WALL RADIAL DEPTH	2'-0 3/4"	±1"
G	SIMULATE TRANSVERSE FLOW	1'-0"	±1"
L	LENGTH OF FIXTURE	3'-0"	NC
W	MAX. HEIGHT OF GAP	3/8"	±1/32"
S	SHIM SEPARATION LENGTH	3"	NC
T	MIN. HEIGHT OF GAP	1/16"	+1/32" -0
X	MAX WIDTH OF GAP	2 1/2"	±1/8"
Y	MIN. WIDTH OF GAP	1/16"	+1/32" -0
Z	NON-INTERFERING TRANSVERSE FLOW ZONE	3"	±1"



NC=NOT CRITICAL.

SHIM STOCK

GAP

PLATE

PROTOTYPE TEST FIXTURE
(PLATES TO BE HELD TOGETHER BY "C" TYPE CLAMPS)

FIGURE I (NOT TO SCALE)

REF DOC., PCN	RFI		WPPSS NUCLEAR PROJECT NO. 2
REF SPEC. SECTION	PAGE.	PARA.	BURNS AND ROE, INC.
REF DWG.	DWG. ZONE		PED 215-M-3320 SHT 3 OF 3
SCALE. NONE	DRAWN BY LKN DATE 5/6/80; CHKD BY JSW DATE 5-6-80	APPVD JSW DATE 5-6-80	TITLE SSW SHIM GAP PROTOTYPE FIXTURE

BURNS AND ROE, INC. WPPSS NUCLEAR PROJECT NO. 2	PROJECT ENGINEERING DIRECTIVE	CODE: 2 1	PROJECT ENGINEERING DIRECTIVE: 215-M-3604	DATE: 05/29/80	PRIORITY: I

REASON FOR P. E. D.:

1. The mock-up fixture per section IIB of PED-215-M-2746 is used soley for the qualification of the shield material with respect to expected heat input during welding.
2. The mock-up fixture will be destructively cut for the purpose of observing shield cross sections after welding to evaluate if any detrimental affects have occurred.
3. The "fill procedure" has been qualified per section IIA of PED-215-M-2746.

INFORMATION COPIES W

SHEET 1 OF 2

REFERENCES	
SUBJECT	SSW Shim Gap Mock-up Testing
LOCATION	Offsite
ENG. SYSTEM	N/A
S/U SYSTEM	N/A
QUALITY CLASS	I

ORIGINATING DOCUMENTS NONE

DESCRIPTION OF WORK:

Per reasons 1, 2, and 3 above, it is not necessary to the fill the weld mock-up fixture using the finalized SSW shim gap fill procedure as originally called out in section IIB of PED-215-M-2746. It is only required that the gap in the mock-up be completely filled with the shield material and cured before preheat and welding commence.

Note that this direction does not constitute new work since the mock-up fixture has already been constructed by C215 and is approved by the owner.
Replace in its entirety, section IIB on sheet 5 of 6 of PED-215-M-2746 by the following:

B. Contract 215 shall construct a test mock-up fixture with configuration similiar to the fixture constructed to qualify welders per PED-215-M-2749. Construction of this mock-up shall be at the direction of the B&R welding engineer. This mock-up shall contain four (4) gaps. Two (2) gaps shall be 1/16 x 1/16 x depth of mock-up. The other two (2) gaps shall be 5/8 x 2 1/2 x depth of mock-up. The depth of the mock-up shall be a minimum of one (1) foot. Mock-up is subject to final approval by owner.
All four (4) gaps shall be filled completely with the approved shield material per Section I of this PED. The shield material shall be allowed to cure.

NOTES

1. THIS PED REVISES DIRECTION IIB on sheet 5 of 6 of PREVIOUSLY PROVIDED BY 215-M-2746 THE FOLLOWING PED(s):
2. THIS PED VOIDS DIRECTION PREVIOUSLY PROVIDED BY N/A THE FOLLOWING PED(s):
3. THIS PED WORK SHOULD BE COORDINATED WITH KNOWN OTHER WORK UNDER THE FOLLOWING PED'S: 215-W-1604, 215-W-2749
4. THIS PED DEPENDS ON THE PRIOR INSTALLATION OF THE FOLLOWING PED'S: 215-W-2749

REVISE:
NONE X
DRAWINGS
SPECIFICATION

APPROVALS:

Signature	Date
DISCIPLINE ENGINEER	6-03-80
LEAD DISCIPLINE ENGINEER	6-03-80
S/U LIAISON ENGINEER	6-3-80
RESIDENT PROJECT ENGINEER	6-3-80

REV 1 BR 803-2

The mock-up shall then be prepared for welding by cleaning and then inserting at owner's direction insulatory material and/or backing rings into the gaps. The recommended thermal insulatory material shall be Babcock and Wilcox ceramic fiber product Roll Board which can be inserted in between the installed shielding and the backing ring for the weld.

Welding shall then be performed at the direction of the owner. The weld shall be made in accordance with the weld requirements of PED-215-W-1604 and the welder shall be qualified per PED-215-W-2749. Preheat shall be applied as required. It is intended to perform the entire 2 inch circumferential weld, however, the owner may stop the welding process at his discretion.

After welding and after the mock-up fixture is brought back down to ambient temperature, the fixture shall be cut in order to observe the cross sections of the four (4) gaps. This cutting shall be at the direction of the owner who must be present at this time. It is recommended that the gaps be cut near their edges at first and then delicately ground from the side until a suitable cross section of the material is observed. The owner will evaluate the cross sections for acceptability.

If a thermal insulator is deemed necessary from the results of this mock-up test, then this requirement shall be incorporated in the final filling procedure developed in section IIA of this PED.

Prototype and mock-up testing shall be implemented as soon as the shield material is delivered to the site.

REF. DOC.: PCN	RFI		WPPSS NUCLEAR PROJECT NO. 2
REF SPEC. SECTION:	PAGE:	PARA:	BURNS AND ROE, INC.
REF DWG.:	DWG. ZONE:		PED 215-M-3604 SHT. 2 OF 2
SCALE: None	DRAWN BY JGW DATE 5-29-80		TITLE: SSW Shim Gap Mock-up Testing.
	CHKD BY JGW DATE 5-29-80	APPVD JGW DATE 5-29-80	

(4)

VENDOR/CONTRACTOR DRAWING TRANSMITTAL FORM
CONTRACTOR TO COMPLETELY FILL IN AREA WITHIN HEAVY BORDER

TO: BURNS & ROE, INC. ATTN: MR. J. J. VERDERBER
ADDRESS: 185 CROSSWAYS PARK WOODBURY (L.I.) NEW YORK 11797
SUBJECT: WPPSS NUCLEAR PROJECT NO. 2
FROM: WSH/BOECON/GERI ATTN: E. A. HARRINGTON
ADDRESS: P.O. BOX 1040 RICHLAND, WASHINGTON 99352

THE FOLLOWING PUBLICATIONS/DRAWINGS ARE SUBMITTED FOR:
[X] APPROVAL [ ] DISTRIBUTION [ ] INFORMATION

NO. OF PRINTS 0 OF EACH NO. OF REPRODUCIBLES 6 OF EACH
SUBMITTED BY: E. A. HARRINGTON TITLE: GENERAL MANAGER
SUBVENDOR S. WOOD CONT./P.O. NO.

Page 1 Of 1
Transmittal No. WBGBR-215- 5139 B
[ ] New [X] Re-Submittal.
Date Submitted 7/1/80
Contract No. 215
P.O. No. N/A
Work Order No. N/A
Spec. No. 2808
Spec. Sect. No. 17.D

B & R PRINT FILE NO.	PUBLICATION OR DRAWING NO.	REV. NO.	PUBLICATION OR DRAWING TITLE	MANUFACTURER	B & R ACTION
	FCAW		FCAW PROCEDURE		A
	WPS#26	1	DUAL SHIELD		
			SAC WALL REPAIR		
			PER PED 215-W-1604		

BURNS AND ROE, INC. — ENGINEERS AND CONSTRUCTORS

One copy of each of the above submittals is returned with action as indicated above.

TO BE REVIEWED BY:—

ENG.	DES.	PM/E	DATE

ROUTING RECORD

RECORDS IN ____ OUT ____
COMPUTER IN ____ OUT ____
ENG'G. IN ____ OUT ____
DESIGN IN ____ OUT ____
PROJECT FILE IN ____

DISTRIBUTION

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	Client		
	Constr. Cont.		

RET'D BY: [signature] TITLE: RPE DATE: 7-3-80

B & R ACTION LEGEND:— A = App'd for Fabrication; AN = App'd as Noted for Fabrication; P = Released for Prelim. Info.; NA = Not Approved

NF-110 Rev. 0

WPPSS NUCLEAR PROJECT NO. 2

WRIGHT, SCHUCHART, & HARBOR BOECON RICHGERI.

CONTRACT NO. 2808-215
WBGBR · 215 ·
TRANSMITTAL NO. 5139B

ITEM: FCAW PROCEDURE
WPS-#26, REV. 1

SECTION: 17-D

APPROVED BY: DATE

Q.A. [signature] 7/1/80

ENGR. W. E. Thomas 6-20-80

FORM NF-105
REV 1

BOVEE & CRAIL / GERI
(a joint venture)

COVER SHEET

DOCUMENT NUMBER: WELDING PROCEDURE SPECIFICATION NO. 26

ORIGINAL DATED: 6/19/80

TITLE:
WELDING PROCEDURE SPECIFICATION
FCAW
DUAL SHIELD SAC WALL REPAIR

SCOPE OF REVISION:
NEW PROCEDURE PER REQUIREMENTS
OF PED 215-W-1604

ATTACHMENTS:
NONE

APPROVALS, DATES, SIGNATURES, & INITIALS

	REV	INIT. & DATE	REV	INIT. & DATE	REV	INIT. & DATE
AUTHOR	1	[signature] 7-1-80				
Q.A. MGR.	1	[signature] 7/1/80				
ENGINEER	1	[signature] 7-1-80				
CONST.		N/A				
B & R						

WBGBR-215-51398

WEH-Bogcon GERI

WELDING PROCEDURE SPECIFICATION

MANUAL STRUCTURAL WELDING

WPS no. 26 Rev. 0 DATE 6/10/80 QUALIFIED [XXX] PREQUALIFIED [ ]

Process FCAW Dual Shield CODE AWS - D1.1 SPEC. 17D

BASE METALS

PLATE PIPE OTHER

(1) ASTM SPEC. A36 GR. n/a

(2) ASTM SPEC. ______ GR. ______

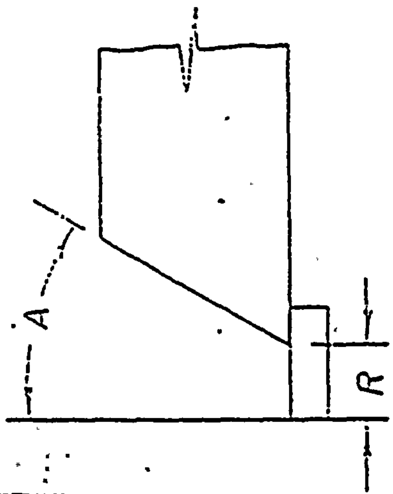
(3) ASTM SPEC. ______ GR. ______

THICKNESS RANGE QUALIFIED unlimited

OTHER ______

Supporting Welding Procedure Qualifications

(PQR) 2601-2G, 2602-3G, 2603-4G, 2608-3G, 26014-4G, 26017-2G.



A	30°, 45°
R	3/8 to 5/8 Root Opening

JOINT DESIGN(S)

FILLER METALS

	(A)	(B)
AWS CLASSIFICATION	E70T-1	
AWS SPECIFICATION	A5.20	
APPROVED SIZES	.045	
OTHER	n/a	

POSITIONS

GROOVE JOINTS all FILLETS all

SHIELDING GAS

COMPOSITION Argon 75% CO_2 25%

FLOW RATE 50 CFH

ELECTRICAL CHARACTERISTICS

CURRENT TYPE Direct POLARITY Reverse

PASS NO.	PROCESS	FILLER MATERIALS TYPE	FILLER MATERIALS SIZE	AMPS	VOLTS	TRAVEL SPEED IN./MIN.
	SEE PAGE 3 OF 3					

TECHNIQUE

PASS(ES) MULTIPLE [XXX] SINGLE [ ]

WELD PROGRESSION Upward - forehand/backhand

MAXIMUM BEAD WIDTH 3/8

PREHEAT & INTERPASS (°F)

THICKNESS RANGE	PREHEAT MINIMUM	INTERPASS MAXIMUM
All	70°	250°

WBGBR-215-51598

PREPARED BY G. Chaney DATE 6-19-80

WSH·Beacon·GERI

WELDING PROCEDURE SPECIFICATION

MANUAL STRUCTURAL WELDING

WPS No. 26 Rev. 0 Date 6/10/80

ADDITIONAL INFORMATION

NOTES:

1) The General Structural Welding Standard (GWS #1) shall be used in conjunction with this procedure. It establishes the requirements for documentation, joint design, base metal preparation, fit-up, preheating methods, workmanship, technique, weld appearance, and defect repairs. P.E.D. 215-W-1604 shall be used in conjunction with this procedure.

2) Preheat and interpass temperature for welding to P.E.D. 215-W-1604 shall be as shown below.

	PREHEAT	MAXIMUM INTERPASS TEMPARATURE
Welds to Sacrificial Shield Wall and within 24" of the Sacrificial Shield Wall.	200 ± 25°F	250°

3) The joint design on page 1 does not fall within the limits set for prequalified joint design TC-U4C so was qualified by test per AWS D1.1 Section V.

4) All fillet welds and prequalified joint designs in GWS 1 are approved for use with this procedure.

WSH-Boecon-GERI

WELDING PROCEDURE SPECIFICATION

MANUAL STRUCTURAL WELDING

WPS No. 26 Rev. 0 Date 6/10/80

PASS NUMBER	PROCESS	FILLER TYPE	MATERIALS SIZE	AMPS	VOLTS	TRAVEL SPEED IPM	WIRE FEED IPM	NOT
1 thru 40	FCAW	E70T-1	.045	210	27	12	213	(1
1 thru 31	FCAW	E70T-1	.045	210	27	12	213	(2
32 thru 38	FCAW	E70T-1	.045	180	25	9 1/4	114	
1 thru 8	FCAW	E70T-1	.045	190	25	8.1	180	(3
9 thru 26	FCAW	E70T-1	.045	210	27	12	212	
27 thru 32	FCAW	E70T-1	.045	180	26	12	142	
1 thru 8	FCAW	E70T-1	.045	180	25	8.5	180	(4
9 thru 20	FCAW	E70T-1	.045	210	27	12	213	
21 thru 25	FCAW	E70T-1	.045	180	26	12	143	
1 thru 6	FCAW	E70T-1	.045	190	25	8.1	180	(5
7 thru 29	FCAW	E70T-1	.045	210	27	12	213	

* NOTE 1 45° Bevel 2G (horizontal) and 4G (overhead) position 11/16 cup size.

* NOTE 2 45° Bevel 3G (vertical) position 11/16 cup size.

* NOTE 3 30° Bevel 3G (vertical) position 7/16 and 11/16 cup size.

* NOTE 4 30° Bevel 2G (horizontal) position 7/16 and 11/16 cup size.

*NOTE 5 30° Bevel 4G (Overhead) position 7/16 and 11/16 cup size.

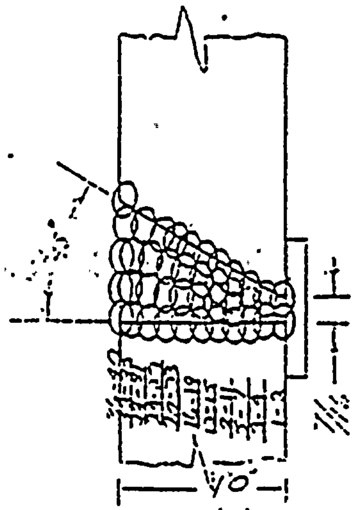
WBGBR-215-51398

WSH/Boecon/GERI
A Joint Venture

PROCEDURE QUALIFICATION RECORD
Manual Welding

Procedure Qualification Record No 26Q1-2G Date: 6/06/80
WPS No. 26 Process(es) FCAW

BASE METALS
PLATE ☒ PIPE ☐ OTHER ☐ see below
(1) Spec. No. A36 to
(2) Spec. No. A36
ASME P. No. 1 Gp. No. ___ to
P. No. 1 Gp. No. ___
Thickness 1" Dia. ___
Other ___



JOINT DESIGN(S) USED

FILLER METALS

	(a)	(b)
AWS Classification	E70T-1	
ASME Weld Metal A No.	1	
ASME Filler Metal F No.	6	
Specification	SFA 5.20	
Filler Diameters	.045	

Other Dual Shield
45° Bevel

SHIELDING GAS(ES)

	Torch	Purge
Flow Rate CFH	50	
Composition	25% 75%	

Other CO^2 Argon

ELECTRICAL CHARACTERISTICS

Current Type Direct Polarity Reverse Other

Pass No.	Process	Filler Type	Filler Dia.	Amperage	Volts	Travel Speed IPM	Wire Feed IPM	Stringer	Weave
1 thru 40	FCAW	E70T-1	.045	210	27	12"	213	X	

INFORMATION ONLY
WBGBR-215-5139B

POSITION
Joint Position Horizontal 2G
Weld Progression Forehand/Backhand
Other ___

POSTWELD HEAT TREATMENT none ☒
Temperature ___
Holding Time ___
Other ___

PREHEAT AND INTERPASS
Min. Preheat Temp 70°
Max. Interpass Temp 250°
Preheat Maintenance or Reduction
Discontinued upon weld completion
Other ___

TECHNIQUE
Pass(es): multiple ☒ single ☐
Single Electrode ☒
Max. Bead Width 3/8 GTAW Cup n/a
Tungsten: dia. n/a AWS No. n/a
Backgouging none
Initial & Interpass Cleaning filing brushing, grinding, chipping
Other ___

WSH/Boecon/GERI
A Joint Venture

PROCEDURE QUALIFICATION RECORD
Manual Welding

PQR Number 26Q1-2G

TENSILE TEST

Type Transverse Reduced Section

SPECIMEN No.	DIMENSIONS, INCHES THICKNESS	WIDTH	AREA SQ.IN.	ULTIMATE LOAD, LBS.	ULTIMATE TENSILE STRENGTH, PSI	CHARACTER OF FAILURE AND LOCATION
88752-2	1.004	1.487	1.493	103,400	69,300	outside weld
88752-2	.988	1.497	1.479	104,800	70,900	outside weld

GUIDED BEND TESTS

Figure No. 5.10.1.3.J

Specimen No.	Type	Indications	Result
88752-1	side	none reported	pass
88752-3	side	none reported	pass
88752-4	side	none reported	pass
88752-6	side	none reported	pass

TOUGHNESS TESTS

Notch Type: Size(mm): Orientation: Test Temp:

Specimen No.	Notch Location	Impact Values Ft. lbs.	Average Ft. lbs.	Lateral Expansion Mils	% Shear

FILLET WELD TEST N/A

Minimum Size Multiple Pass ____ Maximum Size Single Pass ____
Contour, Leg Size, Penetration ____ Macro Examination ____

OTHER TESTS

Type and Result: Radiography, Acceptable 5/09/80

INFORMATION ONLY

REMARKS: WBGBR-215-5139B

Welder's Name Fred Hughes Stamp No. B-108
Mechanical Tests Conducted by Koon-Hall Testing Corp. Lab. Test No. 88752

We certify that to the best of our knowledge the statements made in this record are correct and that the test welds were prepared, welded and tested in accordance with the requirements of AWS D1.1 and Burns & Roe Spec. 215-17D

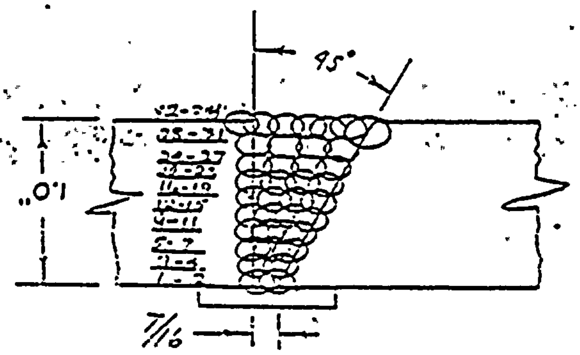
Witnessed by: [signature] Date 6-19-80 By [signature] Date 6-19-80
WSH/Boecon/GERI

WSH/Boecon/GERI
A Joint Venture

PROCEDURE QUALIFICATION RECORD
Manual Welding

Procedure Qualification Record No. 26Q2-3G Date: 6/06/80
WPS No. 26 Process(es) FCAW

BASE METALS
PLATE ☒ PIPE ☐ OTHER ☐ see below
(1) Spec. No. A36 to
(2) Spec. No. A36
ASME P. No. 1 Gp. No. ___ to
P. No. 1 Gp. No. ___
Thickness 1" Dia. ___
Other ___



JOINT DESIGN(S) USED

FILLER METALS

	(a)	(b)
AWS Classification	E70T-1	
ASME Weld Metal A No.	1	
ASME Filler Metal F No.	6	
Specification	SFA 5.20	
Filler Diameters	.045	

Other Dual Shield

SHIELDING GAS(ES)

	Torch	Purge
Flow Rate CFH	50	n/a
Composition	25% 75%	

Other Argon - CO2

ELECTRICAL CHARACTERISTICS

Current Type Direct Polarity Reverse Other

Pass No.	Process	Filler Type	Filler Dia.	Amperage	Volts	Travel Speed IPM	Wire Feed IPM	(Check One) Stringer	Weave
1 thru 31	FCAW	E70T-1	.045	210	27	12	213	X	
32 thru 38	FCAW	E70T-1	.045	180	25	9 1/4	114	X	

WBGBR-215-5139B

POSITION
Joint Position Vertical 3G
Weld Progression upward
Other ___

POSTWELD HEAT TREATMENT none ☒
Temperature
Holding Time
Other

PREHEAT AND INTERPASS
Min. Preheat Temp 70°
Max. Interpass Temp 250°
Preheat Maintenance or Reduction
Discontinued upon weld completion
Other ___

TECHNIQUE
Pass(es): multiple ☒ single ☐
Single Electrode ☒
Max. Bead Width 3/8 GTAW Cup n/a
Tungsten: dia n/a AWS No. n/a
Backgouging n/a
Initial & Interpass Cleaning ___
Other Dual Shield

WSH/Boecon/GERI
A Joint Venture

PROCEDURE QUALIFICATION RECORD
Manual Welding

PQR Number 26Q2-3G

TENSILE TEST

Type Transverse Reduced Section

SPECIMEN No.	DIMENSIONS, INCHES THICKNESS	WIDTH	AREA SQ.IN.	ULTIMATE LOAD, LBS.	ULTIMATE TENSILE STRENGTH, PSI	CHARACTER OF FAILURE AND LOCATION
2	1.006	1.490	1.499	102,500	68,400	outside weld
5	1.001	1.507	1.509	106,000	70,200	outside weld

GUIDED BEND TESTS

Figure No. 5.10.1.3J

Specimen No.	Type	Indications	Result
1	side	none reported	pass
3	side	none reported	pass
4	side	none reported	pass
6	side	none reported	pass

TOUGHNESS TESTS

Notch Type: Size(mm): Orientation: Test Temp:

Specimen No.	Notch Location	Impact Values Ft. lbs.	Average Ft. lbs.	Lateral Expansion Mils	% Shear

FILLET WELD TEST N/A

Minimum Size Multiple Pass ________ Maximum Size Single Pass ________
Contour, Leg Size, Penetration ________ Macro Examination ________

OTHER TESTS

Type and Result: Radiography - acceptable - 5/09/80

REMARKS:

WBGBR-215-5139B

INFORMATION ONLY

Welder's Name Fred Hughes Stamp No. B-108
Mechanical Tests Conducted by Koon Hall Testing Corp. Lab. Test No. 88753

We certify that to the best of our knowledge the statements made in this record are correct and that the test welds were prepared, welded and tested in accordance with the requirements of AWS D1.1 and Burns & Roe Spec. 215-17D

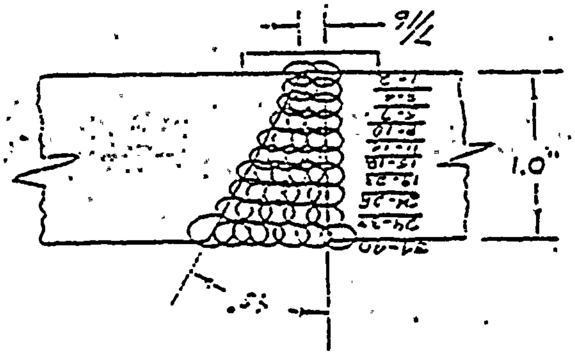
Witnessed by: [signature] Date 6-19-80 By [signature] Date 6-19-80
WSH/Boecon/GERI

WSH/Boecon/GERI
A Joint Venture

PROCEDURE QUALIFICATION RECORD
Manual Welding

Procedure Qualification Record No. 26Q3-4G Date: 6/06/80
WPS No. 26 Process(es) FCAW

BASE METALS
PLATE ☒ PIPE ☐ OTHER ☐ see below
(1) Spec. No. A36 to
(2) Spec. No. A36
ASME P. No. 1 Gp. No. ___ to
P. No. 1 Gp. No. ___
[illegible]
Thickness: 1" Dia. ___
Other ___



JOINT DESIGN(S) USED

FILLER METALS

	(a)	(b)
AWS Classification	E70T-1	
ASME Weld Metal A No.	1	
ASME Filler Metal F No.	6	
Specification	SFA 5.20	
Filler Diameters	.045	

Other Dual Shield

SHIELDING GAS(ES)

	Torch	Purge
Flow Rate CFH	50	
Composition	25% 75%	

Other CO_2 Argon

ELECTRICAL CHARACTERISTICS
Current Type Direct Polarity Reverse Other

Pass No.	Process	Filler Type	Filler Dia.	Amperage	Volts	Travel Speed IPM	Wire Feed IPM	Stringer	Weave
1 thru 40	FCAW	E70T-1	.045	210	27	12	213	X	

[illegible]

POSITION
Joint Position Overhead 4G
Weld Progression Forehand/Backhand
Other ___

POSTWELD HEAT TREATMENT none ☒
Temperature ___
Holding Time ___
Other ___

PREHEAT AND INTERPASS
Min. Preheat Temp 70°
Max. Interpass Temp 250°
Preheat Maintenance or Reduction ___
Discontinued upon weld completion
Other ___

TECHNIQUE WBGBR-215-5159B
Pass(es): multiple ☒ single ☐
Single Electrode ☒
Max. Bead Width 3/8 GTAW Cup n/a
Tungsten: dia. n/a AWS No. n/a
Backgouging none
Initial & Interpass Cleaning
brushing, filing
Other ___

WSH/Boecon/GERI
A Joint Venture

PROCEDURE QUALIFICATION RECORD
Manual Welding

PQR Number 2603-4G

TENSILE TEST

Type Transverse Reduced Section

SPECIMEN No.	DIMENSIONS, INCHES THICKNESS	DIMENSIONS, INCHES WIDTH	AREA SQ.IN.	ULTIMATE LOAD, LBS.	ULTIMATE TENSILE STRENGTH, PSI	CHARACTER OF FAILURE AND LOCATION
88754-2	.995	1.496	1.489	103,400	69,400	outside weld
88754-5	1.006	1.499	1.508	104,100	69,000	outside weld

GUIDED BEND TESTS

Figure No. 5.10.1.3J (77 ed.)

Specimen No.	Type	Indications	Result
88754-1	side	none reported	pass
88754-3	side	none reported	pass
88754-4	side	none reported	pass
88754-6	side	none reported	pass

TOUGHNESS TESTS

Notch Type: Size(mm): Orientation: Test Temp:

Specimen No.	Notch Location	Impact Values Ft. lbs.	Average Ft. lbs.	Lateral Expansion Mils	Lateral Expansion % Shear

FILLET WELD TEST N/A

Minimum Size Multiple Pass ______ Maximum Size Single Pass ______
Contour, Leg Size, Penetration ______ Macro Examination ______

OTHER TESTS

Type and Result: Radiography - acceptable - 5-09-80

INFORMATION ONLY

REMARKS:

WBGBR-215-5139B

Welder's Name Fred Hughes Stamp No. 3-108
Mechanical Tests Conducted by Koon-Hall Testing Corp. Lab. Test No. 88754

We certify that to the best of our knowledge the statements made in this record are correct and that the test welds were prepared, welded and tested in accordance with the requirements of AWS D1.1 and Burns & Roe Spec. 215-17D

Witnessed by: D Chaney Date 6-19-80 By D Chaney Date 6-19-80
WSH/Boecon/GERI

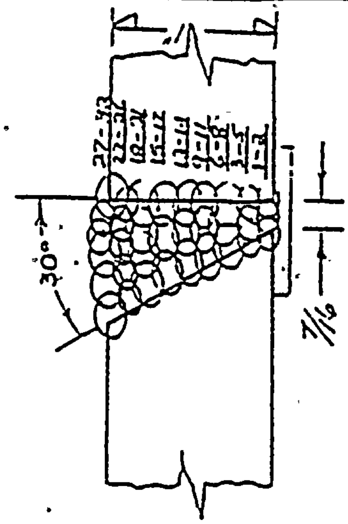
WSH/Boecon/GERI
A Joint Venture

PROCEDURE QUALIFICATION RECORD
Manual Welding

NF-289 REV. 1

Procedure Qualification Record No. 2608-3G Date: 6/04/80
WPS No. 26 Process(es) FCAW

BASE METALS
PLATE ☒ PIPE ☐ OTHER ☐ see below
(1) Spec. No. A36 to
(2) Spec. No. A36
ASME P. No. ____ Gp. No. ____ to
P. No. ____ Gp. No. ____
Thickness 1" Dia. ____
Other ____



JOINT DESIGN(S) USED

FILLER METALS

	(a)	(b)
AWS Classification	E70T-1	
ASME Weld Metal A No.	1	
ASME Filler Metal F No.	6	
Specification	SFA 520	
Filler Diameters	.045	

Other Dual Shield

SHIELDING GAS(ES)

	Tourch	Purge
Flow Rate CFH	50	
Composition	25% 75%	

Other CO^2 Argon

ELECTRICAL CHARACTERISTICS
Current Type Direct Polarity Reverse Other ____

Pass No.	Process	Filler Type	Filler Dia.	Amperage	Volts	Travel Speed IPM	Wire Feed IPM	Stringer	Weave
1 thru 8	FCAW	E70T-1	.045	190	25	8.1	180	X	
9 thru 26	FCAW	E70T-1	.045	210	27	12	212	X	
27 thru 32	FCAW	E70T-1	.045	180	26	12	142	X	

INFORMATION ONLY

POSITION
Joint Position Vertical 3G
Weld Progression Upward
Other 30° Bevel

POSTWELD HEAT TREATMENT none ☒
Temperature ____
Holding Time ____
Other ____

WBGRR-215-5139B

PREHEAT AND INTERPASS
Min. Preheat Temp 70°
Max. Interpass Temp 250°
Preheat Maintenance or Reduction
Discontinued upon weld completion
Other ____

TECHNIQUE
Pass(es): multiple ☒ single ☐
Single Electrode ☒
Max. Bead Width 3/8 GTAW Cup n/a
Tungsten: dia. n/a AWS No. n/a
Backgouging none
Initial & Interpass Cleaning filing brushing, grinding, chipping
Other ____

WSH/Boecon/GERI
A Joint Venture

PROCEDURE QUALIFICATION RECORD
Manual Welding

PQR Number 2608-3G

TENSILE TEST

Type Transverse Reduced Section

SPECIMEN No.	DIMENSIONS, INCHES THICKNESS	WIDTH	AREA SQ. IN.	ULTIMATE LOAD, LBS.	ULTIMATE TENSILE STRENGTH, PSI	CHARACTER OF FAILURE AND LOCATION
2	.981	1.490	1.462	99,400	68,000	Outside weld
5	.972	1.506	1.464	98,200	67,100	Outside weld

GUIDED BEND TESTS

Figure No. 5.10.1.3J

Specimen No.	Type	Indications	Result
1	side	none reported	Pass
3	side	none reported	Pass
4	side	none reported	Pass
6	side	none reported	Pass

TOUGHNESS TESTS

Notch Type: Size(mm): Orientation: Test Temp:

Specimen No.	Notch Location	Impact Values Ft. lbs.	Average Ft. lbs.	Lateral Expansion Mils	% Shear

FILLET WELD TEST

N/A

Minimum Size Multiple Pass ______ Maximum Size Single Pass ______
Contour, Leg Size, Penetration ______ Macro Examination ______

OTHER TESTS

Type and Result: INFORMATION ONLY

REMARKS:

WBGBR-215-5139B

Welder's Name Fred Hughes Stamp No. B-108
Mechanical Tests Conducted by ______ Lab. Test No. 88755

We certify that to the best of our knowledge the statements made in this record are correct and that the test welds were prepared, welded and tested in accordance with the requirements of AWS D1.1 and Burns & Roe Spec. 215-17D

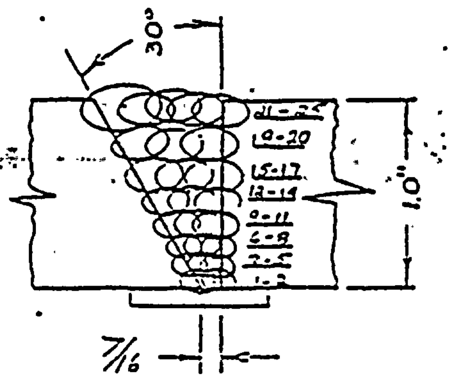
Witnessed by: D Chaney Date 6-19-80 By D Chaney Date 6-19-80
WSH/Boecon/GERI

WSH/Boecon/GERI
A Joint Venture

PROCEDURE QUALIFICATION RECORD
Manual Welding

Procedure Qualification Record No. 26Q17-2G   Date: 6/05/80
WPS No. 26   Process(es) FCAW

BASE METALS
PLATE ☒ PIPE ☐ OTHER ☐ see below
(1) Spec. No. A36 to
(2) Spec. No. A36
ASME P. No. 1 Gp. No. n/a to
P. No. 1 Gp. No. n/a
Thickness 1" Dia.
Other



JOINT DESIGN(S) USED

FILLER METALS

	(a)	(b)
AWS Classification	E70T-1	
ASME Weld Metal A No.	1	
ASME Filler Metal F No.	6	
Specification	SFA 5.20	
Filler Diameters	.045	

Other Dual Shield

SHIELDING GAS(ES)

	Tourch	Purge
Flow Rate CFH	50	
Composition	25% 75%	

Other CO_2 Argon

ELECTRICAL CHARACTERISTICS
Current Type Direct   Polarity Reverse   Other

Pass No.	Process	Filler Type	Filler Dia.	Amperage	Volts	Travel Speed IPM	Wire Feed IPM	Stringer	Weave
1 thru 8	FCAW	E70T-1	.045	108	25	8.5	180	X	
9 thru 20	FCAW	E70T-1	.045	210	27	12	213	X	
21 thru 25	FCAW	E70T-1	.045	180	26	12	143	X	

INFORMATION ONLY

POSITION
Joint Position Horizontal 2G
Weld Progression Forehand/backhand
Other

POSTWELD HEAT TREATMENT none ☒
Temperature
Holding Time
Other

WBGBP-215-5139B

PREHEAT AND INTERPASS
Min. Preheat Temp 70°
Max. Interpass Temp 250°
Preheat Maintenance or Reduction
Discontinued upon weld completion
Other

TECHNIQUE
Pass(es): multiple ☒ single ☐
Single Electrode ☒
Max. Bead Width 3/8   GTAW Cup n/a
Tungsten: dia. n/a   AWS No. n/a
Backgouging none
Initial & Interpass Cleaning filing, brushing, grinding, chipping
Other

WSH/Boecon/GERI
A Joint Venture

PROCEDURE QUALIFICATION RECORD
Manual Welding

PQR Number 26017-2G

TENSILE TEST Type Transverse Reduced Section

SPECIMEN No.	DIMENSIONS, INCHES THICKNESS	WIDTH	AREA SQ.IN.	ULTIMATE LOAD, LBS.	ULTIMATE TENSILE STRENGTH, PSI	CHARACTER OF FAILURE AND LOCATION
2	1.003	1.505	1.510	103,300	68,400	outside weld
5	.987	1.497	1.478	102,000	69,000	outside weld

GUIDED BEND TESTS Figure No. 5.10.1.3.J

Specimen No.	Type	Indications	Result
1	side	none reported	pass
3	side	none reported	pass
4	side	none reported	pass
6	side	none reported	pass

TOUGHNESS TESTS

Notch Type: Size(mm): Orientation: Test Temp:

Specimen No.	Notch Location	Impact Values Ft. lbs.	Average Ft. lbs.	Lateral Expansion Mils	% Shear

FILLET WELD TEST N/A

Minimum Size Multiple Pass ______ Maximum Size Single Pass ______
Contour, Leg Size, Penetration ______ Macro Examination ______

OTHER TESTS

Type and Result: Radiography Acceptable 5/16/80

INFORMATION ONLY

REMARKS:

WBGBR-215-5139B

Welder's Name Wm. Martin Jr. Stamp No. F-7
Mechanical Tests Conducted by Koon-Hall Testing Corp. Lab. Test No. 88757

We certify that to the best of our knowledge the statements made in this record are correct and that the test welds were prepared, welded and tested in accordance with the requirements of AWS D1.1 & Burns & Roe Spec. 215-17D

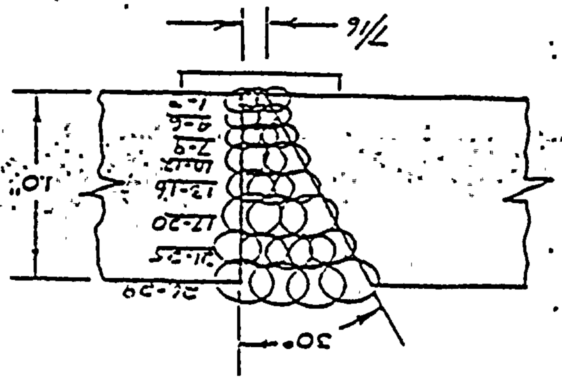
Witnessed by: *[signature]* Date 6-19-80 By *[signature]* Date 6-19-80
WSH/Boecon/GERI

WSH/Boecon/GERI
A Joint Venture

PROCEDURE QUALIFICATION RECORD
Manual Welding

Procedure Qualification Record No. 26014-4G Date: 6/05/80
WPS No. 26 Process(es) FCAW

BASE METALS
PLATE [x] PIPE [ ] OTHER [ ] see below
(1) Spec. No. A36 to
(2) Spec. No. A36
ASME P. No. 1 Gp. No. n/a to
P. No. 1 Gp. No. n/a
Thickness 1" Dia.
Other



JOINT DESIGN(S) USED

FILLER METALS

	(a)	(b)
AWS Classification	E70T-1	
ASME Weld Metal A No.	1	
ASME Filler Metal F No.	6	
Specification	SFA 5.20	
Filler Diameters	.045	

Other Dual Shield
30° Bevel

SHIELDING GAS(ES)

	Tourch	Purge
Flow Rate CFH	50	n/a
Composition	25%, 75%	n/a

Other CO_2 Argon

ELECTRICAL CHARACTERISTICS
Current Type Direct Polarity Reverse Other

Pass No.	Process	Filler Type	Filler Dia.	Amperage	Volts	Travel Speed IPM	Wire Feed IPM	Stringer	Weave
1-6	FCAW	E70T-1	.045	190	25	8.1	180	X	
7-29	FCAW	E70T-1	.045	210	27	12	213	X	

POSITION
Joint Position Overhead 4G
Weld Progression Forehand/backhand
Other

POSTWELD HEAT TREATMENT none [x]
Temperature
Holding Time
Other

WBGBR-215-5139B

PREHEAT AND INTERPASS
Min. Preheat Temp 70°
Max. Interpass Temp 250°
Preheat Maintenance or Reduction
Discontinued upon weld completion.
Other

TECHNIQUE
Pass(es): multiple [x] single [ ]
Single Electrode [x]
Max. Bead Width 3/8 GTAW Cup n/a
Tungsten: dia. n/a AWS No. n/a
Backgouging None
Initial & Interpass Cleaning Filing, Brushing, Grinding, Chipping
Other

WSH/Soecon/GERI
A Joint Venture

PROCEDURE QUALIFICATION RECORD
Manual Welding

PQR Number 26014-4G

TENSILE TEST Type Transverse Reduced Section

SPECIMEN No.	DIMENSIONS, INCHES THICKNESS	WIDTH	AREA SQ. IN.	ULTIMATE LOAD, LBS.	ULTIMATE TENSILE STRENGTH, PSI	CHARACTER OF FAILURE AND LOCATION
2	.983	1.502	1.476	100,300	68,000	outside weld
5	.969	1.500	1.454	98,700	67,900	outside weld

GUIDED BEND TESTS Figure No. 5.10.1.3J (77 ED.)

Specimen No.	Type	Indications	Result
1	side	none reported	pass
3	side	none reported	pass
4	side	none reported	pass
6	side	none reported.	pass

TOUGHNESS TESTS

Notch Type: Size(mm): Orientation: Test Temp:

Specimen No.	Notch Location	Impact Values Ft. lbs.	Average Ft. lbs.	Lateral Expansion Mils	% Shear

FILLET WELD TEST N/A

Minimum Size Multiple Pass ______ Maximum Size Single Pass ______
Contour, Leg Size, Penetration ______ Macro Examination ______

OTHER TESTS

Type and Result: Radiography — Acceptable 5/15/80

INFORMATION ONLY

REMARKS:

WBGBR-215-5139B

Welder's Name Fred Hughes Stamp No. B-108
Mechanical Tests Conducted by Koon-Hall Testing Corp. Lab. Test No. 88756

We certify that to the best of our knowledge the statements made in this record are correct and that the test welds were prepared, welded and tested in accordance with the requirements of AWS D1.1 and Burns & Roe Spec. 215-17D

Witnessed by: D. Chaney Date 6-19-80 By D. Chaney Date 6-19-80
WSH/Boecon/GERI

Koon-Hall Testing Corporation

Metallurgical Testing

1959 1979

P.O. BOX 986
ALBANY, OREGON 97321
Phone 503-928-1668

Customer WSH/BOECON/CERT

Customer Order No. 215-184010; Req. # 13799 Date 5-27-80

Heat Number

Work Order 18775

Item Description STEEL, 1" PLATE, SINGLE BEVEL GROOVE WELD, PROCEDURE#2601-2C

Specification AWS D1.1-Rev. 2-77

IDENTIFICATION	WIDTH (IN)	THICKNESS (IN)	AREA (IN^2)	ULTIMATE LOAD(lbs)	UTS (PSI)	LOCATION OF FRACTURE
88752-2	1.487	1.004	1.493	103,400	69,300	OUTSIDE WELD
88752-5	1.497	.988	1.479	104,800	70,900	OUTSIDE WELD

GUIDED BEND TEST

	TYPE	RESULTS
88752-1	SIDE	PASS
88752-3	SIDE	PASS
88752-4	SIDE	PASS
88752-6	SIDE	PASS

INFORMATION ONLY

WBG BR-215-5139B

By *Robert L. Adrian*

Koon-Hall Testing Corporation

Metallurgical Testing

P.O. BOX 986
ALBANY, OREGON 97321
Phone 503-928-1668

Customer: WSH/BOECON/GERT

Customer Order No. 215-184010; Req. # 13799 Date 5-27-80

Heat Number Work Order 18775

Item Description STEEL, 1" PLATE, SINGLE BEVEL GROOVE WELD, PROCEDURE#2602-3G

Specification AWS D1.1-Rev. 2-77

IDENTIFICATION	WIDTH (IN)	THICKNESS (IN)	AREA (IN^2)	ULTIMATE LOAD(lbs)	UTS (PSI)	LOCATION OF FRACTURE
88753-2	1.490	1.006	1.499	102,500	68,400	OUTSIDE WELD
88753-5	1.507	1.001	1.509	106,000	70,200	OUTSIDE WELD

GUIDED BEND TEST

	TYPE	RESULTS
88753-1	SIDE	PASS
88753-3	SIDE	PASS
88753-4	SIDE	PASS
88753-6	SIDE	PASS

INFORMATION ONLY

WBGBR-215-5139B

By Robert L. Adrian

Koon-Hall Testing Corporation

Metallurgical Testing

1959 20 1979

P.O. BOX 986
ALBANY, OREGON 97321
Phone 503-928-1668

Customer: WSH/BOECON/GERT

Customer Order No. 215-184010; Req. #13799 Date 5-27-80

Heat Number ______ Work Order 18775

Item Description: STEEL, 1" PLATE, SINGLE BEVEL GROOVE WELD, PROCEDURE#2603-4G

Specification: AWS D1.1-Rev. 2-77

IDENTIFICATION	WIDTH (IN)	THICKNESS (IN)	AREA (IN^2)	ULTIMATE LOAD(lbs)	UTS (PSI)	LOCATION OF FRACTURE
88754-2	1.496	.995	1.489	103,400	69,400	OUTSIDE WELD
88754-5	1.499	1.006	1.508	104,100	69,000	OUTSIDE WELD

GUIDED BEND TEST

	TYPE	RESULTS
88754-1	SIDE	PASS
88754-3	SIDE	PASS
88754-4	SIDE	PASS
88754-6	SIDE	PASS

INFORMATION ONLY

WBGBR-215-5139B

By *Robert L. Adrian*

Koon-Hall Testing Corporation

Metallurgical Testing

1969 1979

P.O. BOX 986
ALBANY, OREGON 97321
Phone 503-928-1668

Customer WSH/BOECON/GERI

Customer Order No. 215-184010; Req. # 13798 Date 5-27-80

Heat Number Work Order 18775

Item Description STEEL, 1" PLATE, SINGLE BEVEL GROOVE WELD, PROCEDURE#2608-3G

Specification AWS D1.1-Rev. 2-77

IDENTIFICATION	WIDTH (IN)	THICKNESS (IN)	AREA (IN^2)	ULTIMATE LOAD(lbs)	UTS (PSI)	LOCATION OF FRACTURE
88755-2	1.490	.981	1.462	99,400	68,000	OUTSIDE WELD
88755-5	1.506	.972	1.464	98,200	67,100	OUTSIDE WELD

GUIDED BEND TEST

	TYPE	RESULTS
88755-1	SIDE	PASS
88755-3	SIDE	PASS
88755-4	SIDE	PASS
88755-6	SIDE	PASS

INFORMATION ONLY

WBGBR-215-5139B

By Robert L. Adris

Koon-Hall Testing Corporation

Metallurgical Testing

P.O. BOX 986
ALBANY, OREGON 97321
Phone 503-928-1668

Customer WSH/BOECON/GERT

Customer Order No. 215-184010; Req. # 13798 Date 5-27-80

Heat Number ______ Work Order 18775

Item Description STEEL, 1" PLATE, SINGLE BEVEL GROOVE WELD, PROCEDURE#2601L-LG

Specification AWS D1.1-Rev. 2-77

IDENTIFICATION	WIDTH (IN)	THICKNESS (IN)	AREA (IN^2)	ULTIMATE LOAD(lbs)	UTS (PSI)	LOCATION OF FRACTURE
88756-2	1.502	.983	1.476	100,300	68,000	OUTSIDE WELD
88756-5	1.500	.969	1.454	98,700	67,900	OUTSIDE WELD

GUIDED BEND TEST

	TYPE	RESULTS
88756-1	SIDE	PASS
88756-3	SIDE	PASS
88756-4	SIDE	PASS
88756-6	SIDE	PASS

INFORMATION ONLY

WBGBR-215-5139B

By Robert L. Adrian

Koon-Hall Testing Corporation

Metallurgical Testing

1959 KH 1979
P.O. BOX 986
ALBANY, OREGON 97321
Phone 503-928-1668

Customer WSH/BOECON/GERI

Customer Order No. 215-184010; Req. #13798 Date 5-27-80

Heat Number Work Order 18775

Item Description STEEL, 1" PLATE, SINGLE BEVEL GROOVE WELD, PROCEDURE#26017-2G

Specification AWS D1.1-Rev. 2-77

IDENTIFICATION	WIDTH (IN)	THICKNESS (IN)	AREA (IN^2)	ULTIMATE LOAD(lbs)	UTS (PSI)	LOCATION OF FRACTURE
38757-2	1.505	1.003	1.510	103,300	68,400	OUTSIDE WELD
38757-5	1.497	.987	1.478	102,000	69,000	OUTSIDE WELD

GUIDED BEND TEST

	TYPE	RESULTS
38757-1	SIDE	PASS
38757-3	SIDE	PASS
38757-4	SIDE	PASS
38757-6	SIDE	PASS

INFORMATION ONLY

WBGBR-215-5139B

By *Robert L. Adrian*

BURNS AND ROE, INC.
Headquarters Office—Oradell, N.J.

W.O. No. ____ Date 6/17/80 Calc. No. ____ Book No. ____ Page No. ____

Drawing No. 3783 Checked (LWP) Approved ____ Sheet ____ Cont. on Sheet ____

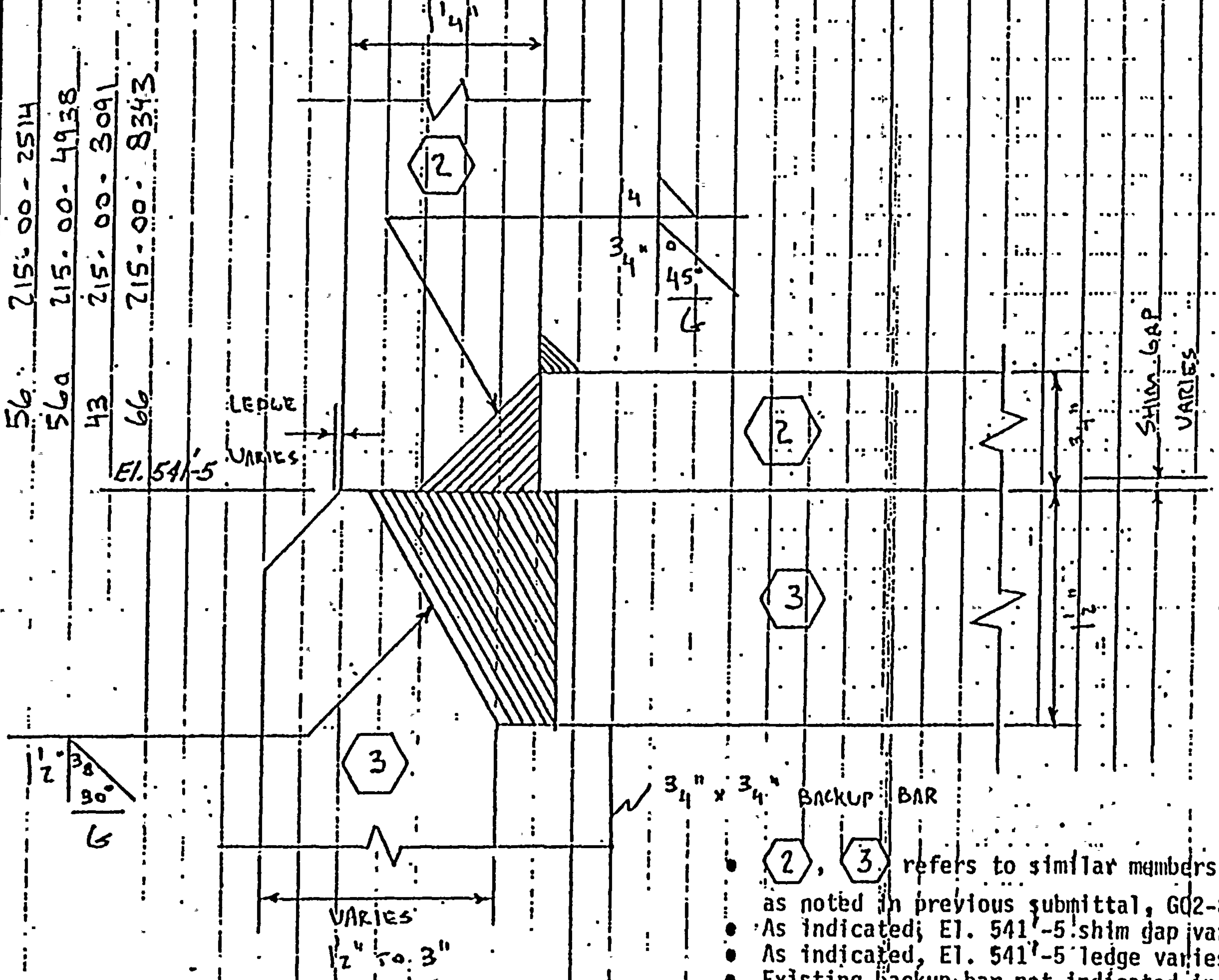
By MEAD

Title WPPSS HANFORD 2 SAC SHIELD WALL

SKETCH = 1

REFER TO LECKENBY SHOP DRAWINGS

56 215.00-2514
56a 215.00-4938
43 215.00-3091
66 215.00-8343



- (2), (3) refers to similar members as noted in previous submittal, G02-80-95
- As indicated, El. 541'-5 shim gap varies
- As indicated, El. 541'-5 ledge varies
- Existing backup bar not indicated in previou[s] submittal, G02-80-95
- Existing welds in (2) not indicated in previous submittal, G02-80-95

ORIGINAL (CONFIGURATION) AT PROPOSED PERIPHERAL WELD

ATTACHMENT 4 ENCLOSURE

PARTIAL PENETRATION WELD STRUCTURAL CONSIDERATIONS

I. INTRODUCTION

For the overall Sacrificial Shield Wall structure, a description of the design loads, load combinations, and methods of analysis, including assumptions and postulations, is furnished in the enclosed paper entitled: Analysis and Design of Sacrificial Shield Wall. The description of the loads, load combinations, and analysis specifically applicable to the proposed partial penetration weld is given in calculation 6.19.37 (attached).

The following paragraphs discuss: the influence of the SSW as-built conditions on the analyses for the partial penetration weld, the contact bearing areas at the subject interface, the influence of the partial penetration weld eccentricity, and load considerations used in the evaluation of the partial penetration weld.

II. EFFECTS OF SSW AS-BUILT CONDITIONS

The effect of as-built conditions on the analysis and design of the partial penetration weld is discussed herein. The significant as-built deviations from design conditions are of two types. The first type includes deviations from the dimensioned SSW configuration due to construction out-of-roundness and non-verticality. The second type includes defects in the welds of the SSW.

The as-built deviations from the design configuration which may affect the internal force system of the SSW and the design of the partial penetration weld are discussed in Technical Memorandum No. 1173, attached. Additional information on these deviations is given in pages 55-69 of the enclosed calculation. As indicated in these documents, the deviations involve displacement of one end of a member relative to the other end in the direction perpendicular to the length and result in changes in the member shears and moments. Assuming conservative values for the displacement, it is shown in the calculations that the changes in stress in the members are minor and that the partial penetration weld has sufficient capacity to sustain the additional shear due to the deviations.

The internal force system used in the analysis of the partial penetration weld is based on the investigation of the SSW in its design configuration as described in the enclosed paper, Analysis and Design of Sacrificial Shield Wall. The member properties used in the analysis correspond to the prismatic nature of the members and do not include the effects of local deviations in cross section such as those due to reduced weld section at member ends. The internal force system of the SSW which results from the analysis represents a set of forces which is in equilibrium with the applied external forces, which satisfies the boundary conditions, which has directions in conformance with the SSW configuration and which is compatible with the linear elastic stress-strain law. The local weld defects have influence on the internal force system only through the last requirement for satisfying linear elasticity and only insofar as changes in member stiffness result from the weld defect. The defects in structural members are only local compared to the overall member length so that no substantial change in member stiffness will occur. Considering all the requirements which must be satisfied by the internal force system, it is apparent that no effective redistribution of internal forces will result due to the weld defects.

III. ELEVATION 541'-5" CONTACT BEARING AREAS

In the design of the SSW it was postulated that all vertical stress would be transmitted across the interface via the vertical splice plates at the columns and that all horizontal shear would be transmitted across the interface via the slot welds between the channel member above and the box member below the interface. Consequently, these splice plates, which join the flanges of the columns above to the box member below the interface, have sufficient capacity to transmit all internal vertical forces and bending moments across the interface. Additional contact areas exist at the interface which will transmit vertical stress, but these are not included for this purpose in the analysis. In this category are the shim plates inserted at the interface to plumb the structure and the partial penetration weld to transmit horizontal shear in replacement of the slot welds. Leckenby drawing No. F124, indicating the location of the shim plates, is enclosed. The vertical splice plates at the columns are shown on Burns and Roe drawing S-835, refer to Attachment 5 to this report.

IV. PARTIAL PENETRATION WELD ECCENTRICITY

The subject of the relative locations of the partial penetration weld and the original welds is considered here. As stated in Technical Memorandum No. 1173, the partial penetration weld with fillet weld reinforcement is installed along the exterior circumference between the channel ring above and the box ring below the interface. It is proposed as a substitute for the original requirement for slot welds symmetrically located with respect to the wall centerline. The analysis and design for the partial penetration weld have taken due account of the location of forces, welds, and members in the transmission of shear across the interface. As shown in the attached calculation, the eccentricity of the shear load with respect to the partial penetration weld has been accounted for in the design of the weld and in the investigation of the stresses in the adjoining channel member. It is shown in the calculations that under design load conditions, the maximum stress in the weld due to the loads is less than half the permissible stress and that the resultant stresses in the member are small. It is also pertinent to note that, although the design margins afforded by the partial penetration weld and the slot weld are about equal, the shear area of the partial penetration weld is 2.8 times as large as the slot weld area to account for the eccentricity associated with the partial penetration weld.

V. ELEVATION 541'-5" INTERFACE DESIGN

In the SSW interface design, the vertical splice plates which join the flanges of the columns above the interface to the box ring beam below, have sufficient capacity to transmit across the interface all vertical forces and bending moments causing vertical stresses. Thus, sufficient capacity to transmit all required vertical forces and moments (causing tension or compression) is available without any requirement for participation by the partial penetration weld in transmission of vertical stress.

It is also noted that under controlling design conditions for transmission of vertical stress, the portion of the total transmitted vertical stress applied by the column above is eighty-four percent of the total, and applied by the skin plates above is sixteen percent of the total.

Analysis shows the partial penetration weld to have adequate capacity to carry both the design horizontal shear and the preceding vertical stresses. If the tension from the skin plate above the weld is carried together with the design shear, the design margin decreases from 2.39 to 2.27. If the total vertical tension on the weld side of the SSW is taken by the partial penetration weld together with the design shear, the design margin decreases to 1.78.

VI. LOAD DEFINITIONS USED FOR THE PARTIAL PENETRATION WELD

Technical Memorandum No. 1173 describes the generic load types which are significant with respect to the partial penetration weld design. Two of the principal loads are feedwater pipe break loads and seismic loads.

The feedwater pipe break loads used in the partial penetration weld design are the original loads used in the design of the SSW as described in the design report WPPSS-74-2-R2-B. With current definition of the feedwater pipe break loads in Technical Memorandum No. 1185, (refer to Appendix B to this report), the annulus pressures and the pipe break reactions are substantially reduced so that increase in the design margin above the value of 2.39 would result from design based on the current definition.

However, the seismic loads used in the partial penetration weld design are based on the current definition of seismic loads, Technical Memorandum No. 1188 (refer to Appendix B), and not on the original seismic loads used in the SSW design. Calculations have been made to determine the effect of using the original seismic load definition together with current NRC criteria as to combination of the effects of three orthogonal seismic events by the square root of the sum of the squares method. The calculations show that, as a result, the design margin decreases from 2.39 to 2.07; also the controlling load combination is SRP combination 6 instead of combination 5.

TECHNICAL MEMORANDUM

DATE 3/19/80

TO R. E. Snaith

FROM M. N. Fialkow

SUBJECT W. O. 2808
Washington Public Power Supply System
WPPSS Nuclear Project No. 2
Sacrificial Shield Wall - Assessment Program
Connection of Upper and Lower Wall Segments
TECHNICAL MEMORANDUM NO. 1173

COPIES TO:
JJVerderber w/1
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EJWagner w/1
GHarper w/1
HTuthill w/1
SF-2 w/2
pf w/1
db w/0
TM File w/1

REFERENCES:

1. NRC Letter from R. H. Engelken to N. O. Strand dated 2/8/80, Subject: Washington Nuclear Project No. 2, Pipe Whip Restraints and Sacrificial Shield Wall.

2. WPPSS Letter WPBR-80-96 from R. M. Foley to J. J. Verderber, dated 3/6/80, Subject: WPPSS Nuclear Project No. 2, Sacrificial Shield Wall (SSW) Assessment Program.

3. Calculation No. 6.19.37, Book No. SV 489 Pages 45 - 61 Title: WPPSS-Hanford No. 2 - Reactor Bldg. - Sacrificial Shield Wall, Subject: Correction Measures at Interface El. 541'-5".

4. Washington Public Power Supply System Nuclear Project No. 2 Report No. WPPSS-74-2-R2-B, "Sacrificial Shield Wall Design Supplemental Information".

5. ASCE Manual No. 41, "Plastic Design in Steel", 2nd Edition, 1971, Chapter 10: Multistory Frames, pp. 246-247: PΔ Effects.

INTRODUCTION:

It has been determined that the horizontal rings in the Sacrificial Shield Wall (SSW), located above and below the interface at Elevation 541'-5", are not welded together as shown on the contract drawings. Correction measures to transmit the design horizontal shear between the channel ring above the interface and the box ring below the interface are required.

The contract requires that at each of 24 locations around the SSW, four slot welds are to be provided in the web of the upper channel ring connecting to the lower box ring. In lieu of this unfulfilled requirement, it is proposed to install a partial penetration groove weld along the exterior circumference between the two rings.

Structural analysis in justification of the proposed correction has been accomplished (Reference 3). This memorandum furnishes pertinent information relative to this analysis in compliance with letters from USNRC and WPPSS (References 1, 2). The following is included:

a. Description of correction weld
b. Design considerations
c. Analysis based on the design SSW configuration
d. Analysis for as-built SSW dimensions.

DESCRIPTION OF CORRECTION WELD

The correction weld is a partial penetration groove weld with fillet weld reinforcement to be installed along the exterior circumference between the rings above and below the interface at Elevation 541'-5". The location and extent of the weld are shown in Figure 1; weld details are shown in Figure 2.

As shown in the figures, the correction weld is to be installed in each of the 24 panels around the SSW for the width available between the column splice plates. Preparation for the groove weld requires removal of material from the channel ring. The specific configuration of the weld in each panel, including the groove depth and the size of the fillet weld reinforcement, depends on the width of ledge at the interface. From the design viewpoint, a minimum overall weld depth of 2 inches, corresponding to an effective weld throat of 1 7/8 inches, is maintained in all configurations.

DESIGN CONSIDERATIONS FOR CORRECTION WELD

1. Basic Data

The analysis and design of the proposed correction weld utilizes the values of the stress resultants in the members and skin plates obtained in the analysis of the overall sacrificial shield wall. A description of the analysis and design of the SSW including loads, load combinations, and acceptance criteria was submitted to NRC by Report No. WPPSS-74-2-R2-B (Reference 4) and approved by NRC by letter dated October 15, 1975.

The analysis and design of the correction weld is in conformance with NRC Standard Review Plan (SRP) 3.8.3. In particular, requirements relative to loads, load combinations, and acceptance criteria are complied with. The basis of design is the elastic working stress method, Part 1 of the 1969 AISC design specification.

2. Significant Loads

The following significant loads, considered in the analysis and design of the sacrificial shield wall, are applicable to the correction measures:

Dead and live loads
Seismic loads: OBE and SSE
Pressurization of the annulus between RPV and SSW
Reactions due to pipe break

Annulus pressurizations include those due to postulated pipe breaks in the following lines:

Recirculation outlet lines
Recirculation inlet lines
Feedwater lines
RHR/LPCI lines

Pipe break reactions include those due to the preceding breaks and due to other severe postulated breaks occurring in the drywell proper. Ten controlling breaks in the drywell are included.

3. Controlling Loading and Load Combination

The significant loads are considered in the load combinations of SRP 3.8.3 with regard to horizontal loads at the interface. The controlling loading with associated acceptance criteria with regard to horizontal loading per panel is noted below:

SRP Combination 5: $1.6S \geq D + L + P_a + Y_r + E$
D, L: dead, live load
P_a: annulus pressure due to break in feedwater line at azimuth 90°.
Y_r: pipe reaction due to the feedwater line break
E: combined effect (by SRSS) due to OBE seismic events in the easterly, northerly, and vertical directions.

ANALYSIS BASED ON DESIGN SSW CONFIGURATION

1. Design Concept

The correction weld carries the horizontal shear loads which are transmitted between the ring channel above the interface and the ring box member below the interface. The horizontal loads from the channel are due to horizontal reactions from the skin plates and columns which connect to the channel from above. Reactions from the analysis of the SSW in its design configuration are used. The shear loads from the skin plates are tangential (circumferential) in direction. Shear loads from the columns have tangential and radial components. The connection design is based on the largest combined shear load in any one panel due to the associated skin plates and columns. The same correction is applied to all panels.

2. Design Loads

The largest combination of shear loads per panel in the controlling load combination 5 has magnitudes as listed below:

Skin plates:	Tangential shear	=	318.1 kips
Column:	Tangential shear	=	8.9 kips
	Radial shear	=	27.4 kips

The total panel tangential shear, 327.0 kips, is taken to act with half applied along each flange of the ring channel. The total panel radial shear, 27.4 kips, is taken to act along the line of the column web.

3. Weld Design Criteria

Welding procedures will be qualified in accordance with the requirements of the Structural Welding Code AWSD1.1. Weld design is based on allowable stresses associated with partial penetration groove welds.

4. Correction Weld Stress Analysis

The panel design loads result in tangential and radial shear resisting forces in the panel correction weld. The total panel tangential load causes a uniform tangential force in the weld of 9.9 kips per inch. A radial weld force which varies linearly between extreme values at the ends of the weld resists the moment on the weld due

to the eccentricity of the applied tangential load along the interior face; the maximum value of this radial force is 21.6 kips per inch. An additional radial weld force with constant magnitude equal to 2.7 kips per inch acts over a limited portion of the weld near its end to resist the applied radial load along the column web line. The maximum value of the resultant weld force occurs at the end of the weld and is equal to 26.3 kips per inch.

5. Controlling Design Margin

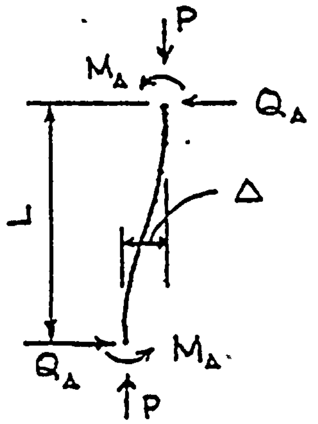
The design margin, which is the ratio of the permissible stress to the actual stress, equals 2.3 for the above maximum value of the weld force.

ANALYSIS FOR AS-BUILT SSW DIMENSIONS

1. Concept for Analysis

As-built deviations of the SSW which affect the proposed correction weld at interface Elevation 541'-5" are illustrated in Figure 3. As shown in the figure, the deviations from verticality of the columns above the interface and the deviations from the design circularity of the ring channel members above the interface are involved.

The lateral displacement of one end of a member, Δ, relative to the other end in conjunction with the primary axial load in the member, P, results in additional (secondary) shears and moments in the member (reference 5). This $P\Delta$ effect with the associated end bending moments and shears is shown below:



From equilibrium considerations, it is determined that:

$$P\Delta = Q_\Delta L + 2M_\Delta$$

Conservatively, the additional end moment M_Δ and the additional end shear Q_Δ are each evaluated as though the other is non-existent. This is done in the following equations.

$$M_\Delta = .5 P\Delta$$

$$Q_\Delta = P\Delta/L$$

2. Design Loads

The controlling axial loads in the columns and ring channels are due to the same applied loads taken in SRP Combination 5 which control for the transmission of shear across the interface. The axial force in the ring channel is taken equal to the design panel tangential shear of 327.0 kips. The axial force in the column is taken as the total panel vertical load due to both column and skin plate reactions. Conservatively, the maximum vertical loads in the column and skin plates are used even though these are not located in the same panel as the panel which controls for shear. The design vertical axial load is 316.5 kips.

3. Effect on Annulus Pressurization

With respect to the effect of as-built SSW dimensions on annulus pressurization calculations, the following is noted:

a. The measurements of concern apply to the annulus space between the sacrificial shield wall and the reflective insulation. These measurements are very difficult to obtain and are not available. However, it is noted that the insulation support system is mounted on the SSW so that the dimension between insulation and wall would tend to be unaffected by the as-built deviations.

b. For the design of the wall, NRC required that calculated annulus pressurization loads be increased by 40 percent. One of the reasons for this requirement was to account for as-built conditions being different from the conditions assumed in the analysis.

4. Magnitude of As-Built Deviations

The as-built deviations used in the analysis are based on the most conservative interpretation of the revised erection tolerances which were adopted for the erection of the SSW together with a supplementary field check of the deviations.

Prior to erection of the wall, the contractor requested and was granted relaxation of the original contract requirements on erection tolerances. The maximum permissible deviation from circularity was changed to $\pm$ 0.90 inches in lieu of the original $\pm$ 0.125 inches. The maximum horizontal deviation at the top of the wall from the vertical line through the corresponding point in the base of the wall was revised to $\pm$ 0.90 inches in lieu of the original $\pm$ 0.25 inches.

The most conservative interpretation of the adopted tolerances results in the deviation values noted below. These values are used in the analysis.

a. Circularity - The maximum tolerance is taken to occur at one column relative to the adjacent columns on either side.
Referring to Figure 3,

$$\Delta_{ci} - \Delta_{ci+1} = \Delta_{ci} - \Delta_{ci-1} = 0.90 - (-0.90) = 1.80 \text{ inches}.$$

b. Verticality - The maximum tolerance is taken to occur at a column between Elevation 541'-5" and Elevation 549'-5½". Using the terminology of Figure 3,

$$\Delta_v = 0.90 - (-0.90) = 1.80 \text{ inches}.$$

Field measurements pertinent to the vertical and circular deviations have recently been made. The magnitudes of Δ_v as defined in Figure 3 were determined around the shield wall. However, precise determination of the circular deviation is not practical due to interference of existing construction. As a measure of the circular deviation, the radial deviation between the ring box member below the interface and the ring channel above the interface is used.

Comparison of the deviations from field measurements with those based on the tolerances makes apparent the conservative basis of the analysis. Thus the analysis uses Δ_v = 1.8 inches compared to a maximum measured value of 0.625 inches. Also, the analysis uses $\Delta_{Ri} - \Delta_{Ri+1}$ = 1.8 inches compared to a corresponding value of 0.875 inches based on field data.

5. Correction Weld Stress Analysis

As noted in the Concept for Analysis, the design axial loads acting with the adopted design deviations result in additional end moments and shears in the columns and ring channels located above the interface.

The additional end moments in the column and ring channel are 285.0 inch kips and 294.3 inch kips respectively. The associated increases in flexural stress in the members are less than 0.7 kips per square inch. This increase in stress is relatively small and is within the capacity of the wall members.

The additional column radial shear is 5.9 kips. The additional radial shear in each of the two ring members at the column is 13.4 kips. Thus, a total of 32.7 kips of additional radial shear results due to the design deviations. Conservatively, this additional radial shear is taken to occur in the controlling panel used for the design of the correction weld. The total panel radial shear is increased to 60.1 kips and the resulting local radial weld force increases to 6.0 kips per inch from the previous value of 2.7 kips per inch in the Analysis Based on Design SSW Configuration.

6. Design Margin

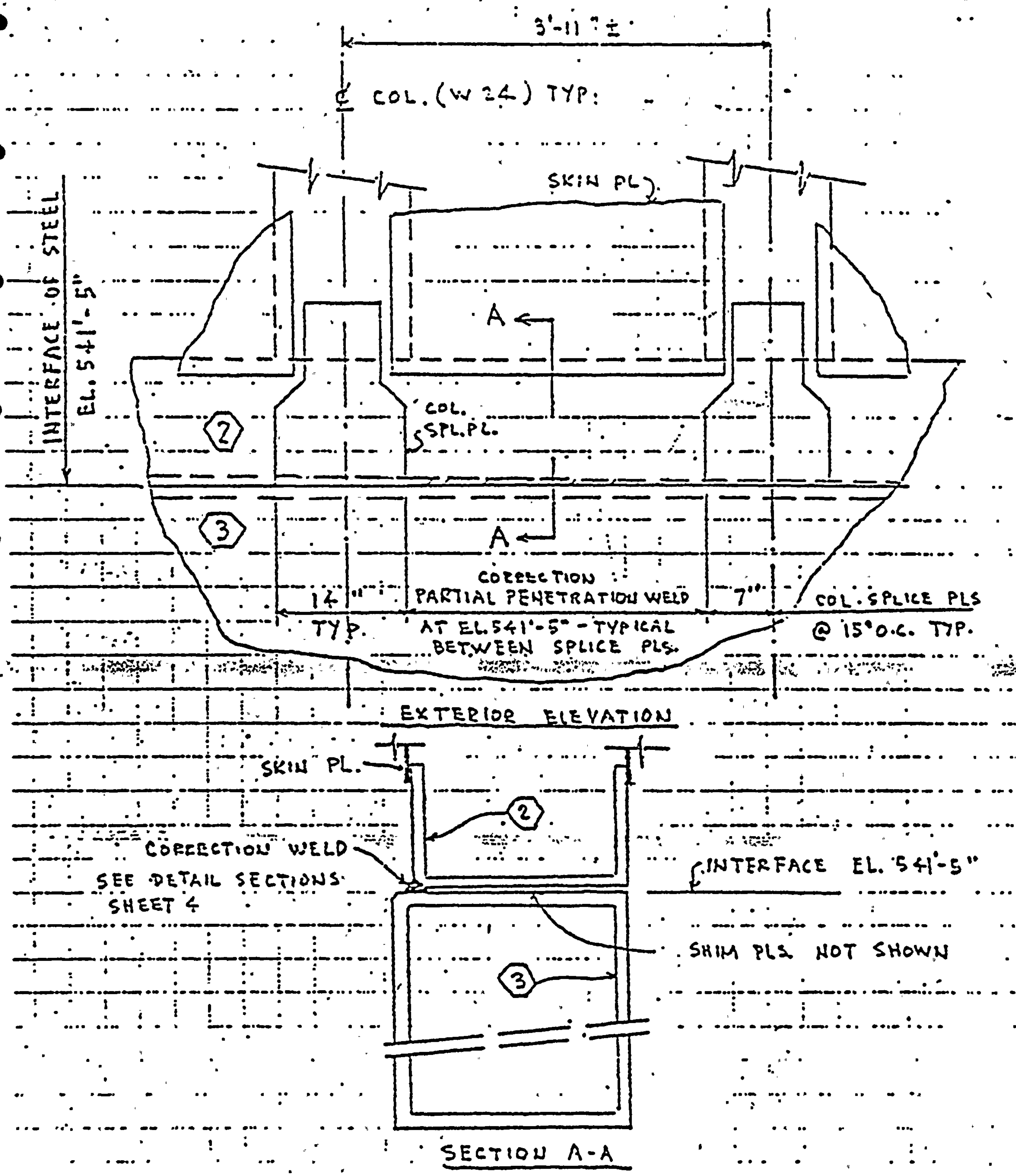
With the above increase in panel radial shear, the design margin is 2.1 as compared to the previous value of 2.3.

CONCLUSION

Based on the preceeding analysis, the proposed correction weld at interface Elevation 541'-5" has sufficient capacity to sustain the required loads. The correction provides a design margin in excess of 2.1.

Prepared by: M. N. Fialkow
M.N. Fialkow

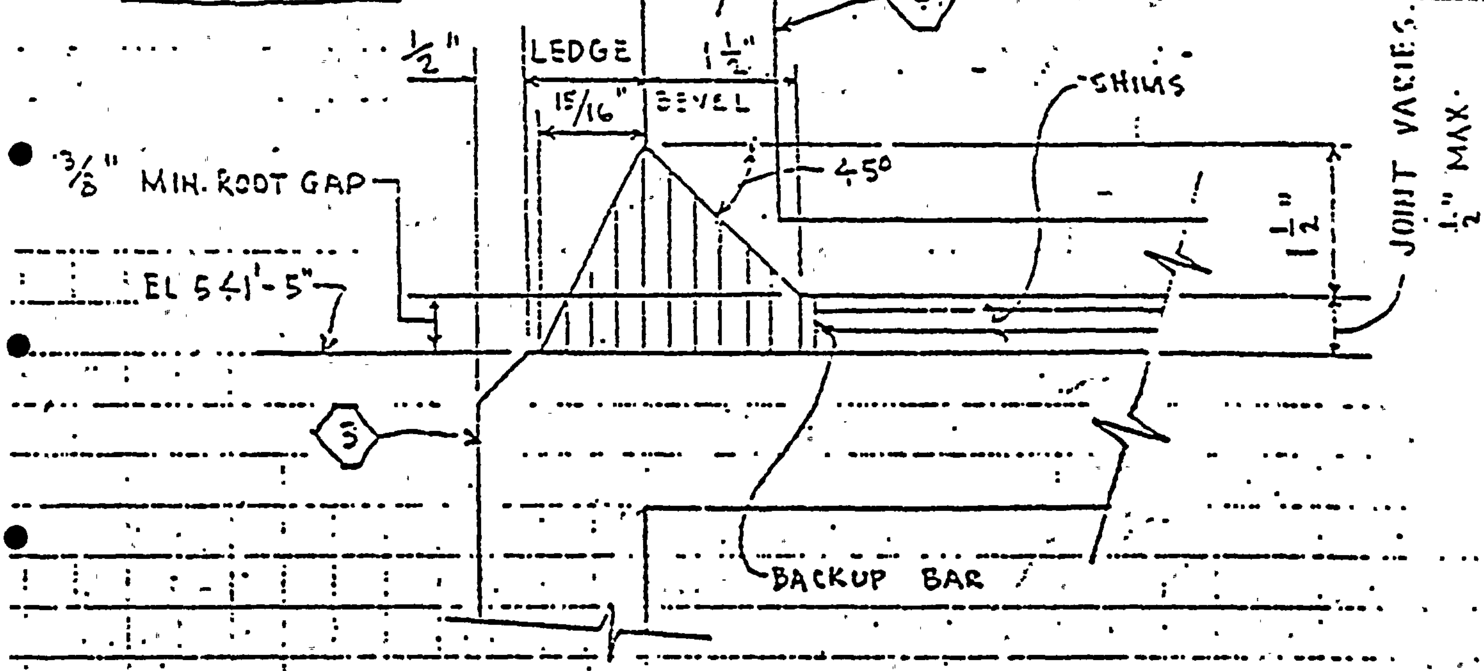
Approved by: J. F. O'Donnell
J. F. O'Donnell



ELEVATION AND SECTION OF SSW SHOWING CORRECTION WELD

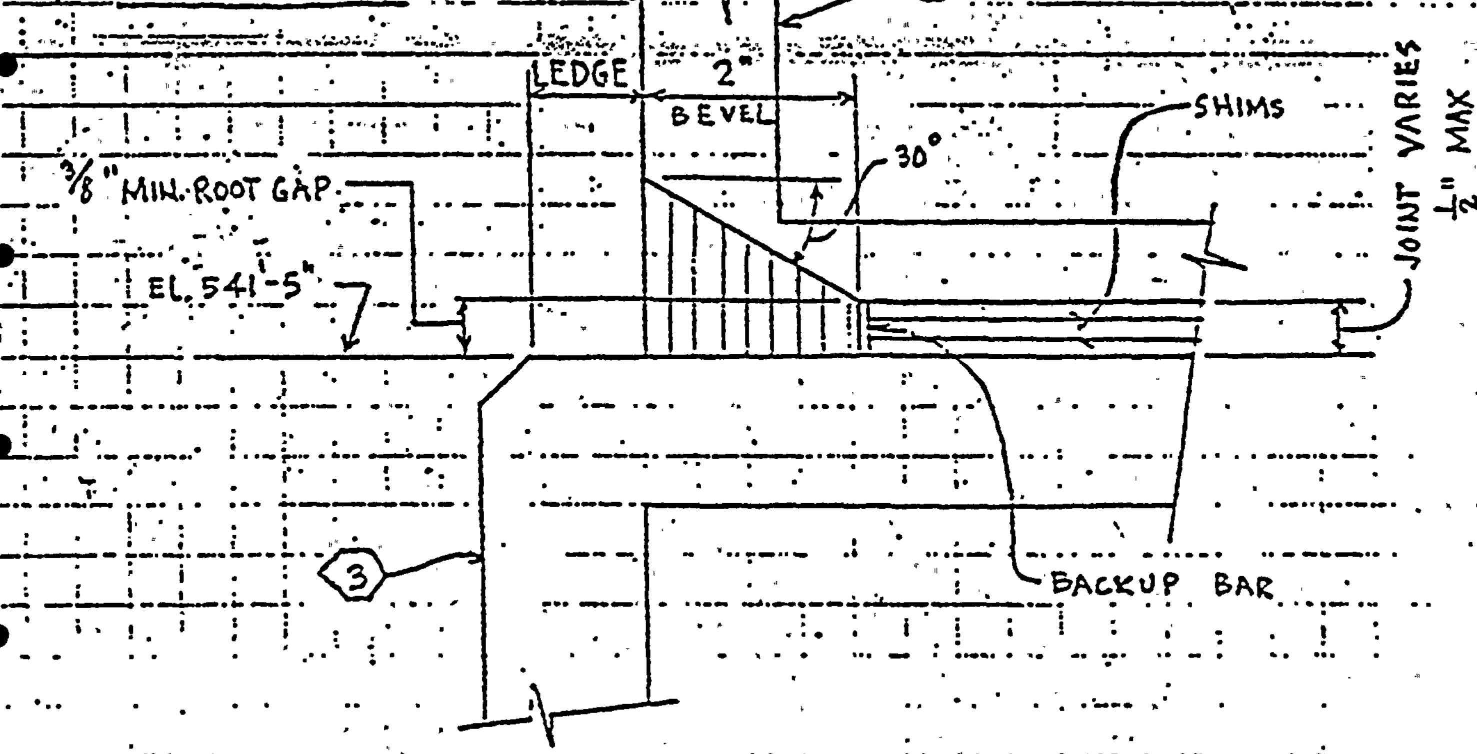
FIGURE 1

1. CASE 1 : LEDGE ≥ 1"



SECTION WHERE LEDGE IS A MINIMUM OF 1" WIDE

2. CASE 2 : LEDGE < 1"



SECTION WHERE LEDGE IS LESS THAN 1" WIDE

REINFORCING FILLET TO BE ADDED AS SHOWN ON SHEET 5 OF PED-215-CS-2741.

DCJ
3/24/80

CORRECTION WELD DETAILS

FIGURE 2

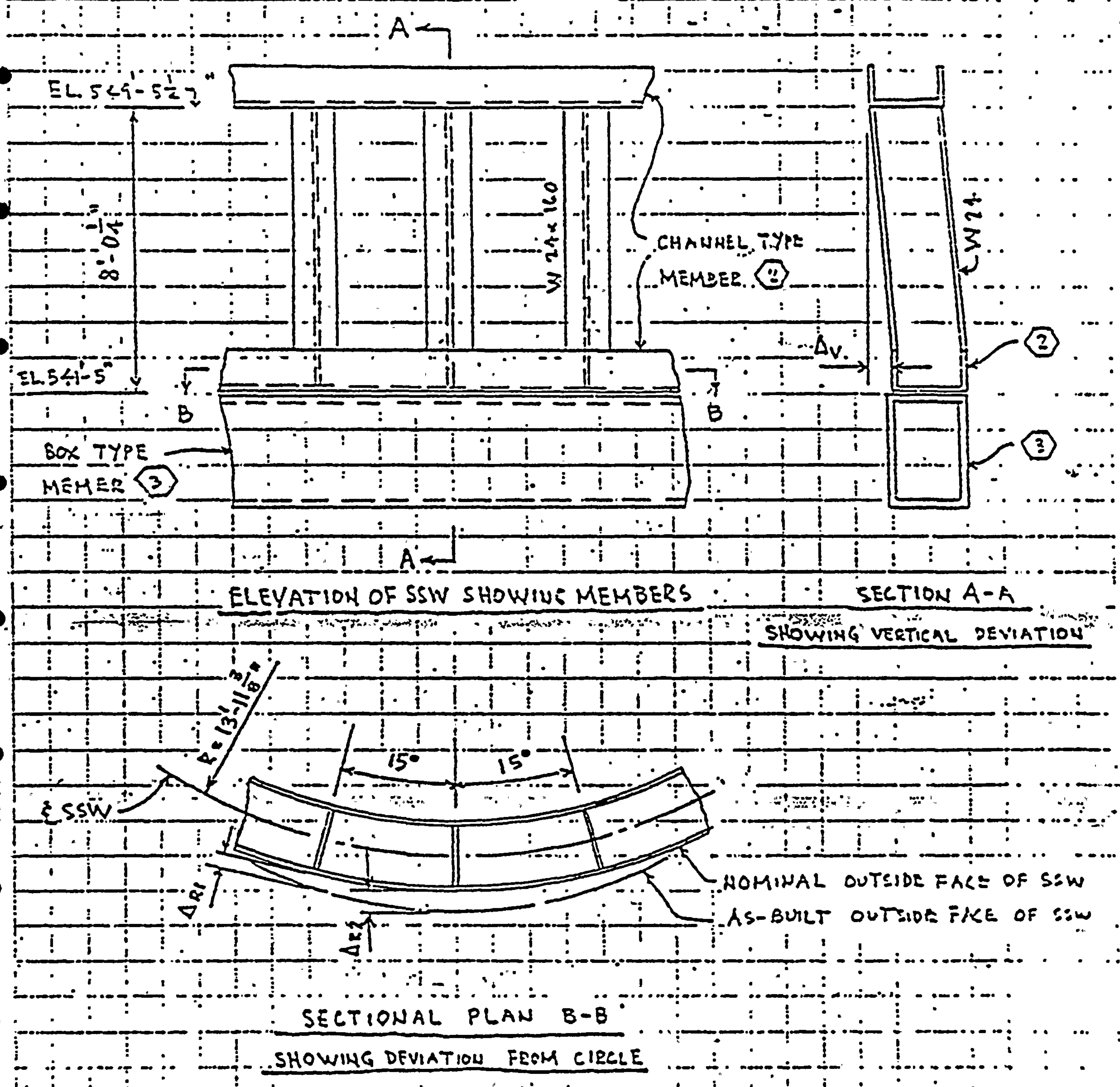


DIAGRAM ILLUSTRATING AS-BUILT DEVIATIONS

FIGURE 3

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W.O. No. 3900-03 Date ______ Book No. SV 489 Page No. ______
Drawing No. S783 Calc. No. 6.19.37 Sheet INDEX of ______
By M. [illegible] Checked ______ Approved [illegible] 7/21/80
Title WPPSS - HANFORD NO. 2 - REACTOR BLDG. - SACRIFICIAL SHIELD WALL

SUBJECT: CORRECTION MEASURES AT INTERFACE EL. 541'-5"

CALCULATIONS INDEX

BURNS AND ROE, INC.

W.O. No. 3900-03 Date 12/31/79 Book No. S V 489 Page No. 45
Drawing Nos. S 733 Calc. No. 6.19.37 Sheet 1 of 24
By M. [illegible] Checked [illegible] 1-11-80 Approved [illegible] 7/21/80
Title WPPSS-HANFORD NO. 2 - REACTOR BLDG - SACRIFICIAL SHIELD WALL

SUBJECT: CORRECTION MEASURES AT INTERFACE EL. 541'-5"

A. GENERAL

1. REQUIRED CORRECTION

a. CONTRACT REQUIREMENTS FOR TRANSMISSION OF HORIZONTAL SHEAR ACROSS INTERFACE EL. 541'-5" HAVE NOT BEEN IMPLEMENTED.

b. CORRECTIVE MEASURES TO TRANSMIT THE DESIGN HORIZONTAL SHEAR BETWEEN THE RING CHANNEL (2) ABOVE THE INTERFACE AND THE RING BOX BEAM (3) BELOW THE INTERFACE ARE REQUIRED.

2. CONTRACT REQUIREMENTS (NOT IMPLEMENTED)

a. REFERENCE DRAWINGS - THE REQUIRED CONNECTIONS ARE SHOWN ON THE FOLLOWING DRAWINGS:

S 782 DETAIL D-2038

S 783 SECTION 1602

b. CONTRACT CONNECTIONS

AT EACH OF 24 LOCATIONS AROUND THE SSW, CENTRED ON THE W 24 COLUMNS, 4 SLOT WELDS ARE PROVIDED IN THE WEB OF THE UPPER RING CHANNEL (2). THE SLOT WELDS CONNECT TO THE LOWER RING BOX BEAM (3).

Form BR 8002-2

BURNS AND ROE, INC.

W.O. No. 3900-03 Date 12/31/79 Book No. SV 489 Page No. 46
Drawing No. 5783 Calc. No. 6.19.37 Sheet 2 of 22
By M. Fiechter Checked 1-11-80 Approved 7/21/80
Title WPPSS-HANFORD NO.2 - REACTOR BLDG. - SACRIFICIAL SHIELD WALL

SUBJECT: CORRECTION MEASURES AT INTERFACE EL. 541'-5"

B. DESIGN REQUIREMENTS

1. REFERENCES FOR PREVIOUS ANALYSIS

a. DEFINITIONS OF LOADINGS & COMBINATIONS

BOOKS NOS. SV 86; SV87, SV 90.

b. RESULTS OF COMPUTER PROGRAM (STRUPL) ANALYSIS

BOOKS NOS. SV 153, 154, 155

c. APPROVAL DOCUMENT

REPORT NO. WPPSS-74-2-R2-B, "SACRIFICIAL SHIELD WALL DESIGN SUPPLEMENTAL INFORMATION" SUBMITTED TO NRC BY WPPSS LETTER GO2-75-240 DATED 8/19/79 AND APPROVED BY NRC BY LETTER DATED 10/15/75, DOCKET NO. 50-397.

2. GENERAL

a. ANALYSIS HEREIN AND PREVIOUS ANALYSIS, INCLUDING LOADS, LOAD COMBINATIONS AND ACCEPTANCE CRITERIA, ARE IN CONFORMANCE WITH NRC STANDARD REVIEW PLAN 3.8.3.

b. DESIGN IS BASED ON THE ELASTIC WORKING STRESS METHOD OF PART 1, AISC, 1969.

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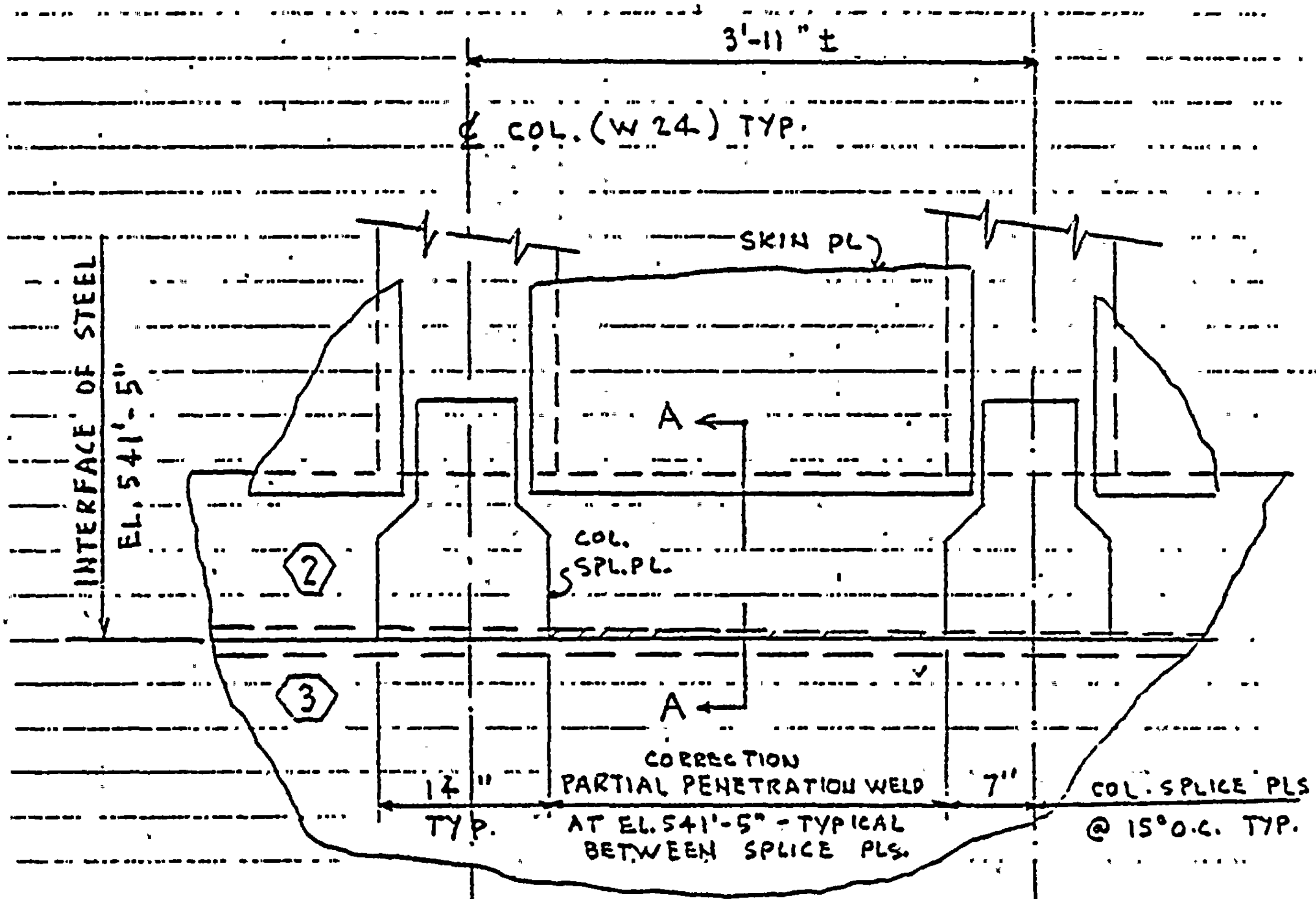
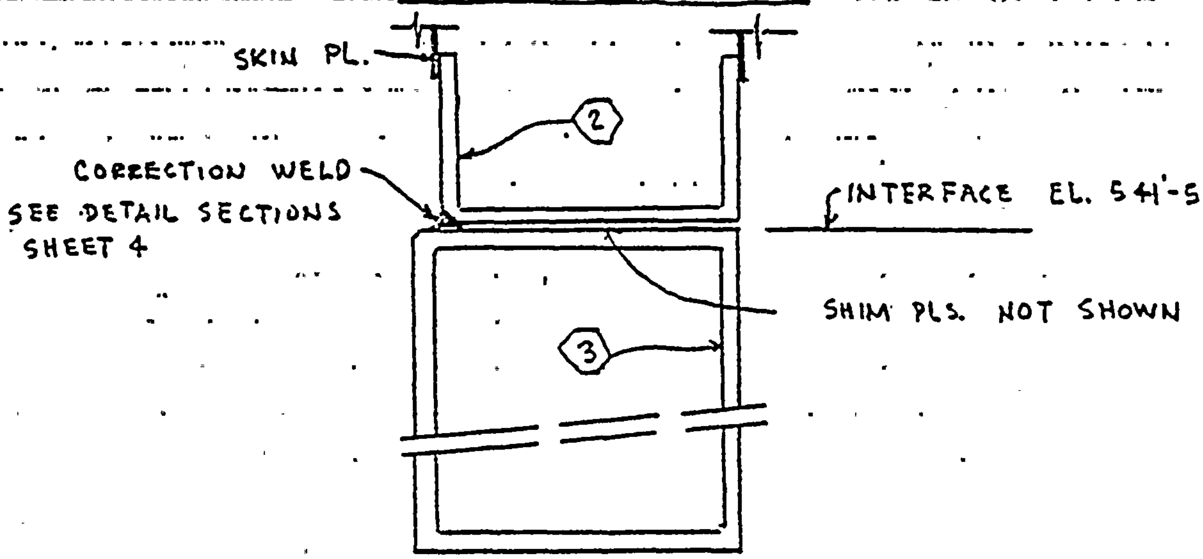
W.O. No. 3900-03 Date 12/31/79 Book No. SV 489 Page No. 47
Drawing Nos. S 783 Calc. No. L.11.37 Sheet 3 of 24
By M. [illegible] Checked [illegible] 1-11-80 Approved [illegible] 7/21/80
Title WPPSS - HANFORD NO.2 - REACTOR BLDG. - SACRIFICIAL SHIELD WALL

SUBJECT: CORRECTION MEASURES AT INTERFACE EL 541'-5".

C. TYPICAL EXTERIOR ELEVATION AT INTERFACE - SHOWING EXTENT OF CORRECTION



EXTERIOR ELEVATION



SECTION A-A

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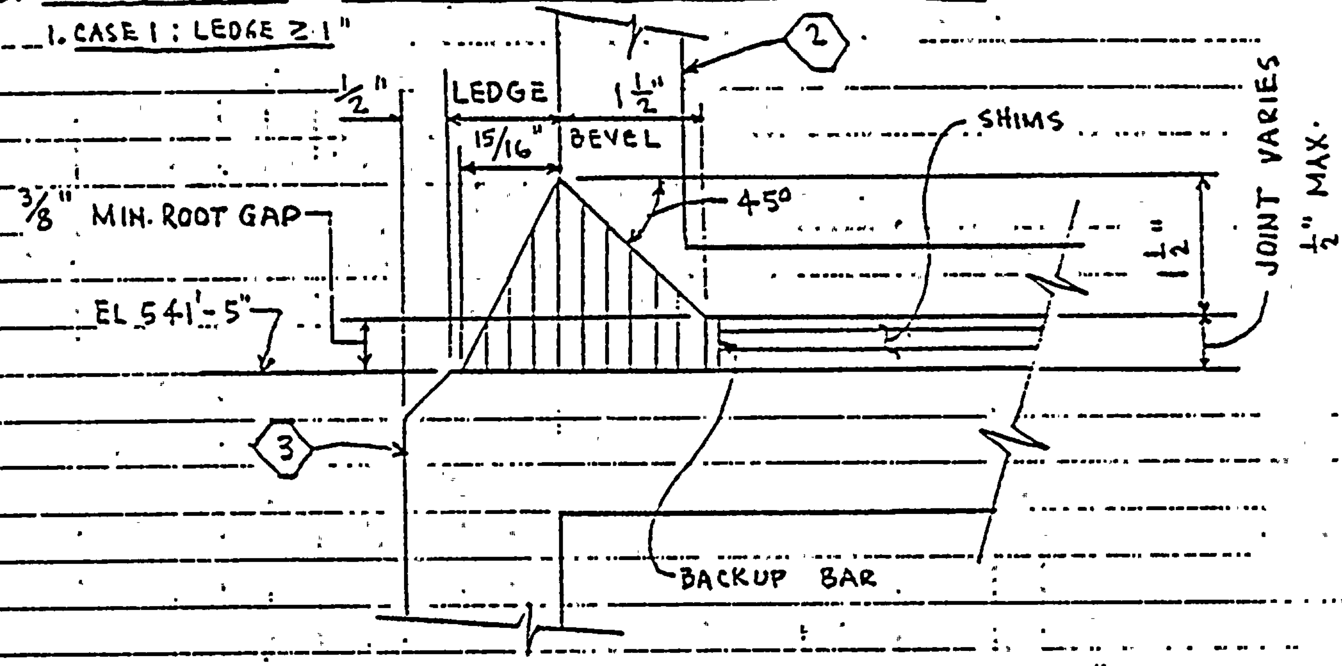
W.O. No. 3900-03 Date 12/31/79 Book No. SV 489 Page No. 48
Drawing No. S733 Calc. No. 6.19.37 Sheet 4 of 24
By [illegible] Checked [illegible] 1-11-80 Approved [illegible] 7/21/80
Title WPPSS - HANFORD NO. 2 - REACTOR BLDG - SACRIFICIAL SHIELD WALL

SUBJECT: CORRECTION MEASURES AT INTERFACE EL. 541'-5"

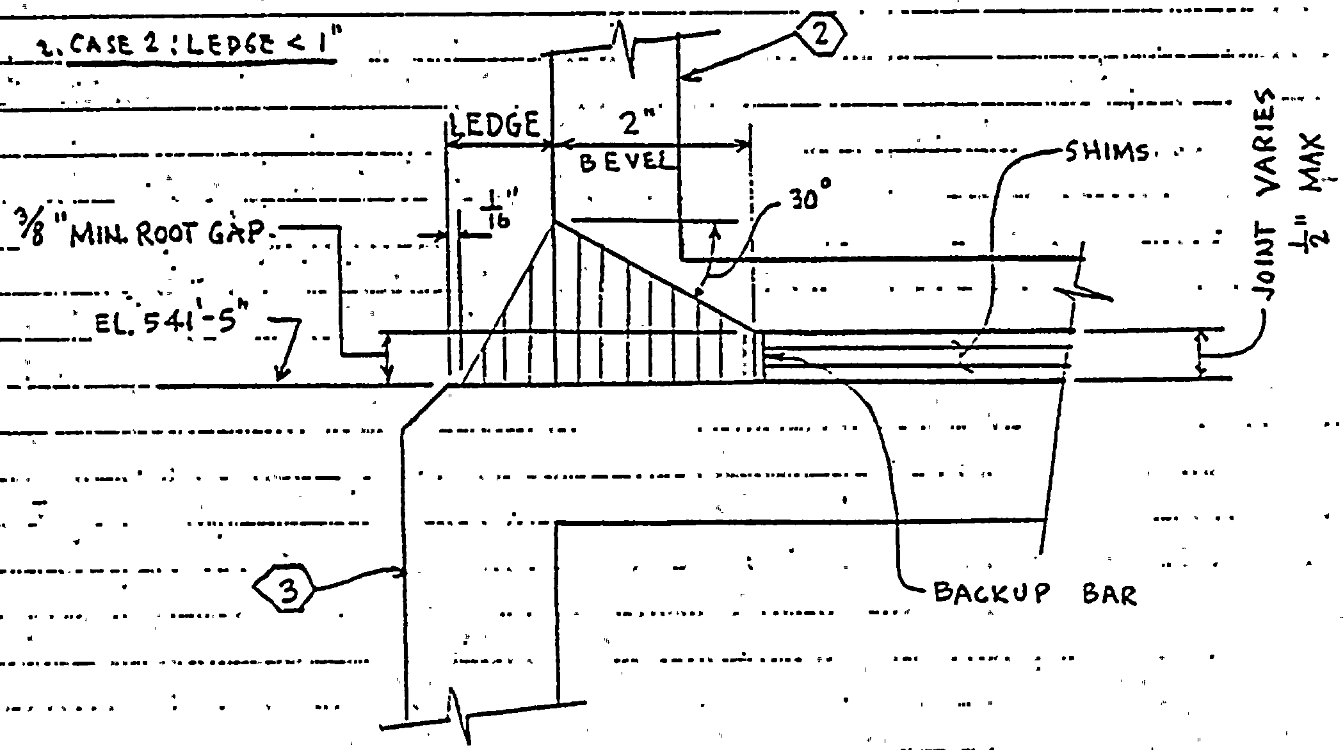
D. DETAIL SECTIONS - CORRECTION WELD AT INTERFACE

1. CASE 1: LEDGE ≥ 1"



SECTION WHERE LEDGE IS A MINIMUM OF 1" WIDE

2. CASE 2: LEDGE < 1"



SECTION WHERE LEDGE IS LESS THAN 1" WIDE

BURNS AND ROE, INC.

W.O. No. 3900-03 Date 1/2/80 Book No. SV 489 Page No. 49
Drawing No. S.7.83 Calc. No. 6.19.37 Sheet 5 of 24
By [signature] Checked [signature] 1-11-80 Approved [signature] 7/21/80
Title WPPSS-HANFORD NO.2 - REACTOR BLDG. - SACRIFICIAL SHIELD WALL

SUBJECT : CORRECTION MEASURES AT INTERFACE EL. 541'-5"

E. SIGNIFICANT LOADS

THE FOLLOWING SIGNIFICANT LOADS, CONSIDERED IN THE ANALYSIS AND DESIGN OF THE SACRIFICIAL SHIELD WALL, ARE APPLICABLE TO THE CORRECTION MEASURES:

DEAD (D) AND LIVE (L) LOADS

SEISMIC LOADS ; OBE (E) AND SSE (E')

PRESSURIZATION OF THE ANNULUS BETWEEN RPV AND SSW.

REACTIONS DUE TO PIPE BREAK.

ANNULUS PRESSURIZATIONS INCLUDE THOSE DUE TO POSTULATED PIPE BREAKS IN THE FOLLOWING LINES:

RECIRCULATION OUTLET LINES

RECIRCULATION INLET LINES

FEEDWATER LINES

RHR/LPCI LINES

PIPE BREAK REACTIONS INCLUDE THOSE DUE TO THE PRECEDING BREAKS AND DUE TO OTHER SEVERE POSTULATED BREAKS OCCURRING IN THE DRYWELL PROPER. TEN CONTROLLING BREAKS IN THE DRYWELL ARE INCLUDED.

Form BR 8002-2

SUBJECT: CORRECTION MEASURES AT INTERFACE EL. 541'-5"

F. DESIGN CONCEPT

1. HORIZONTAL SHEAR LOADS ARE TRANSMITTED BETWEEN RING CHANNEL ⟨2⟩ ABOVE THE INTERFACE AND RING BOX MEMBER ⟨3⟩ BELOW THE INTERFACE.

2. THE HORIZONTAL LOADS FROM CHANNEL ⟨2⟩ ARE DUE TO HORIZONTAL REACTIONS FROM THE SKIN PLATES AND THE COLUMNS (W24's) WHICH CONNECT TO THE CHANNEL FROM ABOVE. THE COLUMNS DIVIDE THE SHIELD WALL AT THE INTERFACE INTO 24 PANELS, EACH SUBTENDING AN ANGLE OF 15°.

3. SHEAR LOADS FROM THE SKIN PLATES ARE TANGENTIAL (CIRCUMFERENTIAL) IN DIRECTION. SHEAR LOADS FROM THE COLUMNS HAVE TANGENTIAL AND RADIAL COMPONENTS.

4. CORRECTION IS BASED ON THE LARGEST COMBINED SHEAR LOAD IN ANY ONE PANEL DUE TO THE ASSOCIATED SKIN PLATES AND COLUMNS. THE SAME CORRECTION IS APPLIED TO ALL PANELS.

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W.O. No. 3900-03 Date 1/2/80 Book No. SV 489 Page No. 51
Drawing No. -S 783 Calc. No. 6.19.37 Sheet 7 of 24
By M. [illegible] Checked [illegible] 1-11-80 Approved [illegible] 7/21/80
Title WPPSS - HANFORD NO. 2 - REACTOR BLDG - SACRIFICIAL/SHIELD WALL

SUBJECT: CORRECTION MEASURES AT INTERFACE EL. 541'-5"

G. CONTROLLING LOADING AND LOAD COMBINATION

1. IN PREVIOUS CALCULATIONS, THE SIGNIFICANT LOADS (PAR. E) WERE CONSIDERED IN THE LOAD COMBINATIONS OF STANDARD REVIEW PLAN 3.8.3 WITH REGARD TO HORIZONTAL LOADS AT THE INTERFACE. THE CONTROLLING LOAD COMBINATION WAS ASCERTAINED. PERTINENT VERTICAL LOADS WERE ALSO CALCULATED.

2. THE CONTROLLING LOAD COMBINATION WITH ASSOCIATED ACCEPTANCE CRITERIA WITH REGARD TO HORIZONTAL LOADING PER PANEL ARE NOTED BELOW.

SRP COMBINATION 5: $1.6S \geq D + L + P_a + Y_r + E$

D, L : DEAD, LIVE LOAD

P_a : ANNULUS PRESSURIZATION DUE TO FEED WATER BREAK AT AZIMUTH 90°.

Y_r : PIPE REACTION DUE TO ABOVE FEED WATER BREAK.

E : COMBINED EFFECT (BY SRSS) DUE TO OBE SEISMIC EVENTS IN EASTERLY, NORTHERLY, AND VERTICAL DIRECTIONS.

3. THE SHEAR LOADS PER PANEL REPRESENTED BY THE ABOVE CONTROLLING LOAD COMBINATION ARE NOTED BELOW.

SKIN PLATES	TANGENTIAL SHEAR	=	318.1^k
COLUMN	TANGENTIAL SHEAR	=	8.9^k
	RADIAL SHEAR	=	27.4^k
TOTAL PANEL	TANGENTIAL SHEAR	=	327.0^k
TOTAL PANEL	RADIAL SHEAR	=	27.4^k

4. THE MAXIMUM VERTICAL PANEL LOAD UNDER THE ABOVE LOADING IS PERTINENT TO THE DETERMINATION OF THE EFFECT OF AS-BUILT DEVIATIONS FROM THE DESIGN CONFIGURATION (SEE SUBSEQUENT PAR I).

FOR SRP COMBINATION 5, MAX. VERT. PANEL LOAD, P_v

$$P_v = D + L + P_a + Y_r + E$$
$$= 316.5^k$$

(SEE PAR R9c PP 43, 44)

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W.O. No. 3900-03 Date 1/2/80 Book No. SV 479 Page No. 52
Drawing No. S 773 Calc. No. 6.19.37 Sheet 5 of 14
By M. Fielkow Checked [illegible] 1-11-80 Approved [illegible] 7/7/80
Title WPPSS - HANFORD NO. 2 - REACTOR BLDG. - SACRIFICIAL SHIELD WALL

SUBJECT: CORRECTION MEASURES AT INTERFACE EL. 541'-5"

H. ANALYSIS OF PROPOSED CORRECTION MEASURES

1. BASIS OF ANALYSIS

a. PROPOSED CORRECTION MEASURES (WELDS) ARE SHOWN IN PRECEDING PARAGRAPHS C & D.

b. CONTROLLING PANEL LOADING, LOAD COMBINATION, & ACCEPTANCE CRITERION ARE GIVEN IN PRECEDING PAR. G.

c. CONTROLLING PANEL LOADING WILL BE RESISTED IN SAME PANEL.

d. WELDING PROCEDURES WILL BE QUALIFIED IN ACCORDANCE WITH AWS REQUIREMENTS. ANALYSIS IS BASED ON S = ALLOWABLE STRESS ASSOCIATED WITH PARTIAL PENETRATION GROOVE WELDS.

2. EFFECTIVE WELD THROAT

a. CASE 1 WELD: LEDGE ≥ 1"

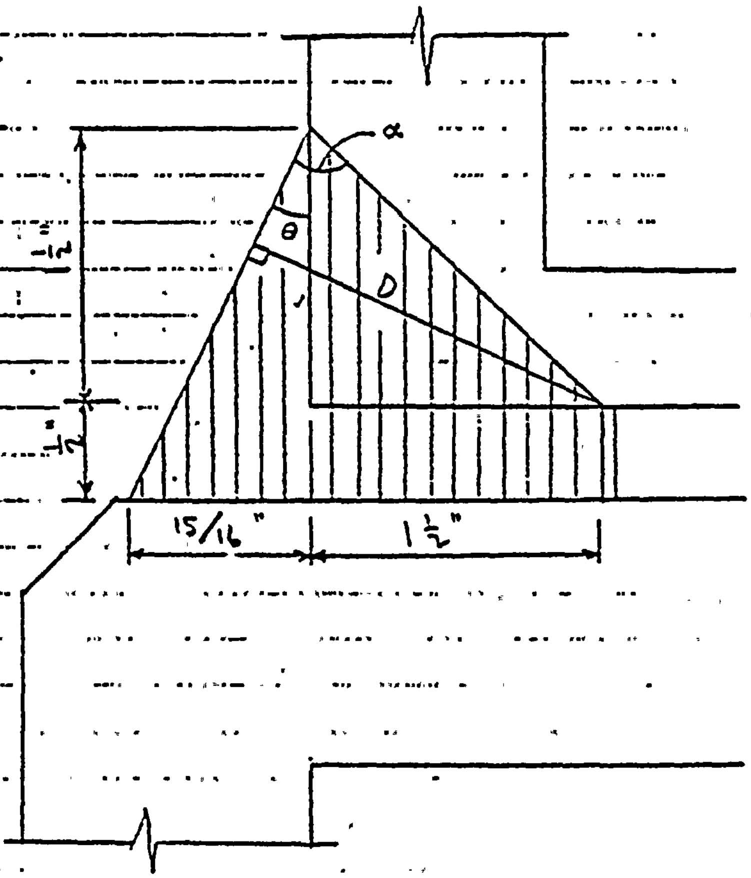
MINIMUM CASE 1 WELD IS SHOWN.

$\theta = \tan^{-1} \frac{15/16}{2} = 25.115°$

$\alpha = 45° + \theta = 70.115°$

$D = 1.5 \times 1.414 \sin\alpha = 1.995$

$T_e = 1.995 - .125 = 1.87"$



b. CASE 2 WELD: LEDGE < 1"

REVIEW OF CASE 2 WELD DETAIL (PAR D2) SHOWS MINIMUM DEPTH = 2". HENCE

$T_e = 2.0 - .125 = 1.875"$

c. EFFECTIVE THROAT: USE $T_e = 1.87"$

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W.O. No. 3900-03 Date 1/2/80 Book No. SV 439 Page No. 53
Drawing No. 5783 Calc. No. 6.19.37 Sheet 9 of 24
By M. [illegible] Checked [illegible] 1-11-80 Approved [illegible] 7/21/80
Title WPPSS - HANFORD NO.2 - REACTOR BLDG - SACRIFICIAL SHIELD WALL

SUBJECT: CORRECTION MEASURES AT INTERFACE EL. 541'-5"

H. ANALYSIS OF PROPOSED CORRECTION MEASURES

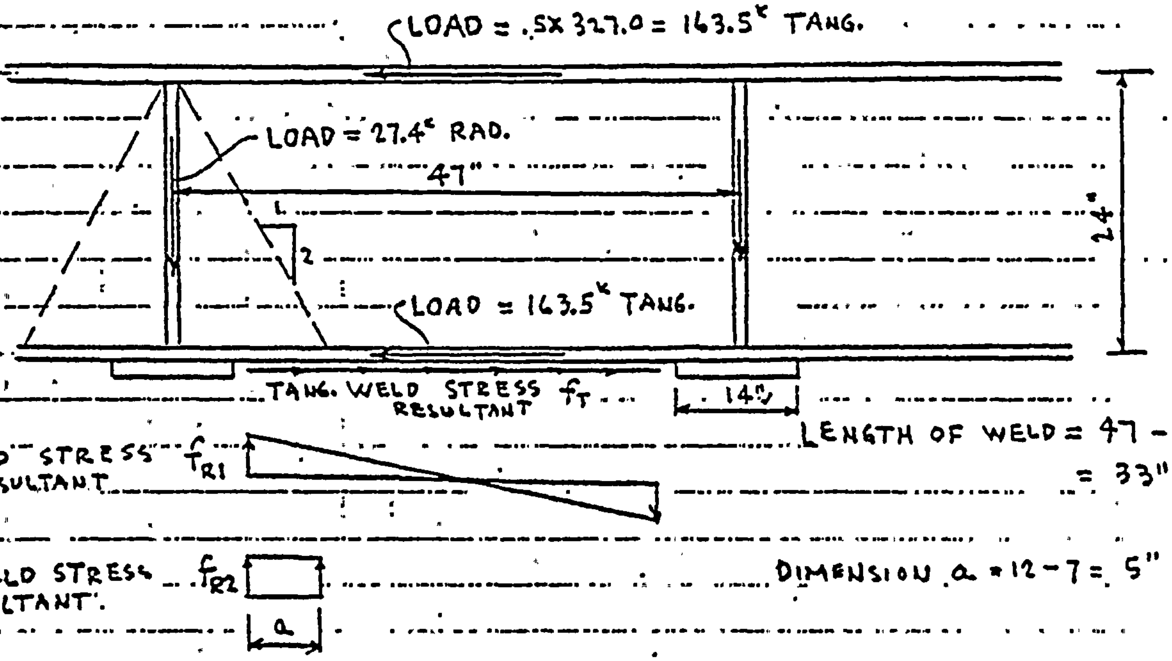
3. STRESSES IN CORRECTION WELDS

a. HORIZONTAL FORCES PER PANEL - CONTROLLING LOADING

$H_R = 27.4^k$ RADIAL AT COLUMN WEB

$H_T = 327.0^k$ TANGENTIAL TAKEN AS ACTING WITH HALF ALONG EACH SKIN PLATE LINE.

b. PLAN OF PANEL SHOWING LOADS & WELD STRESS RESULTANTS



LENGTH OF WELD = 47 - 14 = 33"

DIMENSION a = 12 - 7 = 5"

c. WELD STRESS RESULTANTS

TANGENTIAL: $f_T = \frac{327.0}{33.0} = 9.91^{k/''}$

RADIAL: $f_{R1} = \frac{163.5 \times 24 \times 6}{33^2} = 21.62^{k/''}$ DUE TO 163.5^k AT 24" ECCENTRIC.

$f_{R2} = \frac{.5 \times 27.4}{5.} = 2.74^{k/''}$ DUE TO 27.4^k

MAX. SHEAR FORCE PER INCH $= [9.91^2 + (21.62 + 2.74)^2]^{\frac{1}{2}} = 26.3^{k/''}$

d. MAX. PERMISSIBLE WELD SHEAR PER INCH (LOAD COMB. 5)

$f_M = 1.6 \times 21 \times 1.87 = 62.8^{k/''}$

MATERIAL: A36
ELECTRODES: E70XX

e. DESIGN MARGIN

$D.M. = \frac{62.8}{26.3} = 2.39$

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W.O. No. 3900-03 Date 1/4/80 Book No. SU 489 Page No. 54
Drawing No. 5783 Calc. No. 6.19.37 Sheet 10 of 24
By M. Friedman Checked 1-11-80 Approved 7/21/80
Title WPPSS - HANFORD NO. 2 - REACTOR BLDG. - SACRIFICIAL SHIELD WALL

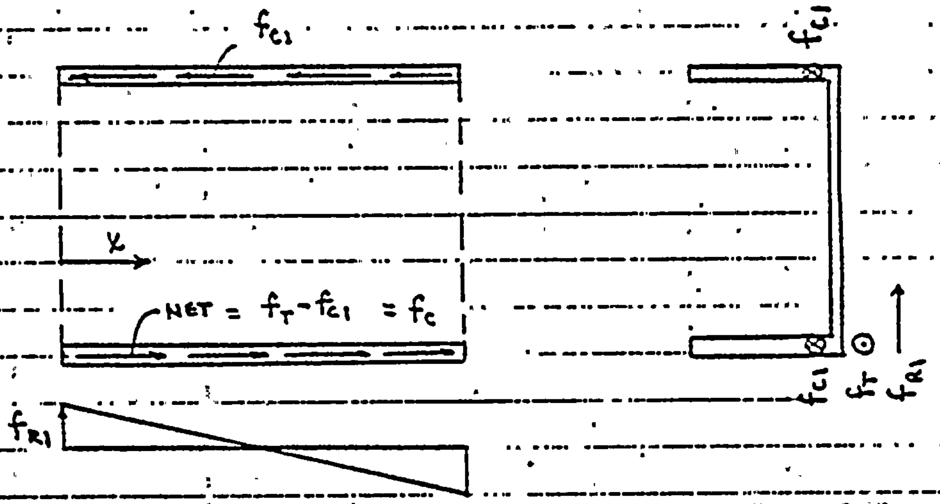
SUBJECT: CORRECTION MEASURES AT INTERFACE EL 541'-5"

H. ANALYSIS OF PROPOSED CORRECTION MEASURES

4. CHECK CHANNEL MEMBER ⟨2⟩ UNDER CORRECTION DESIGN LOADING

a. LOADING LAYOUT

AS A CONSERVATISM, CONTINUITY OF CHANNEL IS IGNORED.



b. LOADING MAGNITUDES

$f_{c1} = \frac{163.5}{33} = 4.95^{k/in}$ $\quad f_T = 9.9^{k/in}$ $\quad$ NET = f_c = 9.9 − 4.95 = $4.95^{k/in}$

$f_{R1} = 21.6^{k/in}$

c. BENDING

$$M = \frac{21.6x^2}{2} - \frac{21.6x}{16.5}\cdot\frac{x}{2}\cdot\frac{x}{3} - 4.95(24)x = 10.8x^2 - .218x^3 - 118.8x$$

FOR MAX M, $\frac{dM}{dx} = 21.6x - .654x^2 - 118.8 = 0$ OR $x^2 - 33.03x + 181.65 = 0$

$$x = .5\left[33.03 \pm \sqrt{33.03^2 - 4\times181.65}\right] = .5\left[33.03 \pm 19.09\right] = 6.97'', 26.06''$$

$M_{MAX} = 10.97(6.97)^2 - .218(6.97)^3 - 118.8(6.97) = 369.^{"k}$

$S_w = 460^{in^3}$

$f_b = \frac{369}{460} = 0.80^{k/\square''}$ O.K.

d. SHEAR

MAX V = .5 × 21.6 × 16.5 = 178.2^k

$v = \frac{178.2}{24\times.75} = 9.9^{k/\square''}$ O.K.

BURNS AND ROE, INC.

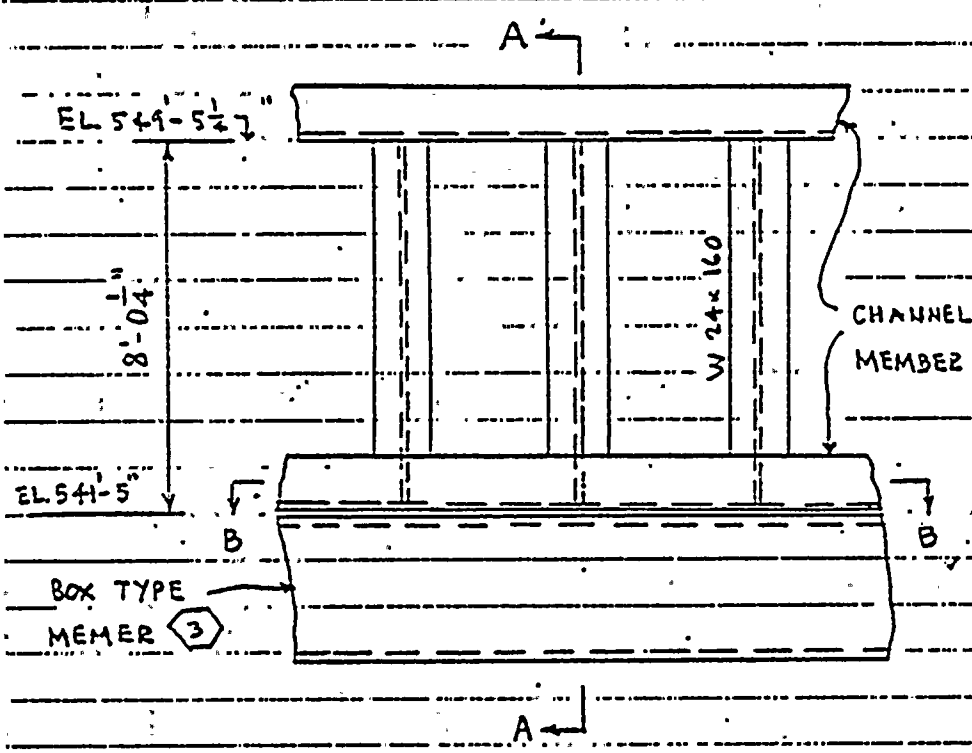
W.O. No. 3900-03 Date 3/5/80 Book No. SV 479 Page No. 55
Drawing No. S-783 Calc. No. 6.19.37 Sheet 11 of 24
By [signature] Checked [signature] 7/9/80 Approved [signature] 7/21/80
Title WPPSS - HANFORD No. 2 - REACTOR BLDG - SACRIFICIAL SHIELD WALL

SUBJECT: CORRECTION MEASURES AT INTERFACE EL. 541'-5"

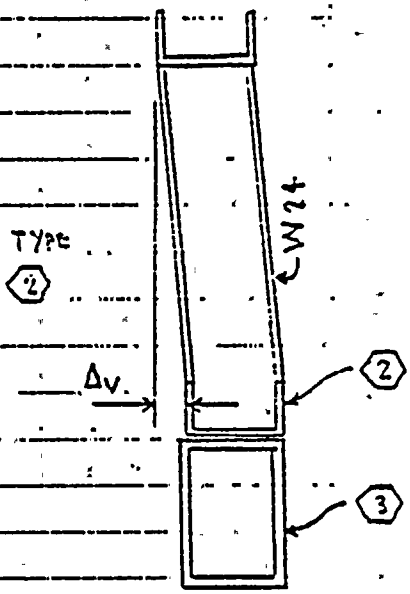
I. EFFECT OF AS-BUILT DEVIATIONS FROM DESIGN CONFIGURATION

1. MAGNITUDE OF AS-BUILT DEVIATIONS

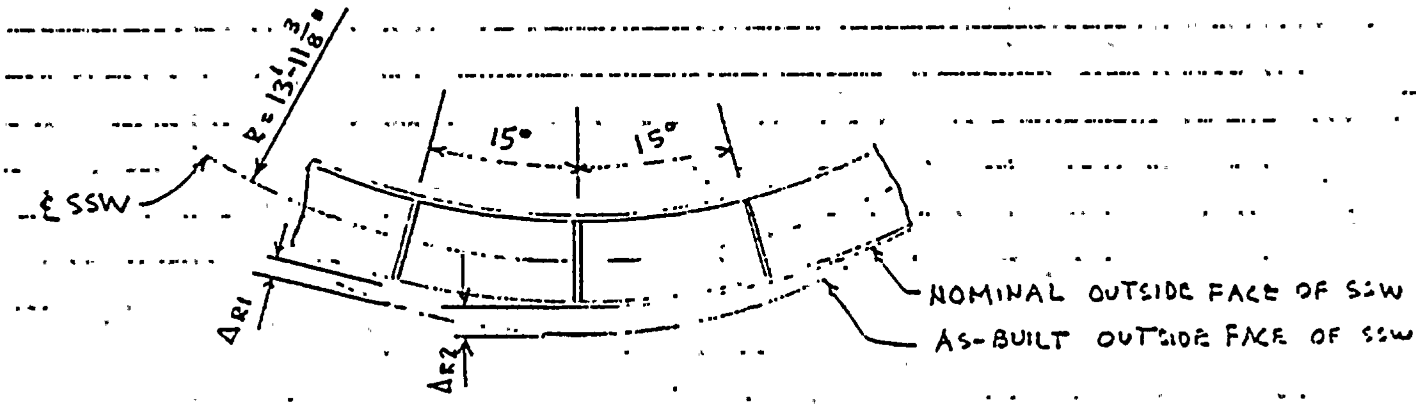
a. DIAGRAMS ILLUSTRATING DEVIATIONS



ELEVATION OF SSW SHOWING MEMBERS



SECTION A-A
SHOWING VERTICAL DEVIATION



SECTIONAL PLAN B-B
SHOWING DEVIATION FROM CIRCLE

SUBJECT: CORRECTION MEASURES AT INTERFACE EL. 541'-5"

I. EFFECT OF AS-BUILT DEVIATIONS FROM DESIGN CONFIGURATION

1. MAGNITUDE OF AS-BUILT DEVIATIONS

b. DETERMINATION OF MAGNITUDE OF DEVIATIONS BY REVISED TOLERANCES

(1) GENERAL

THE AS-BUILT DEVIATIONS USED IN THESE CALCULATIONS ARE BASED ON THE MOST CONSERVATIVE INTERPRETATION OF REVISED ERECTION TOLERANCES REQUESTED BY THE SSW ERECTION CONTRACTOR TOGETHER WITH SUPPLEMENTARY FIELD CHECK OF THE DEVIATIONS.

(2) APPROVED REVISED ERECTION TOLERANCES

CONTRACT 215 TRANSMITTAL NO. 3CBR 215-437D, DATED 10/18/76, (BR FILE NO. 215-00-0282) APPROVES REQUEST BY THE ERECTION CONTRACTOR FOR REVISIONS OF THE SSW ERECTION TOLERANCES AS NOTED BELOW. COPY OF THE APPROVED REVISIONS IS INCLUDED HEREWITH.

(a) TOLERANCE ON CIRCULARITY

THE MAXIMUM TOLERANCE FROM CIRCULARITY IS ± 0.90 INCHES IN LIEU OF PREVIOUS ± 1/8 INCH.

(b) TOLERANCE ON VERTICALITY

THE MAXIMUM HORIZONTAL DEVIATION OF THE WALL AT THE TOP EL. 567'-4½" FROM THE VERTICAL LINE THROUGH THE CORRESPONDING POINT IN THE BASE OF THE WALL IS ± 0.90 INCHES IN LIEU OF ± 0.25 INCHES.

(3) MOST CONSERVATIVE INTERPRETATION OF THE APPROVED TOLERANCES RESULTS IN DEVIATION VALUES NOTED BELOW. THESE VALUES ARE USED IN THE CALCULATIONS HEREINAFTER.

(a) CIRCULARITY - THE MAXIMUM TOLERANCE SHALL BE TAKEN TO OCCUR AT ONE COLUMN RELATIVE TO THE ADJACENT COLUMNS ON EITHER SIDE. THUS $\Delta_{ci} - \Delta_{c_{i+1}} = \Delta_{ci} - \Delta_{c_{i-1}} = 0.90 - (-0.90) = 1.80''$.

(b) VERTICALITY - THE MAXIMUM TOLERANCE SHALL BE TAKEN TO OCCUR AT A COLUMN BETWEEN EL. 541'-5" AND EL 549'-5¼". THUS $\Delta_V = 0.90 - (-0.90) = 1.80''$.

BURNS AND ROE, INC.

W.O. No. 3900-03 Date 3/6/80 Book No. SV 489 Page No. 57
Drawing No. S-783- Calc. No. 6.19 37 Sheet 13 of 24
By [illegible] Checked [illegible] 7/9/80 Approved [illegible] 7/21/80
Title WPPSS-HANFORD NO.2-REACTOR BLDG-SACRIFICIAL/SHIELD WALL

SUBJECT : CORRECTION MEASURES AT INTERFACE EL. 541'-5"

I. EFFECT OF AS-BUILT DEVIATIONS FROM DESIGN CONFIGURATION

1. MAGNITUDE OF AS-BUILT DEVIATIONS

c. FIELD CHECK OF AS-BUILT DEVIATIONS

(1) AS-BUILT INFORMATION

FIELD MEASUREMENTS PERTINENT TO VERTICAL AND CIRCULAR DEVIATIONS HAVE RECENTLY BEEN MADE AND ARE INCLUDED HEREWITH. THIS AS-BUILT INFORMATION IS DISCUSSED BELOW.

(2) VERTICAL DEVIATION : Δ_V, SEE DIAGRAM ON SHEET 11.

TABLE A OF THE FIELD MEASUREMENTS SHOWS THAT THE MAXIMUM VALUE OF Δ_V IS

MAX. Δ_V = 5/8 INCH AT AZIMUTH 0°.

(3) CIRCULAR DEVIATION : $\Delta_{R_i} - \Delta_{R_{i+1}}$, SEE DIAG. ON SHEET 11.

PRECISE DETERMINATION OF CIRCULAR DEVIATION IS NOT PRACTICAL DUE TO INTERFERENCE OF EXISTING CONSTRUCTION. AS A MEASURE OF THE CIRCULAR DEVIATION, THE RADIAL DEVIATION BETWEEN BOX BEAM ⟨3⟩ BELOW THE INTERFACE AND CHANNEL BEAM ⟨2⟩ ABOVE THE INTERFACE IS USED.

TABLE B OF THE FIELD MEASUREMENTS SHOWS THAT THE MAXIMUM VALUE OF $\Delta_{R_i} - \Delta_{R_{i+1}}$ IN 15° AZIMUTH IS

$$MAX.(\Delta_{R_i} - \Delta_{R_{i+1}}) = 1\tfrac{3}{4} - \tfrac{3}{4}$$

= 1 INCH BETWEEN AZIMUTHS 310° & 295°.

d. COMPARISON OF MAX. DEVIATIONS - REVISED TOLERANCES VS. AS-BUILT INFORMATION

DEVIATION TYPE	REVISED TOLERANCES (PAR 1b)	AS-BUILT INFO. (PAR 1c)
Δ_V	1.8"	.625"
$\Delta_{R_i} - \Delta_{R_{i+1}}$	1.8"	1.00"

IT IS NOTED THAT DEVIATIONS BASED ON REVISED TOLERANCES ARE MORE THAN TWICE AS GREAT AS THOSE BY AS-BUILT INFORMATION.

2. CONCLUSION

CONSERVATIVELY, CALCULATIONS HEREIN ARE BASED ON DEVIATIONS USING REVISED TOLERANCES.

Form BR 8002.2

BURNS AND ROE, INC.

W.O. No. 3900-03 Date 3/7/80 Book No. SV 489 Page No. 58
Drawing No. S-783 Calc. No. 6.11.37 Sheet 14 of 24
By M. [signature] Checked [signature] 7/9/80 Approved [signature] 7/21/80
Title WPPSS - HANFORD NO 2 - REACTOR BLDG - SACRIFICIAL SHIELD WALL

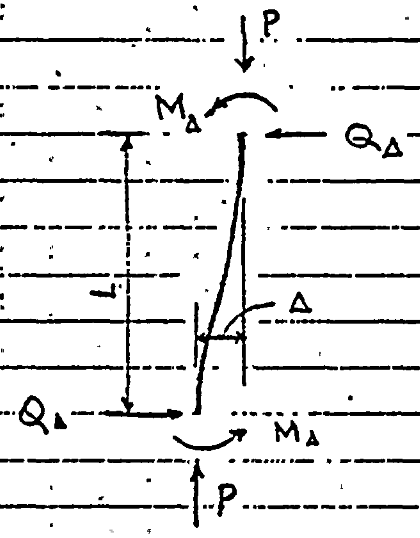
SUBJECT: CORRECTION MEASURES AT INTERFACE EL. 541'-5"

I. EFFECT OF AS-BUILT DEVIATIONS FROM DESIGN CONFIGURATION

2. CONCEPT FOR ANALYSIS

a. THE DEVIATIONS OF THE AS-BUILT SSW FRAMEWORK FROM THE DESIGN CONFIGURATION ARE TREATED AS SECOND ORDER DEFLECTIONS.
REF: ASCE MANUAL NO. 41, "PLASTIC DESIGN IN STEEL", 2ND EDITION, 1971, CHAPTER 10; P Δ EFFECTS, PP 246, 247.

b. THE DEVIATIONS FOR A MEMBER IN CONJUNCTION WITH THE AXIAL FORCE IN THE MEMBER CAUSE ADDITIONAL END MOMENTS AND SHEARS AS SHOWN BELOW.



FROM EQUILIBRIUM CONSIDERATIONS:

$$P\Delta = Q_\Delta L + 2M_\Delta$$

c. CONSERVATIVELY, THE ADDITIONAL END MOMENT M_Δ AND THE ADDITIONAL END SHEAR Q_Δ WILL EACH BE EVALUATED AS THOUGH THE OTHER IS NON-EXISTANT.

$$M_\Delta = \frac{P\Delta}{2}$$

$$Q_\Delta = P\frac{\Delta}{L}$$

Form BR 8002-2

SUBJECT: CORRECTION MEASURES AT INTERFACE EL. 541'-5"

I. EFFECT OF AS-BUILT DEVIATIONS FROM DESIGN CONFIGURATION

3. INCREASE IN STRESS RESULTANTS DUE TO DEVIATIONS

a. DUE TO VERTICAL DEVIATION

AXIAL COLUMN LOAD = P_V = 316.5^k

Δ_V = 1.8" COLUMN L = 96"

(1) ADDITIONAL COLUMN END MOMENT

$$\delta M_V = \frac{P_V \Delta_V}{2} = \frac{316.5 \times 1.8}{2} = 285.0^{\text{"k}}$$

$$\delta f_b = \frac{\delta M_V}{S} = \frac{285.0}{414.} = 0.7^{k/\square"}$$ ADDITIONAL FLEXURAL STRESS : NOT SIGNIFICANT

(2) ADDITIONAL COLUMN RADIAL SHEAR

$$\delta H_{R1} = -\frac{P_V \Delta_V}{L} = -\frac{316.5 \times 1.8}{96} = -5.93^k$$

b. DUE TO CIRCULAR DEVIATION

AXIAL (HORIZONTAL) LOAD IN RING CHANNEL ⟨2⟩ = P_H = 327.0^k

$\Delta_{R_n} - \Delta_{R_{n+1}} = \Delta_{R_n} - \Delta_{R_{n-1}}$ = 1.8" LENGTH (15° ARC) = 44"

(1) ADDITIONAL END MOMENT IN CHANNEL

$$\delta M_R = \frac{P_H (\Delta_{R_n} - \Delta_{R_{n+1}})}{2} = \frac{327. \times 1.8}{2} = 294.3^{\text{"k}}$$

$$\delta f_b = \frac{\delta M_R}{S} = \frac{294.3}{460} = 0.64^{k/\square"}$$ ADDITIONAL FLEXURAL STRESS NOT SIGNIFICANT

(2) ADDITIONAL RADIAL SHEAR IN CHANNEL

$$\delta H'_{R2} = \frac{P_H (\Delta_{R_n} - \Delta_{R_{n+1}})}{L} = \frac{327. \times 1.8}{44} = 13.38^k$$

$$\delta H'_{R2} = \frac{P_H (\Delta_{R_n} - \Delta_{R_{n-1}})}{L} = \frac{327. \times 1.8}{44} = 13.38$$

$$\delta H_{R2} = \quad = 26.76^k$$

BURNS AND ROE, INC.

W.O. No. 3900-03 Date 3/10/80 Book No. SV 489 Page No. 60
Drawing No. S 783 Calc. No. 6.17.37 Sheet 16 of 24
By M. Fielkow Checked 7/9/80 Approved 7/21/80
Title WPPSS - HANFORD NO.2 - REACTOR BLDG - SACRIFICIAL SHIELD WALL

SUBJECT : CORRECTION MEASURES AT INTERFACE EL. 541'-5"

I. EFFECT OF AS-BUILT DEVIATIONS FROM DESIGN CONFIGURATION

4. EFFECT OF ADDITIONAL RADIAL SHEAR ON CORRECTION WELD

a. HORIZONTAL FORCES PER PANEL

(1) DUE TO DEVIATIONS

ADDITIONAL RADIAL FORCE = 5.93 + 13.38 + 13.38 = 32.7^k AT COL. WEB

(2) DUE TO PRIMARY LOADS

RADIAL FORCE = 27.4^k

TANGENT FORCE = 327.0^k

(3) TOTAL HORIZONTAL FORCES

RADIAL FORCE AT COL. WEB = 32.7 + 27.4 = 60.1^k

TANGENTIAL FORCE = 327.0^k

b. WELD STRESS RESULTANTS

REFER TO PAR. H3.

TANGENTIAL : $f_T = \frac{327.0}{33.0} = 9.91\ ^k/''$

RADIAL : $f_{R1} = \frac{163.5 \times 24 \times 6}{33^2} = 21.62\ ^k/''$

$f_{R2} = \frac{60.1 \times .5}{5} = 6.01\ ^k/''$

MAX. SHEAR FORCE PER INCH = $\left[9.91^2 + (21.62 + 6.01)^2\right]^{\frac{1}{2}}$
$= 29.4\ ^k/''$

c. MAX. PERMISSIBLE WELD SHEAR PER INCH

$f_M = 1.6 \times 21 \times 1.87 = 62.8\ ^k/''$

d. DESIGN MARGIN WITH AS-BUILT DEVIATIONS

$D.M. = \frac{62.8}{29.4} = 2.14$ o.k.

BURNS AND ROE, INC.

W.O. No. 3900-03 Date 3/11/80 Book No. SV-429 Page No. 61
Drawing No. 5773 Calc. No. 6.19.37 Sheet 17 of 24
By M. [illegible] Checked [illegible] 7/9/80 Approved [illegible] 7/21/80
Title WPPSS - HANFORD NO. 2 - REACTOR BLDG. - SACRIFICIAL SHIELD WALL

SUBJECT : CORRECTION MEASURES AT INTERFACE EL. 541'-5"

I. EFFECT OF AS-BUILT DEVIATIONS FROM DESIGN CONFIGURATION

5. CONCLUSIONS

a. ADDITIONAL BENDING STRESSES

THE DEVIATIONS CAUSE ADDITIONAL BENDING STRESSES IN THE VERTICAL COLUMNS AND THE CHANNEL RING BEAMS, BOTH LOCATED ABOVE THE INTERFACE. HOWEVER THE MAGNITUDE OF THIS STRESS INCREASE USING VERY CONSERVATIVE VALUES FOR THE DEVIATIONS IS LESS THAN 1 K.S.I. SO THAT SIGNIFICANT EFFECT ON CAPACITY IS NOT INVOLVED.

b. ADDITIONAL HORIZONTAL LOAD ON INTERFACE CORRECTION WELD

ADDITIONAL RADIAL SHEAR LOAD ALONG THE LINE OF THE COLUMN WEB RESULTS FROM THE DEVIATIONS. THE DESIGN MARGIN FOR THE CORRECTION WELD WITH THE ADDITIONAL RADIAL LOAD IS 2.1 COMPARED TO THE DESIGN MARGIN OF 2.3 WITHOUT THIS LOAD.

c. SUMMARY

THE PROPOSED CORRECTION AT INTERFACE EL. 541'-5" HAS SUFFICIENT CAPACITY TO SUPPORT THE REQUIRED LOADS WITH A DESIGN MARGIN OF 2.1 OR MORE, TAKING INTO ACCOUNT THE AS-BUILT CONFIGURATION OF THE SHIELD WALL.

BURNS AND ROE, INC.
W.O. 3900-03 DATE 3/11/80
BOOK # SV-489 PAGE 62
CALC. # 6.19.37
SHEET # 18 OF 24
BY [illegible] CHECKED [illegible] 7/2/80

CONTRACT
215-00-30282
WASHINGTON PUBLIC POWER SUPPLY SYS. WPPSS NUCLEAR PROJECT NO. 2 W. O. 2808
BURNS AND ROE, INC. ORADELL, N.J.-HEMPSTEAD, N.Y.-LOS ANGELES, CAL.
REVIEWED AS CHECKED BELOW
☐ APPROVED FOR FABRICATION .... A
☐ NOT APPROVED .... NA
☒ APPROVED AS NOTED FOR FABRICATION ...... AN
☐ FOR INFORMATION ONLY I
SUBJECT TO ALL CONTRACTUAL PROVISIONS
THIS REVIEW DOES NOT IMPLY ACCEPTANCE OF ANY MATERIAL OR EQUIPMENT NOT FULFILLING ALL SPECIFICATION REQUIREMENTS.
K. Fox / JDT — 10-28-76
PROCESSED BY — DATE

WPPSS NUCLEAR PROJECT NO. 2

BOVEE & CRAIL CONSTRUCTION CO.
AND GENERAL ENERGY RESOURCES, INC.
A JOINT VENTURE

CONTRACT NO. 2808-215

TRANSMITTAL NO. BCBR-215-437D

ITEM: LFEP-1 LC
REV 3

SECTION: 5B

APPROVED BY: DATE

Q. A. [signature] 10-18-76

ENGR. [signature] 10-18-76

Leckenby

BURNS AND ROE, INC.	
W.O. 3900-03	DATE 3/11/80
BOOK # SV 439	PAGE 63
CALC. # 6.19.37	
SHEET # 19	OF 24
BY WJ	CHECKED 7.6.80

IV PAINTING

IV - A SHOP PAINTING (Not Required)

IV - B FIELD PAINTING

The following procedure shall be used for the surface preparation and coating of the steel for the Sacrificial Shield Wall.

Surfaces of the SSW to be painted are:

1. All outboard and inboard surfaces, including skin plates and exposed surfaces of beams and columns
2. All exposed surfaces of shieldwall openings
3. The top surface of the SSW at elevation 567' - 4-1/2"
4. The stabilizer truss and miscellaneous brackets at the top of the SSW
5. All surfaces of the shieldwall opening doors and their components

Paint is not required in the areas of the SSW which are filled with concrete.

Cleaning: Prior to painting all surfaces to be blast cleaned per Spec. SSPC-SP-10.

Painting: All surfaces after blast cleaning to receive one prime coat of No. 6548 epoxy white primer manufactured by Keeler & Long, Inc. Dry film thickness to be not less than 2.5 mil.

Repair: Any repair to be done must follow above procedure of cleaning and painting.

See Attachment VI-C, "Painting and Cleaning Procedure".

CHECKED BY B & C/G.E.R.I.
JOB #215

Rev. 3, 10-4-76

Leckenby

V. SPECIFICATIONS & TOLERANCES

Leckenby Company takes exception to the tolerances specified in the contract drawings and specifications for fabrication and erection of the SSW. As provided for in Burns & Roe specification Section 15A, Attachment 3, Paragraph 2.2, we are presenting along with our construction procedure, the necessary tolerances for the fabrication and erection of the SSW required to achieve the intent of the design drawings. Our proposal is based upon the tolerance changes as noted in the following items 1, 2, 3 and 4. See Attachment VI-A, "Tolerance Control in Fabrication of SSW".

1. Specification Section 15A, Attachment 3, page 15A-133, para. 4, states, "The maximum tolerance from circularity is established as 1/8 inch."

   However, on Page 15-131, paragraph 2.2, it was recognized that the tolerances set forth in paragraph 4.0 were tight and the general contractor had the right to submit alternate procedures, including appropriate tolerances, to insure fabrication and erection of the wall in accordance with the intent of Section 15A.

   Leckenby Company proposes the wall to be built with the following tolerances. The difference between maximum and minimum diameters to be:

$$\frac{311.5 \text{ inch} + 50}{200} = 1.80 \text{ inches}$$

   which means that the I.D. of the wall would fall inside two circles 1.8" apart. By this interpretation maximum tolerance from circularity will be .90", in lieu of 1/8" as defined in specifications.

   It is recognized that these tolerances might have an impact on other parts of the overall containment assemblies, and Leckenby Company proposes to submit to the Owner all "as-built" dimensions for his approval. Any dimensions not conforming with the foregoing proposal, that do not meet with the Owner's approval, shall be changed in accordance with the Contract Change Order Procedure. However, if the above tolerances do not permit the wall to be installed in the manner stipulated, that is to permit the upper SSW to be installed pre-fabricated, these changes will be to the General Contractor's account.

2. Note 5 on Drawing S-782, Rev. 10, states, "The erection of structural steel shall be considered plumb and acceptable if the tolerance does not

Leckenby

exceed ±1/4" at elevation 567' - 4-1/2" (top of wall)."

Leckenby Company proposes the following:

"The erection of structural steel shall be considered plumb and acceptable if the tolerance does not exceed ± .90" at elevation 567' - 7-1/4".

3. Note 5 also states, "Tolerance of vertical elevation of the sacrificial shield elevation of the sacrificial shield ring beam at elevation 567' - 4-1/2", reference shall be ±1/8".

Leckenby Company proposes the following:

"Tolerance of vertical elevation of the sacrificial shield ring beam at elevation 567' - 4-1/2", reference shall be ±1/4" in lieu of specified ±1/8".

4. Tolerance in setting the base bearing plate:

Drawing S-836, Rev. A, Note 3.8, states that the top surface of the bearing be level within 1/32".

Leckenby Company proposes the following:

"The top surface of the bearing plate shall be level within 1/4 inch."

DATE 10/29/76

TRANSMITTAL # 437D

CONTRACTOR 215

TITLE LFEP-1

REVIEWED BY: MJ Giannini MJG

DISPOSITION AN

DATE DUE

COMMENTS:

BURNS AND ROE, INC.
W.O. 3900-03 DATE 3/11/80
BOOK # SV 489 PAGE 16
CALC. # 6.19.37
SHEET # 21A OF 24
BY MJ CHECKED [illegible] 7/1/80

This transmittal 437D is AN with following comments:

"Final approval pending submittal of complete information on oil and effect of radiation on oil."

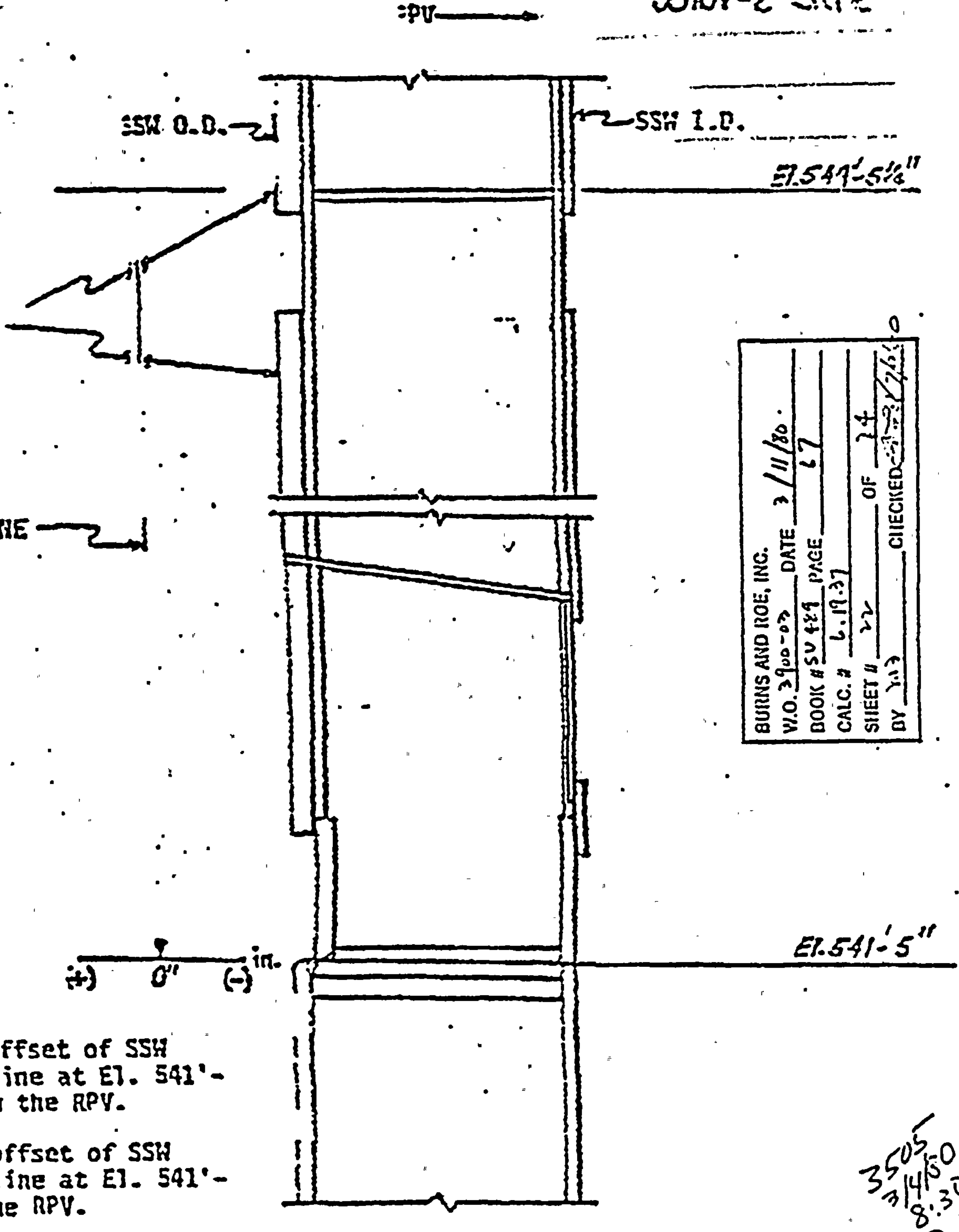
SKETCH A

Telecopy

To: M. Fialkow } B&R
J. O'Donnell } NY

From: D. Timmins
WNP-2 Site

PLUMB LINE ILLUSTRATION
(Ref. Dwg. S783)



BURNS AND ROE, INC.
W.O. 3900-07 DATE 3/11/80
BOOK # SV 484 PAGE 67
CALC. # 6.19.37
SHEET # 22 OF 24
BY [illegible] CHECKED [illegible]

(+) Horizontal offset of SSW from plumb line at El. 541'-5" away from the RPV.

(-) Horizontal offset of SSW from plumb line at El. 541'-5" toward the RPV.

3505
3/14/80
8:30

TABLE A

ESW VERTICAL DEVIATION

El. 549'-5½" to 541'-5"

BURNS AND ROE, INC.
W.O. 3900-03 DATE 3/11/81
BOOK # SV 479 PAGE 68
CALC. # 6.19.37
SHEET # 23 OF 24
BY [illegible] CHECKED [illegible]

AZIMUTH	HOR. OFFSET (IN.) POS. (+)	HOR. OFFSET (IN.) NEG. (-)	AZIMUTH	HOR. OFFSET (IN.) POS. (+)	HOR. OFFSET (IN.) NEG. (-)
0°	5/8"		255°	3/8"	
10° ~~15°~~	1/4"		270°	5/8"	
30°	3/8"		285°	1/2"	
45°	Skipped		300°	1/2"	
60°	1/8"		315°	Skipped	
75°	1/4"		330°	1/2"	
90°	1/8"		350° ~~345°~~	1/4"	
105°	1/4"				
110° ~~120°~~	3/8"				
135°	Skipped				
150°	1/8"				
165°	Skipped				
180°	0"				
191° ~~195°~~		1/8"			
210°		1/8"			
225°	1/8"				
248° ~~240°~~	0"				

DATA ORIGINATOR ______________________ DATE __________

DATA CHECKER ______________________ DATE __________

TABLE B

DATA ORIGINATOR ____________

DATA CHECKER ____________

DATE ____________

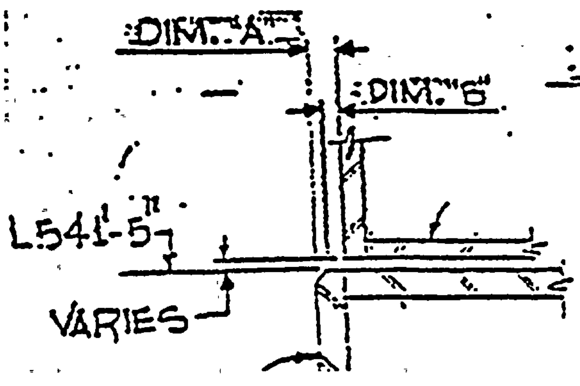
EN LEDGE WIDTH

EL. 541'-5"

AZIMUTH	DIM. "A"	DIM. "B"	AZIMUTH	DIM. "A"	DIM. "B"
5°	1 3/4	1 1/8	185°	2	1 1/4
10°	1 5/8	1 1/8	190°	1 7/8	1 3/8
20°	1 2/8	1	200°	1 3/4	1 1/4
25°	Skipped	—	205°	1 1/2	1 1/8
35°	1 3/8	7/8	215°	1 1/4	7/8
40°	1 1/2	1	220°	1 1/4	7/8
50°	1 5/8	1 1/4	230°	1	7/8
55°	Skipped	—	235°	Skipped	—
65°	1 3/8	7/8	245°	1	1/2
70°	1 1/2	1	250°	1	5/8
80°	1 1/2	1 1/8	250°	1 1/8	5/8
85°	1 1/2	7/8	265°	7/8	1/2
95°	7/8	1/2	275°	7/8	1/2
100°	5/8	1/2	280°	7/8	1/2
110°	5/8	3/8	290°	3/4	1/2
115°	5/8	1/8	295°	3/4	5/8
125°	Skipped	—	305°	Skipped	—
130°	1	1/2	310°	1 3/4	1 1/2
140°	1 1/8	5/8	320°	1 3/8	1 1/8
145°	1 1/8	5/8	325°	1 1/2	7/8
155°	1 1/4	3/4	335°	Skipped	—
160°	1 1/8	3/4	340°	1 5/8	1 1/4
170°	1 3/8	1	350°	1 1/8	1/2
175°	1 5/8	1	355°	1 5/8	1 1/8

BURNS AND ROE, INC.
W.O. 2910-69 DATE 3/11/80
BOOK # SV 471 PAGE 69
CALC. # 6.19.3
SHEET # 24 OF 24
BY ____ CHECKED ____ 7/ /80

REF. DWG. 5783



NOTE:

DIM. "A" EQUALS TOTAL WIDTH OF LEDGE, IN.

DIM. "B" EQUALS PORTION OF LEDGE NOT BEVELED, IN.

ANALYSIS AND DESIGN OF SACRIFICIAL SHIELD WALL

This paper discusses certain structural aspects of the Sacrificial Shield Wall as originally designed. It does not address itself specifically to any of the concerns which are taken up elsewhere but furnishes pertinent background information relative to these concerns.

In connection with the analysis and design of the shield wall, it is first noted that the principal methods used are described in Report No. WPPSS-74-2-R2-B. which was approved by the Commission by letter dated October 15, 1975. The methods used are in conformance with Standard Review Plan 3.8.3. In particular, this conformance holds for the types of loads considered and for the load combination and acceptance criteria which were used.

The Sacrificial Shield Wall is analyzed as a steel framework made up of horizontal circumferential members (ring beams) and vertical columns assembled in cylindrical form. The skin plates which cover the inner and outer surfaces of the wall are included in the analysis as joined to the framework members. The wall extends vertically from its base support on the concrete pedestal to its top where it is supported horzontally by the stabilizer truss spanning between the SSW and the primary containment.

The structural model used in the analysis is shown in Figure 1. The model consists of 378 members, 136 plate elements and 229 joints. Continuity of the beams and columns at the joints is assumed corresponding to full strength welded connections. The inner and outer plates are treated as one plate of thickness equal to the combined thickness of both plates; the equivalent plate is joined to the framework on all sides with displacement compatibility at the joints. In the framework action, the beams and columns carry three components each of force and moment and the plates sustain in-plane normal and shear (membrane) stresses. The analysis is a linear elastic analysis and makes use of the commercial computer program, STRUDL. Design is based on the elastic working stress method of Part 1, AISC, 1969.

The structure is analyzed for the required loads and their combinations in accordance with the standards of the NRC as noted previously. The significant loads applicable to the shield wall design and considered in the load combinations include the following:

a. Dead (D) and live loads (L).

b. Operating basis earthquake (E).

c. Safe shutdown earthquake (E').

d. Pressurization of the annulus between the reactor pressure vessel and the shield wall (P_A).

e. Reactions due to pipe break (Y_R).

The above loads are applied to the structural model as concentrated or distributed loads and at locations corresponding to their occurrence. Seismic forces are distributed throughout the structure in accordance with the component masses and accelerations. Annulus pressurizations are included due to postulated breaks in the various recirculation inlet and outlet lines, the feedwater lines and the LPCI lines. Pipe break reactions due to the preceding breaks and due to numerous other postulated breaks occurring in the drywell proper are applied to the framework members which support the pipe restraints.

The magnitudes of the significant loads are such that only the load combinations under factored load conditions need be considered and these load combinations are listed below together with the associated permissible stress.

$$1.6S > D + L + To + Ro + E' \quad (3)$$

$$1.6S > D + L + Ta + Ra + Pa \quad (4)$$

$$1.6S > D + L + Ta + Ra + Pa + Yj + Yr + Ym + E \quad (5)$$

$$1.7S > D + L + Ta + Ra + Pa + Yj + Yr + Ym + E' \quad (6)$$

In most cases, either combination 5 or combination 6 controlled. It is noted that these combinations include all the significant loads previously listed. Other load terms in the above combinations are not significant.

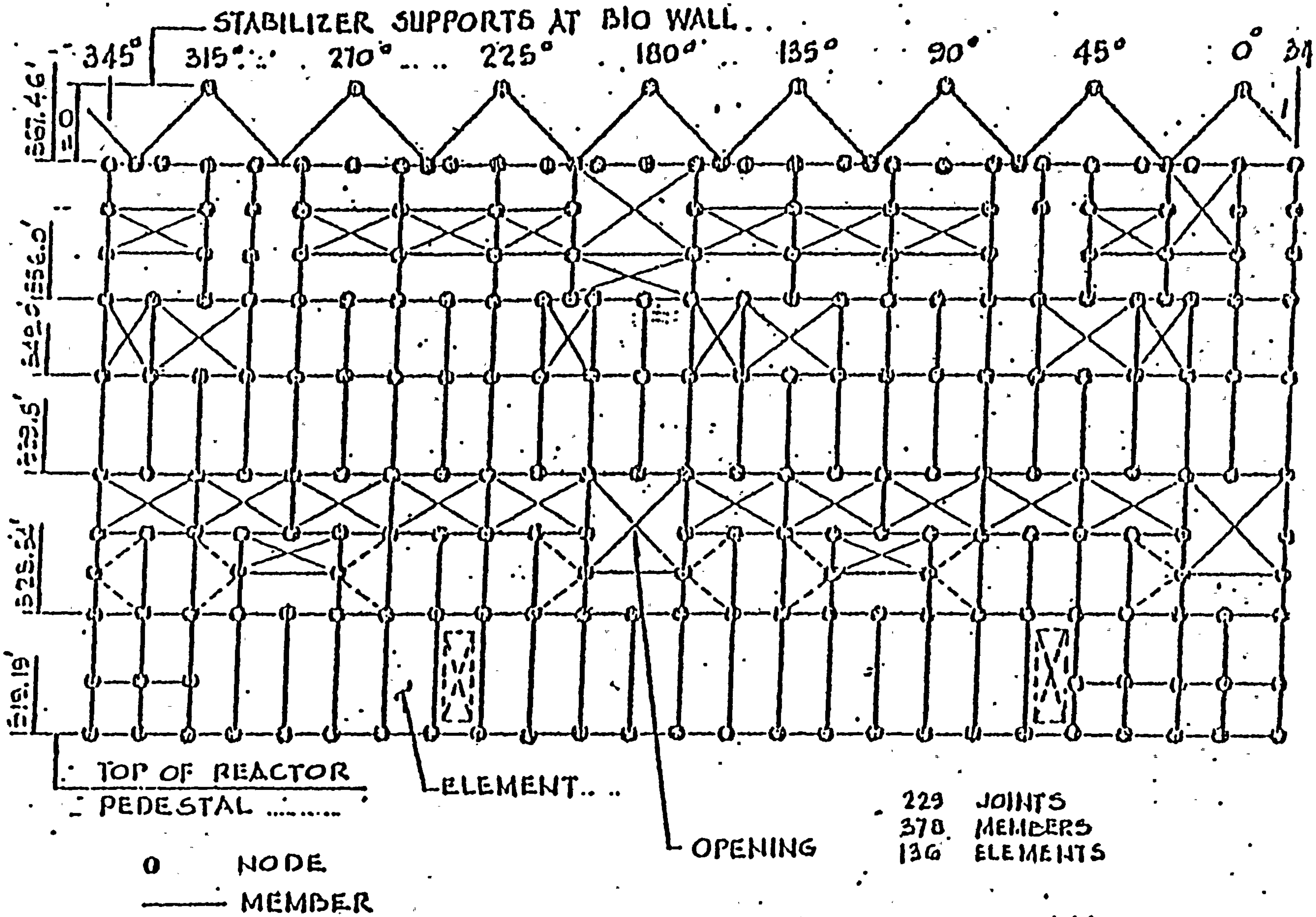
The boundary conditions adopted for the analysis are in conformance with the actual conditions. At each of the 8 joints representing the junctions of the stabilizer truss and the bio-shield wall, the only reaction is in the tangential direction. At each of the 24 boundary nodes along the top of the pedestal with one node located below each of the columns, the restraints are as follows:

a. Vertical deflection is zero.
b. No restraint on radial movement.
c. Horizontal reaction is circumferential.
d. No moment reaction occurs at the joint.

Some of the key points in the design of the shield wall are now noted. As previously stated, the design uses the elastic working stress method, Part 1 of the 1969 AISC design specification. All plates and members in the wall are A36 steel except for the top ring which is high strength A588 steel. Weld metal is E70 series or equivalent.

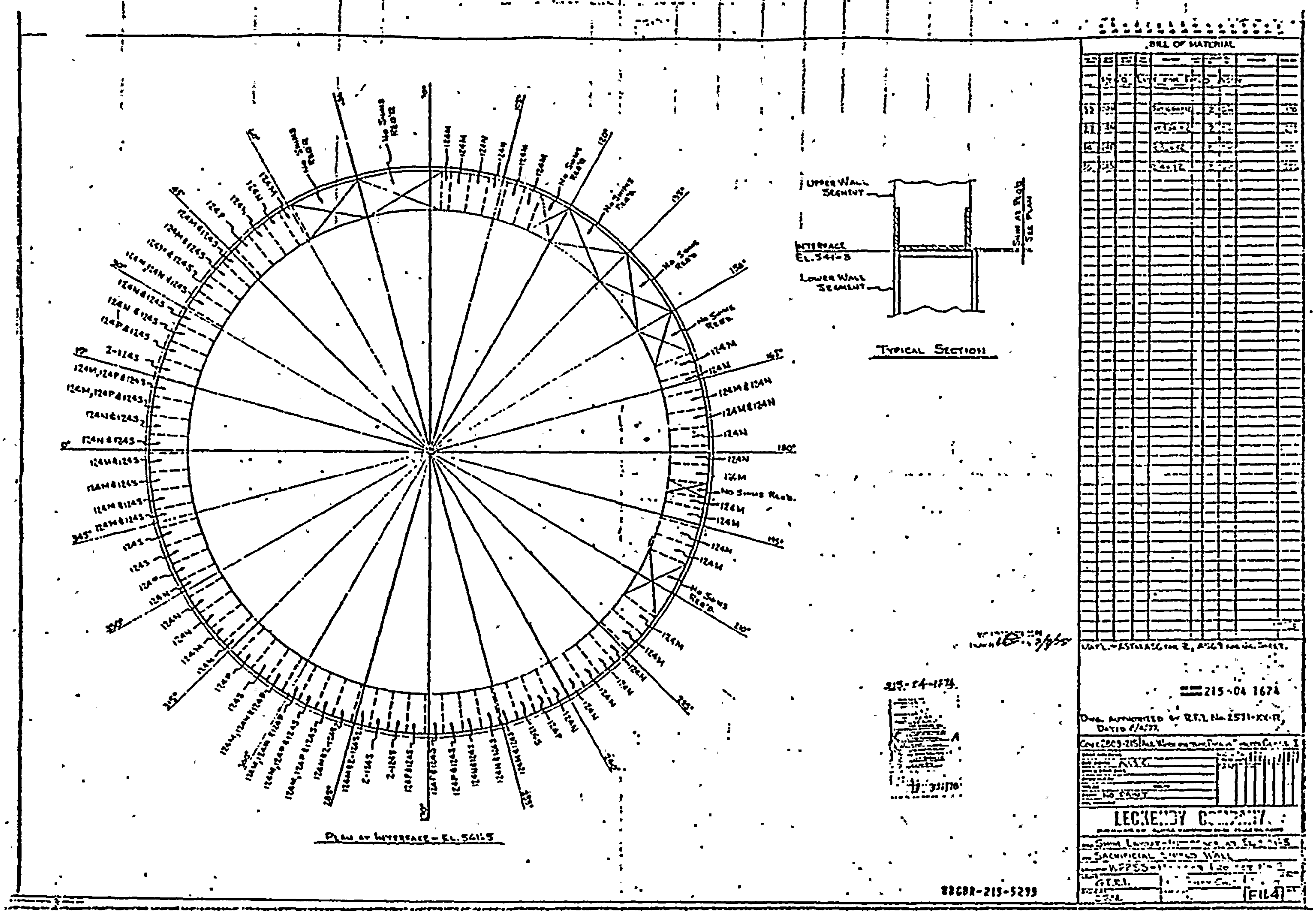
The design of the ring beams and columns starts with the computer output which furnishes 3 components each of force and moment at the ends of all members. Intermediate values of members are obtained as required. Each member type is designed using the controlling stress resultants for that type of member. Full strength welded connections are used at the ends.

The skin plate structural design is based on the computer output which gives the membrane stresses, i.e. the normal and sheer stresses. The plate thickness and attachment welds are determined from the controlling stresses in typical areas of the wall.



COMPUTER MODEL OF THE SACRIFICIAL SHIELD WALL

Figure #1



BILL OF MATERIAL
UPPER WALL SEGMENT
INTERFACE EL. 541-5
LOWER WALL SEGMENT
TYPICAL SECTION
PLAN AT INTERFACE – EL. 541-5
215-04 1674
SACRIFICIAL SHIELD WALL

ATTACHMENT 5

This attachment includes the general SSW erection plan drawing by Leckenby and the Burns and Roe SSW structural design drawings.

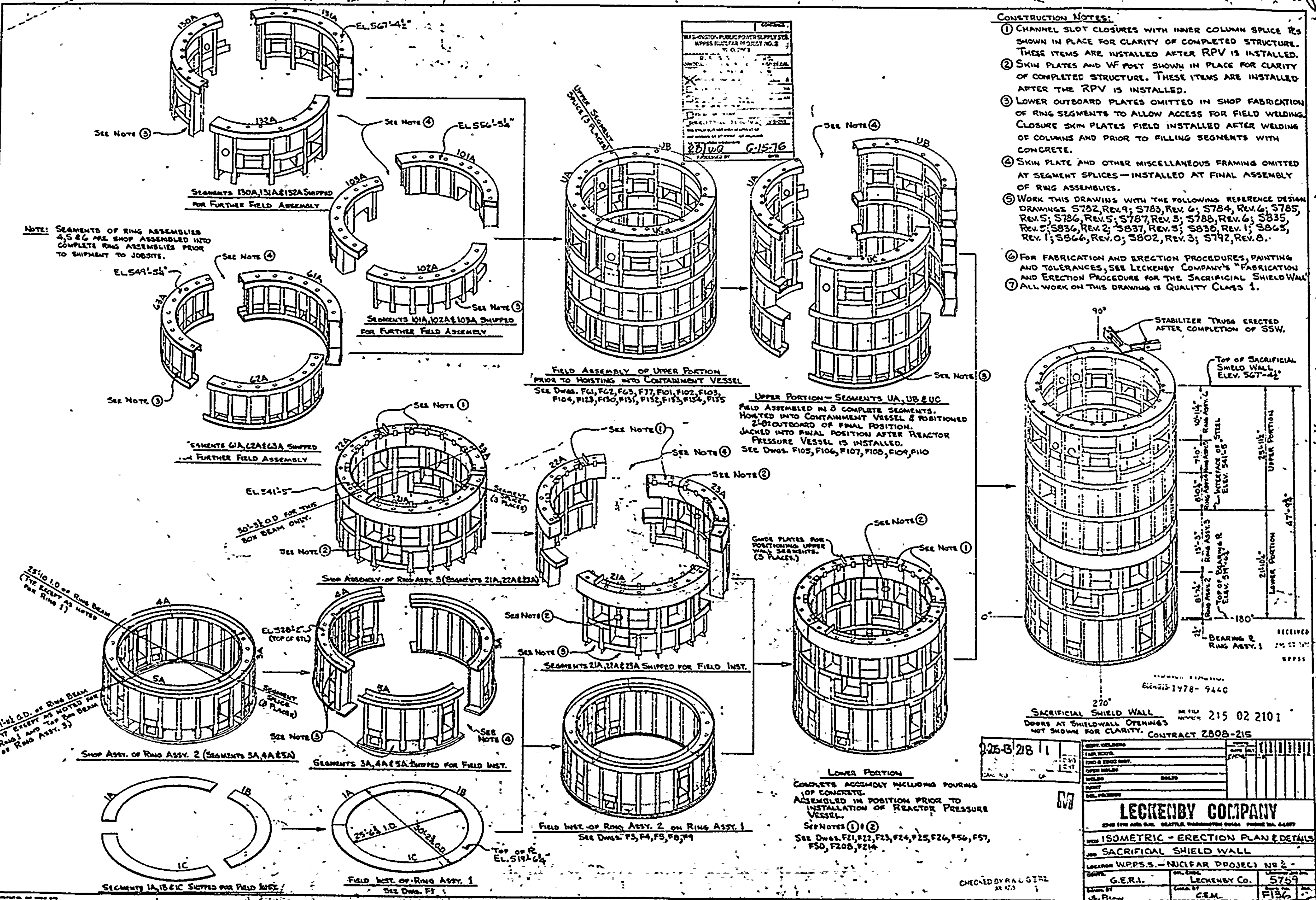
Attached are:

F-136

S-782
S-783
S-784
S-785
S-786
S-787
S-788

S-835
S-836
S-837
S-838

S-865
S-866



Sacrificial Shield Wall

Doors at shieldwall openings not shown for clarity.

Construction Notes:

① Channel slot closures with inner column splice Rs shown in place for clarity of completed structure. These items are installed after RPV is installed.

② Skin plates and WF post shown in place for clarity of completed structure. These items are installed after the RPV is installed.

③ Lower outboard plates omitted in shop fabrication of ring segments to allow access for field welding. Closure skin plates field installed after welding of columns and prior to filling segments with concrete.

④ Skin plate and other miscellaneous framing omitted at segment splices—installed at final assembly of ring assemblies.

⑤ Work this drawing with the following reference design drawings S782, Rev. 9; S783, Rev. 6; S784, Rev. 6; S785, Rev. 5; S786, Rev. 5; S787, Rev. 3; S788, Rev. 6; S835, Rev. 5; S836, Rev. 2; S837, Rev. 5; S838, Rev. 1; S865, Rev. 1; S866, Rev. 0; S802, Rev. 3; S792, Rev. 8.

⑥ For fabrication and erection procedures, painting and tolerances, see Leckenby Company's "Fabrication and Erection Procedure for the Sacrificial Shield Wall"

⑦ All work on this drawing is Quality Class 1.

Contract 2808-215

215 02 2101

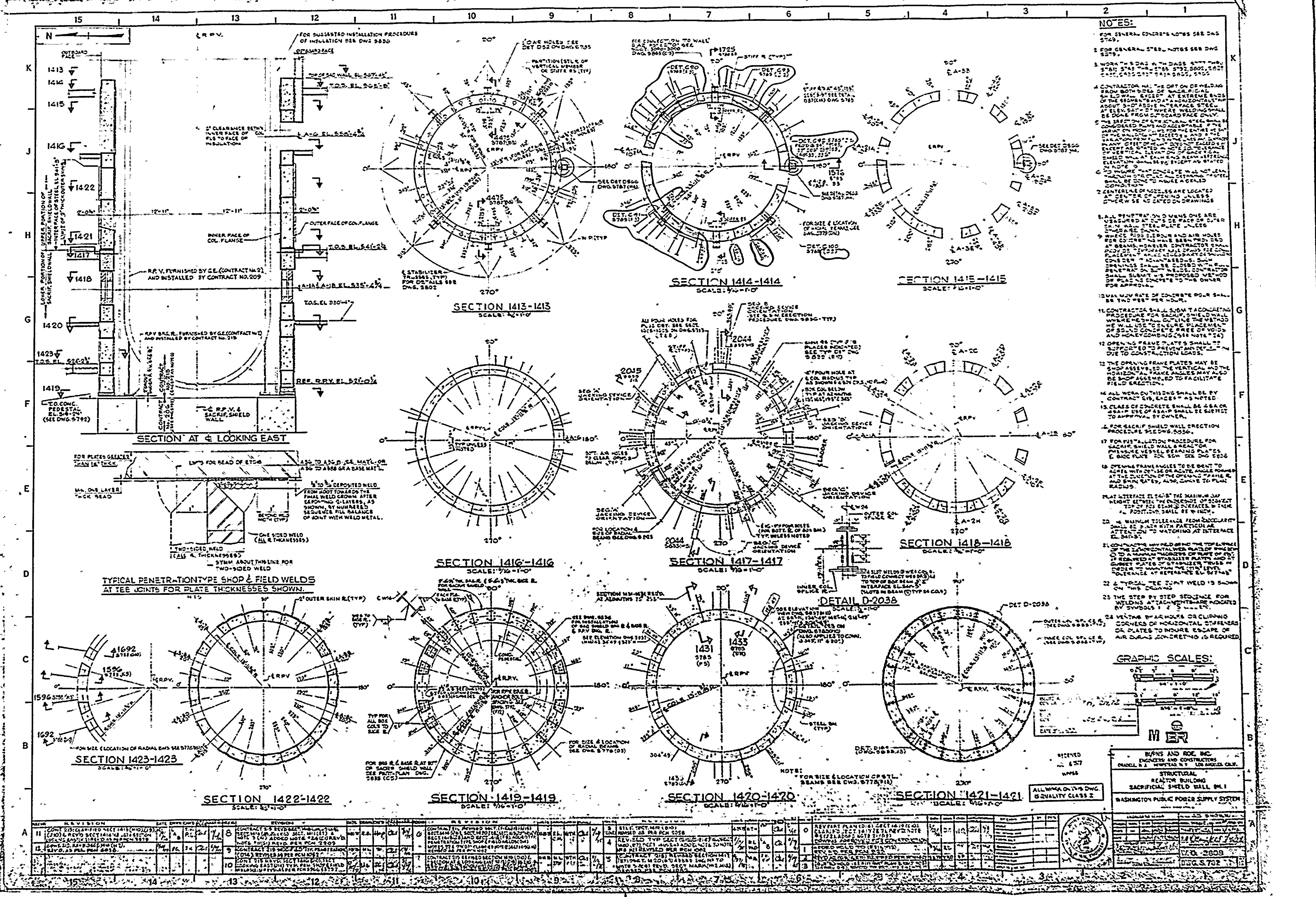
ECC-215-1978-9440

Checked by R.A.C. Gerl

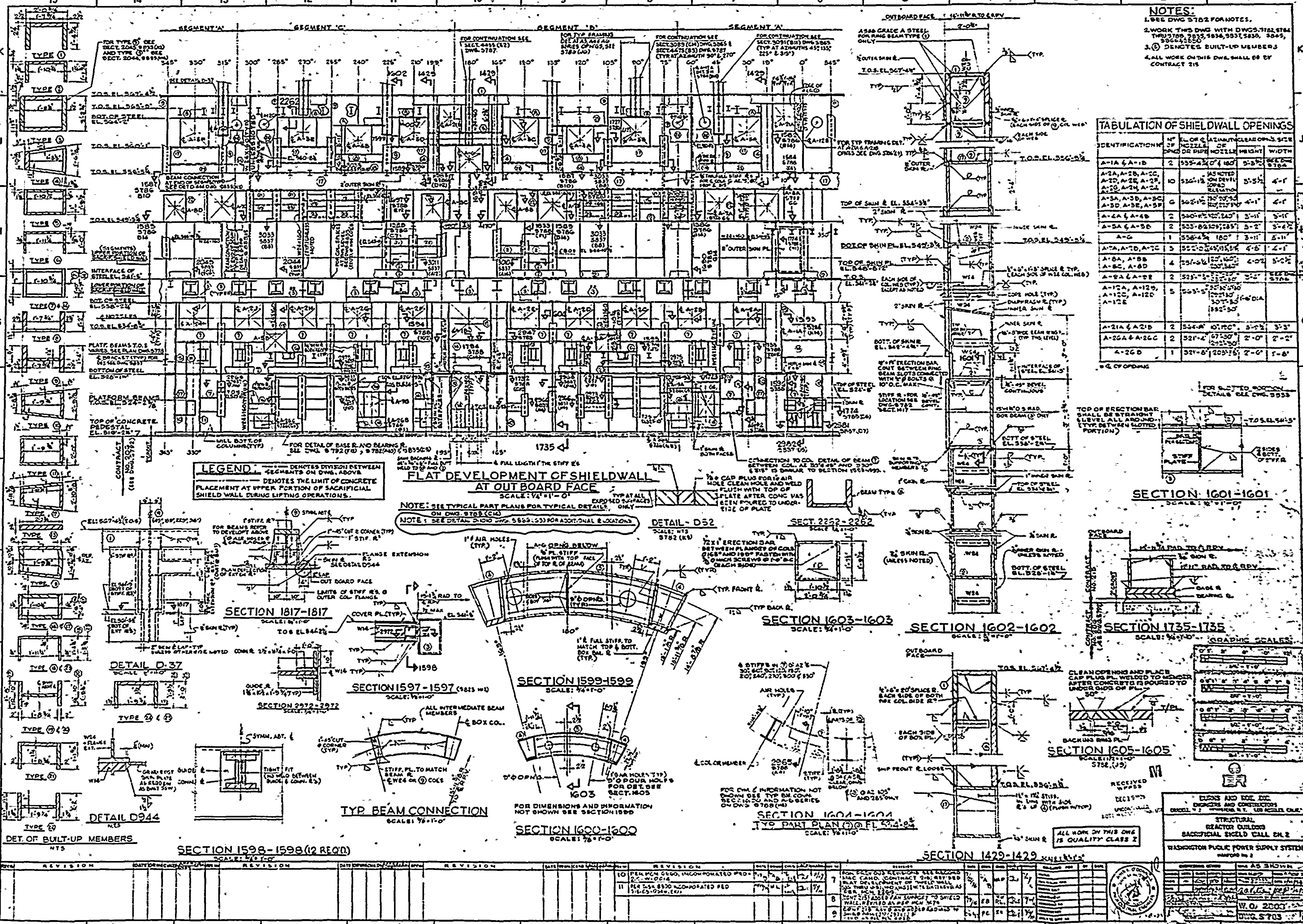
LECKENBY COMPANY

Isometric - Erection Plan & Details
Sacrificial Shield Wall
Location W.P.P.S.S. - Nuclear Project No. 2 -
G.E.R.I. | Leckenby Co. | 5759
S. Bray | C.E.M. | F136

215 02 2101



NOTES:
SECTION AT ℄ LOOKING EAST
TYPICAL PENETRATION TYPE SHOP & FIELD WELDS AT TEE JOINTS FOR PLATE THICKNESSES SHOWN.
SECTION 1413-1413
SECTION 1414-1414
SECTION 1415-1415
SECTION 1416-1416
SECTION 1417-1417
SECTION 1418-1418
DETAIL D-2038
SECTION 1423-1423
SECTION 1422-1422
SECTION 1419-1419
SECTION 1420-1420
SECTION 1421-1421
GRAPHIC SCALES:
BURNS AND ROE, INC.
ENGINEERS AND CONSTRUCTORS
STRUCTURAL
REACTOR BUILDING
SACRIFICIAL SHIELD WALL SH. 1
WASHINGTON PUBLIC POWER SUPPLY SYSTEM
ALL WORK ON THIS DWG. IS QUALITY CLASS I



NOTES:

1. SEE DWG 5782 FOR NOTES.
2. WORK THIS DWG WITH DWGS. 5782, 5784 THRU 5788, 5835, 5836, 5837, 5838, 5845, 5866 & 5850
3. (B) DENOTES BUILT-UP MEMBERS
4. ALL WORK ON THIS DWG. SHALL BE BY CONTRACT 215

TABULATION OF SHIELDWALL OPENINGS

IDENTIFICATION Nº	Nº OF OPNGS	EL. OF ℄ NOZZLE OR PIPE	AZIMUTH OF NOZZLE	CLEAR OPNG. SIZE HEIGHT	CLEAR OPNG. SIZE WIDTH
A-1A & A-1B	2	535'-4¾	0° & 180°	5'-3½	SEE DWG 5704
A-2A, A-2B, A-2C, A-2D, A-2E, A-2F, A-2G, A-2H, A-2J, A-2K	10	526'-1½	AS NOTED ON DEVELOPED ELEVATION	3'-5½	4'-1"
A-3A, A-3B, A-3C, A-3D, A-3E, A-3F	6	562'-1½	[illegible]	4'-1"	4'-1"
A-4A & A-4B	2	550'-[illegible]	[illegible], 240°	3'-11"	3'-11"
A-5A & A-5B	2	533'-8¼	[illegible], 285°	3'-2"	3'-4½
A-6	1	556'-4¾	180°	3'-11"	3'-11"
A-7A, A-7B, A-7C	3	[illegible]	45°, 135°, [illegible]	4'-6"	4'-1"
A-8A, A-8B, A-8C, A-8D	4	531'-6¼	[illegible]	4'-0½	3'-0½
A-9A & A-9B	2	525'-[illegible]	[illegible]	[illegible]	SEE DWG 5706
A-12A, A-12B, A-12C, A-12D, A-12E	5	563'-5"	[illegible], 307°-30', 352°-30'	1'-6" DIA	
A-21A & A-21B	2	526'-[illegible]	10°, 190°	3'-3½	3'-3"
A-26A & A-26C	2	521'-4"	67°-30', 292°-30'	2'-0"	2'-2"
A-26B	1	521'-8"	205°-[illegible]	2'-6"	1'-8"

* ℄ OF OPENING

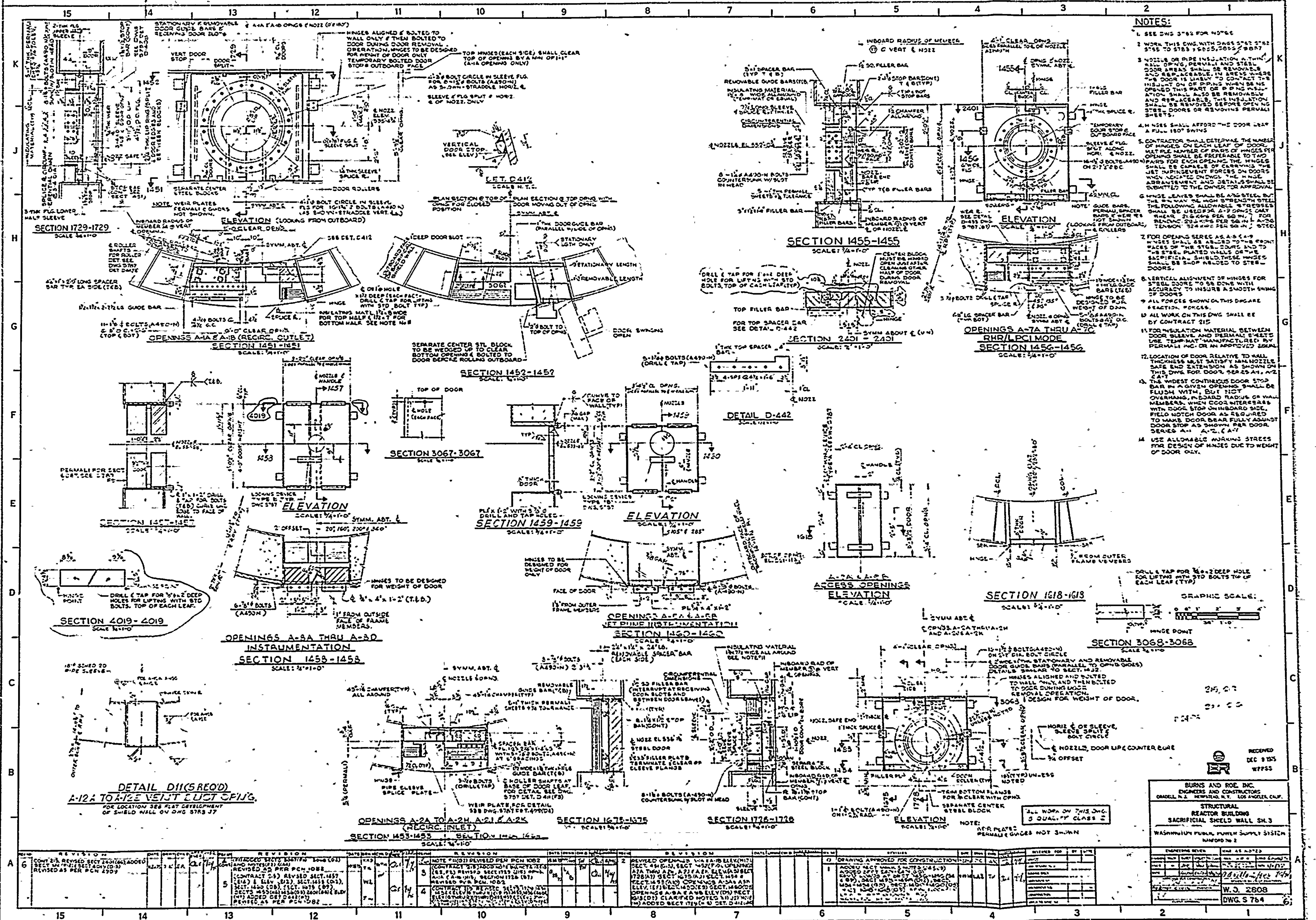
ALL WORK ON THIS DWG IS QUALITY CLASS I

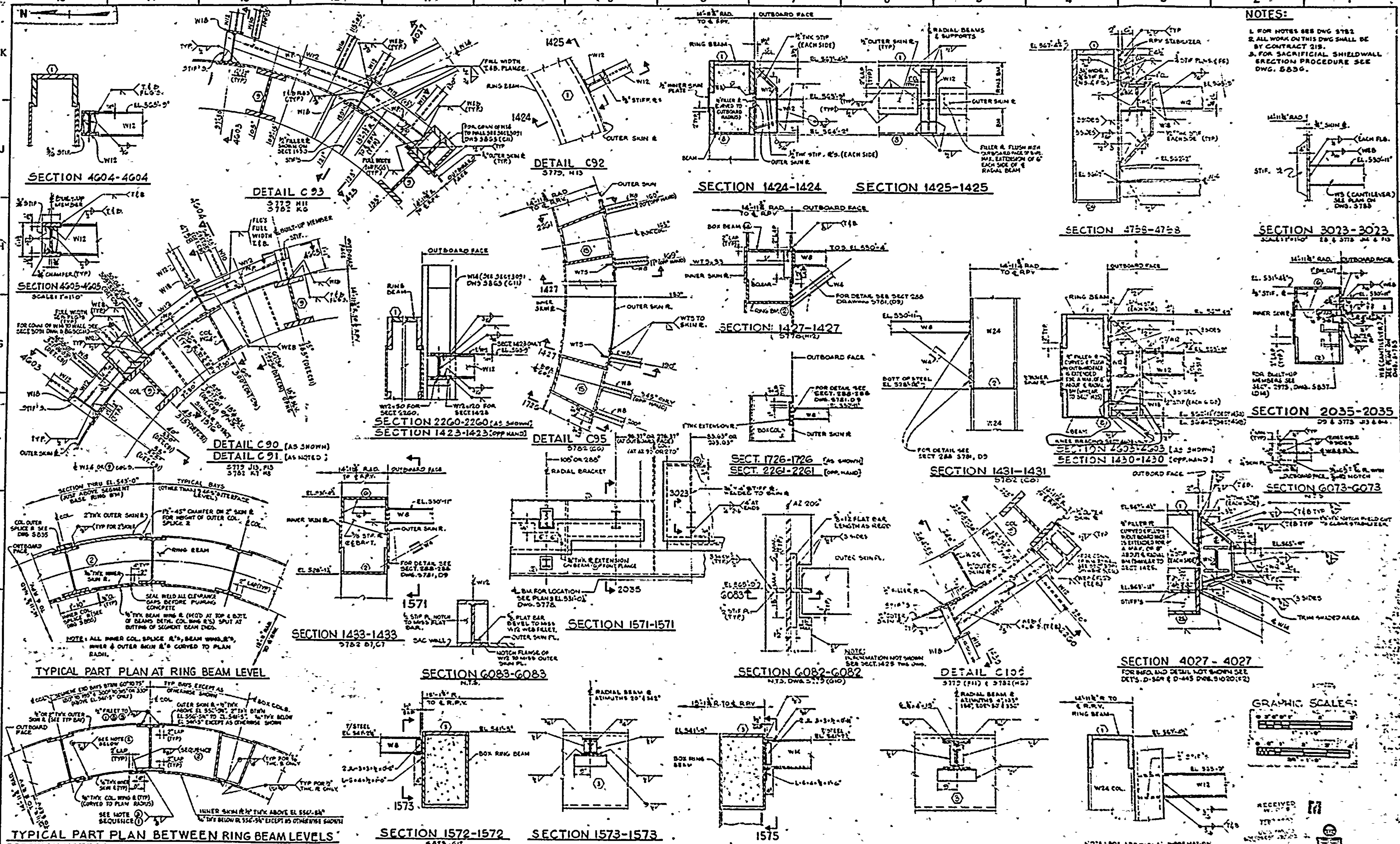
BURNS AND ROE, INC.
ENGINEERS AND CONSTRUCTORS

STRUCTURAL
REACTOR BUILDING
SACRIFICIAL SHIELD WALL SH. 2

WASHINGTON PUBLIC POWER SUPPLY SYSTEM
HANFORD No. 2

SCALE AS SHOWN
W.O. 2003
DWG. 5703


NOTES:
SECTION 1729-1729
ELEVATION (LOOKING FROM OUTBOARD)
OPENINGS A-1A & A-1B (RECIRC. OUTLET)
SECTION 1451-1451
DET. D412
SECTION 1452-1452
SECTION 1455-1455
SECTION 2401-2401
DETAIL D-442
ELEVATION
OPENINGS A-7A THRU A-7C
RHR/LPCI MODE
SECTION 1456-1456
SECTION 1457-1457
ELEVATION
SECTION 3067-3067
SECTION 1459-1459
ELEVATION
SECTION 4019-4019
OPENINGS A-8A THRU A-8D
INSTRUMENTATION
SECTION 1458-1458
OPENINGS A-6A & A-6B
JET PUMP INSTRUMENTATION
SECTION 1460-1460
A-5A & A-5B
ACCESS OPENINGS
ELEVATION
SECTION 1618-1618
SECTION 3068-3068
GRAPHIC SCALE:
DETAIL D11(5 REQ'D)
A-12A TO A-12E VENT DUCT OPNG.
OPENINGS A-2A TO A-2H, A-2J & A-2K
(RECIRC. INLET)
SECTION 1453-1453
SECTION 1675-1675
SECTION 1726-1726
ELEVATION
ALL WORK ON THIS DWG. IS QUALITY CLASS I
RECEIVED
DEC 9 1975
WPPSS
BURNS AND ROE, INC.
ENGINEERS AND CONSTRUCTORS
ORADELL, N.J. HEMPSTEAD, N.Y. LOS ANGELES, CALIF.
STRUCTURAL
REACTOR BUILDING
SACRIFICIAL SHIELD WALL SH. 3
WASHINGTON PUBLIC POWER SUPPLY SYSTEM
HANFORD No. 2
W.O. 2808
DWG. S 764
6



NOTES:

1. FOR NOTES SEE DWG 5782
2. ALL WORK ON THIS DWG SHALL BE BY CONTRACT 215.
3. FOR SACRIFICIAL SHIELDWALL ERECTION PROCEDURE SEE DWG. 5836.

ERECTION NOTES: (SEE DWG 5836 FOR ERECTION PROCEDURE.)

(1) INNER SKIN PL SHALL BE WELDED FROM RPV SIDE OF WALL EXCEPT AS NOTED IN NOTE (2) BELOW
(2) INNER SKIN PL TO BE WELDED FROM OUTBOARD FACE ONLY DURING ERECTION PROCEDURE AFTER SEGMENTS ARE IN FINAL POSITION
(3) COLUMN WING PL'S AS SHOWN ABOVE SHALL BE WELDED CONTINUOUSLY BETWEEN BEAMS PLUS 2" LAP ON HORIZONTAL MEMBERS. THESE WING PLS ARE TO BE PLACED AFTER COLS & BEAMS INVOLVED ARE ERECTED AND FULLY WELDED. COL. WING PLS MAY BE SHOP WELDED TO COLUMNS TO GREATEST EXTEND BUT MUST CLEAR ALL AREAS PREPARED FOR FIELD WELDING OR INNER COL. SPLICE PL @ EL 541'-5"

ALL WORK ON THIS DRAWING IS QUALITY CLASS I

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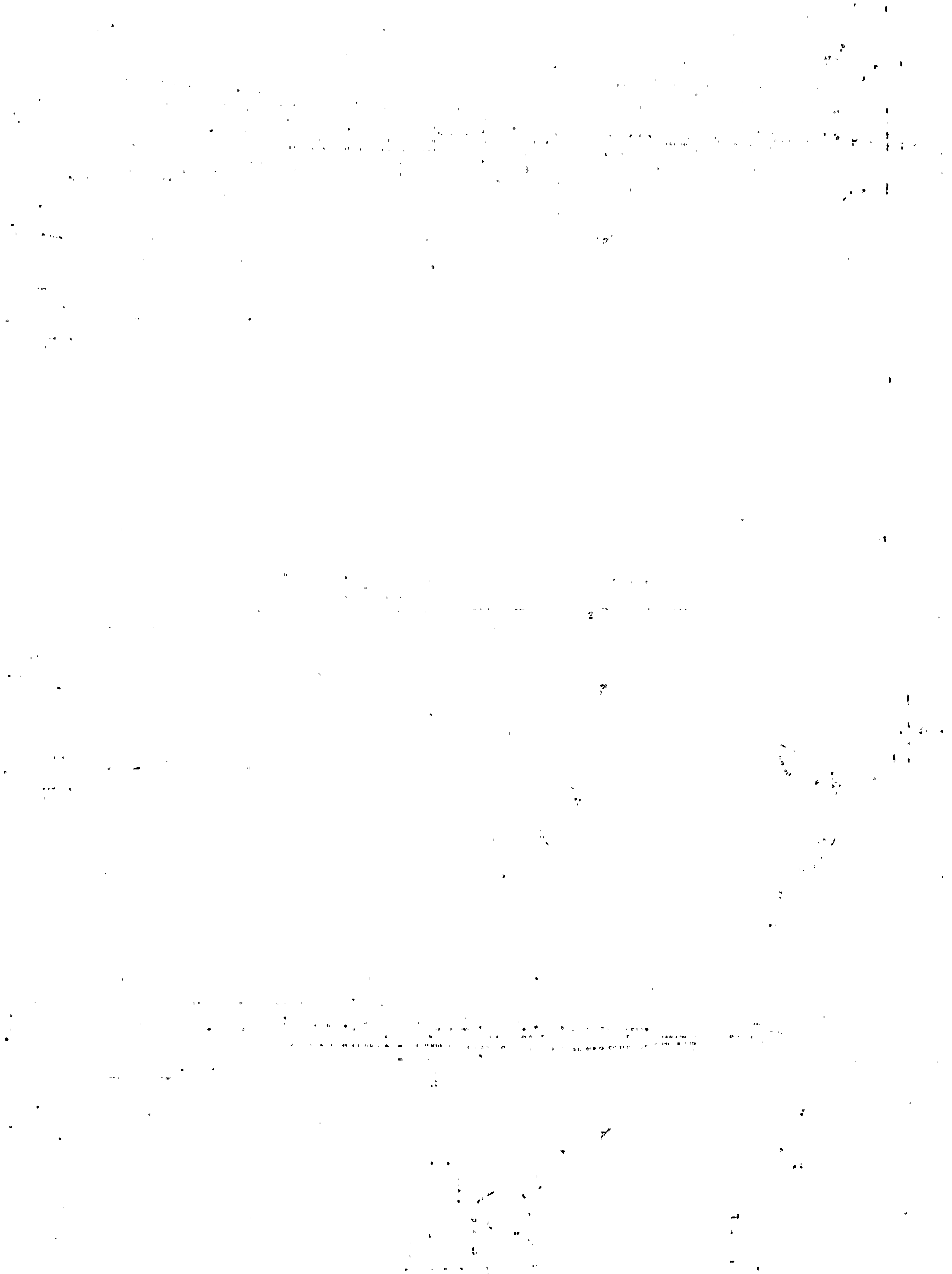
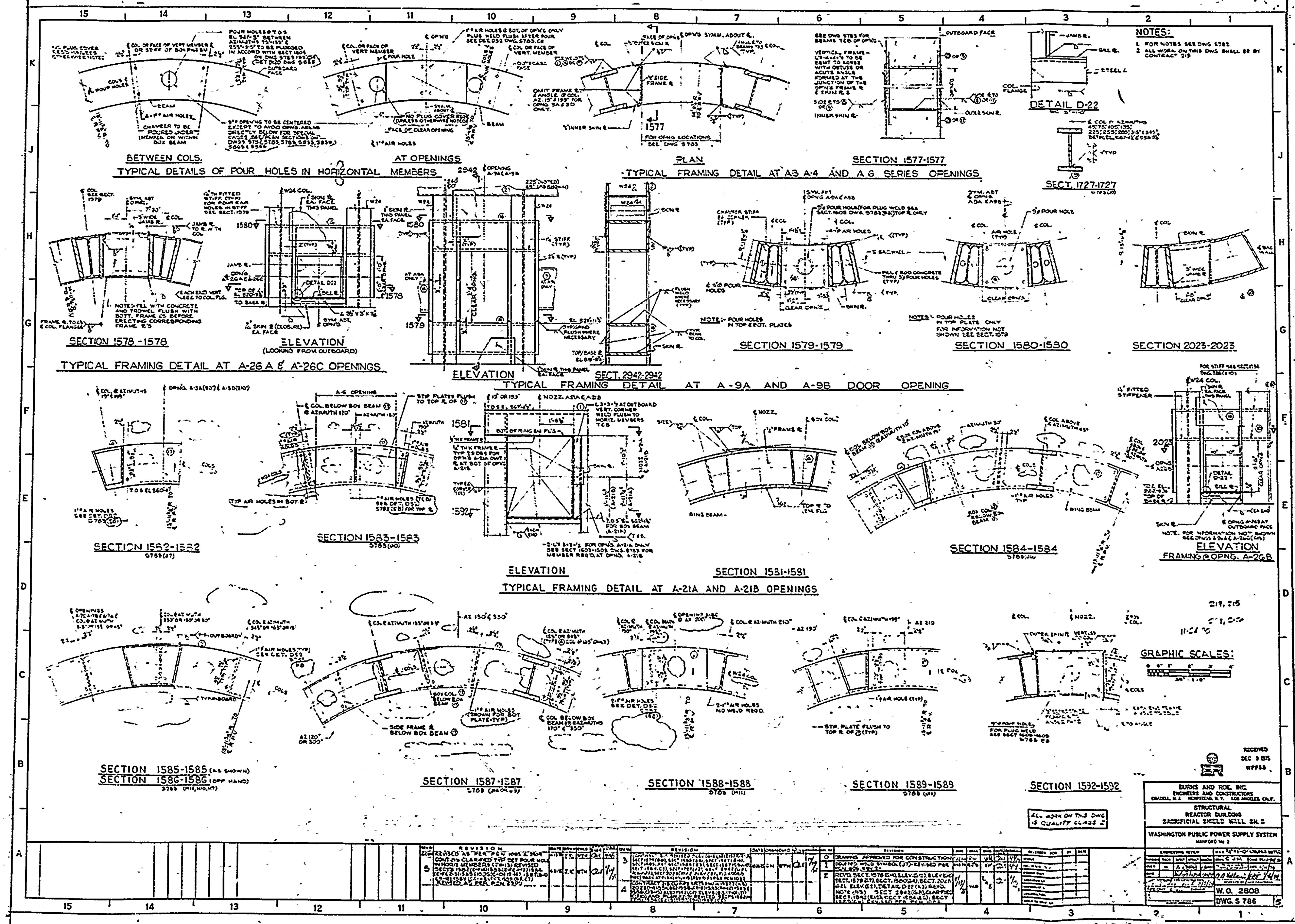
STRUCTURAL
REACTOR BUILDING
SACRIFICIAL SHIELD WALL SH. 4

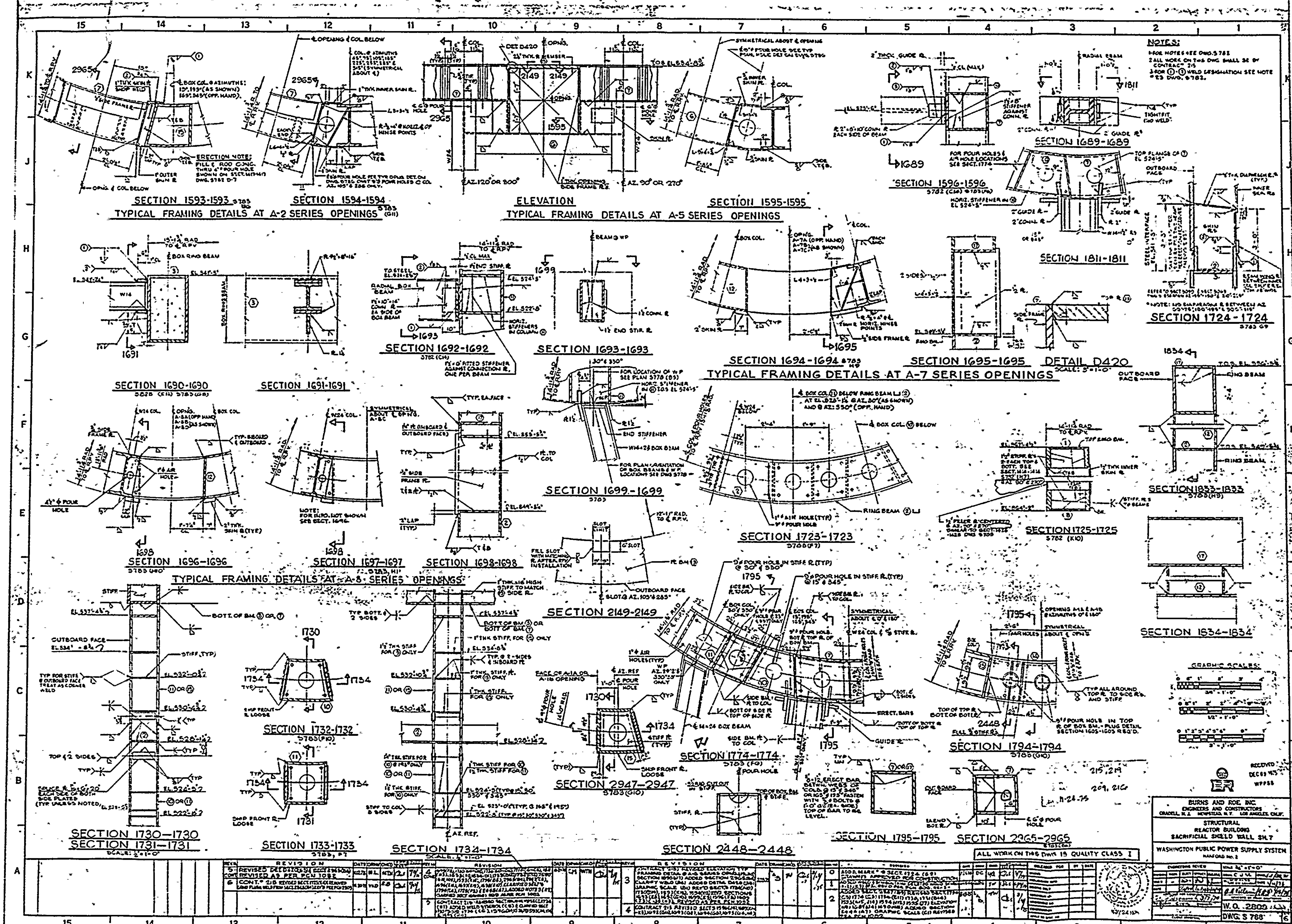
WASHINGTON PUBLIC POWER SUPPLY SYSTEM
HANFORD No. 2

W.O. 12808
DWG. 5785 5





NOTES:
1. FOR NOTES SEE DWG S782
2. ALL WORK ON THIS DWG SHALL BE BY CONTRACT 215
BETWEEN COLS.
AT OPENINGS
TYPICAL DETAILS OF POUR HOLES IN HORIZONTAL MEMBERS
PLAN
SECTION 1577-1577
TYPICAL FRAMING DETAIL AT A3 A-4 AND A 6 SERIES OPENINGS
DETAIL D-22
SECT. 1727-1727
SECTION 1578-1578
ELEVATION
(LOOKING FROM OUTBOARD)
TYPICAL FRAMING DETAIL AT A-26 A & A-26C OPENINGS
ELEVATION
SECT. 2942-2942
TYPICAL FRAMING DETAIL AT A-9A AND A-9B DOOR OPENING
SECTION 1579-1579
SECTION 1580-1580
SECTION 2023-2023
SECTION 1582-1582
SECTION 1583-1583
ELEVATION
SECTION 1581-1581
TYPICAL FRAMING DETAIL AT A-21A AND A-21B OPENINGS
SECTION 1584-1584
ELEVATION
FRAMING @ OPNG. A-26B
GRAPHIC SCALES:
SECTION 1585-1585 (AS SHOWN)
SECTION 1586-1586 (OPP HAND)
SECTION 1587-1587
SECTION 1588-1588
SECTION 1589-1589
SECTION 1592-1592
ALL WORK ON THIS DWG IS QUALITY CLASS 2
RECEIVED DEC 9 1975 WPPSS
BURNS AND ROE, INC.
ENGINEERS AND CONSTRUCTORS
ORADELL, N.J. HEMPSTEAD, N.Y. LOS ANGELES, CALIF.
STRUCTURAL
REACTOR BUILDING
SACRIFICIAL SHIELD WALL SH. 5
WASHINGTON PUBLIC POWER SUPPLY SYSTEM
HANFORD No 2
W.O. 2808
DWG. S 786
5


NOTES:
1-FOR NOTES SEE DWG. S782
2-ALL WORK ON THIS DWG SHALL BE BY CONTRACT 215
SECTION 1593-1593
SECTION 1594-1594
TYPICAL FRAMING DETAILS AT A-2 SERIES OPENINGS
ELEVATION
SECTION 1595-1595
TYPICAL FRAMING DETAILS AT A-5 SERIES OPENINGS
SECTION 1596-1596
SECTION 1689-1689
SECTION 1811-1811
SECTION 1724-1724
SECTION 1690-1690
SECTION 1691-1691
SECTION 1692-1692
SECTION 1693-1693
SECTION 1694-1694
SECTION 1695-1695
DETAIL D420
TYPICAL FRAMING DETAILS AT A-7 SERIES OPENINGS
SECTION 1699-1699
SECTION 1723-1723
SECTION 1725-1725
SECTION 1833-1833
SECTION 1696-1696
SECTION 1697-1697
SECTION 1698-1698
TYPICAL FRAMING DETAILS AT A-8 SERIES OPENINGS
SECTION 2149-2149
SECTION 1834-1834
GRAPHIC SCALES
SECTION 1732-1732
SECTION 1774-1774
SECTION 1794-1794
SECTION 2947-2947
SECTION 1730-1730
SECTION 1731-1731
SECTION 1733-1733
SECTION 1734-1734
SECTION 2448-2448
SECTION 1795-1795
SECTION 2965-2965
ALL WORK ON THIS DWG IS QUALITY CLASS I
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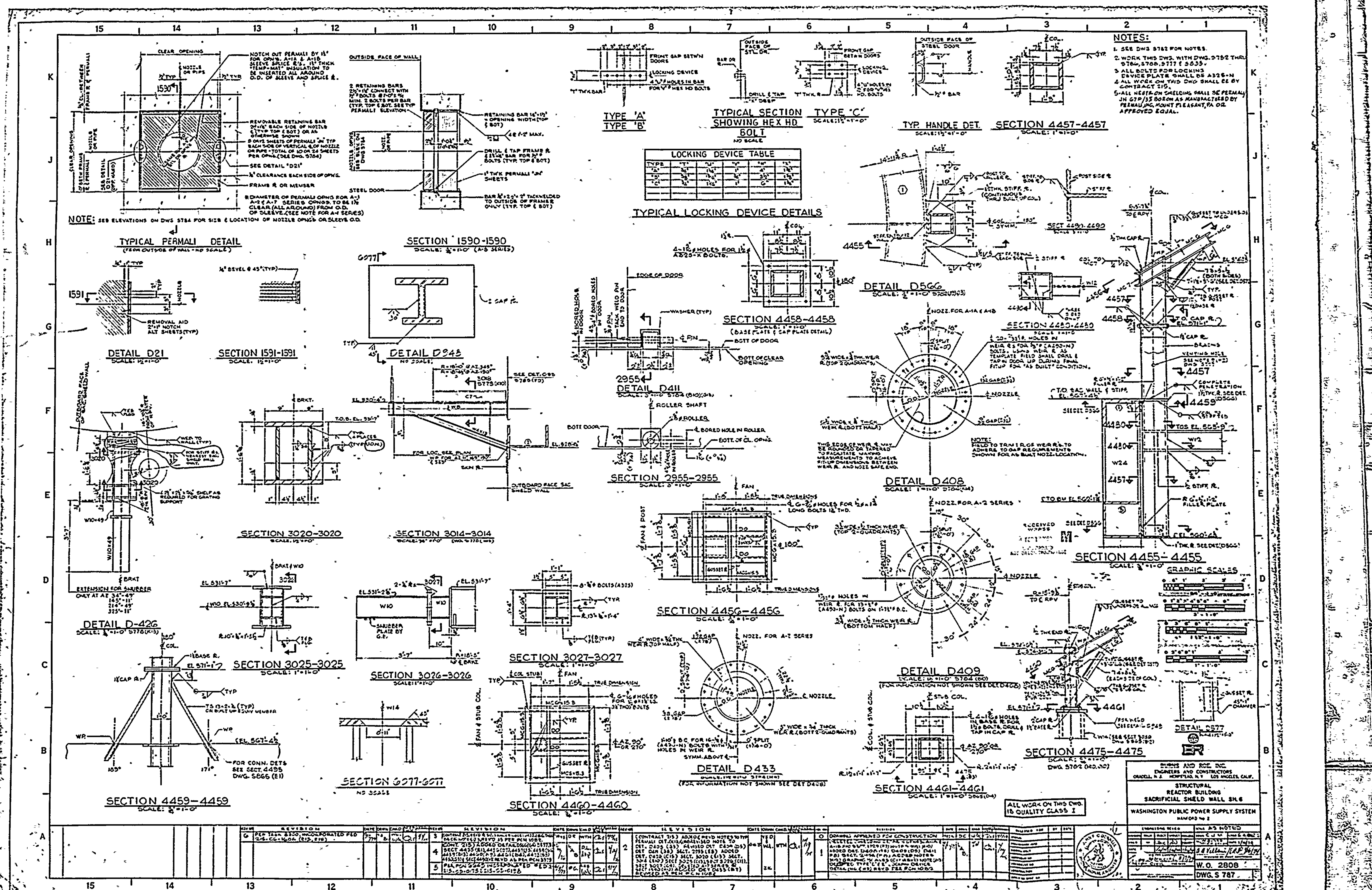
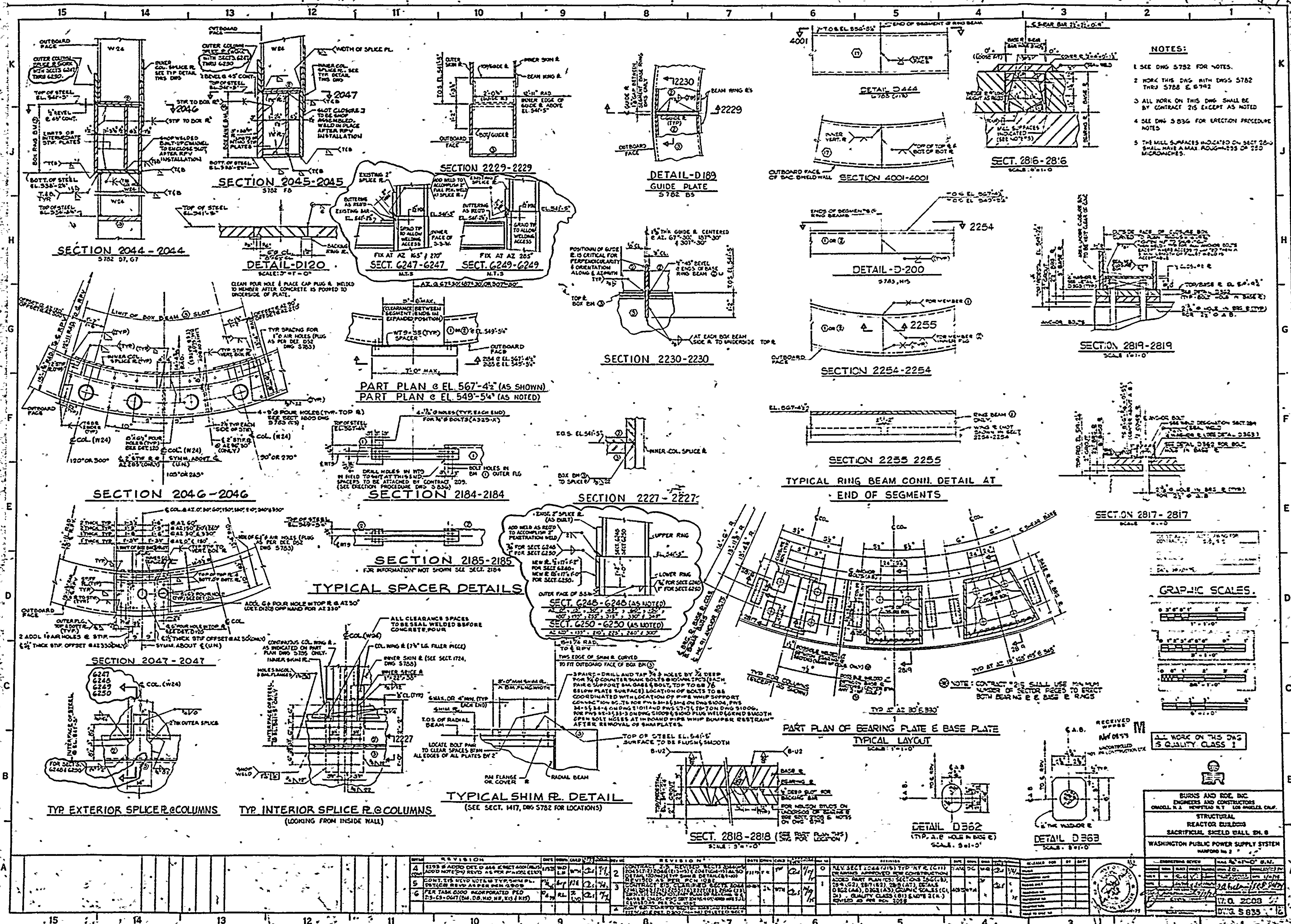
ORADELL, N.J. HEMPSTEAD, N.Y. LOS ANGELES, CALIF.
STRUCTURAL
REACTOR BUILDING
SACRIFICIAL SHIELD WALL SH.7
WASHINGTON PUBLIC POWER SUPPLY SYSTEM
HANFORD No. 2
W.O. 2809
DWG. S 788
6



NOTES:
1. SEE DWG 5782 FOR NOTES.
2. WORK THIS DWG. WITH DWG. 5782 THRU 5786, 5700, 5777 & 5835.
3. ALL BOLTS FOR LOCKING DEVICE PLATE SHALL BE A325-N
4. ALL WORK ON THIS DWG SHALL BE BY CONTRACT 215.
5. ALL NEUTRON SHIELDING SHALL BE PERMALI JN 67P/33 BORON AS MANUFACTURED BY PERMALI INC. MOUNT PLEASANT, PA OR APPROVED EQUAL.
TYPICAL PERMALI DETAIL
SECTION 1590-1590
TYPE 'A'
TYPE 'B'
TYPICAL SECTION SHOWING HEX HD. BOLT
TYPE 'C'
TYP. HANDLE DET.
SECTION 4457-4457
LOCKING DEVICE TABLE
TYPICAL LOCKING DEVICE DETAILS
DETAIL D566
SECTION 4458-4458
DETAIL D21
SECTION 1591-1591
DETAIL D948
DETAIL D411
SECTION 4459-4459
DETAIL D408
SECTION 3020-3020
SECTION 3014-3014
SECTION 2955-2955
SECTION 4455-4455
GRAPHIC SCALES
DETAIL D-426
SECTION 3025-3025
SECTION 3026-3026
SECTION 3027-3027
SECTION 4456-4456
DETAIL D409
SECTION 6077-6077
SECTION 4460-4460
DETAIL D433
SECTION 4461-4461
SECTION 4475-4475
DETAIL D577
ALL WORK ON THIS DWG. IS QUALITY CLASS I
BURNS AND ROE, INC.
ENGINEERS AND CONSTRUCTORS
ORADELL, N.J. HEMPSTEAD, N.Y. LOS ANGELES, CALIF.
STRUCTURAL
REACTOR BUILDING
SACRIFICIAL SHIELD WALL SH. 6
WASHINGTON PUBLIC POWER SUPPLY SYSTEM
HANFORD No 2
AS NOTED
W.O. 2808
DWG. S 787



SECTION 2044 - 2044
SECTION 2045-2045
SECTION 2229-2229
DETAIL-D189
GUIDE PLATE
DETAIL D444
SECTION 4001-4001
SECT. 2816-2816
NOTES:
1 SEE DWG S782 FOR NOTES.
2 WORK THIS DWG WITH DWGS S782 THRU S788 & S792
3 ALL WORK ON THIS DWG SHALL BE BY CONTRACT 215 EXCEPT AS NOTED
4 SEE DWG S836 FOR ERECTION PROCEDURE NOTES
5 THE MILL SURFACES INDICATED ON SECT 2816 SHALL HAVE A MAX. ROUGHNESS OF 250 MICROINCHES.
DETAIL-D120
SECT. 6247-6247
SECT. 6249-6249
DETAIL-D-200
SECTION 2230-2230
SECTION 2254-2254
SECTION 2819-2819
PART PLAN @ EL. 567'-4½" (AS SHOWN)
PART PLAN @ EL. 549'-5¼" (AS NOTED)
SECTION 2046-2046
SECTION 2184-2184
SECTION 2227-2227
SECTION 2255 2255
TYPICAL RING BEAM CONN. DETAIL AT END OF SEGMENTS
SECTION 2817-2817
SECTION 2185-2185
TYPICAL SPACER DETAILS
SECT. 6248-6248 (AS NOTED)
SECT. 6250-6250 (AS NOTED)
GRAPHIC SCALES
SECTION 2047-2047
PART PLAN OF BEARING PLATE & BASE PLATE
TYPICAL LAYOUT
ALL WORK ON THIS DWG IS QUALITY CLASS I
TYP. EXTERIOR SPLICE PL @ COLUMNS
TYP. INTERIOR SPLICE PL @ COLUMNS
(LOOKING FROM INSIDE WALL)
TYPICAL SHIM PL. DETAIL
(SEE SECT. 1417, DWG S782 FOR LOCATIONS)
SECT. 2818-2818
DETAIL D362
DETAIL D363
BURNS AND ROE, INC.
ENGINEERS AND CONSTRUCTORS
STRUCTURAL
REACTOR BUILDING
SACRIFICIAL SHIELD WALL SH. 8
WASHINGTON PUBLIC POWER SUPPLY SYSTEM
HANFORD No. 2
W.O. 2008
DWG S835

NOTES:

1. FOR ADDITIONAL NOTES SEE DWG S782.
2. INSTALLATION PROCEDURE FOR REACTOR PRESSURE VESSEL BEARING PLATE.:
   A) PREPARE THE TOP SURFACE OF THE PEDESTAL FOR GROUTING AS SPECIFIED IN SECTION 3A OF THE SPECIFICATION.
   B) CLEAN BOTTOM OF BEARING PLATE POSITION THE BEARING PLATE AT DESIGN ELEVATION AND ALIGN THE 90° AND 270° TEMPLATE/BEARING PLATE AZIMUTHS WITH THE 90° AND 270° REFERENCES FOR VESSEL ORIENTATION. ALIGN ALL AZIMUTH SCRIBE LINES ON TEMPLATE/BEARING PLATE COINCIDENT WITH THE PRE-ESTABLISHED DATUM LINES OF SIGHT WITHIN 1/16 INCH.
   C) INSTALL THE LEVELING BOLTS IN THE BEARING PLATE AND RE-INSTALL THE BEARING PLATE ON THE PEDESTAL. SET THE TOP OF THE BEARING PLATE TO THE REQUIRED TILT ELEVATIONS SPECIFIED IN SECTION 3.2.2 OF GE DOCUMENT "GENERAL INSTRUCTIONS FOR REACTOR ASSEMBLY" IN APPENDIX [illegible] OF SPECIFICATION USING 12 LEVELING BOLTS. BEARING PLATE AND LEVELING BOLTS FURNISHED BY CONTRACT 2(6.6)
   D)
   E) WHEN NO INFORMATION ABOUT THE VESSEL SKIRT FLANGE OUTAGE IS AVAILABLE THE BEARING PLATE SHALL BE SET LEVEL WITHIN 0.015 INCHES. SEE NOTE 5 FOR DEFINITION OF TERM "LEVEL".
   F) INSTALL WASHERS AND NUTS ON ANCHOR BOLTS TO MAINTAIN BEARING PLATE POSITION DURING GROUTING.
   G) FILL GAP BETWEEN BOTTOM OF BEARING PLATE AND CONCRETE WITH GROUT CONFORMING TO SECTION 3A OF THE SPECIFICATION. A PROCEDURE SHALL BE PREPARED FOR GROUTING UNDER THE BEARING PLATE WHICH SHALL INSURE THAT THE GAP IS COMPLETELY FILLED, WITH NO VOIDS REMAINING AFTER GROUTING. APPROVAL OF THIS PROCEDURE MUST BE OBTAINED FROM OWNER PRIOR TO GROUTING. GROUT TO BE f'c = 5000 PSI.
   H) REMOVE THE DOWEL PINS, SPLICE PLATES AND THE LEVELING BOLTS FROM THE BEARING PLATE AND CUT AND REMOVE THE BRACING 2" FROM BEARING PLATE INSIDE DIAMETER.
   I) IN THE TILT POSITION THE BEARING PLATE SHALL BE FLAT (NOT LEVEL). GRIND THE BEARING PLATE TOP SURFACE TO THE REQ'D FLATNESS FINISH OF 0.015 INCHES AND PROTECT THE SURFACE FROM DAMAGE WITH APPROVED PROTECTIVE COVERING. SEE NOTE 6 FOR DEFINITION OF "FLATNESS".
   J) AFTER THE REACTOR PRESSURE VESSEL IS IN PLACE AND CHECKED FOR PLUMBNESS WHICH IS DETERMINED ACCEPTABLE, FILL SPACE AROUND ANCHOR BOLTS IN HOLES IN BEARING PLATE AND SKIRT FLANGE WITH DEVCON F2. INSTALL WASHERS AND NUTS ON THE ANCHOR BOLTS AND TIGHTEN THE NUTS TO A TORQUE OF 50 FT. LBS.
   K) THE DOWELS PROVIDED WITH ANCHOR BOLTS MK 82 (SEE DWG. S782) SHALL BE USED FOR THE INSTALLATION OF REACTOR PRESSURE VESSEL.
   L) AFTER FINAL SETTING OF BASE PLATE, CONTRACTOR SHALL RECORD THE ELEVATION READINGS AND SUBMIT TO OWNER.
3. INSTALLATION PROCEDURE FOR SACRIFICIAL SHIELD WALL BEARING AND BASE PLATES BY CONTRACT 215.
   A) PREPARE THE TOP SURFACE OF THE PEDESTAL FOR GROUTING.
   B) INSTALL THE BEARING PLATE ON THE PEDESTAL AND SET THE TOP OF THE BEARING PLATE TO THE REQUIRED ELEVATION OF 519'-6 3/4" USING SHIMS. THE TOP SURFACE OF THE BEARING PLATE SHALL BE LEVEL WITHIN (±) 1/32 INCH. WELD BEARING PLATE SECTORS TOGETHER TO FORM ONE UNIT. THEN WELD SHEAR BARS TO BEARING PLATE.
   (NOTES C) AND D) CONTINUED IN COLUMN FOUR THIS SHEET)
4. SACRIFICIAL SHIELD WALL (SSW) ERECTION PROCEDURE.:
   A) ERECT COLUMNS FROM AZIMUTH 15° TO 165° AND 195° TO 345° UP TO RING BEAM AT EL. 528'-1 1/4". OMIT FRONT PLATES OF BOX COLS. WELD CLOSURE BOXES OVER ALL ANCHOR BOLTS.
   B) ERECT COLUMNS AT AZIMUTH 0° AND AT 180° UP TO THE BOTTOM OF BOX BEAM AT EL. 522'-6" FOLLOWED BY THE BOTTOM AND TWO SIDES OF BOX BEAMS BETWEEN AZIMUTHS 315° CLOCKWISE TO 45° AND 165° TO 195°. OMIT TOP PLATE OF BOX BEAMS.
   C) ERECT RING BEAM (2) LI AT EL. 528'-1 1/4" AND WELD THE FRONT PLATES OF BOX COLUMNS. ALL WELDING SHALL BE DONE FROM RPV AND OUTBOARD SIDES OF WALL UP TO EL. 528'-1 1/4". A CLOSE TOLERANCE FOR LEVELNESS AND ORIENTATION AT EACH SUCCEEDING RING BEAM SHALL BE MAINTAINED IN ACCORDANCE WITH NOTE 5, DWG.S782.
   D) WELD THE INNER AND OUTER SKIN PLATES BELOW BOX BEAM (7) AND (14) BETWEEN COLUMNS AZ. 315° TO 45° AND 165° TO 195°. PLACE CONCRETE UP TO THE BOTTOM OF THESE BOX BEAMS THRU 8 INCH DIA. POUR HOLES PROVIDED IN THE BOTTOM PLATES OF BOX BEAMS. AFTER A MINIMUM OF 3 DAYS, TOP PLATES ON BOX BEAMS SHALL BE WELDED AND COLUMNS AT AZ. 0° AND 180° SHALL BE ERECTED TO EL. 528'-1 1/4" AND BOX BEAMS FILLED WITH CONCRETE. SEE TYPICAL DETAILS ON DWG. S786 FOR POUR HOLES AND AIR HOLES. ONLY HOLES ON EXPOSED SURFACES ARE TO BE PLATED OVER AND WELDED FLUSH PER SECTIONS AND DETAILS ON DWGS.
   E) ERECT FRAMING FOR OPENINGS A-9 & A-26 SERIES.
   F) ALL COLUMNS STARTING AT EL. 528'-1 1/4" UP TO EL. 534'-8 3/4" OR EL. 538'-2 1/4" SHALL BE ERECTED. OMIT FRONT PLATES OF BOX COLUMNS FOR THIS HEIGHT.
   G) INNER SKIN PLATES FROM AZ. 45° TO 165° AND FROM AZ. 195° TO 315° SHALL BE ERECTED. INNER SKIN PLATES BETWEEN COLUMNS 315° TO 45° AND 165° TO 195° FROM EL. 524'-6" TO EL. 528'-1 1/4" SHALL THEN BE ERECTED. CORRESPONDING OUTER SKIN PLATES ARE ERECTED.
   H) CONCRETE UP TO RING BEAM (2) LI AT EL. 528'-1 1/4" SHALL BE POURED THRU 9" DIAMETER POUR HOLES PROVIDED IN THE WEB OF RING BEAM (2) LI.
   I) ERECT SECONDARY BEAMS UP TO AND INCLUDING T.O.S. EL. 534'-8 3/4". OMIT TOP PLATE ON BOX BEAMS. SLOTS AT AZ. 105° AND 285° IN BEAM MEMBERS (13) TO BE LEFT OPEN AT THIS TIME.
   J) OPENING SIDE FRAMING FOR A-5A AND A-5B ARE THEN PLACED. INNER AND OUTER SKIN PLATES BELOW THESE OPENINGS AND BOX BEAMS (7) ARE WELDED. THESE CHAMBERS ARE THEN POURED THRU FOUR HOLES PROVIDED.
   K) THE BOX BEAM (3) SECTIONS BETWEEN SLOTTED PORTIONS, AS DESIGNATED ON DRAWINGS S782 AND S835 ARE NOW ERECTED ALONG WITH FILLER PIECES IN FRONT OF SLOTS FOR COMPLETE OUTER FACE CONTINUITY ON BOX BEAM (3). MAINTAIN CLOSE TOLERANCE ON TOP SURFACE OF BOX RING BEAM. (SEE NOTE 19, DWG.S782) USE A SPIDER TEMPLATE ON BOX BEAM DURING THIS OPERATION TO INSURE ACCURACY IN PLAN LAYOUT. (SEE NOTE 20, DWG.S782) THE BOX BEAM (3) INNER SLOT CLOSURE PIECES AND TOP PLATES OF SECTIONS BETWEEN SLOTTED PORTIONS SHALL BE OMITTED AT THIS TIME.
   L) WELD FRONT PLATES OF BOX COLS. AND TOP PLATES OF BOX BEAMS (7). FILL THESE BOX BEAMS WITH CONCRETE.
   M) INSTALL INNER OPENING FRAME ANGLES AT A-2 SERIES OPNGS. AND ERECT REMAINING INNER SKIN PLATES UP TO EL. 538'-2 1/4" (BOT. OF RING BEAM (3)) BUT OMIT ALL STEEL MEMBERS AND PLATES BETWEEN OPENINGS A-2C TO A-2D AND A-2H TO A-2J AT THIS TIME. INNER COL. SPLICE PLATES ARE SHOP WELDED TO BOX BEAM (3) SECTIONS BETWEEN SLOTTED PORTIONS.
   N) INSTALLATION OF INSULATION SHALL PROCEED UP TO EL. 534'-8 3/4". SUBSEQUENT COORDINATION AND INSTALLATION OF INSULATION IS SHOWN ON B&R DWG.M038.
   O) REMAINING OUTER SKIN PLATES UP TO EL. 534'-8 3/4" SHALL BE PLACED AND CHAMBERS FILLED WITH CONCRETE TO THAT LEVEL.
   P) INSTALL OUTER FRAME ANGLES FOR A-2 SERIES OPNGS. PLUS OUTER SKIN PLATES, BUT OMIT AT AREAS STATED IN STEP (M). WELD SIDE FRAME PLATES AT ABOVE LOCATIONS AND POUR THESE ENCLOSURES BETWEEN A-2 SERIES OPNGS. THRU BOTTOM OF RING BEAM (3). PLACE CONCRETE IN ALL (10) BOX COLS.
   Q) BOX BEAM (3) SECTIONS BETWEEN SLOTS SHALL BE ENCLOSED BY WELDING ON THE BOX BEAM TOP PLATES AND THEN ATTACH PLATFORM BEAMS AT 541'-0" LEVEL. FOLLOW BY PLACING CONCRETE IN THESE SECTIONS THRU POUR HOLES PROVIDED IN TOP PLATES.
   R) INSULATION MAY BE HUNG BETWEEN A-2 SERIES OPNGS. AT THIS TIME. BUT AGAIN, OMIT AT AREAS BETWEEN A-2C TO A-2D AND A-2H TO A-2J OPNGS. AS PER INSULATION DWG.M038.
   S) ATTACH TEMPORARY SHIM PLATES TO DESIGNATED PLATFORM BEAM ENDS FOR A FLUSH SURFACE AT EL. 541'-5" AND AT FACE OF SSW (SEE DETAIL ON DWG.S835). THIS COMPLETES THE LOWER PORTION OF SSW PRIOR TO INSTALLATION OF UPPER PORTION OF SSW AND RPV. THIS TOP SURFACE MUST BE SMOOTH AND LEVEL TO PERMIT SLIDING OF SEGMENTS. STEPS (A) TO (S) ARE PERFORMED BY CONTRACT 215.
   T) THE UPPER PORTION OF THE SSW SHALL BE ERECTED IN THREE (3) SEGMENTS OUTSIDE THE CONTAINMENT VESSEL. STARTING WITH EL. 541'-5" (BOTTOM OF RING BEAM (2) LI) AS THE SEGMENT BASE. CONTRACT 215 SHALL PROVIDE ALL NECESSARY FOUNDATIONS AND STRUCTURES REQUIRED FOR FABRICATING THE SSW SEGMENTS AT SOME POINT AWAY FROM DEISEL GENERATOR BLDG. IT IS IMPERATIVE, FOR STATED MATING TOLERANCES, BETWEEN TOP OF BOX BEAM (3) AND THE SEGMENT BASE RING BEAM (2) LI, THAT THE INTERFACE EL. 541'-5" BE SMOOTH AND LEVEL FOR SLIDING AND MINIMUM GAP. AGAIN, FOR CIRCULARITY, A SPIDER TEMPLATE SHALL BE USED. SEGMENT FABRICATION BY CONTRACT 215.
   U) THESE SEGMENTS "A", "B" AND "C", AS INDICATED ON FLAT DEVELOPMENT ON DWG. S783, SHALL BE ASSEMBLED UP TO EL. 549'-5 1/4" INCLUDING RING BEAM (2) AT EL. 549'-5 1/4". FOR TYPICAL WALL DETAILS SEE SECTION 1602-1602 ON DWG. S783 AND TYPICAL PART PLANS ON DWG. S785. SEGMENT FIELD WELDING CAN BE DONE FROM EITHER SIDE OF SSW AT THIS STAGE. FURNISH TEMPORARY LOCKING DEVICES AT THE BUTTING OF RING BEAMS BETWEEN SEGMENTS TO INSURE FINAL PROPER FIT-UP AROUND RPV.
   V) THE INNER SKIN PLATES SHALL BE PLACED FROM EL. 544'-5" UP TO EL. 549'-5 1/4" THEN THE OUTER SKIN PLATES BETWEEN EL. 544'-8" UP TO 549'-5 1/4" SHALL BE INSTALLED WITH DIAPHRAGM PLATES AS PER SECTION 1724-1724, DWG. S788. ALL SKIN PLATES SHALL BE OMITTED AT BAYS WHERE SEGMENTS "A", "B" AND "C" BUTT BETWEEN 68° TO 75°, 180° TO 185° AND 308° TO 315°. OPENING FRAMING FOR A-7C SHALL ALSO BE OMITTED AT THIS TIME. PLACE CONCRETE IN CHAMBERS BELOW RING BEAM (2) AT EL. 549'-5 1/4".
   W) ERECTION OF REMAINING SSW ABOVE EL. 549'-5 1/4" SHALL NOW PROCEED. COLUMNS, BEAMS, OPENING FRAMING AND INNER SKIN PLATES SHALL BE ERECTED IN THAT ORDER. OPENING FRAME PLATES MAY BE INSTALLED LAST WHERE NECESSARY FOR ACCESSIBILITY.
   X) OUTER SKIN PLATES SHALL BE WELDED BETWEEN EL. 549'-5 1/4" AND EL. 556'-5 1/4" AND CONCRETE PLACED THRU POUR HOLES PROVIDED IN RING BEAM (2) AT EL. 556'-5 1/4". THIS PROCEDURE IS TO BE REPEATED FOR SUCCEEDING LEVELS UP TO TOP OF SSW EL. 567'-4 1/2". AGAIN, EXCLUDE ALL SKIN PLATES AND CONCRETE AT BAYS BETWEEN 68° TO 75°, 180° TO 185° AND 308° TO 315° EXCEPT AS STATED IN STEP (Y).
   Y) PLACE CONCRETE TO THE GREATEST EXTENT POSSIBLE IN THE AREA FROM AZ. 165° TO FACE OF BOX COL. (4) AT CENTERLINE AZ. 198° AND FROM TOP OF RING BEAM (2) AT EL. 556'-5 1/4" UP TO TOP OF SSW EL. 567'-4 1/2" AT THIS TIME. OUTER SKIN PLATES AND TOP OF BOX BEAM (5) IN THIS AREA SHALL BE OMITTED TEMPORARILY WHERE ERECTION AND PLACING OF CONCRETE IN SUBSEQUENT PROCEDURE IS IMPEDED.
   Z) CONTRACT 215 SHALL PROVIDE ANCHOR BOLTS AND OTHER EMBEDMENTS AT EL. 606'-10 1/2" FOR WINCHES AND COME-A-LONGS. WINCHES AND COME-A-LONGS SHALL BE FURNISHED AND INSTALLED BY CONTRACT 209. THESE EMBEDMENTS SHALL BE SHEARED OFF AND CONCRETE REPAIRED BY CONTRACT 206. AFTER FABRICATING THE SEGMENTS, TO THE GREATEST EXTENT, CONTRACT 215 SHALL MOVE IT TO A POINT ACCESSIBLE TO THE MAIN RPV RIGGING HOOK AS DIRECTED BY CONTRACT 209.
   AA) TEMPORARY LIFTING LUGS (TWO PER SEGMENT) SHALL BE PROVIDED ON THE TOP RING BEAM (1) AT EL. 567'-4 1/2" BY CONTRACT NO. 215. THESE LIFTING LUGS SHALL HAVE POSITIONING NOTCHES FOR ADJUSTING NORMAL TO SEGMENT AND A STRONGBACK WITH ABILITY TO ADJUST PARALLEL TO SEGMENT FOR A SAFE, BALANCED CONDITION DURING LIFTING OPERATION. THE STRONGBACK SHALL BE SUFFICIENTLY CLEAR OF THE TOP OF EACH SEGMENT SUCH THAT THE STRONGBACK IS ABOVE EL. 606'-10 1/2" WHEN THE UPPER SSW SITS ON TOP OF THE LOWER SSW. THIS WILL PERMIT WINCHES TO MOVE THE STRONGBACKS AND SEGMENTS INTO THE OUTBOARD POSITION. CONTRACT 209 SHALL PROVIDE ALL NECESSARY STRONGBACKS AND OTHER LIFTING ACCESSORIES FOR PLACING EACH SEGMENT IN ITS OUTBOARD POSITION.
   BB) THE SSW SEGMENTS SHALL BE LIFTED INDIVIDUALLY WITH THE RPV ERECTION RIG & LOWERED INTO CONTAINMENT VESSEL IN ITS PROPER ORIENTATION BY CONTRACT NO. 209.
   CC) EACH SEGMENT SHALL BE SET DOWN 2'-8" OUTWARD RADIALLY FROM ITS FINAL AZIMUTH POSITION OVER LOWER PORTION OF SSW AND IT SHALL REST ON TEMPORARY SHIMS SET ON PLATFORM BEAMS AS PER DWG. S835. A COORDINATED EFFORT AMONG ERECTION RIG, WINCHES AND COME-A-LONGS SHALL BE MADE.
   DD) BEFORE SETTING DOWN SEGMENTS IN THEIR EXPANDED POSITIONS THE ENTIRE UNDERSIDE SURFACE OF SEGMENT BASE RING BEAM (2) LI AND TOP SURFACES OF SHIMS AND BOX RING BEAM (3) SHALL BE LUBRICATED FOR SLIDING WITH A COATING OF MINERAL OIL. SEE MINERAL OIL REQUIREMENTS IN NOTE 7.
   EE) EACH SEGMENT SHALL BE SECURED FOR STABILITY BY CONTRACT NO. 209 BEFORE RELEASING LIFTING CABLES.
   FF) AFTER THE SECOND SEGMENT IS PLACED, TEMPORARY SPACERS SHALL BE ATTACHED BETWEEN SEGMENTS, TWO PER JOINT AS SHOWN BY DETAIL ON DWG. S835. THESE SPACERS ARE ATTACHED BY CONTRACT NO. 209 AND FURNISHED BY CONTRACT 215.
   GG) THE RPV SHALL THEN BE LIFTED AND LOWERED INTO POSITION ON TOP OF RPV BEARING PLATE BY CONTRACT NO. 209. SEE PRIOR "INSTALLATION PROCEDURE FOR RPV BEARING PLATE" ON THIS DWG. BY CONTRACT NO. 215.
   HH) BOX BEAM (3) SLOTTED AREAS SHALL NOW BE ENCLOSED WITH SHOP FABRICATED BUILT-UP CHANNEL PIECES WITH CORRESPONDING INNER COLUMN SPLICE PLATES FULLY ATTACHED AS PER SECTIONS 2044 AND 2345 ALONG WITH SPLICE PLATE DETAILS ON DWG. S835. THESE CLOSURE PIECES MUST FIT FLUSH ON ALL SURFACES INCLUDING WELDMENT. THE SLOTTED PORTIONS SHALL BE FILLED WITH CONCRETE AND THE POUR HOLES COVERED PER DETAIL D123 ON DWG. S835.
   II) INSERT AND FULLY WELD MATCHING 2 1/4" THK. PLATE TO FILL PLATE BEAM (13) SLOTS AT CENTERLINE AZ. 105° AND 285° FOR A SMOOTH AND FLUSH FIT ON ALL SURFACES. SEE A-5 OPNG. DET. ON DWG. S788.
   JJ) WELD W24 COL. PIECES AT CENTERLINE AZ. 105° AND 285° BETWEEN PLATE BEAM (13) AND RING BEAM (3) PLUS INNER OPENING FRAME ANGLES.
   KK) SIX JACKING DEVICES (TWO PER SEGMENT) LOCATIONS ARE SHOWN ON DWG. S782. THE JACKING DEVICES ARE SECURED TO THE PLATFORM BEAMS AT T.O.S. EL. 541'-2 1/4" FOR THE MOVEMENT OF SEGMENTS INTO THEIR FINAL LOCATION AROUND RPV. PLATES, AS BEARING POINTS ON FACE OF SEGMENTS, SHALL BE PROVIDED BY CONTRACT 215.
   LL) AFTER REMOVING THE SPACERS FROM THE FIRST SEGMENT A COORDINATED JACKING EFFORT SHALL PROCEED UTILIZING RADIALLY ORIENTED GUIDE BARS PROTRUDING FROM THE TOP OF BOX BEAM (3) FOR AN ACCURATE FINAL LOCATION AGAINST THE INNER COLUMN SPLICE PLATES EXTENDING ABOVE LOWER SSW. WHEN THE SEGMENTS ARE MOVED INTO THEIR FINAL LOCATION REATTACH TEMPORARY LOCKING DEVICES AT BUTTING OF SEGMENT RING BEAMS FOR ALIGNMENT AND STABILITY.
   MM) THIS OPERATION IS REPEATED FOR EACH SEGMENT.
   NN) EACH SEGMENT SHALL NOW BE ATTACHED TO THE LOWER SSW BY WELDING COLUMNS TO INNER AND OUTER COLUMN SPLICE PLATES AND SLOT WELDING BOTTOM SEGMENT RING BEAM (2) TO TOP OF BOX RING BEAM (3) (DET. D-2838 ON DWG. S782). ALL THIS WELDING IS DONE FROM OUTBOARD FACE. BEFORE WELDING, REMOVE THE MINERAL OIL FROM THE VICINITY WITH NON-CHLORINATED AND NON-FLUORINATED SOLVENT. ALSO REMOVE TEMPORARY SHIMS BEFORE WELDING.
   OO) FOUR RING BEAMS AT THE BUTTING OF SEGMENTS "A", "B" AND "C" SHALL BE WELDED AND MADE FLUSH AT OUTSIDE SURFACES.
   PP) AGAIN, FOR INSULATION INSTALLATION DURING STEPS (CC) TO (OO) SEE B&R DWG. M038.
   QQ) INNER SKIN, OUTER SKIN AND THEN OPENING SIDE FRAME PLATES BETWEEN A-2C TO A-2D AND A-2H TO A-2J SHALL BE PLACED. THESE CHAMBERS SHALL THEN BE FILLED WITH CONCRETE FROM OUTBOARD FACE OF WALL BY MEANS OF TEMPORARY HOPPER SHAPED ATTACHMENT OVER PORTAL AT TOP OF CHAMBER. CONCRETE IS PLACED TO A SLIGHTLY HIGHER LEVEL IN HOPPER TO CHAMBER TO INSURE ABSENCE OF VOIDS FOR A CRITICAL CORE AREA SHIELDING REQUIREMENT. AFTER INITIAL CONCRETE SET, THE HOPPER SHALL BE REMOVED AND EXCESS CONCRETE IS TRIMMED AND CLEANED TO INSIDE FACE OF SKIN PLATE. PLATE OVER PORTAL WITH MATCHING PLATE AND WELD FLUSH WITH SKIN PLATE. THIS SURFACE MUST BE CLEAN AND FLUSH TO RECEIVE STEEL DOOR HINGE WELDMENT LATER.
   RR) REMAINING INNER AND THEN OUTER SKIN PLATES BETWEEN EL. 541'-5" TO 544'-5" AND 544'-8" ARE WELDED FROM OUTBOARD FACE. THESE CHAMBERS SHALL BE FILLED WITH CONCRETE FROM OUTBOARD FACE THRU ATTACHED HOPPER PORTALS, TO INSURE ABSENCE OF VOIDS. SIMILAR TO PRECEDING STEP (QQ).
   SS) AT THE THREE CONNECTING SEGMENT BAYS ANY OMITTED FRAMING MEMBERS SHALL BE WELDED ALONG WITH INNER SKIN PLATES. OUTER SKIN PLATES SHALL THEN BE ERECTED PROGRESSIVELY UPWARD. POUR EACH CHAMBER THRU FOUR HOLES PROVIDED IN RING BEAMS, FROM OUTBOARD FACE, BEFORE WELDING THE NEXT HIGHER OUTER SKIN PLATE UNTIL TOP OF WALL AT EL. 567'-4 1/2".
   TT) REMOVE JACKING DEVICES, BEARING PLATES FOR JACKING AND LIFTING LUGS AT TOP OF WALL. STEPS (HH) TO (TT) ARE PERFORMED BY CONTRACT 215.
   UU) FOR SSW SPECIAL WELDING TECHNIQUES SEE SPECIFICATIONS.
5. IN NOTE 2E, THE TERM "LEVEL" DENOTES A LEVEL TOLERANCE (NOT AN ELEVATION TOLERANCE OF THE TOP OF THE BEARING PLATE) IN WHICH THE TOP SURFACE OF THE BEARING PLATE SHALL LIE BETWEEN TWO PARALLEL HORIZONTAL PLANES SPACED 0.015 INCHES APART.
6. IN NOTE 2I, THE FLATNESS FINISH REFERRED TO SPECIFIES A TOLERANCE ZONE CONFINED BY TWO PARALLEL PLANES WITHIN WHICH THE ENTIRE SURFACE MUST LIE.
7. THE REQUIREMENTS OF THE MINERAL OIL REFERRED TO IN NOTE 4DD SHALL BE AS FOLLOWS:
   A) ANY PHYSICAL OR CHEMICAL BREAKDOWN WHICH THE OIL MAY UNDERGO DUE TO ENVIRONMENTAL CONDITIONS, INCLUDING BREAKDOWN DUE TO RADIATION EMANATING FROM THE REACTOR PRESSURE VESSEL, SHALL NOT CAUSE HARMFUL OR DELETERIOUS EFFECTS TO STRUCTURAL STEEL.
   B) THE OIL SHALL NOT CONTAIN, OR OTHERWISE BE ADEQUATELY LOW, IN THE FOLLOWING:
      (1) SULPHUR
      (2) CHLORIDES AND HALIDES SUCH AS CHLORINE, BROMINE, FLUORINE AND IODINE.
   C) THE OIL SHALL NOT BE A MOLYBDENUM DISULPHIDE LUBRICANT OR A LEAD BASE LUBRICANT.
3. INSTALLATION PROCEDURE OF SACRIFICIAL SHIELD WALL BEARING AND BASE PLATES. (CONTINUED FROM FIRST COLUMN)
   C) FILL GAP BETWEEN BOTTOM OF BEARING PLATE AND CONCRETE WITH EXPANSIVE GROUT AS CALLED FOR IN SPECIFICATIONS. TOP OF GROUT BETWEEN RPV & SSW BEARING PLATES SHALL BE LEVEL AT EL. 519'-4 1/4". GROUT TO BE f'c = 5000 PSI
   D) INSTALL SACRIFICIAL SHIELD WALL BASE PLATE SECTORS ON TOP OF THE SSW BEARING PLATE AND WELD BASE PLATE SECTORS TOGETHER TO FORM ONE UNIT. THEN INSTALL LEDGE PLATES IN BASE PLATE SHEAR BAR HOLES WITH PROPER FIT AND WELD LEDGE PLATES TO SHEAR BARS. WELD COVER PLATES TO BASE PLATE OVER SHEAR BAR HOLES. DETAILS SHOWN ON DWGS. S782 AND S835.

REV	REVISION
1	ADDED NOTE 3D(C4) [illegible] REVD AS PER 2058
2	CONTRACT 215 DELETED NOTE [illegible] REVISED

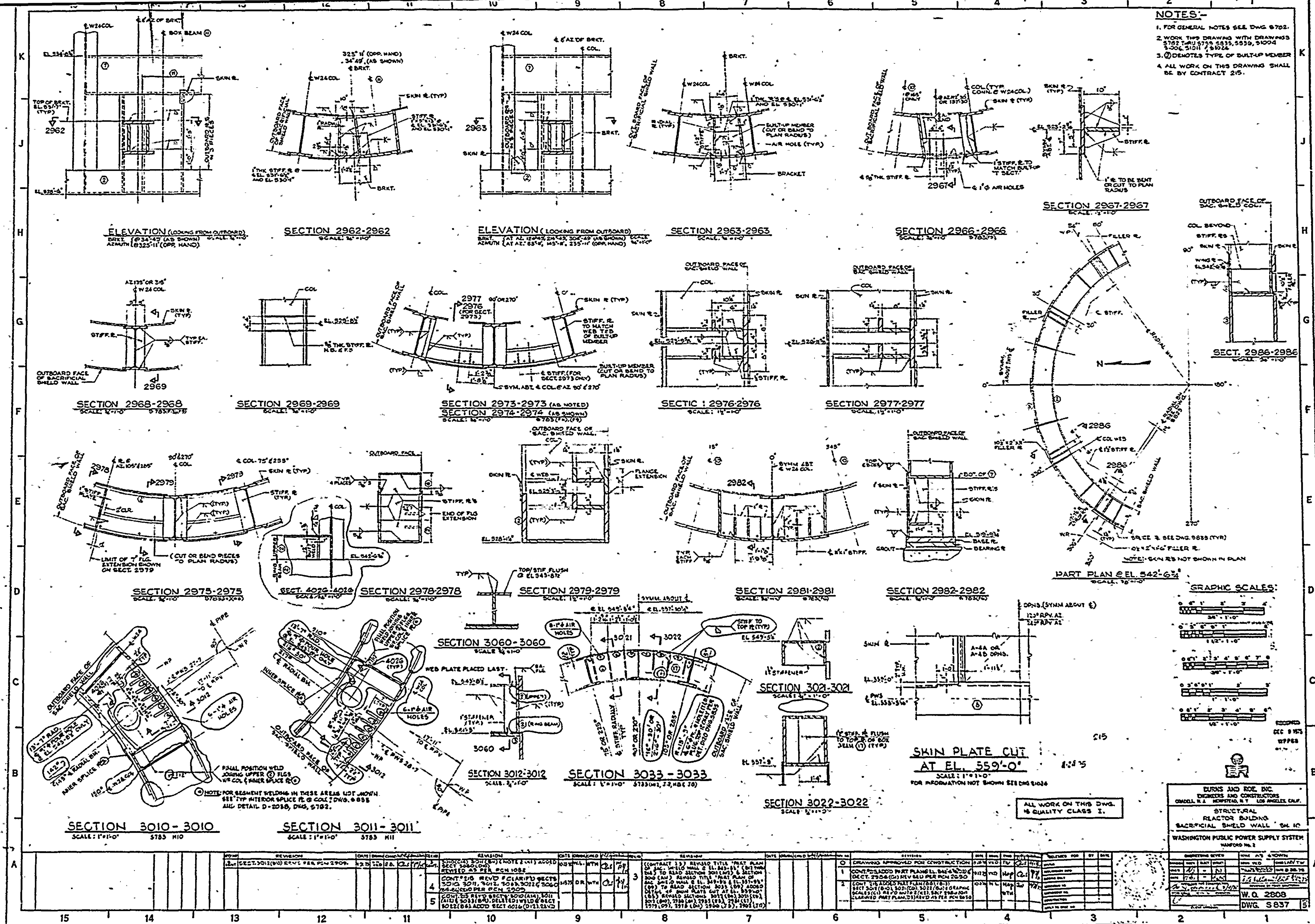
ISSUED AS CONTRACT DRAWING FOR CONTRACTS [illegible]
ISSUED FOR INFORMATION FOR CONTRACTS [illegible]
DATE [illegible]

BURNS AND ROE, INC.
ENGINEERS AND CONSTRUCTORS
ORADELL, N.J. HEMPSTEAD, N.Y. LOS ANGELES, CALIF.

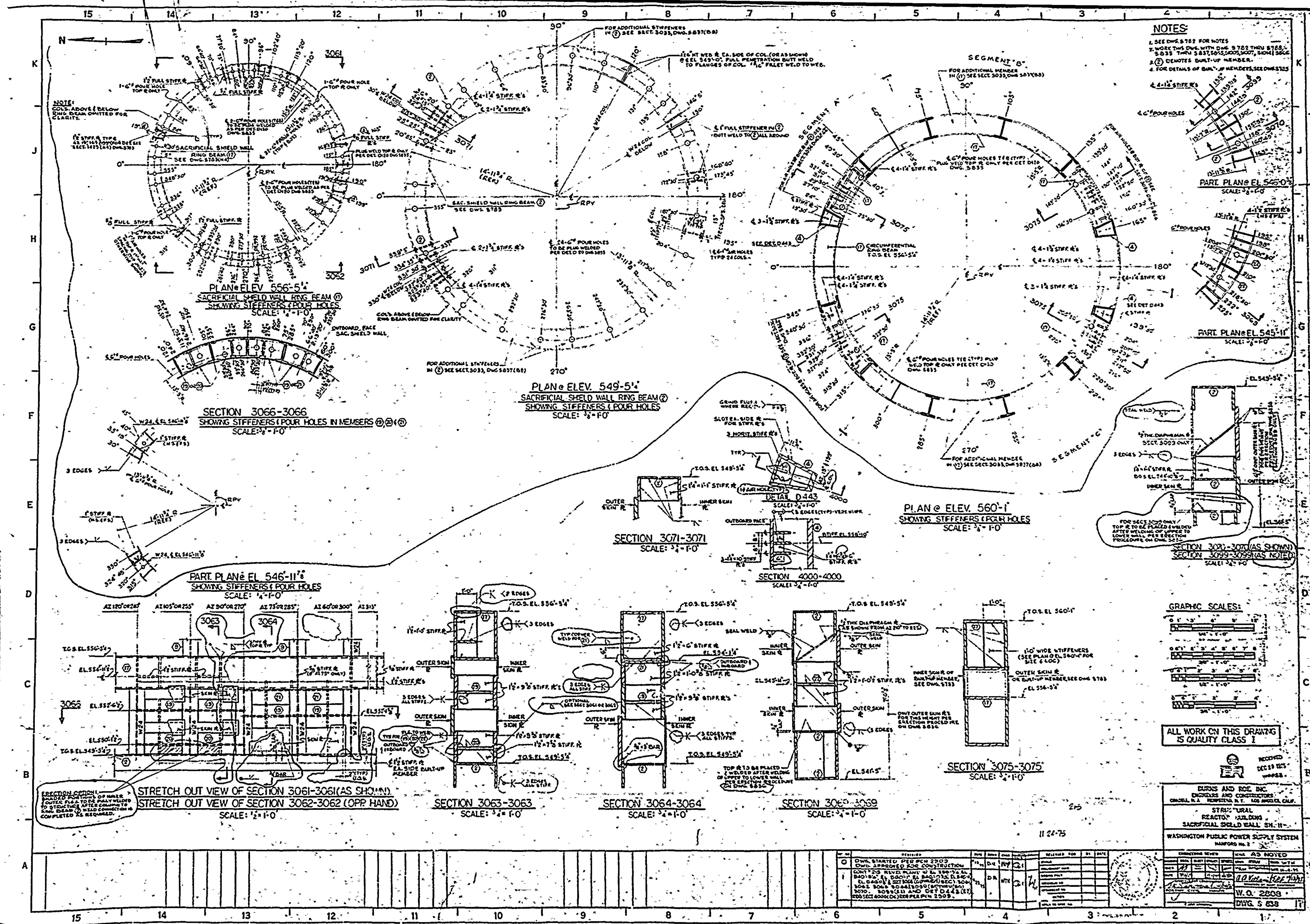
STRUCTURAL
REACTOR BUILDING
SACRIFICIAL SHIELD WALL SH.8

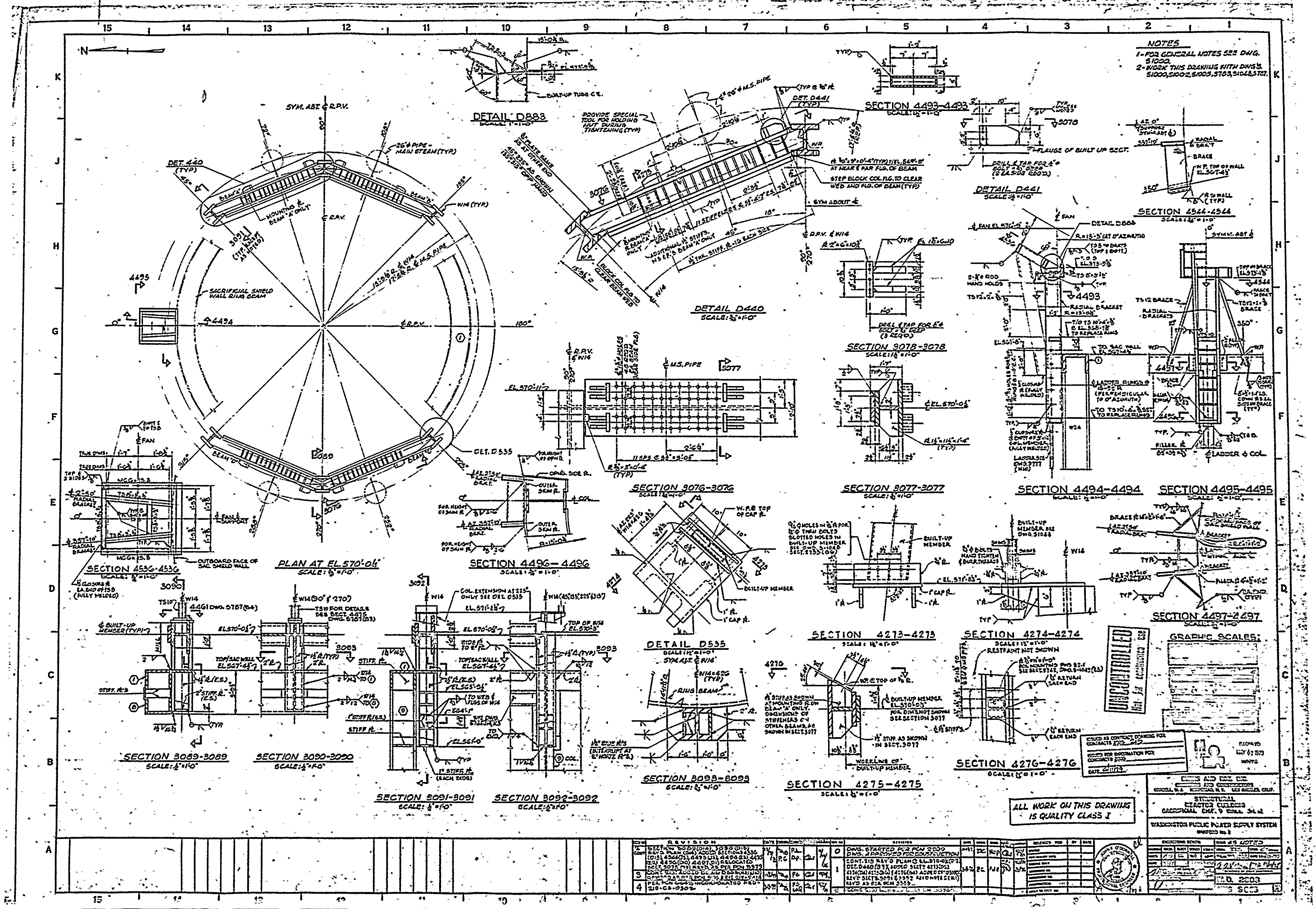
WASHINGTON PUBLIC POWER SUPPLY SYSTEM
HANFORD No. 2

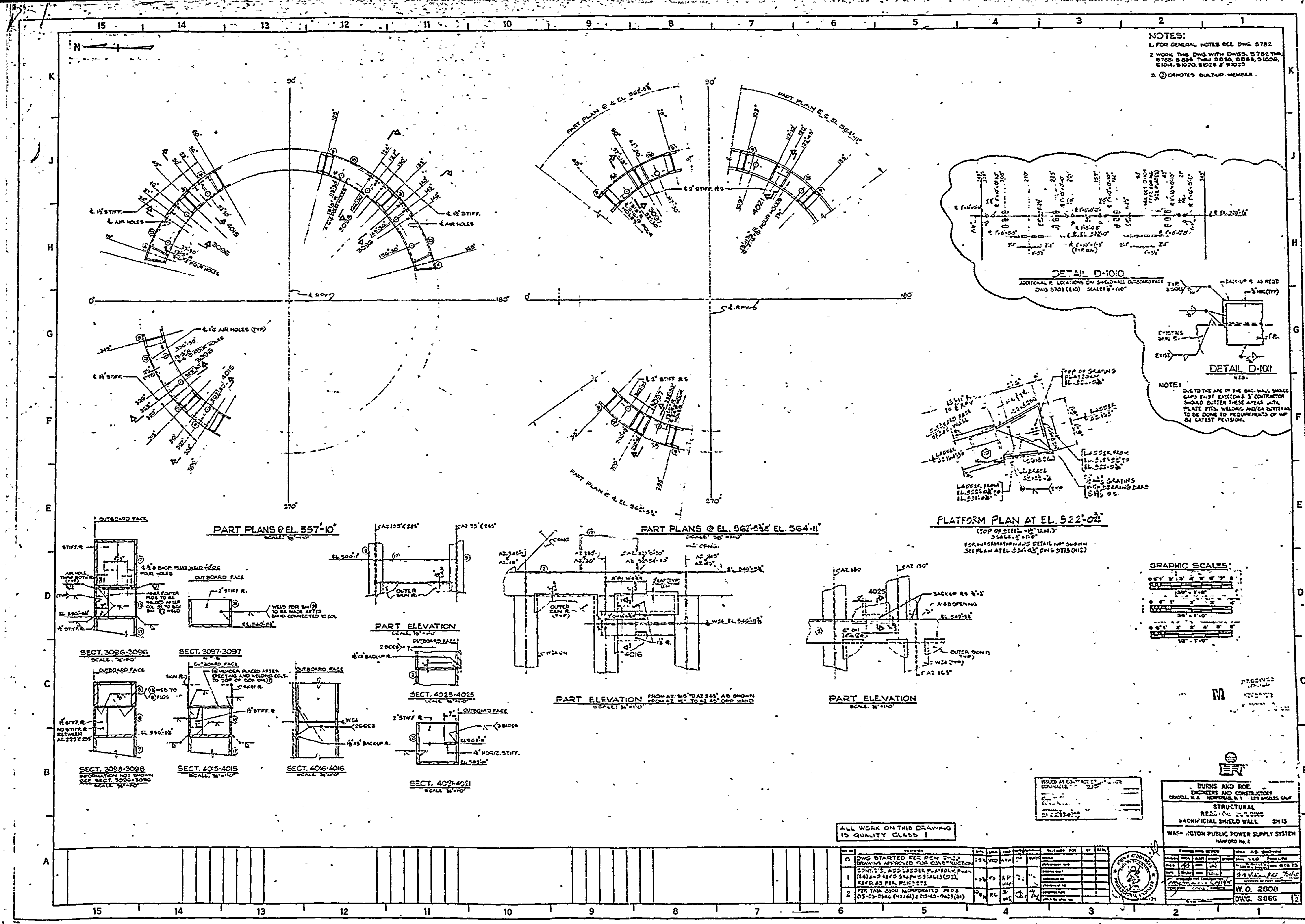
W.O. 2808
DWG. S 836 2



NOTES:-
1. FOR GENERAL NOTES SEE DWG S702.
2. WORK THIS DRAWING WITH DRAWINGS S702 THRU S799, S835, S836, S1004 S1006, S1011 & S1024
3. ② DENOTES TYPE OF BUILT-UP MEMBER
4. ALL WORK ON THIS DRAWING SHALL BE BY CONTRACT 215.
ELEVATION (LOOKING FROM OUTBOARD)
SECTION 2962-2962
SECTION 2963-2963
SECTION 2966-2966
SECTION 2967-2967
SECTION 2968-2968
SECTION 2969-2969
SECTION 2973-2973 (AS NOTED)
SECTION 2974-2974 (AS SHOWN)
SECTION 2976-2976
SECTION 2977-2977
SECT. 2986-2986
SECTION 2975-2975
SECT. 4026-4026
SECTION 2978-2978
SECTION 2979-2979
SECTION 2981-2981
SECTION 2982-2982
PART PLAN @ EL. 542'-6¾"
GRAPHIC SCALES:
SECTION 3060-3060
SECTION 3021-3021
SECTION 3010-3010
SECTION 3011-3011
SECTION 3012-3012
SECTION 3033-3033
SECTION 3022-3022
SKIN PLATE CUT AT EL. 559'-0"
ALL WORK ON THIS DWG. IS QUALITY CLASS I.
BURNS AND ROE, INC.
ENGINEERS AND CONSTRUCTORS
ORADELL, N.J. HEMPSTEAD, N.Y. LOS ANGELES, CALIF.
STRUCTURAL
REACTOR BUILDING
SACRIFICIAL SHIELD WALL SH. 10
WASHINGTON PUBLIC POWER SUPPLY SYSTEM
HANFORD No. 2
AS SHOWN
W.O. 2808
DWG. S837
5


NOTES:
1. SEE DWG. 5782 FOR NOTES
2. WORK THIS DWG. WITH DWG. 5782 THRU 5785
3. (2) DENOTES BUILT-UP MEMBER.
4. FOR DETAILS OF BUILT-UP MEMBERS, SEE DWG 5725
PLAN @ ELEV. 556'-5¼"
SACRIFICIAL SHIELD WALL RING BEAM (17)
SHOWING STIFFENERS & POUR HOLES
SCALE: ¼"=1'-0"
PLAN @ ELEV. 549'-5¼"
SACRIFICIAL SHIELD WALL RING BEAM (2)
SHOWING STIFFENERS & POUR HOLES
SCALE: ⅛"=1'-0"
PLAN @ ELEV. 560'-1"
SHOWING STIFFENERS & POUR HOLES
SCALE: ¼"=1'-0"
SEGMENT "A"
SEGMENT "B"
SEGMENT "C"
PART PLAN @ EL 546'-0"
PART PLAN @ EL 545'-11"
SECTION 3066-3066
SHOWING STIFFENERS & POUR HOLES IN MEMBERS
SCALE: ½"=1'-0"
PART PLAN @ EL 546'-11⅞"
SHOWING STIFFENERS & POUR HOLES
SCALE: ¼"=1'-0"
DETAIL D443
SECTION 3071-3071
SCALE: ¾"=1'-0"
SECTION 4000-4000
SCALE: ¾"=1'-0"
SECTION 3070-3070 (AS SHOWN)
SECTION 3099-3099 (AS NOTED)
STRETCH OUT VIEW OF SECTION 3061-3061 (AS SHOWN)
STRETCH OUT VIEW OF SECTION 3062-3062 (OPP. HAND)
SCALE: ½"=1'-0"
SECTION 3063-3063
SCALE: ¾"=1'-0"
SECTION 3064-3064
SCALE: ¾"=1'-0"
SECTION 3069-3069
SCALE: ¾"=1'-0"
SECTION 3075-3075
SCALE: ¾"=1'-0"
GRAPHIC SCALES:
ALL WORK ON THIS DRAWING IS QUALITY CLASS I
BURNS AND ROE, INC.
STRUCTURAL
REACTOR BUILDING
SACRIFICIAL SHIELD WALL SH. 11
WASHINGTON PUBLIC POWER SUPPLY SYSTEM
HANFORD No. 2
SCALE AS NOTED
W.O. 2808
DWG. 5 838
0 DWG. STARTED PER PCN 2903
DWG. APPROVED FOR CONSTRUCTION


NOTES
1-FOR GENERAL NOTES SEE DWG. S1000.
2-WORK THIS DRAWING WITH DWGS. S1000, S1002, S1005, S783, S1068, S787.
DETAIL D883
SECTION 4493-4493
DETAIL D441
SECTION 4544-4544
DETAIL D440
PLAN AT EL.570'-0¼"
SECTION 4536-4536
SECTION 4496-4496
SECTION 3076-3076
SECTION 3077-3077
SECTION 3078-3078
SECTION 4494-4494
SECTION 4495-4495
SECTION 4497-4497
SECTION 4273-4273
SECTION 4274-4274
SECTION 4276-4276
SECTION 4275-4275
DETAIL D535
SECTION 3089-3089
SECTION 3090-3090
SECTION 3091-3091
SECTION 3092-3092
SECTION 3093-3093
GRAPHIC SCALES:
ALL WORK ON THIS DRAWING IS QUALITY CLASS I
UNCONTROLLED
WASHINGTON PUBLIC POWER SUPPLY SYSTEM
AS NOTED
2803
SC03


NOTES:
1. FOR GENERAL NOTES SEE DWG. S782
2. WORK THIS DWG. WITH DWGS. S782 THRU S783, S836 THRU S838, S848, S1006, S1014, S1020, S1026 & S1029
3. (2) DENOTES BUILT-UP MEMBER
PART PLANS @ EL. 557'-10"
PART PLANS @ EL. 562'-5 3/16" EL. 564'-11"
PART PLAN @ ℄ EL. 562'-5 3/16"
PART PLAN @ ℄ EL. 564'-11"
DETAIL D-1010
DETAIL D-1011
PLATFORM PLAN AT EL. 522'-0 3/4"
GRAPHIC SCALES
SECT. 3096-3096
SECT. 3097-3097
SECT. 3098-3098
SECT. 4015-4015
SECT. 4016-4016
SECT. 4025-4025
SECT. 4021-4021
PART ELEVATION
ALL WORK ON THIS DRAWING IS QUALITY CLASS I
BURNS AND ROE
ENGINEERS AND CONSTRUCTORS
ORADELL, N.J. HEMPSTEAD, N.Y. LOS ANGELES, CALIF
STRUCTURAL
REACTOR BUILDING
SACRIFICIAL SHIELD WALL SH 13
WASHINGTON PUBLIC POWER SUPPLY SYSTEM
HANFORD No. 2
AS SHOWN
W.O. 2808
DWG. S866
0 DWG STARTED PER PCN; DRAWING APPROVED FOR CONSTRUCTION
1 CONT. 2'S, ADD LADDER PLATFORM PLAN (E4) AND REVS GRAPHIC SCALES (D2), REVS AS PER PCN 5272
2 PER TASK 2300 INCORPORATED PEDS 215-CS-0546 (H3161) & 215-CS-0629 (31)