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Weld Evaluation Project Suitability for Service Evaluation Engineering Process

Department of Energy
Weld Evaluation Project
TVA Watts Bar Nuclear Plant Unit 1

Robert K. Blandford

Idaho National Engineering Laboratory

U.S. Department of Energy • Idaho Operations Office

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ENGINEERING PROCESS

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ABSTRACT

The United States Department of Energy/Weld Evaluation Project (DOE/WEP) was formed in December 1985 as the result of an interagency agreement between the DOE and the Tennessee Valley Authority (TVA). The project was assigned by the DOE to EG&G Idaho, Inc., for implementation. The DOE/WEP was tasked to perform an independent evaluation of the documented TVA welding program and the as-constructed weld quality with respect to TVA-performed safety-related welds at the Watts Bar Nuclear Plant Unit 1 (WBNP-1). This is one of ten reports describing the plan, processes, implementation, and results of the DOE/WEP at the plant. This report describes the suitability for service evaluation engineering review process and evaluation methodology for welds found to contain deviations potentially degrading to their safety function.

ACKNOWLEDGMENT

Acknowledgments are extended to the many participants in the suitability for service evaluation activities of the DOE/WEP at the TVA WBNP-1. In particular, acknowledgment is extended to T. L. Bridges, T. C. Chung, B. L. Harris, L. D. Kimbro, and S. E. Moore for their expertise and assistance in the preparation of this report.

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FIGURES

TABLES

ACRONYMS

AC	As Constructed
AD	As Designed
AISC	American Institute of Steel Construction
ANSI	American National Standards Institute
ASME	American Society of Mechanical Engineers
AWS	American Welding Society
CA	Corrective Action
CAP	Corrective Action Plan
CM	Configuration Management
DOE/WEP	Department of Energy/Weld Evaluation Project
DR	Deviation Report
FSAR	Final Safety Analysis Report
LOF	Lack of Fusion
LOP	Lack of Penetration
NA	Not Applicable
NDE	Nondestructive Examination
USNRC	United States Nuclear Regulatory Commission
NX	ASME Code Sections NB, NC and ND
PAC	Project Administration and Control
PSDM	Piping System Design Manual
SFS	Suitability for Service
SP	Standard Practice
SSEE	Suitability for Service Evaluation Engineering
SVS	Support Variance Sheet
TVA	Tennessee Valley Authority
VWAC	Visual Weld Acceptance Criteria
WAP	Weld Analysis Program (a computer code)
WBNP-1	Watts Bar Nuclear Plant Unit 1
WEP	Weld Evaluation Project

WELD EVALUATION PROJECT SUITABILITY FOR SERVICE EVALUATION ENGINEERING PROCESS

1. INTRODUCTION

The United States Department of Energy/Weld Evaluation Project (DOE/WEP) was formed in December 1985 as the result of an interagency agreement between the DOE and the Tennessee Valley Authority (TVA) to provide the TVA with an independent assessment of the quality of safety-related welding performed by the TVA during construction of the Watts Bar Nuclear Plant Unit 1 (WBNP-1). The DOE/WEP was conducted by EG&G Idaho, Inc., as contractor to the DOE.

The specific objectives of the DOE/WEP were to:

1. Assess compliance of the TVA's documented weld program to the requirements in the WBNP Final Safety Analysis Report (FSAR)[1] and amendments through February 1, 1986.
2. Assess the applicable TVA employee concerns (ECs) and quality documents to determine if they identify quality problems with the TVA-performed, safety-related welds.
3. Evaluate the TVA's as-constructed plant weld status by conducting an examination of the plant welds, evaluating the results, and when deviations[a] were determined to be unacceptable, analyzing and concurring with the TVA's corrective action proposals for these deviations.
4. Provide the TVA with a statement of the compliance of the plant welds with applicable construction welding codes.

a. *Deviation* or *deviant* weld denotes a condition that does not meet the applicable code inspection acceptance criteria for the weldment specified by the engineer. These terms are used before an evaluation of the condition has been performed in accordance with other applicable code provisions to determine the acceptability of the condition.

This report is one of ten reports describing the plan, processes, implementation, and results of the DOE/WEP at the WBNP-1. The assessment to meet Objective 1 was accomplished with the completion of the report, "Weld Program Review."[2] The other eight reports are listed as References 3 through 10. In addition to the Weld Program Review cited above, these reports delineate: the program organization and work scope, the formation of homogeneous groupings of welds, the formation of the weld/component data base, the data bases for weld reinspection results and status reports, the processes of component inspection and examination, and the generic problem analysis of deviations found during the examinations, an aggregate assessment of weld reinspection results, and a final summary.

This report describes the purpose and function of the suitability for service evaluation process applied by the DOE/WEP in meeting program objectives.

Section 2 presents the technical approach used by the DOE/WEP. The project interfaces are discussed in Section 3, and the review process is presented in Section 4. Section 5 discusses the weld evaluation methodology, and the conclusions are given in Section 6. Appendix A contains the computer program [Weld Analysis Program (WAP)] developed by the DOE/WEP for evaluating stresses for any weld geometry. Appendix B presents the criteria used for determining if the American Society of Mechanical Engineers (ASME) components demonstrate compliances with the Code. The ASME Code Inquiry is contained in Appendix C; Appendix D contains an analysis of integral pipe attachments; Appendix E contains the WEP standard practices applicable to examination and acceptance criteria; and Appendix F contains suitability of service relevant communications.

2. TECHNICAL APPROACH

The assessment of TVA's as-constructed plant welds involved evaluating the suitability for service of weld conditions that could potentially jeopardize the safety function of a component. The Suitability For Service Evaluation Engineering (SSEE) section of the DOE/WEP was responsible for confirming the suitability for service status of welds found to contain deviant attributes. Specifically, SSEE performed a review function to ensure that engineering evaluations of deviant welds completed by the TVA were correct.

A deviant weld was considered "suitable for service" (SFS) when it could be demonstrated by appropriate evaluations to be in compliance with the applicable code requirements committed to in the FSAR. Governing regulations for the construction of nuclear power plants do not mandate demonstration of error free construction.[11] Assurance must be provided that the as-built facility can be operated without endangering the public health and safety. Compliance with relevant codes provides sufficient assurance that the facility will be safe to operate.

The basis for disposition of deviant welds is unchanged from the requirements of the original acceptance criteria of the codes and standards committed to by the TVA in the FSAR. The SFS evaluation demonstrated that the design contained sufficient conservatism to account for the deviant conditions. If suitability for service could not be established, corrective action for the deviant component was required.

The traditional approach to the development of weld acceptance criteria by the majority of the current codes and standards has been one of establishing size and extent limits from a workmanship standpoint. The codes and standards provide general conditions intended to cover any situation, blanketing a broad range of users. They are written to deal with the aesthetic aspects of workmanship as well as function, and avoid the time and costs associated with a rigorous engineering evaluation. The American Welding Society[12] (AWS), for example, states that "The fundamental premise of the Code is to provide general stipulations adequate to cover any situation. . . alternate acceptance criteria can be based upon evaluation of suitability-for-service using past experience, experimental evidence or engineering analysis. . . ." Conformance to codes provides assurance that safe operation can be attained. The application of alternate acceptance criteria, as allowed by the relevant code, does not mean that performance and safety have been jeopardized.

The technical approach taken by the DOE/WEP accepted the TVA use-as-is disposition of welds found deviant from inspection criteria, if a review of an appropriate TVA engineering evaluation demonstrated compliance of the welds with the applicable code requirements. Design requirements that were initially imposed on weld quality at WBNP-1 provide a generally conservative basis for assessment, but in some cases are more conservative than necessary to assure performance and safe operation. Allowance exists within the original codes and quality assurance program requirements for use-as-is dispositioning of certain deviant conditions based on a demonstration of code compliance.

Where the engineering evaluation was a stress analysis accounting for a deviant condition, the calculated stresses were required to satisfy the stress criteria of the applicable design code as specified in the WBNP-1 FSAR. Any welds that were found not meeting these requirements were identified for corrective action to bring the component into compliance with the requirements of the original codes and standards.

3. PROJECT INTERFACES

The SSEE's function in the DOE/WEP is illustrated in Figure 1. Following weld inspection, discrepant weld conditions were reported to TVA on deviation reports. An engineering evaluation, which may have included documentation review, detailed analysis, or experimental verification was performed by TVA using applicable codes and standards. Upon completion of the TVA evaluation, the documented effort was transmitted to SSEE where the SFS independent review process began.

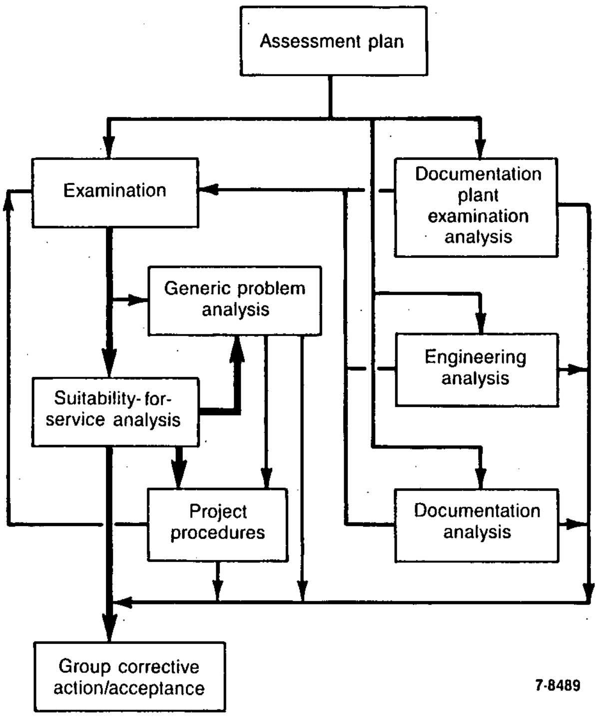

Figure 1. Weld evaluation program assessment and disposition showing SSEE interfacing functions (heavy lines) with other DOE/WEP activities.

The SFS evaluation review procedure is defined in Standard Practice (SP) WEP 3.3.1.[a] All evaluation packages received from the TVA were reviewed to the detail necessary to substantiate TVA SFS conclusions. Stresses in welds were reviewed to determine if they had been correctly calculated and compared to the applicable code allowables.

When concurrence was reached with TVA engineering evaluations and SSEE was satisfied that the correct SFS conclusion for the discrepant weld had been made, the approved evaluation package was transmitted to the DOE/WEP Configuration Management (CM) for storage. Results were reported (as shown in Figure 1) for generic problem analysis, project procedures, corrective action, and group acceptance, as appropriate.[10]

Section 4 of this report contains a detailed description of the SSEE review and concurrence process. A discussion of specific design considerations for various weld types found at WBNP-1 is contained in Section 5.

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a. The DOE/WEP Standard Practices Manual is a compilation of more than 60 written procedures adopted to delineate responsibilities and practices for accomplishing DOE/WEP functions and activities. The SP WEP 3.3.1, "Suitability-For-Service Evaluation Review," provides guidelines for performing review of the TVA suitability for service evaluations of deficient welds and is included in Appendix E of this report.

4. SSEE REVIEW PROCESS

The review process, as applied to the TVA proposed dispositioning of deviant welds, represents an independent assessment of the engineering parameters controlling the affected component. The review function, defined in DOE/WEP SP WEP 3.3.1 and illustrated in Figure 2, consists of a comprehensive evaluation of the solution methodology and engineering applied by the TVA to assess the deviant welds. In addition, a review was made of the dispositioning of the deviations based on the evaluation results and criteria from the applicable codes and standards. Components found unacceptable for service and not in compliance with applicable codes required corrective action by the TVA with concurrence by the DOE/WEP.

4.1 Evaluation

The review of the TVA engineering evaluation included all areas relating to design of the affected component required to ensure no loss of needed function and conformance to the applicable codes and standards. As a minimum, areas of review consisted of confirming proper methodology, correct geometry, loads and load combinations, accurate determination of stresses and correct application of code criteria. Engineering parameters required for weld evaluations not identified as a result of the DOE/WEP inspection were obtained from the TVA design documentation.

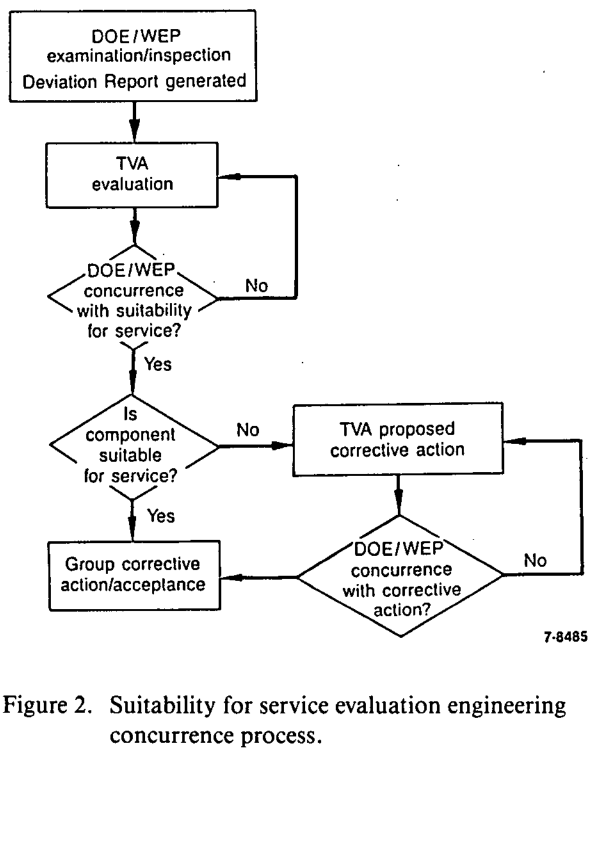

Figure 2. Suitability for service evaluation engineering concurrence process.

Component configuration and weld geometry were verified. Data used in the evaluation were reviewed to establish that they were in accordance with pertinent drawings and any field conditions reported by the DOE/WEP inspector. When calculations were based on geometries found to be in conflict with design or as-built conditions, all relevant dimensions were verified in the field.

Verification of the magnitude of design loads was outside the scope of the DOE/WEP. Loads derived by the TVA for the purposes of original design were assumed to be correct when they appeared reasonable for all required load combinations and when the source of the loading was identified. For those cases where load paths within a given component changed as a result of the discrepant weld condition or where new design loads were derived using analysis, all related calculations and SFS conclusions were confirmed by the DOE/WEP.

Actual loads based on as-constructed field conditions were often determined to be significantly lower than original design loads that were generated using conservative procedures that improved design efficiency by bounding a range of variables. The use of actual loads for the evaluation of deviant conditions was acceptable when the loads were determined accurately and consistent with original FSAR requirements.

The review verified that all reported weld deficiencies for attributes specified in the assessment plan,[4] had been accounted for in the evaluation. Table 1 lists those weld attributes that were assessed by visual inspection. Each attribute reported as affecting weld quality was addressed in a manner consistent with sound engineering practice. Reducing the effective weld size and neglecting the deviant weld areas was an acceptable method of determining the load resisting weld properties.

The TVA proposed use-as-is dispositions were acceptable for certain deviant attributes that have no effect on weld function. Weld spatter, arc strikes, porosity, and crater cracks were acceptable

Table 1. Weld attributes assessed by visual inspection

Attribute	Acceptance Criteria[a] ASME/ANSI	AWS(NCIG-01)
Cracks	1.1	1.2.2.1
Overlap	1.1	1.2.2.4
Undercut	1.1	1.2.2.7
Lack of fusion	1.1	1.2.2.3
Incomplete penetration	1.1	NA
Slag	1.1	1.2.2.11
Visible porosity	1.1	1.2.2.8
Weld spatter	1.1	1.2.2.11
Arc strikes	1.1	1.2.2.10
Coarse ripples	2.1	NA
Grooves	2.1	NA
Abrupt ridges	2.1	NA
Valleys	2.1	NA
Minimum section thickness	3.1	NA
Taper	2.3	NA
Maximum offset	3.1	NA
Reinforcement	4.1, 4.2, 4.3, 4.4	NA
Fillet/Socket weld size	5.1, 5.2	NA
Weld size	NA	1.2.2.2
Underfilled craters	NA	1.2.2.5
Weld profiles	NA	1.2.2.6
Length and location	NA	1.2.2.9
Missing or inaccessible	Appendix E	Appendix E

a. Acceptance criteria is given in appendixes to WEP Standard Practice WEP 3.2.3, "Visual Examination Methods and Acceptance Criteria." Numbers in "ASME/ANSI" column are numbered sections in Appendix A of SP WEP 3.2.3. Numbers in "AWS (NCIG-01)" column are numbered sections in Appendix C of SP WEP 3.2.3. SP WEP 3.2.3 (with Appendixes A and C) is contained in Appendix E of this report. Reference 6 provides a complete description of the DOE/WEP weld inspection/examination activities.

were acceptable based on the following justification.[a] Weld spatter has no metallurgical significance with respect to weld function. Arc strikes that have no visually detected cracking or reduction in the base material thickness below design minimum were considered to be a welding-related condition not affecting function or quality of the weld. Porosity 1/16 in. or less in diameter observed in welds receiving only visual examination was considered as not affecting weld strength. Suspected crater cracks were confirmed by liquid penetrant examination. If evaluation to the liquid penetrant acceptance criteria indicates that the weld(s) meet the criteria, the weld area is acceptable.

Surface slag reported as a result of visual inspection was not in itself considered to affect the static strength properties of a weld. The problem with surface slag is the masking effect on other, more detrimental weld attributes. Weld areas with surface slag were assumed to be a missing weld area in determining the cross-sectional area of the weld, or the slag was removed and the quality of the underlying weld determined.

a. T. L. Bridges letter to K. G. Therp, "Disposition of Weld Spatter, Arc Strike, Crater Cracks, Porosity, and Overlap Weld Discrepancies," TLB-05-86, EG&G Idaho, Inc., June 30, 1986. This communication is included in Appendix F as Exhibit 1.

Areas of overlap, lack of fusion (LOF), and lack of penetration (LOP) required consideration of potential propagation in addition to loss of weld area. Overlap existing within the weld or at weld edges was considered acceptable provided fusion at the root of the overlap could be confirmed by visual or liquid penetrant examination. The effect of LOF/LOP on the static strength properties of the weld must be considered from the standpoint of loss-of-cross-sectional area.

Weld size, length, location and profile are geometrical attributes that require an evaluation of weld strength. Undercut generally has no effect on weld strength; however, it results in a reduction of thickness of the base metal requiring evaluation including the effects of stress concentration.

Cracking, in all forms, is a deviation most detrimental to performance. A crack, by its very nature, is sharp at its extremities and acts as a stress concentrator. The stress concentration effect provided by cracks is greater than that of other discontinuities and is more intangible. In welds governed by AWS criteria, cracks may be acceptable if assessed by engineering evaluation using a rational approach with regard to the true influence of the crack size, orientation, location, and potential for growth. Crack discontinuities may be treated with a fracture mechanics approach or it may be demonstrated that crack growth will not be detrimental to the function of the weldment. For example, a crack in one of a series of intermittent welds can be acceptable if that intermittent weld can be neglected in the strength evaluations.

Crater cracks found in the ductile materials of AWS civil structural welds used at WBNP-1 would not propagate prior to yielding of the weld[a,13] and were not considered to contribute to weld failure provided other design requirements were satisfied. Areas of weld containing crater cracks were neglected in the development of weld strength properties. Cracks, including crater type, are not permitted in weldments governed by the ASME Code. Cracks must be removed from ASME weldments and the welds repaired as required.

Inaccessible welds present a particular problem for assessment of a deviant component because their quality cannot be determined. In these cases for purposes of SFS evaluations, no assumptions were made for relevant weld quality. When a component with deviant welds was reported to also contain inaccessible welds, an SFS disposition was acceptable if the component was shown to meet all appropriate criteria neglecting the inaccessible weld in its entirety.

If a deviant component failed to satisfy applicable criteria, presuming acceptable quality (i.e., not deviant) for an inaccessible weld, the component was declared unsuitable for service. When use of an inaccessible weld was required to demonstrate SFS of a deviant component, the component was declared indeterminate. Indeterminate components were removed from the group and replaced with new components selected randomly in accordance with defined procedures. Deviant conditions found in components declared indeterminate were reported to the TVA for assessment and disposition independent of the DOE/WEP.

All aspects of the TVA analysis procedures used to quantify the as-constructed (AC) and as-designed (AD) stress behavior of the weld were reviewed. Pertinent TVA design criteria documents are listed in Table 2. The AC stresses were determined for the weld in the deviant condition and were reviewed for accuracy in establishing suitability for service. The AD stresses were used to determine the effect of the deviations on weld calculated stresses (ratio of AC/AD) for performance of root cause and generic problem analysis.[8] Therefore, the DOE/WEP's review verified that the same loading was used to calculate the AD stresses as was used to determine the AC stresses. Assumptions made on expected behavior of the component and its various welds under load were reviewed for validity and consistency with standard engineering practice.

The behavior of the weld and component under the postulated loading and the manner in which these loads were treated in conjunction with other coexistent loads were reviewed. The effects of torsion and unsymmetrical bending, resulting from changes in the weldment centroid location, were appraised when evaluating peak weld stresses. When a weld was reported to contain more than one deviant attribute, it was verified that cumulative effects that decrease the weld load capacity had been properly addressed. Independent analyses were performed by SSEE when necessary to verify questionable results. A computer program developed by SSEE, Weld Analysis Program (WAP), was used to confirm deviant weld stress results reported by the TVA (Appendix A).

Fatigue was not considered a controlling factor in the civil structural weld evaluations. Structures whose design is governed by fatigue are those

a. S. J. Chang notegram to T. L. Bridges, "Safety Significance of Crater Cracks," EG&G Idaho, Inc., November 20, 1986 (see Exhibit 2 of Appendix F).

Table 2. Applicable TVA design criteria for Watts Bar Nuclear Plant Unit 1

Document	Issue Date	Revision	Title
WB-DC-20-1.2	10/06/80	R6	Reinforced Concrete Structural, and Miscellaneous Steel (after 07/23/79)
WB-DC-20-21	05/15/72	R4	Miscellaneous Steel Components for Seismic Class I Structures (after 07/23/79)
WB-DC-20-21.1	08/26/86	R2	Category I Cable Tray Supports
WB-DC-20-24	09/05/72	R2	Dynamic Earthquake Analysis of Category I and I(L) Piping Systems
WB-DC-40-31.7	01/30/76	R7	Analysis of Category I and I(L) Piping Systems
WB-DC-40-31.8	08/05/74	R4	Seismically Qualifying Round and Rectangular Duct
WB-DC-40-31.9	08/29/75	R6	Location and Design of Piping Supports and Supplemental Steel in Category I Structures
WB-DC-40-31.10	04/11/75	R3	Seismically Qualifying Conduit Supports
WB-DC-40-31.15	01/27/77	R4	Piping System Anchors Installed in Category I Structures
CEB-76-5	04/16/76	R3	Alternate Criteria for Piping Analysis and Support
CEB-76-20	09/23/75	R3	Design Data for Rectangular Support Lug Attachments to Class 2 and 3 Piping Systems
G-29C	03/10/75	R9	General Construction Specification
PSDM Vol. 1-4	05/18/82	R6	Pipe Support Design Manual
RAH-143	03/24/83	R3	Rigorous Analysis Handbook Class 2 and 3 Analysis
SAH-63	12/07/84	R1	Simplified Analysis Handbook Class 2 and 3 Analysis

structures for which analysis is required for cyclic service and whose endurance limit must be considered in the design. The design of civil structural components at WBNP-1 are not in this cyclic service category.[a] Seismic response represented the governing load condition for the majority of components evaluated. Fatigue is not the controlling design consideration for seismically loaded structures. The evaluation of piping system welds included the effects of cyclic loading by satisfying the ASME Code fatigue requirements.

The allowable stresses used in the evaluation were reviewed and compared to acceptable limits as specified in the applicable codes. Basic stress limits are those of the American Institute of Steel Construction (AISC)[14] for AWS structural welds and pipe supports and American National Standards Institute (ANSI) B31.1[15] or ASME Section III[16] for pipe welds. Increases in basic allowable stresses for load combinations, including postulated accident loads with normal loads, were acceptable when consistent with the applicable criteria documents listed in Table 2.

In addition to satisfying code stress criteria and demonstrating that reported deviant attributes would not cause loss of needed function, all mandatory code requirements had to be satisfied before a SFS conclusion could be made. Further discussion of these requirements and specific weld evaluation methods applied by the SSEE are presented in Section 3 of this report.

The DOE/WEP's examination/inspection of components welds for the plant general and specific groups was consistent with the original inspection requirements for all recreatable weld attributes. The DOE/WEP's special and expansion groups inspections were limited to those attributes necessary and sufficient to resolve the issue of interest as required by the group assessment plan.[4] For example, the assessment plan for some of the expansion groups required only inspection of weld size, profile, length, and location. Weld deviations outside of the scope of the DOE/WEP were reported to the TVA on independent discrepancy reports using a TVA form, namely, a Weld Task Group (WTG) Discrepancy Report. These deviations will be tracked,[a] analyzed, evaluated, and dispositioned by the TVA.

a. J. C. Standifer memorandum to L. E. Martin "Watts Bar Nuclear Plant Unit 1—Weld Reinspection Program—Applicability and Justification For Using NCIG-01 R2-Weld Inspection Criteria," P-104-SB-K, April 22, 1986 (see Exhibit 3 in Appendix F).

4.2 Disposition

The SSEE concurrence was required for dispositioning of deviant weld conditions and was responsible for resolution of any questionable areas of review regarding the TVA engineering evaluation that may have affected the final disposition. When portions of the analysis were unclear or when significant errors were discovered during the review, the analysis package was returned to the TVA with a description of the problem area. Package modifications, as required, were performed by the TVA and returned to the SSEE for concurrence. It was the policy of the SSEE that minor errors discovered in the evaluation, which did not affect the conclusion, could be corrected by the SSEE and noted in the summary sheet Form WEP 324 (Figure 3).

Analysis packages that were returned to the TVA for further evaluation, following the SSEE review, used Form WEP 324. Upon resolution of the evaluation issue, the SSEE approved the evaluation package and transmitted it to the DOE/WEP Configuration Management (CM) for storage. Both AC and AD stress results were reported on Form WEP 324. The AC stresses reflect the SFS status of the weld and AD stresses were reported for root cause and generic problem evaluation. The package status was further reported to the DOE/WEP Project Administration and Control (PAC) organization for tracking.

When a component or group of components were determined to be unsuitable for the performance of their intended safety function or in noncompliance with mandatory code requirements, corrective action was required. In response to that requirement, the TVA submitted a Corrective Action Plan (CAP) to the DOE/WEP for concurrence in accordance with SP WEP 3.3.3,[b] "Review of TVA Proposed Corrective Action for DOE/WEP Identified Hardware and/or Programmatic Deficiencies." The objective of the DOE/WEP concurrence review was to determine if, upon completion of the proposed CAP, the TVA would be in compliance with the applicable code requirements and, as appropriate, the TVA commitments.

a. Tracking of these activities is accomplished in accordance with the TVA WBN Administrative Instruction-AI-6.11, "Welding Evaluation Project Coordination."

b. SP WEP 3.3.3 is included in Appendix E of this report.

Form WEP 324
Rev. 7/86

SUITABILITY FOR SERVICE REVIEW SUMMARY SHEET

Analysis Package/Examination Package ID: ____________________

Weld ID Numbers of Nonconformance welds evaluated in this package:

____

____

____

_____ Attached Analysis Package has been thoroughly reviewed and in the opinion of the reviewer contains sufficient error as to invalidate the conclusions stated as to stresses being within Code Allowable Values.

_____ Attached Analysis Package has been thoroughly reviewed and to the best of my knowledge, stresses have been correctly calculated and conclusions relative to stresses being within Code Allowables are correctly stated.

_____ Comments and/or calculations are attached to support the review conclusion. Number of attached sheets is _____.

_____ Do any of the welds require corrective action _____?

_____ Summarize weld stresses on attached Weld Summary Table in terms of percent allowable.

	Name	Signature	Date
Reviewer:	________	________	________
SSEE Manager:	________	________	________

	SSEE Manager	Date
Δ	________	________
Δ	________	________

Additional Comments: ____________________

____

____

Figure 3. Suitability for service summary sheet, Form 324.

4.3 Summary

This process, which is consistent with applicable codes, represents a valid engineering approach to the resolution of weld discrepancies reported as a result of the DOE/WEP conducted inspections. The process assures the proper engineering appraisal of problem areas and provides an effective means of assessing the impact of discrepancies on plant safety and the need for specific corrective actions.

5. WELD EVALUATION METHODOLOGY

This section presents acceptable methods of demonstrating code compliance by engineering evaluation of reported weld deviations for the various types of welds at WBNP-1. The basic documents related to the evaluation of the reported deviant weld conditions of WBNP-1 include the AWS Structural Welding Code, ANSI/AWS D1.1; the AISC Manual of Steel Construction; Power Piping, ANSI B31.1; and the ASME Code Section III (References 12, 14, 15, and 16, respectively). These documents are supplemented by the design criteria listed in Table 2.

5.1 Structural Welds

The Structural Welding Code, ANSI/AWS D1.1-72 Rev. 2, 1974, was the controlling document for the welding of structures at the WBNP-1. This code covers welding requirements and is used in conjunction with a complementary code or specification for the design and construction of steel structures. The AWS Code does not, in general, deal with such design concerns as loading and the computation of stresses in members and their connections. Such considerations are assumed to be covered elsewhere and at the WBNP-1 the 7th Edition AISC Manual[14] was the governing specification, supplemented with the numerous criteria documents listed in Table 2. As an exception, the AWS Code does provide allowable stresses in welds for building and tubular structures, which are consistent with the AISC code.

The AWS Code provides acceptance criteria for visual inspection of structural welds that is in some cases more stringent than the visual weld acceptance criteria (VWAC)[17] utilized by the DOE/WEP. The use of VWAC meets the code in accordance with the provisions regarding alternate acceptance criteria. In addition, the VWAC has been approved by the United States Nuclear Regulatory Commission (USNRC) as a "technically acceptable approach for visual inspection of structural weldments of nuclear power plants that are under the purview of American Welding Society Standard D1.1 or other non-ASME class structures."[a] Thus VWAC represents an acceptable way to verify that the visual inspection requirements of the AWS have been met. Use of the AISC design techniques and allowable stresses with the VWAC inspection criteria does not compromise commitment to or compliance with the AWS code.

The general approach to the analysis of deviant weld conditions was to neglect those areas of weld reported to contain unacceptable attributes and demonstrate that the remaining weld could satisfy code stress criteria for all loading conditions. An overstressed weld within a component was not considered to affect suitability for service of the component when the stresses in all remaining members and welds of the component were determined to be below design allowables assuming failure of the overstressed weld. This approach requires that sufficient conservatism exists in the original design to accept the deviant conditions.

5.1.1 Weld Size Limits. The AISC Manual has specific requirements on the design minimum size of welds (AISC Manual Tables 1.17.2A and 1.17.2B). Minimum size fillet welds vary from 1/8 in. leg size for 1/4 in. or less thickness of material up to 5/16 in. leg size for material over 3/4 in. in thickness. Minimum size partial-penetration groove welds vary from 1/8 in. effective throat for 1/4 in. or less material thickness up to 5/8 in. effective throat for materials over 6 in. in thickness. The 1/8 in. represents the smallest practical design weld size.

The AISC minimum size requirements are design requirements. Welds not satisfying these requirements, reported as a result of the DOE/WEP inspection, could be found acceptable by valid engineering analysis. The analyses used the actual weld dimensions and showed compliance with AISC weld stress limits. This was acceptable practice provided all other weld attributes were of acceptable quality.

5.1.2 Flare Bevel Groove Welds. The TVA design drawings called for flare bevel groove welds against the curved edges of tubular structures and unistruts when welded to adjacent surfaces or to each other. The effective throat of these welds is dependent upon the depth of penetration of weld metal into the groove that may be limited by the radius of the bevel.

A criterion is required to determine the effective throat because the penetration depth cannot be

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a. J. P. Knight letter to D. E. Dutton, "Visual Weld Acceptance Criteria for Structural Welding at Nuclear Power Plants (VWAC)," Revision 2, June 26, 1985. This letter is included in Appendix F as Exhibit 4.

easily measured in the field, nor can full groove depth penetration be assured for all bevel radii. The 7th Edition of the AISC Manual, which is the design code of record, does not provide criteria for establishing the effective throat of flare bevel groove welds. The 8th Edition AISC (1980) code recommends determining the effective throat of flare bevel groove welds by multiplying the flare radius by 5/16. Larger effective throats than those obtained from this calculation are permitted when the fabricator can establish, by qualification, that he can consistently provide such larger effective throats.

For flare bevel penetration welds associated with tube steel components, the TVA design criteria were based on a qualification approach. Criteria contained in the TVA design documentation Piping System Design Manual (PSDM) Volume 3 treats the weld as a fillet weld with a maximum effective leg size equivalent to the thickness of the tube steel. This approach was acceptable to the SSEE as satisfying AISC Code requirements for the WBNP-1 tube steel structures.

For P1000 and P1001A unistrut connections, the design of the flare bevel weld is based on the TVA Mechanical Hanger Drawing Note 64 which states:

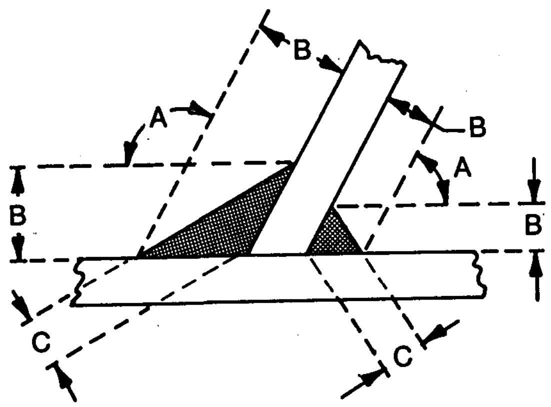
> "Where a 1/8 in. fillet weld is called for against the curved surface of P1000 and P1001A unistrut, a minimum corresponding amount of groove weld is to be substituted, optional 1/4 in. fillet maximum."

The TVA interprets this note to mean that a flush flare bevel groove weld satisfies the design requirement for a weld equivalent to a 1/8 in. fillet.

The AWS D1.1-72 code does not provide design criteria for establishing the effective throat of flare bevel groove welds and the AISC design criteria is not applicable to material thicknesses less than 1/8 in. Alternate criteria must be applied to the evaluation of flare bevel welds on the 0.105-in. thick unistrut. As recommended by later editions of AWS D1.1, the requirements of AWS D1.3, Structural Welding Code—Sheet Steel,[18] are appropriate. The allowable load capacity of flare bevel groove welds per this standard is considered to be governed by the thickness of the sheet steel adjacent to the weld with the stipulation that an effective throat at least equal to the thickness of the sheet material is consistently obtained. This would be established by qualification tests.

Qualification testing of unistrut flare bevel welds was performed by the TVA to demonstrate the strength of the welds and to establish the effective weld throat.[a] Although the results of these tests did not support the TVA interpretation of Note 64 as stated above, a basis was provided from which to evaluate deviant conditions. Suitability for service evaluations based on the qualification test results were considered by the SSEE to be acceptable and in compliance with the code.

5.1.3 Skewed Connections. Skewed T-joints (see Figure 4) in civil structures at WBNP-1 were



Legend:

A - Dihedral angle
B - Weld leg size
C - Weld throat

8-3013

Figure 4. Typical skewed T-joint.

designed with fillet and partial penetration welds or both at the toe and heel of the skewed joints depending upon the dihedral angle of the skew. The evaluation of these connections was performed in one of two ways: (a) in accordance with Watts Bar Design Criteria[b] when the fillet weld all-around symbol was specified by design or (b) in accordance with the TVA Pipe Support Design Manual when individual fillet weld symbols were specified. The fillet weld symbol is often used to call out the partial penetration weld on the heel side of connections with dihedral angles less than 60 degrees. A penalty on the effective throat size of partial

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a. R. C. Weir memorandum to C. G. Lundin, "Watts Bar Nuclear Plant (WBNP)—Weld Tests—Unistrut P-1000 Material," Tennessee Valley Authority RIMS No. B45 870511 254, May 11, 1987 (see Exhibit 5 in Appendix F).

b. Watts Bar Design Criteria, "Location and Design of Piping Supports and Supplemental Steel in Category I Structures," WB-DC-40-31.9, TVA, August 29, 1975.

penetration groove welds, governed by the dihedral angle, was accounted for in the evaluation.

Paragraph 7.15.7.3 of the TVA Pipe Support Design Manual defines the weld symbols applied by the TVA design and describes the intended weld geometries and dimensions. Because groove welds are called out as fillet welds, the evaluation of weld stresses must be performed with a thorough understanding of the design weld symbols and their relationship to weld dimensions determined from inspection. For example, the weld size symbol, S, used by the TVA design on a skewed T-joint with dihedral angle less than 60 degrees is intended to achieve an effective throat equivalent to that of a 90 degree fillet weld of leg size S (leg size S implies effective throat = 0.707S). The weld dimension, reported as a result of the DOE/WEP inspection, is the leg size corresponding to the actual measured effective throat size. When evaluating deviations from design, the actual effective throat obtained in the field must be compared to the intended design effective throat, not weld leg size.

5.1.4 Tack Welds. Tack welds used as load resisting welds were unacceptable . Tack welds only required to maintain position during installation and not required to transmit load or maintain position after installation were acceptable. A tack weld required to maintain component position during plant operation was considered load resisting and unacceptable.

5.2 Pipe Welds

Section III of the ASME Code was the governing document for the design, fabrication, and inspection of nuclear piping systems at the WBNP-1. Requirements for nonnuclear power piping were governed by the ANSI B31.1 Code.[15]

The ASME Code of record at the WBNP-1, identified in the FSAR, is the 1971 edition including Addenda through the Summer 1973 edition. The 1973 edition of ANSI B31.1 is also noted in the FSAR. The WBNP Design Criteria WB-DC-40-31.7[a] contains the general piping analysis criteria for piping systems that serve a safety-related function or can affect the function of a safety-related system. As stated in that criteria, piping systems requiring analysis are analyzed to the methods specified in the ASME Code for either Class 1 or Class 2. Systems classified as B31.1 and requiring analysis are evaluated to the ASME Code Class 2 criteria.

5.2.1 Code Analysis. An engineering evaluation of each piping weld identified by the DOE/WEP as not satisfying the provisions of Article NX-4000, Section III, of the ASME Code was made to determine whether the affected component will still satisfy all the design criteria of Article NX-3000. An acceptable analysis must include consideration of the original design conditions as well as the altered conditions resulting from the particular deviation. Specifically, the design evaluations must satisfy NB/NC-3100 "General Design," NB/NC-3640 "Pressure Design of Piping Products," and NB/NC-3650 "Analysis of Piping Systems" as appropriate for the class of pipe.

The acceptable approach for satisfying the design requirements of NX-3000 of the Code for reported deviant weld conditions is detailed in Appendix B. The analysis procedure consists of satisfying the pressure design requirements of NX-3640 using the reduced wall thickness condition caused by the deviation and accounting for any stress raisers that could increase the membrane stress. Additionally, the piping system analysis requirements of Subarticle NX-3650, using all relevant design loadings, must be satisfied. Code stress equations must be modified to account for any change in section wall thickness or cross-sectional modulus. The deviant condition stress intensification factor (SIF) or stress indices (B, C, K), as appropriate to the class of pipe, must be considered in the Code equations.

Section III of the ASME Code does not allow the use of engineering evaluation for the acceptance of Code components found in noncompliance of Article NX-5000, Examination. For welds designed in accordance with Section III of the ASME Code to be considered acceptable, all design, fabrication, and examination requirements must be satisfied. However, minor local deviations from the workmanship standards for welded joints in Section III components and pipe systems, given in Subarticle NX-4420, may exist without compromising Code compliance. In accordance with a recently submitted and approved Code Inquiry (Appendix C), minor local deviations from the provisions of NX-4420 may be acceptable if it is demonstrated that existing conditions satisfy the design criteria of Article NX-3000. Weld deviations that may be evaluated for Code compliance by

a. Watts Bar Design Criteria, "Analysis of Category I and I(L) Piping Systems," WB-DC-40-31.7, TVA, January 30 1976.

satisfying the criteria of Article NX-3000 are surface conditions such as undercut, minimum taper, minimum section thickness, maximum offset, maximum reinforcement and fillet and socket weld size.

Visually detected porosity smaller than 1/16 in. in diameter was considered as not affecting suitability for service. This is consistent with ASME rounded indication acceptance criteria. Arc strikes and surface spatter are not addressed by ASME Code requirements and are therefore not rejectable. Arc strikes, with no associated cracking or violation of minimum wall thickness requirements, were not considered to affect suitability for service. Surface slag, which could mask other indications, is rejectable by NX-5000 and must be removed.

Deviant weld conditions, reported in piping systems designed to the ANSI B31.1 Code, may be determined suitable for service when the stress requirements of ASME Code Article NX-3000 are satisfied, clearly accounting for all the effects of the deviant condition. The use of engineering evaluation for the acceptance of B31.1 welding does not violate commitment to that Code when the approach demonstrates the use of valid engineering principles.

5.2.2 Integral Pipe Lugs. Integral type pipe support lug attachments on ASME and ANSI B31.1 code designed pipe systems at the WBNP-1 were inspected/examined per DOE/WEP SP WEP 3.2.3. Lug attachments are made integral with the pipe by being welded to it using a full penetration or fillet type weld.

Numerous pipe lugs were reported to have inaccessible ends because of their proximity to stops. When the quality of the weld at the ends of these lugs could not be determined because of access, the lugs were conservatively evaluated neglecting 20% of the lug length, in addition to accounting for all other reported deviations.

When evaluating the effects of weld deviations on lug and weld stresses for acceptance to Code criteria, consideration must be given to stresses induced in the pipe by the lug. As stated in ASME Code Section III Article NC-3645, the attachment must not cause flattening of the pipe or excessive localized bending or thermal stresses. Lug induced pipe stresses must be added to all other design stresses when evaluating Code allowables. Stresses in the pipe are determined using an approach that satisfies the conditions of ASME Code Case N-318-3[a] and accounts for the reported deviations. This Code case has provisions for both fillet and full penetration welds. For the fillet weld design, the lug-to-pipe weld stress must be evaluated in addition to the lug-induced pipe stress. Reducing the lug size to account for weld defects is a conservative means of evaluating the lug-induced pipe stress and a realistic means of evaluating the weld stress.

A detailed procedure for accomplishing such an evaluation is contained in Appendix D. This evaluation will provide adequate justification that the piping and lug will perform its intended safety function for all design loading conditions without compromising the pipe pressure boundary. This procedure is applicable for all ANSI B31.1 piping integral lug weld deviations. It is not currently ASME Code approved for weld deviations not meeting the examination requirements of Article NX-5000. Components with these deviations cannot be dispositioned suitable for service without corrective action.

a. Cases of ASME Boiler and Pressure Vessel Code, N-318-3, Approved September 5, 1985.

6. REFERENCES

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9. L. C. Brown and R. J. Wade, *WEP Aggregate Results of Weld Assessments*, DOE/ID-10175-8, November 1987.

10. F. C. Fogarty, *Weld Evaluation Project Final Report, DOE/ID-10175-9*, November 1987.

11. United States Nuclear Regulatory Commission, Atomic Safety and Licensing Appeal Board, Judgement 22 USNRC 59 (1985), ALAB-13, July 26, 1985.

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13. R. D. Stout and W. D. Doty, *Weldability of Steels*, Weld Research Council, New York, 1978.

14. American Institute of Steel Construction, Inc., Manual of Steel Construction, 7th Edition, 1973.

15. The American Society of Mechanical Engineers, "Power Piping," ANSI B31.1, June 15, 1973, with Summer 1973 Addenda.

16. The American Society of Mechanical Engineers, "Rules for Construction of Nuclear Power Plant Components," ASME Boiler and Pressure Vessel Code, Section III—Division 1, 1971 Edition with Summer 1973 Addenda.

17. Nuclear Construction Issues Group, "Visual Weld Acceptance Criteria for Structural Welding at Nuclear Power Plants," NCIG-01, Rev. 2, May 7, 1985.

18. American Welding Society Inc., "Specification for Welding Sheet Steel in Structures," AWS D1.3-78, 1978.

19. R. F. Reedy and W. H. Miller, "ASME Nuclear Code-Construction Turnover and Local Site Issues," *Mechanical Engineering*, ASME, September 1984.

APPENDIX A

WELD ANALYSIS PROGRAM (WAP)

APPENDIX A
WELD ANALYSIS PROGRAM (WAP)

WAP is a weld analysis program for evaluating stresses in arbitrary configured continuous and broken weldment geometries. WAP was developed by WEP-SSEE for expeditious, independent evaluation of stresses in weld configurations which can be extremely unsymmetrical. Results of WAP analysis were compared to TVA engineering evaluations of deviant welds in the assessment of weld suitability for service.

Input to WAP consists of weld geometry, effective weld thickness, loads and allowable stresses.

Weld geometry is defined by dividing the weld into a number of straight-line segments. Curved weldments can be approximated and weld segments can be disjointed from each other. The coordinates of the segment end points are the program data that serve to define the weld geometry.

The effective weld thickness input corresponds to the weld or adjacent base metal material being evaluated. Each weld segment may have a different thickness. For analysis of the weld strength, the effective thickness is equal to the weld effective throat dimension. For analysis of the weld adjacent base metal, the effective thickness is equal to the weld leg size.

The weldment area and centroid are determined by the program and moments of interia are evaluated about the calculated centroidal location. By defining loads about this centroidal location any effects of an unsymmetrical configuration are properly addressed (unsymmetrical bending and twisting).

In addition to weldment section properties, maximum weld stresses are determined at each end of each weld segment. To account for the direction of seismic loading, signs on loads are taken in that combination that produces the maximum stress. All stress combinations are output using both algebraic and absolute summations.

```
10      REM : adjust for the eccentric loads on the weld space, 6/16/87
20      REM : include the ploting of weld segments on screen,  6/ 1/87
30      REM : allow for input of ALLOWABLE STRESSE ,           3/10/87
40      REM : work with TOSHIBA printer,                       4/30/87
50      DEFINT G
60      OPTION BASE 1
70      RANDOMIZE TIMER
80      ON ERROR GOTO 4320
90      DIM GARRAY(3)
100      DIM XI(20),XJ(20),YI(20),YJ(20),B(20),L(20),A(20)
110      DIM XIP(20),XJP(20),YIP(20),YJP(20),YIM(20),YJM(20)
120      DIM I(20),IX(20),IY(20),AX(20),AY(20),TI(20,2),TAI(20,2)
130      SCREEN 0,1
140      COLOR 15,1
150      CLS
160      KEY OFF
170             PLOTFLAG = 0  'CONTROL FLAG FOR THE SCREEN DUMP SUBROUTINE
180             XLOAD = 0     'INITIATE THE ECCENTRIC LOAD FLAG
190             YLOAD = 0
200             ZLOAD = 0
210      M$ = "manual input"
220      CLS
230 PRINT "*********************************************************************"
240 PRINT "*   WELD PROPERTY EVALUATION PROGRAM  by Tom Bridges - E.G.& G.    *"
250 PRINT "*********************************************************************"
260     COLOR 14,1
270     PRINT
280     PRINT "DO YOU WANT TO USE DATA FROM AN EXISTING FILE ?....Y/N "
290     PRINT
300     A$ = INKEY$
310     IF A$ = "y" OR A$ = "n" THEN 330
320     IF A$ = "Y" OR A$ = "N" THEN 330 ELSE 300
330     OPEN "ZYX" FOR OUTPUT AS #2
340     CLOSE #2
350     INPUT "ENTER FILE NAME FOR DATA OUTPUT ? ",F$
360     PRINT
370     F$=LEFT$(F$,8)
380     NAME "ZYX" AS F$
390     REM ERROR TRAPPING ROUTINE STARTS HERE !
400     OPEN F$ FOR OUTPUT AS #2
410     IF A$ = "N" OR A$="n" THEN 960
420     REM ***************************************************************
430     REM            THIS SECTION FOR FILE INPUT ONLY
440     REM ***************************************************************
450     INPUT "ENTER EXISTING INPUT FILE NAME ? ",M$
460     M$=LEFT$(M$,8)
470     OPEN M$ FOR INPUT AS #1
480     REM INPUT PROBLEM DESCRIPTIONS OR TITLE
490     LINE INPUT #1, PN$
500     PRINT #2, PN$
510     REM  INPUT NUMBER OF WELD SEGMENTS
520     INPUT #1, N
530     PRINT #2, N
540     REM INPUT WELD COORDINATES FROM START TO END POINTS
550     FOR I=1 TO N
```

```
560    INPUT #1,XI(I),YI(I),XJ(I),YJ(I),B(I)
570    PRINT #2, XI(I),",";YI(I),",";XJ(I),",";YJ(I),",";B(I)
580    NEXT I
590    GOSUB 4480
600    SCREEN 0,1
610    COLOR 14,1
620    REM ***** SKIP THE NEXT LINE OF INPUT FILE
630    LINE INPUT #1, QN$
640    PRINT #2,    " X-FORCE","Y-FORCE","Z-FORCE"
650    REM INPUT FORCE IN X-DIRECTION
660    INPUT #1, FX
670    PRINT #2, FX
680    REM INPUT FORCE IN Y-DIRECTION
690    INPUT #1, FY
700    PRINT #2, FY
710    REM INPUT FORCE IN Z-DIRECTION
720    INPUT #1, FZ
730    PRINT #2, FZ
740    REM ***** SKIP THE NEXT LINE OF INPUT FILE
750    LINE INPUT #1, QN$
760    PRINT #2,     "X-MOMENT","Y-MOMENT","TORQUE"
770    REM INPUT MOMENT IN X-DIRECTION
780    INPUT #1, MX
790    PRINT #2, MX
800    REM INPUT MOMENT IN Y-DIRECTION
810    INPUT #1, MY
820    PRINT #2, MY
830    REM INPUT TORQUE
840    INPUT #1, T
850    PRINT #2, T
860    INPUT #1, ALLOW
870    IF ALLOW = 0 THEN ALLOW = 14.4
880    PRINT #2, ALLOW
890    INPUT #1, XLOAD, YLOAD, ZLOAD        'INPUT COORDINATES FOR THE
900    PRINT #2, XLOAD,","; YLOAD,","; ZLOAD       'ECCENTRIC LOADS
910    REM
920    GOTO 1110
930    REM ************************************************************
940    REM                 NEXT SECTION FOR MANUAL INPUT ONLY
950    REM ************************************************************
960    INPUT "          INPUT PROBLEM DESCRIPTION OR TITLE              "; PN$
970    PRINT #2, PN$
980    PRINT
990    INPUT "HOW MANY TOTAL WELD SEGMENTS ARE THERE ? ", N
1000    PRINT #2, N
1010    FOR I=1 TO N
1020    PRINT "WELD SEGMENT NO.",I
1030    PRINT
1040    PRINT "INPUT  X(i) , Y(i) , X(j) , Y(j) , B (width) ?"
1050    INPUT XI(I),YI(I),XJ(I),YJ(I),B(I)
1060    PRINT #2, XI(I),",";YI(I),",";XJ(I),",";YJ(I),",";B(I)
1070    NEXT I
1080    GOSUB 4480
1090    SCREEN 0,1
1100    COLOR 14,1
```

```
1110    REM ***************************************************************
1120        FOR I=1 TO N
1130        B(I) =ABS(B(I))
1140        L(I)=SQR((XJ(I)-XI(I))^2+(YJ(I)-YI(I))^2)
1150        IF L(I) <> 0 THEN 1190
1160        LPRINT
1170     LPRINT " WARNING ! ZERO SEGMENT LENGTH, THE RESULT MAY BE INVALID !"
1180        LPRINT
1190        A(I)=L(I)*B(I)
1200        AX(I)=ABS((XJ(I)-XI(I))*B(I))
1210        AY(I)=ABS((YJ(I)-YI(I))*B(I))
1220        I(I)=B(I)*(L(I)^3)/(12!)
1230           IF B(I) > 0 THEN 1280
1240           PRINT "ZERO WIDTH AT WELD SEGMENT  ";I
1250           IY(I)= 0
1260           IX(I)= 0
1270           GOTO 1300
1280        IY(I)=((AX(I)/A(I))^2)*I(I)
1290        IX(I)=((AY(I)/A(I))^2)*I(I)
1300        REM
1310        NEXT I
1320    REM ***************************************************************
1330    XX=0
1340    YY=0
1350    AA=0
1360    REM area moment calculation
1370       FOR I=1 TO N
1380       XX=XX+(A(I)*(XI(I)+XJ(I))/2)
1390       YY=YY+(A(I)*(YI(I)+YJ(I))/2)
1400       AA=AA+A(I)
1410       NEXT I
1420   REM ***************************************************************
1430   XB=XX/AA
1440   YB=YY/AA
1450   AXT=0
1460   AYT=0
1470   IXT=0
1480   IYT=0
1490   IXY=0
1500       FOR I=1 TO N
1510       AXT=AXT+AX(I)
1520       AYT=AYT+AY(I)
1530       IXT=IXT+IX(I)+A(I)*((YI(I)+YJ(I))/2-YB)^2
1540       IYT=IYT+IY(I)+A(I)*((XI(I)+XJ(I))/2-XB)^2
1550   REM
1560   TERM2 = A(I)*((YJ(I)+YI(I))/2-YB)*((XJ(I)+XI(I))/2-XB)
1570   TERM1 = ((YJ(I)-YI(I))^2 + (XJ(I)-XI(I))^2)
1580   IXY=IXY+I(I)*(YJ(I)-YI(I))*(XJ(I)-XI(I))/TERM1 + TERM2
1590       NEXT I
1600   REM ***************************************************************
1610   J=IXT+IYT
1620  REM  PRINT "CHECK POINT 2"
1630   IF IXT=IYT THEN 1660
1640   TT=ATN(-IXY*2/(IXT-IYT))
1650   GOTO 1720
```

```
1660  IF IXY > 0 THEN 1700
1670  TT = 3.1416/2
1680  IF IXY = 0 THEN TT = 0
1690  GOTO 1720
1700  TT = - 3.1416/2
1710  GOTO 1720
1720  IPX=J/2+((IXT-IYT)*COS(TT)/2)-(IXY*SIN(TT))
1730  IPY=J-IPX
1740  REM ****************************************************************
1750  REM       PLOT THE CENTROID ON SCREEN
1760  REM ****************************************************************
1770  TTDEG = INT(TT*28.65*100+.5)/100
1780  PLOTFLAG = 1             'SET FLAG FOR THE SCREEN DUMP SUBROUTINE
1790  GOSUB 5920
1800  REM
1810  SCREEN 0,1
1820  COLOR 14,1
1830  CLS
1840  KEY OFF
1850  IF A$ = "Y" OR A$ = "y" THEN 2210
1860  REM ****************************************************************
1870  PRINT #2,    "X-FORCE","Y-FORCE","Z-FORCE"
1880  PRINT
1890  INPUT "INPUT FORCE IN X-DIRECTION ";FX
1900  PRINT #2, FX
1910  PRINT
1920  INPUT "INPUT FORCE IN Y-DIRECTION ";FY
1930  PRINT #2, FY
1940  PRINT
1950  INPUT "INPUT FORCE IN Z-DIRECTION ";FZ
1960  PRINT #2, FZ
1970  PRINT #2,    "X-MOMENT","Y-MOMENT","TORQUE"
1980  PRINT
1990  INPUT "INPUT MOMENT IN X-DIRECTION ";MX
2000  PRINT #2, MX
2010  PRINT
2020  INPUT "INPUT MOMENT IN Y-DIRECTION ";MY
2030  PRINT #2, MY
2040  PRINT
2050  INPUT "INPUT TORQUE ";T
2060  PRINT #2, T
2070  PRINT
2080  INPUT "INPUT ALLOWABLE STRESS FOR THE WELD (KSI) "; ALLOW
2090  IF ALLOW = 0 THEN ALLOW = 14.4
2100  PRINT #2, ALLOW
2110  PRINT
2120  INPUT "  DO YOU WANT TO INPUT ECCENTRIC-LOAD COORDINATES ? Y/N  ", EC$
2130  EC$ = LEFT$(EC$,1)
2140  IF EC$ = "Y" OR EC$ = "y" THEN  2170
2150  IF EC$ = "N" OR EC$ = "n" THEN  2190
2160  GOTO 2120
2170  LPRINT
2180  INPUT "ENTER COORDINATES OF THE LOAD, X , Y , Z ? ",XLOAD, YLOAD, ZLOAD
2190  PRINT #2, XLOAD,",", YLOAD,",", ZLOAD        'ECCENTRIC LOADS
2200  REM
```

```
2210 REM *****************************************************************
2220 PRINT
2230 INPUT " DO YOU WANT TO INCLUDE ALL AREA FOR SHEAR CALCULATION ? Y/N ",SR$
2240 SR$ = LEFT$(SR$,1)
2250 IF SR$ = "Y" OR SR$ = "y" THEN 2280
2260 IF SR$ = "N" OR SR$ = "n" THEN 2300
2270 GOTO 2230
2280 FLAG = 1
2290 GOTO 2330
2300 FLAG = 0
2310 REM *****************************************************************
2320 REM
2330 REM LPRINT CHR$(27)"P 0"                    'initialize printer
2340 LPRINT CHR$(27)"0" 'SELECT 1/8 INCH LINE FEED
2350 LPRINT CHR$(18)     'SELECT 10 CPI
2360 IF N < 6 THEN 2390
2370 LPRINT CHR$(27)"1"  'set 1/10 inch line feed
2380 LPRINT
2390 LPRINT "*****************************************************************"
2400 LPRINT "*     WELD  EVALUATION  PROGRAM     by Tom L. Bridges    1986  *"
2410 LPRINT "*****************************************************************"
2420 LPRINT "The allowable stress is (in KSI) : ";ALLOW
2430 REM LPRINT
2440  WIDTH "LPT1:",96
2450 REM LPRINT CHR$(27)"M"  'select 12 CPI print form, epson printer
2460 REM LPRINT CHR$(27)":"  'select 12 CPI print form, toshiba printer
2470 LPRINT CHR$(15)         'select compressed print for IBM printer
2480 LPRINT "Date: ";DATE$;" Time: ";TIME$;"  Files* Input: ";M$;" Output: ";F$
2490 LPRINT
2500 LPRINT CHR$(27)":"      'select 12 CPI for ibm printer
2510 LPRINT "Problem description : ";PN$
2520 LPRINT
2530 REM initiation of maximum stresses
2540    MAXI = 0
2550    MAXJ = 0
2560    ABSMAXI = 0
2570    ABSMAXJ = 0
2580 LPRINT "Number of weld segments = ";N
2590 LPRINT
2600 REM LPRINT CHR$(27)"g"
2610 LPRINT "Segment", " X(i)"," Y(i)"," X(j)"," Y(j)"," Width"
2620 LPRINT
2630 FOR I=1 TO N
2640 LPRINT I,XI(I),YI(I),XJ(I),YJ(I),B(I)
2650 NEXT I
2660 TTDEG = INT(TT*28.65*100+.5)/100
2670 LPRINT
2680 PRINT #2,
2690 LPRINT " Total area","Shear area X","Shear area Y",
2700 LPRINT "Rotation-deg.  X-centroid  Y-centroid"
2710 LPRINT USING "###.#####    ";AA,AXT,AYT,TTDEG,XB,YB
2720 LPRINT
2730 LPRINT "    I-xx ","    I-yy ","    I-xy","    J","    IPx ","    IPy"
2740 LPRINT USING "###.#####    ";IXT, IYT, IXY,J,IPX,IPY
2750 LPRINT
```

```
2760 PRINT #2, " Total area","Shear area X","Shear area Y",
2770 PRINT #2, "Rotation-deg."," X-centroid"," Y-centroid"
2780 PRINT #2, USING "###.######    ";AA,AXT,AYT,TTDEG,XB,YB
2790 PRINT #2,
2800 PRINT #2,"    I-xx ","    I-yy ","    I-xy","    J","       IPx ","    IPy"
2810 PRINT #2, USING "###.######    ";IXT, IYT, IXY,J,IPX,IPY
2820 REM
2830 REM check for shear area option
2840     IF AXT= 0 OR AYT =0 THEN FLAG =1
2850     IF FLAG = 0 THEN 2980
2860     AXT = AA
2870     AYT = AA
2880 PRINT
2890 PRINT #2,
2900 PRINT #2,"****   THE TOTAL AREA IS USED FOR SHEAR CALCULATION   ***"
2910 PRINT "****   THE TOTAL AREA IS USED FOR SHEAR CALCULATION   ***"
2920 LPRINT "****     THE TOTAL AREA IS USED FOR SHEAR CALCULATION     *****"
2930 LPRINT
2940 LPRINT " Total area","Shear area X","Shear area Y",
2950 LPRINT "Rotation-deg.  X-centroid  Y-centroid"
2960 LPRINT USING "###.#####     ";AA,AXT,AYT,TTDEG,XB,YB
2970 LPRINT
2980 REM
2990 IF XLOAD = 0 AND YLOAD= 0 AND ZLOAD= 0 THEN 3110
3000 LPRINT " Eccentric load location:","    X ","    Y ","    Z "
3010 LPRINT "     ", "     ",
3020 LPRINT USING "###.####      ";XLOAD,YLOAD,ZLOAD
3030 LPRINT
3040 LPRINT " Original moments : ","    MX","    MY"," TORQUE"
3050 LPRINT "     ","     ",
3060 LPRINT USING "###.####      ";MX, MY, T
3070 LPRINT
3080 MX = ABS(MX) + ABS((YB-YLOAD)*FZ) + ABS(ZLOAD*FY)
3090 MY = ABS(MY) + ABS((XB-XLOAD)*FZ) + ABS(ZLOAD*FX)
3100 T  = ABS(T)  + ABS((XB-XLOAD)*FY) + ABS((YB-YLOAD)*FX)
3110 LPRINT " Maximum total moments : ","    MX", "    MY", "  TORQUE"
3120 LPRINT "     ","     ",
3130 LPRINT USING "###.####      ";MX, MY, T
3140 LPRINT
3150 REM
3160 COUNT=0
3170 LPRINT " Forces :"," "," X-force "," Y-force"," Z-force  "
3180 LPRINT "     ","     ",
3190 LPRINT USING "###.#####     ";FX, FY, FZ
3200 PRINT #2,"X-force  = ",FX,"Y-force  = ",FY," Z-force = ",FZ
3210 PRINT #2,
3220 COUNT=COUNT+1
3230 LPRINT CHR$(27)":"
3240 LPRINT "****************************************************************"
3250 LPRINT " Moments:"," "," X-moment "," Y-moment "," Torque  "
3260 LPRINT "     ","     ",
3270 LPRINT USING "###.#####     ";MX, MY, T
3280 LPRINT
3290 REM LPRINT CHR$(27)"P" 'NOT NEEDED FOR TOSHIBA PRINTER
3300 LPRINT " WELD ","ALGEBRAIC COMBINED STRESS    ABS-SUM COMBINED STRESS"
```

```
3310 LPRINT "SEGMENT "," I - END "," J - END "," I - END "," J - END"
3320 REM
3330 PRINT #2,"**************************************************************"
3340 PRINT #2,"X-moment = ",MX,"Y-moment = ",MY," Torque = ",T
3350 PRINT #2,
3360 PRINT #2," WELD ","ALGEBRAIC COMBINED STRESS    ABS-SUM COMBINED STRESS"
3370 PRINT #2,"SEGMENT "," I - END "," J - END "," I - END "," J - END"
3380 LPRINT
3390 REM
3400     FOR I=1 TO N
3410       IF B(I)=0  THEN 3920
3420           Z1   =XI(I)
3430           Z2   =YI(I)
3440           FOR K=1 TO 2
3450           IF FLAG = 1 THEN AX(I) = A(I)
3460           REM
3470           SX=(YB-YI(I))*T/J+(FX*AX(I))/(AXT*A(I))
3480           SAX=ABS((YB-YI(I))*T/J)+ABS((FX*AX(I))/(AXT*A(I)))
3490           REM
3500           IF FLAG = 1 THEN AY(I) = A(I)
3510           SY=(XI(I)-XB)*T/J+(FY*AY(I))/(AYT*A(I))
3520           SAY=ABS((XI(I)-XB)*T/J)+ABS((FY*AY(I))/(AYT*A(I)))
3530           REM
3540           MPX=MX*COS(TT/2)+MY*SIN(TT/2)
3550           MPY=-MX*SIN(TT/2)+MY*COS(TT/2)
3560           R=SQR((XI(I)-XB)^2+(YI(I)-YB)^2)
3570      REM  PRINT "CHECK POINT 3"
3580           IF (XI(I)-XB)>0! THEN GOTO 3620
3590   REM zeros are added to the denominator to pass internal error checking
3600           F=3.1416+ATN((YI(I)-YB)/(XI(I)-XB+1E-09))
3610           GOTO 3630
3620           F=ATN((YI(I)-YB)/(XI(I)-XB))
3630           CXP=R*SIN(F-(TT/2))
3640           CYP=-(R*COS(F-(TT/2)))
3650           IF IPX= 0 AND IPY= 0 THEN 3700
3660           IF IPX=0 GOTO 3720
3670           IF IPY=0 GOTO 3740
3680           SZ=FZ/AA+MPX*CXP/IPX+MPY*CYP/IPY
3690           GOTO 3750
3700           SZ=FZ/AA
3710           GOTO 3750
3720           SZ=FZ/AA+MPY*CYP/IPY
3730           GOTO 3750
3740           SZ=FZ/AA+MPX*CXP/IPX
3750           REM
3760           TI(I,K) = SQR(SX^2+SY^2+SZ^2)
3770           TAI(I,K) = SQR(SAX^2+SAY^2+SZ^2)
3780           REM
3790           XI(I)=XJ(I)
3800           YI(I)=YJ(I)
3810           NEXT K
3820        XI(I)=Z1
3830        YI(I)=Z2
3840        LPRINT I,
3850        LPRINT USING "###.######    ";TI(I,1),TI(I,2),TAI(I,1),TAI(I,2)
```

```
3860         PRINT #2,I,
3870       PRINT #2,  USING "###.######    ";TI(I,1),TI(I,2),TAI(I,1),TAI(I,2)
3880         IF ABS(TI(I,1)) > MAXI THEN MAXI = ABS(TI(I,1))
3890         IF ABS(TI(I,2)) > MAXJ THEN MAXJ = ABS(TI(I,2))
3900         IF ABS(TAI(I,1)) > ABSMAXI THEN ABSMAXI = ABS(TAI(I,1))
3910         IF ABS(TAI(I,2)) > ABSMAXJ THEN ABSMAXJ = ABS(TAI(I,2))
3920         REM
3930       NEXT I
3940     IF COUNT=1 THEN GOTO 3960
3950     GOTO 3980
3960     MX=-MX
3970     GOTO 3220
3980     IF COUNT=3 GOTO 4020
3990     MX=-MX
4000     MY=-MY
4010     GOTO 3220
4020   PRINT #2,
4030   LPRINT
4040   SRI = INT(MAXI/ALLOW*10000)
4050   SRI =SRI/10000
4060   SRJ = INT(MAXJ/ALLOW*10000)
4070   SRJ = SRJ/10000
4080   ABSRI = INT(ABSMAXI/ALLOW*10000)
4090   ABSRI = ABSRI /10000
4100   ABSRJ = INT(ABSMAXJ/ALLOW*10000)
4110   ABSRJ = ABSRJ/10000
4120   LPRINT "MAXI. STRESS",
4130   LPRINT USING "###.######    ";MAXI,MAXJ,ABSMAXI,ABSMAXJ
4140   LPRINT "STRESS RATIO",
4150   LPRINT USING "  #.####      ";SRI,SRJ,ABSRI,ABSRJ
4160   PRINT #2,"MAXI. STRESS",
4170   PRINT #2,USING "###.######    ";MAXI,MAXJ,ABSMAXI,ABSMAXJ
4180   PRINT #2,"STRESS RATIO",
4190   PRINT #2,USING "  #.####      ";SRI,SRJ,ABSRI,ABSRJ
4200   CLOSE #1
4210   CLOSE #2
4220   LPRINT
4230   LPRINT
4240   LPRINT
4250   REM LPRINT CHR$(27)"2"
4260   LPRINT CHR$(12)
4270    SOUND 880,10
4280    SOUND 670,3
4290 RESTORE
4300 GOTO 130
4310   END
4320   IF ERR= 58 THEN 4330 ELSE 4450
4330 INPUT "WARNING ! FILENAME ALREADY EXISTS ! O.K. TO OVERWRITE ? Y/N  ",QN$
4340   PRINT
4350   QN$ = LEFT$(QN$,1)
4360    IF QN$ = "Y" OR QN$ = "y" THEN 4370 ELSE 4430
4370      REM  back up the existing filename with a random extension number
4380          V$ = F$+"." + MID$(STR$(INT(RND * 1000)),2)
4390          PRINT "  The existing file will be renamed as     ";V$
4400          NAME F$ AS V$
```

```
4410         PRINT
4420  RESUME NEXT
4430 PRINT "TRY AGAIN !"
4440 RESUME 350
4450 ON ERROR GOTO 0
4460 STOP
4470 REM ***********************************************************************
4480 REM     SUBROUTINE TO PLOT THE WELD PATTERN ON SCREEN
4490 REM ***********************************************************************
4500     SCALE = 1                  'SCALE FACTOR FOR GRAPHICAL PLOT
4510     XMAX = -10000000#
4520     XMIN =  10000000#
4530     YMAX = -10000000#
4540     YMIN =  10000000#
4550     FOR  I = 1 TO N
4560         REM CORRECT FOR MIRROR IMAGE TO DISPLAY ON MONITOR
4570         YIM(I) = - YI(I)
4580         YJM(I) = - YJ(I)
4590     IF XI(I) > XMAX THEN XMAX = XI(I)
4600     IF XJ(I) > XMAX THEN XMAX = XJ(I)
4610     IF YIM(I) > YMAX THEN YMAX = YIM(I)
4620     IF YJM(I) > YMAX THEN YMAX = YJM(I)
4630     IF XI(I) < XMIN THEN XMIN = XI(I)
4640     IF XJ(I) < XMIN THEN XMIN = XJ(I)
4650     IF YIM(I) < YMIN THEN YMIN = YIM(I)
4660     IF YJM(I) < YMIN THEN YMIN = YJM(I)
4670     NEXT I
4680     XBAR = (XMAX + XMIN)/2
4690     YBAR = (YMAX + YMIN)/2
4700     XFACTOR = 640 /(XMAX - XMIN)/2.4
4710     YFACTOR = 200 /(YMAX - YMIN)
4720     FACTOR = XFACTOR
4730     IF YFACTOR < FACTOR THEN FACTOR = YFACTOR
4740     XFACT   = .6 * FACTOR * 2.4         'LEAVE BORDER FOR PLOTS
4750     YFACT   = .6 * FACTOR
4760     SCREEN 2,0
4770     KEY OFF
4780     CLS
4790   FOR I = 1 TO N
4800     IF B(I) = 0 THEN 4880            'skip zero width weld segments
4810         XPAINT = (X1 + X2 + X3 + X4)/4
4820     XIP(I) =INT( (XI(I) - XBAR) *  XFACT  ) + 320
4830     XJP(I) =INT( (XJ(I) - XBAR) *  XFACT  ) + 320
4840     YIP(I) =INT( (YIM(I) - YBAR) * YFACT  ) + 100
4850     YJP(I) =INT( (YJM(I) - YBAR) * YFACT  ) + 100
4860 REM     DRAW "BM=XIP(I);,=YIP(I); M=XJP(I);,=YJP(I);"
4870         GOSUB 5650
4880 REM
4890     NEXT I
4900 REM
4910 REM ***********************************************************************
4920 REM     THIS PROGRAM WILL PLOT THE AXES ON THE SCREEN
4930 REM ***********************************************************************
4940       DRAW "BM64,19 M64,180 M577,180"
4950         TICMAX = INT(510/XFACT  ) + 1
```

```
4960            MULT = 1    ' reduce the tic marks
4970            IF TICMAX > 30 THEN MULT = 10
4980          FOR I = 1 TO TICMAX
4990          XPOINT = I * XFACT * MULT   +64
5000          XHALF = XPOINT - (XFACT * MULT  /2)
5010          IF XPOINT > 577 THEN 5030
5020        DRAW "BM=XPOINT;,180 M+0,-6"
5030          REM
5040          IF XHALF > 577 THEN 5060
5050        DRAW "BM=XHALF;,180 M+0,-3"
5060          YPOINT = 180 - I * YFACT * MULT
5070          YHALF = YPOINT + (YFACT * MULT  /2)
5080          IF YHALF < 19 THEN 5100
5090        DRAW "BM64,=YHALF; M+8,+0"
5100          REM
5110          IF YPOINT < 19 THEN 5130
5120        DRAW "BM64,=YPOINT; M+16,+0"
5130          REM
5140          NEXT I
5150          LOCATE 2,8
5160          PRINT "Y"
5170          LOCATE 23,78
5180          PRINT "X"
5190    IF MULT=10 THEN 5230
5200      LOCATE 25,3
5210      PRINT PN$+"        Scale: 1 tic = 1 in."
5220          GOTO 5250
5230      LOCATE 25,3
5240      PRINT PN$+"        Scale: 1 tic = 10 in."
5250  REM
5260      IF PLOTFLAG > 0 THEN 5370        'CHECK THE PLOT FLAG
5270          SOUND 1000,5
5280      LOCATE 1,30
5290      INPUT "CORRECT WELD GEOMETRY (Y/N)";G$
5300      IF G$ = "Y" THEN 5370
5310      IF G$ = "y" THEN 5370
5320      GOTO 130
5330     DATA &HCD55
5340     DATA &H5D05
5350     DATA &H90CB
5360  REM ************************************************************
5370  REM          SCREEN DUMP SUBROUTINE
5380  REM ************************************************************
5390      IF PLOTFLAG = 0 THEN 5450
5400        SOUND 1000,5
5410      LOCATE 1,28
5420      INPUT"PRINT WELD GEOMETRY ON PAPAER (Y/N)";G$
5430      IF G$ = "Y" THEN 5480
5440      If G$ = "y" THEN 5480
5450  REM
5460      RETURN
5470  REM **************************************************************
5480  REM     THIS IS THE CORE PROGRAM FOR SCREEN DUMP
5490  REM **************************************************************
5500      LOCATE 1,28
```

```
5510       PRINT "                                                    "
5520       FOR I = 1 TO 3
5530       READ GARRAY(I)
5540       NEXT I
5550       SUBRT= VARPTR(GARRAY(1))
5560       CALL SUBRT
5570     LPRINT CHR$(27) "S1"                   'turn on superscripts
5580     LPRINT CHR$(15)          'select compressed print for IBM printer
5590 LPRINT "Date: ";DATE$;" Time: ";TIME$;" File* Input: ";M$;" Output : ";F$
5600     LPRINT CHR$(27) "T"                    'turn off superscripts
5610       LPRINT CHR$(12)     'FORM FEED-ADVANCE A NEW PAGE
5620       CLS
5630       RETURN
5640  REM ********************************************************************
5650  REM    THIS MODULE PLOTS THE WIDTH OF THE WELDS
5660  REM ********************************************************************
5670             IF B(I) = 0 THEN 5890
5680             XOFFSET = - B(I)*XFACT  /2
5690             YOFFSET = 0
5700             IF XIP(I) = XJP(I) THEN 5740
5710             THETA =ATN( (YJ(I) - YI(I)) / (XJ(I) - XI(I)) )
5720             XOFFSET = B(I)/2 * COS(3.1416/2 + THETA) * XFACT
5730             YOFFSET = B(I)/2 * SIN(3.1416/2 + THETA) * YFACT
5740             REM
5750             X1 = XIP(I) + XOFFSET
5760             X2 = XJP(I) + XOFFSET
5770             X3 = XJP(I) - XOFFSET
5780             X4 = XIP(I) - XOFFSET
5790             REM
5800             Y1 = YIP(I) - YOFFSET
5810             Y2 = YJP(I) - YOFFSET
5820             Y3 = YJP(I) + YOFFSET
5830             Y4 = YIP(I) + YOFFSET
5840  DRAW "BM=XIP(I);,=YIP(I);"
5850  DRAW "M=X1;,=Y1; M=X2;,=Y2; M=X3;,=Y3; M=X4;,=Y4; M=XIP(I);,=YIP(I); "
5860             YPAINT = (Y1 + Y2 + Y3 + Y4)/4
5870             DRAW "BM=XPAINT;,=YPAINT;"
5880   REM       DRAW "P0,1"              'fill the weld box with white color
5890   REM
5900             RETURN
5910  REM ********************************************************************
5920  REM THIS PROGRAM PLOT THE CENTROID ON THE SCREEN
5930  REM ********************************************************************
5940        CLS
5950    SCREEN 2,0
5960            XCENTR =INT( (     + XB - XBAR) * XFACT  ) + 320
5970            YCENTR =INT( (     - YB - YBAR) * YFACT  ) + 100
5980  DRAW "BM=XCENTR;,=YCENTR; "
5990  DRAW "L12 R24 L12 U5 D10"
6000   REM ******************************************************
6010   IF XLOAD = 0 AND YLOAD = 0 AND ZLOAD=0 THEN 6080
6020   REM MARK THE PLOT FOR LOAD CENTER
6030            XCLOAD =INT( (     + XLOAD - XBAR) * XFACT  ) + 320
6040            YCLOAD =INT( (     - YLOAD - YBAR) * YFACT  ) + 100
6050  DRAW "BM=XCLOAD;,=YCLOAD; "
```

```
6060  DRAW "TA45"
6070  DRAW "L8 R16 L8 U3 D6"            'DRAW A "X" ON SCREEN
6080   REM ************************************************
6090    FOR D = TIDEG TO 360 STEP 90
6100      DN = -D
6110      DRAW "TA=D;"        'rotate the skew angle
6120        FOR DOT = 1 TO 82 STEP 2
6130        DRAW "BM=XCENTR;,=YCENTR; "
6140        DRAW "BU=DOT; U0"                 'plot every other points
6150        NEXT DOT
6160    NEXT D
6170      DRAW "TA0"        'reset the skew angle
6180  REM
6190        FOR I = 1 TO N
6200        XIP(I) =INT( (XI(I) - XBAR)  * XFACT  ) + 320
6210        XJP(I) =INT( (XJ(I) - XBAR)  * XFACT  ) + 320
6220        YIP(I) =INT( (YIM(I) - YBAR) * YFACT  ) + 100
6230        YJP(I) =INT( (YJM(I) - YBAR) * YFACT  ) + 100
6240   REM     DRAW "BM=XIP(I);,=YIP(I); M=XJP(I);,=YJP(I);"
6250             GOSUB 5650                   'DRAW WIDTH OF WELD
6260        NEXT I
6270   GOSUB 4920                             'DRAW AXES AND TIC MARKS
6280    RETURN
```

APPENDIX B

SUITABILITY-FOR-SERVICE ANALYSIS FOR TVA CATEGORY I and I(L) PIPING AT WBNP-1

APPENDIX B

SUITABILITY-FOR-SERVICE ANALYSIS FOR TVA CATEGORY I AND CATEGORY I(L) PIPING AT WATTS BAR NUCLEAR POWER PLANT, UNIT 1

S. E. Moore

1. INTRODUCTION

For each TVA Category I or Category I(L) piping weld identified by the EG&G Weld Evaluation Project (WEP) for Watts Bar, Unit 1 as not meeting the acceptance criteria of Article NC/ND-4000, Section III of the ASME Code,*,[1] a "Suitability-for-Service" engineering evaluation is made to determine whether the component will still satisfy all the design criteria of Article NC/ND-3000 before initiating repair or corrective action.[2] The purpose of this write-up is to provide the background, justification, and development of the acceptance criteria for these discrepancies.

Section III of the ASME Code does not allow the use of alternative acceptance criteria based on suitability-for-service.[3] In particular, the 1971 Code of Record** requires that all deviations from the weld acceptance criteria listed in Articles NC/ND-4000 for Class 2 or Class 3 piping† be repaired according to the provisions of Subsubarticle NB-4450 for ASME Class 1 piping. None of the later editions of the Code, Addenda to the Code, or Nuclear Code Cases address this specific issue. A recent Code Interpretation, File No. NI-86-047,[4] however, indicates that minor local deviations can be accepted under

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*The term ASME Code as used herein refers to Section III of the ASME Boiler and Pressure Vessel Code, Ref. 1. Specific editions of the Code are identified by date, enclosed in brackets, e.g., [1971 ed.]. Sections, Articles, Subarticles, Paragraphs, and Subparagraphs of the Code are identified by number, e.g., Article NC-3000.

**The Code of Record for Watts Bar, Unit 1 identified in the Final Safety Analysis Report (FSAR) is the 1971 edition of the ASME Code (Ref. 1) including Addenda through the Summer 1973 edition. The term "Section III — Summer 1973" will be used herein to identify the Code of Record.

†TVA Categories I and I(L) piping for the Watts Bar Nuclear Power Plant corresponding to ASME Class 2 and Class 3 and ANSI B31.1 piping are considered in this write-up as ASME Class 2. TVA Class A piping, corresponding to ASME Class 1 piping, is not specifically considered here, although a similar treatment could be developed using the same general outline.

the Code rules provided the examination requirements of Articles NC/ND-5000 have been met, and it can be demonstrated that the existing conditions in the weld meet the design provisions of Articles NC/ND-3000. The Code Interpretation reads as follows:

> Question: "NX-4420 "Rules for Making Welded Joints" contains provisions for in-process control of welding to assure that the completed weld will comply with the acceptance criteria of NX-5000. When Code-stamped components and piping systems are evaluated and it is determined that minor local deviations from the provisions of NX-4420 exist, specifically regarding weld surfaces (NX-4424), weld reinforcement (NX-4426), or size and shape of welds (NX-4427), and the N certificate holder can demonstrate that the existing conditions in the weld meet the design provisions of NX-3000 and it is shown that the acceptance criteria of NX-5000 have been met, does this demonstrate compliance with the provisions of Section III?
>
> Reply: Yes."

Our primary objective is, therefore, to show that a properly executed Suitability-for-Service engineering evaluation for specific deviations, identified later, demonstrate compliance with the design provisions of Articles NC/ND-3000.

This approach is consistent with ASME Code Policy as formalized by the following position statement:[5]

> "The Board on Nuclear Codes and Standards recognizes that the Boiler and Pressure Vessel Code, Section III, does not, nor is it intended to, address all situations which might arise during site construction, such as ... specific corrective action on nonconformances resulting from work performed. It is the sentiment of the Board on Nuclear Codes and Standards that, in these situations, the determination of how to satisfy Code requirements is best resolved through interaction and agreement between the parties involved, taking into account the specific conditions of the situation. Such agreements would include ... the Owner, applicable Certificate Holders, their respective Authorized Inspection Agencies, and appropriate jurisdictional and/or regulatory bodies."

It is also consistent with Subsection NCA "General Requirements for Division 1 and Division 2," [1986 ed.] Subparagraph NCA-1140(f) which now reads:

"(f) Code Editions, Addenda [including the use of specific provisions of Editions or Addenda permitted by (b) or (c) above], and Cases used shall be reviewed by the Owner or his designee for acceptability to the regulatory and enforcement authorities having jurisdiction at the nuclear plant site."

The weld deviations considered here are those identified by visual examination procedures in WEP Standard Practice 3.2.3, Appendix A[6] including undercut, coarse ripples, grooves, abrupt ridges, minimum taper, minimum section thickness, maximum offset, maximum reinforcement, and fillet or socket weld size. These deviations generally correspond with conditions addressed by ASME Code Subarticle NC/ND-4400 "Rules Governing Making, Examining, and Repairing Welds." Crack-like defects require special consideration and are not addressed here.

2. DESIGN BASIS

Although the Code of Record is Section III — Summer 1973, all TVA Category I and I(L) piping corresponding to ASME Class 2 and 3 and ANSI B31.1 piping is designed and analyzed to the requirements of Subsection NC of the 1974 edition of the Code. This is because the ASME Code rules for piping were in a continual state of flux during the period 1969 to 1974 when rules for the design and construction of nuclear piping were being transferred from the industrial piping codes into Section III. ASME III [1974 ed.] was the first complete edition of the Code to fully incorporate design rules for both Class 2 and Class 3 nuclear piping. These are contained in Articles NC-3600 and ND-3600, respectively. Since 1974 the NC-3600 and ND-3600 design analysis rules have been identical.

Permission to use the 1974 Code basis rather than the 1971 Code of Record is given by Subparagraphs NA-1140(f) and (g) [1971 ed.] which read:

"(f) Code Editions, Addenda and Cases which have not become mandatory on the contract date for a component may be used by mutual consent of the Owner or his agent ... on or after the dates permitted by NA-1140(a), (b), and (c). It is permitted to use specific provisions within an Edition or Addenda provided that all related requirements are met.

"(g) Owners, Manufacturers, and Installers are cautioned against using Addenda or Cases that are less restrictive than former requirements without having assurance that they are acceptable to the enforcement authorities having jurisdiction at the location ...."

These paragraphs not only give permission to use the 1974 edition as the design analysis basis, but, in effect, also give permission to qualify the Watts Bar WEP piping weld deviations to the design requirements of NC-3600 [1974 ed.] as long as the evaluations are fully consistent so that "all related requirements are met" and as long as "the enforcement authorities agree that the acceptance criteria are not less restrictive than former requirements.

3. SUITABILITY-FOR-SERVICE ANALYSIS

To be fully consistent with the original design basis, an acceptable analysis must include consideration of the original design conditions as well as the altered conditions resulting from the particular deviation. Specifically the analysis must satisfy NC-3100 "General Design," NC-3640 "Pressure Design of Piping Products," and NC-3650 "Analysis of Piping Systems."

3.1 General Design Requirements

Subarticle NC-3100 includes two paragraphs that need to be addressed. These are NC-3110 "Loading Criteria" and NC-3112 "Design Conditions." Paragraph NC-3111 identifies the loadings that must be considered. It reads as follows:

> "The loadings that shall be taken into account ... shall include, but are not limited to those of (a) through (f) below.
> (a) Internal and external pressure,
> (b) Weight of the component and normal contents ... ,
> (c) Superposed loads ... ,
> (d) Wind loads, snow loads, vibrations, and earthquake loads where specified,
> (e) Reactions of supporting lugs, rings, saddles, or other types of supports,
> (f) Temperature effects.

Therefore, a correct suitability-for-service analysis must include consideration of all of the loads that were considered in the original design analysis.

Subsubparagraph NC-3112.4(c) requires the component wall thickness to be sufficient to resist the combined effects of all the design loadings. For any WEP weld deviations that involve a reduction in wall thickness, the suitability-for-service analysis must demonstrate that the remaining wall thickness still satisfies NC-3112.4(c), which reads:

"(c) The wall thickness of a component computed by these rules shall be determined so that the maximum direct membrane stress due to any combination of loadings that are expected to occur simultaneously does not exceed the maximum allowable stress value ...."

3.2 Pressure Design

The minimum wall thickness prescribed in Paragraph NC-3641 for straight pipe, in Paragraph NC-3642 for pipe bends, and the reinforcement requirements for branch connections given in NC-3643 assure that Subparagraph NC-3111(a) is satisfied for the minimum wall thickness identified in the Design Specification, i.e.,

$$t_{min} = t_{nom} - 0.125\, t_{nom} = 0.875\, t_{nom} \,. \qquad (1)$$

When the weld deviation results in a reduction in wall thickness so that Eq. (1) is not satisfied, the suitability-for-service analysis must first establish that the maximum direct membrane stress allowable has not been violated. This may be done by checking NC-3640 for the reduced wall thickness condition, taking into account the corrosion allowance and any stress raisers that could alter the membrane stress. If the weld deviation is at a branch connection, the reinforcement requirements of NC-3643 also need to be checked for the reduced wall thickness. For other piping products, the specific paragraph under NC-3640 should be checked.

3.3 Piping System Analysis

The bulk of the analysis requirements is contained in Subsubarticle NC-3650. These rules satisfy the general design requirements identified in Paragraph NC-3611 "Acceptability." The formulas given in NC-3650 and listed in Fig. 5.2-2 of the TVA Watts Bar Design Criteria Manual[7] (attached) are a set of design criteria statements written in terms of nominal stresses, stress intensification factors (SIFs), and stress limits. The intent of those criteria statements is that the conservative combination of pressure stresses, cross-section moment stresses, and thermal stresses (where appropriate) represented by the left-hand side of the equations will not be greater than the allowable stress intensity limit on the right-hand side. For the suitability-for-service analysis to satisfy NC-3650, it is necessary to modify the left-hand terms so as to properly represent the stresses in the deviant condition.

Using Code Eq. (8) as an example,*

$$S_{SL} = \frac{1}{2}\frac{PD_o}{2\,t_n} + 0.75i\,\frac{M_A}{Z} < 1.0\,S_h \,, \qquad (2)$$

it may be noted that three quantities need to be modified: the nominal wall thickness t_n, the SIF i, and the pipe section modulus Z. Appropriate modifications are to replace t_n by the reduced wall thickness t_r; to replace Z by the reduced section modulus $Z_r \equiv \pi(r'_{rm})^2 t_r$, where r'_{rm} is the mean cross-sectional radius for the reduced section; and to replace i by an appropriate SIF, i_s, for the particular deviation being evaluated.

SIFs for commonly used piping products are given in Subsubparagraph NC-3673.2(b), and approved SIFs for Watts Bar piping design are listed in Ref. 8. Generally accepted SIFs for the types of deviations being evaluated under the Watts Bar WEP program do not exist. Therefore, appropriate SIFs must be developed.

SIFs are normally developed from component test data, and, if appropriate analytical information is not available, an experimental program to obtain the necessary test data might be required. In 1977 the Code provided instructions for converting Class 1 pipe component stress indices to SIFs. Subsubparagraph NC-3673.2(b) [1983 ed., S84] now reads:

> "(b) .... Flexibility factors and stress intensification factors are shown in Fig. NC-3673.2(b)-1. For components not shown in Fig. NC-3673.2(b)-1, the stress intensification factor may be taken as:
>
> $i = C_2K_2/2$, but not less than 1.0
>
> where C_2 and K_2 are stress indices for Class 1 components."

The product C_2K_2 represents the peak stress intensity for cross-section moments.

---

*The Code permits replacing the pressure term of the NC-3650 equations by $P\,d^2/(D_o^{\,2} - d^2)$, and that form is listed in the TVA Design Criteria Manual. For our purpose, however, the original Code form is more convenient.

This paragraph provides access to the Class 1 rules, and, although Class 1 stress indices for the WEP piping deviations are not listed in the Code, instructions for developing Class 1 stress indices are given. Subparagraphs NB-3681(d) and (e) [1983 ed., S82] read:

> "(d) For piping products not covered by NB-3680, the stress indices and flexibility factors shall be established by experimental analysis (Appendix II) or theoretical analysis. Such test data or theoretical analysis shall be included in the Design Report.
>
> "(e) When determining stress indices by experimental methods, the nominal stress at the point under consideration (crack site, point of maximum stress intensity, etc.) shall be used."

It is, therefore, appropriate to divide the suitability-for-service SIF, i_s, into two parts: one part, i_o, representing the original design SIF and a second part, i_d, representing the stress raiser "at the point under consideration," i.e.,

$$i_s = i_d \, i_o \geq i_o \,, \tag{3}$$

and to define i_d in terms of Class 1 stress indices as the additional peak stress caused by the deviation:

$$i_d = C_{2d} \, K_{2d} \geq 1.0 \,. \tag{4}$$

A value of $C_{2d} = 1.0$ can be used because the primary-plus-secondary stress in the piping component will not be increased by the presence of the weld deviations being evaluated under the Watts Bar WEP program.

There are two options for developing appropriate values for the peak stress index K_{2d}. These are to (1) determine a stress concentration factor or fatigue reduction factor for each deviation being evaluated or (2) determine an upper bound value that would always be conservative. We will only pursue the second option here because the WEP deviations at Watts Bar are generally located in regions of low maximum stress. In those cases where option 2 is too conservative, the designer should use a value for K_{2d} that is more specific.

Rules for analyzing local structural discontinuities are given in Subsubparagraph NB-3222.4(e)(2) [1977 ed.]:

"(2) *Local Structural Discontinuities.* These effects shall be evaluated for all conditions using stress concentration factors determined from theoretical, experimental, or photoelastic studies, or numerical stress analysis techniques .... Except for the case of crack-like defects and specified piping geometries for which specific values are given in NB-3680, no fatigue strength reduction factor greater than five need be used."

Therefore an upper bound value for the product $K_2\ K_{2d}$ is 5.0.

The maximum values for K_2 given in Table NB-3681(a)-1 are $K_2 = 2.0$ for girth fillet welds and 1.8 for as-welded girth buttwelds and tapered transitions. Thus, a reasonable upper limit for K_{2d} is 5.0/2.0 = 2.5. Substituting $C_{2d} = 1.0$ and $K_{2d} = 2.5$ into Eq. (4) gives:

$$i_d = 2.5 \ . \qquad (5)$$

An appropriate upper bound SIF to be used in Eq. (2) and in the other equations of NC-3650, as part of the Watts Bar WEP suitability-for-service evaluation [from Eqs. (5) and (3)] is therefore

$$i_s = 2.5\ i \ . \qquad (6)$$

4. SUMMARY

An appropriate "Suitability-for-Service" analysis procedure for evaluating the TVA Category I and I(L) piping weld deviations identified by the EG&G Weld Evaluation Project at Watts Bar Nuclear Power Plant, Unit 1 is presented. This procedure is developed from and based on the Code of Record for Watts Bar, appropriate later editions of Section III, ASME Boiler and Pressure Vessel Code, and ASME Board on Nuclear Codes and Standards policy statements. Further, it satisfies all the acceptance criteria of Article NC-3000 of the ASME Code.

The analysis procedure consists of the following.

(1) Satisfy the pressure design requirements of Subsubarticle NC-3640 using the reduced wall thickness condition caused by the deviation being evaluated.

(2) Satisfy the piping system analysis requirements of Subsubarticle NC-3650 using all the design loadings and the following three modifications:

(a) Substitute the reduced wall thickness t_r for the nominal wall thickness t_n in all the appropriate Code equations.

6. "Visual Examination Methods and Acceptance Criteria," WEP 3.2.3, Weld Evaluation Project, Standard Practices Manual, DOE Task Force at TVA's Watts Bar Plant, Unit 1, EG&G Idaho, Inc., Aug. 15, 1986.

7. "Design Criteria for Analysis of Category I and I(L) Piping Systems," WB-DC-40-31.7, TVA Watts Bar Nuclear Plant Design Criteria Manual, Tennessee Valley Authority, Rev. 7, Jan. 21, 1986.

8. C. G. Slagis, *Stress Intensification Factors for Brown's Ferry, Sequoyah, Watts Bar, Bellefonte*, C. G. Slagis Associates Report No. 010-003, Rev. 2, August 1984.

FIGURE 5.2-2

RIGOROUS AND SIMPLIFIED ANALYSES CRITERIA FOR TVA CLASS B COMBINED LOADING CONDITIONS

R7

Plant Condition (Load Source Type)	Moment Constituents From Possible Load Sources[6]	Equations and Stress Limits[1]	NC-3652[1] Eq. No.
Normal			
(Pressure + Sustained)	$M_A = M(DW, PL, BL)$[9]	$\frac{Pd^2}{D_o^2-d^2} + \frac{0.75iM_A}{Z} \leq S_h$	(8)
Upset[11]			
(Pressure + Sustained + Occasional)	$M_A = M(DW, PL, BL)$[9] $M_{BU} = M[E1 \text{ or } (VT, WH)]$[2]	$\frac{Pd^2}{D_o^2-d^2} + \frac{0.75i(M_A+M_{BU})}{Z} \leq 1.2\ S_h$	(9U)
Emergency[7,11]			
(Pressure + Sustained + Occasional)	$M_A = M(DW, PL, BL)$[9] $M_{BE} = M(E1, VT, WH)$	$\frac{Pd^2}{D_o^2-d^2} + \frac{0.75i(M_A+M_{BE})}{Z} \leq 1.8\ S_h$	(9E)
Faulted[11]			
(Pressure + Sustained + Occasional + DBA)	$M_A = M(DW, PL, BL)$[9] $M_{BF} = M(E2, VT, WH, EA, LM, BC)$[3,9]	$\frac{Pd^2}{D_o^2-d^2} + \frac{0.75i(M_A+M_{BF})}{Z} \leq 2.4\ S_h$	(9F)
Secondary			
(Expansion)	$M_C = M(T_i, SD, ED^4)$[5]	$\frac{iM_C}{Z} \leq S_A$	(10)
OR	OR		OR
(Pressure + Sustained) + Expansion)	M_A = Same as above M_C = Same as above	$\frac{Pd^2}{D_o^2-d^2} + \frac{0.75iM_A}{Z} + \frac{iM_C}{Z} \leq S_A + S_h$	(11)

FIGURE 5.2-2 (Continued)

RIGOROUS AND SIMPLIFIED ANALYSES CRITERIA FOR TVA CLASS B COMBINED LOADING CONDITIONS

R7

Plant Condition (Load Source Type)	Moment Constituents From Possible Load Sources	Equations and Stress Limits	NC-3652[1] Eq. No.
(One time secondary stress)	M_{CT} = Greater $M(DW,ED)$, $M(CP,CT,ED)$[8]	$\frac{i\,M_{CT}}{Z} \le 3S_C$	(10A)
	or		
(Expansion + One time secondary stress)	$M_C + M_{CT}$ = Greater of $M(Ti,SD,DW,ED)$, $M(Ti,CP,CT,ED)$	$\frac{i}{Z}(M_C + M_{CT}) \le S_A + 3\,S_C$	(10 + 10A)

Test

Plant Condition (Load Source Type)	Moment Constituents From Possible Load Sources	Equations and Stress Limits	NC-3652[1] Eq. No.
(Pressure + Sustained + Test).	M_T = $M(DW,PL,BL,BC)$[9,10]	$\frac{Pd^2}{D_o^2-d^2} + \frac{0.75iM_T}{Z} \le 1.2S_h$	(N/A)

Nomenclature

- P = Design pressure.
- D_o = Outside pipe diameter.
- d = Inside pipe diameter.
- i = Stress intensification factor; $i \geq 1.0$; $0.75i \geq 1.0$ from NC-3673.2(b).
- S_c = Allowable stress at 100°F.
- S_h = Basic material allowable stress at design temperature.
- S_A = Allowable expansion stress defined in subparagraph NC-3611.2.
- U,E,F = Added suffixes for differentiation between upset, emergency, and faulted load conditions.
- Z = Pipe section modulus.

Notes for Figure 5.2-2

1. ASME Boiler and Pressure Vessel Code, Section III, Division 1, 1971 Edition through Summer 1973 Addenda.

2. For the upset condition, use the greater of E1 or (VT,WH).

3. Pipe rupture effects (jet impingement, pipe whip, etc.) are considered to be faulted condition load sources. The design measures that are taken to protect against pipe rupture loads are described in WB-DC-40-31.50 (reference 4).

4. ED may be included in the evaluation of equation (9).

5. All secondary load sources resulting from plant normal or upset conditions Ti, SD, and ED must be identified and evaluated for the limiting operating modes of the system. The effects of these load sources must be used in evaluating equipment loading, support loading and types, and active component qualification. Thermal range was used in stress equations. R7

6. Use of cold spring will be limited by the requirements of subparagraph NC-3673.3 of ASME Section III. The pipe stress due to cold spring must be $\leq 0.5\ (S_A + S_h)$.

7. The emergency condition is checked only when a system can experience E1 and significant VT and/or WH simultaneously.

8. The secondary load sources resulting from a DBA (CP, CT, DM) will be evaluated for piping which penetrates or is supported from the SCV.

9. Stresses will be combined such that the stress due to load case BC or BL does not relieve the stress resulting from other load sources.

10. Pipe stress resulting from test conditions will not exceed 1.2 S_h. Secondary stress resulting from test conditions will be evaluated using equation 10 or 11.

    It is not necessary to use hydrostatic test pressure when evaluating stress due to test conditions. However, design pressure should be used unless it is determined that the test condition does not occur simultaneously with internal pressure.

11. In accordance with ASME III and the design specifications (references 24 and 25), design pressure is used in equation 9 since peak pressure and earthquake need not be taken as acting concurrently.

ABA157.10

APPENDIX C

ASME CODE INQUIRY NI86-047

APPENDIX C

ASME CODE INQUIRY NI86-047

NX-4420 provides rules for making welded joints. It is understood that the provisions of the paragraphs under NX-4420 apply for making welds to assure compliance with the acceptance criteria of NX-5000. It is further understood that the provisions of NX-4420 apply to in-process work and should not be considered as final acceptance criteria taking precedence over the final acceptance criteria of NX-5000.

NX-4424 "Surfaces of Welds" states that the welds shall be "sufficiently free from coarse ripples, grooves, overlaps, abrupt ridges, and valleys to meet the requirements of (a) through (e)." Item (a) refers to surface conditions and states the surfaces shall be "suitable for proper interpretation." Item (b) states "reinforcements are permitted." Item (c) addresses undercut and refers to "encroachment on required thickness." Item (d) states concavity "is permitted." Item (e) states "care shall be taken" during grinding. The quoted words used in these paragraphs imply that they are guidance for making welds and emphasize that judgement must be used in assessing the acceptability of final weld conditions.

NX-4427 "Size and Shape of Fillet Welds" provides guidance regarding the nominal size and shape of welds. The adequacy of welds regarding size and shapes should be determined on the basis of the overall weld and not on minor local deviations from the nominal weld size or shape. In other words, weld size and shape acceptability is not determined solely by the smallest dimensions found in the full length of the completed weld. The geometry of the completed weld may be taken into account to determine whether or not the size and shape of the weld is acceptable.

Misunderstandings of the wording of NX-4420 have caused some serious problems at nuclear power plant sites because welds which have been completed and accepted by the Authorized Nuclear Inspector and the Certificate Holder are subsequently being questioned as to their adequacy due to minor deviations from the guidance provided in NX-4420. Reviewers of welds in stamped components and piping systems also question the authority of the designer to justify local minor deviations on the basis of an engineering analysis showing the final weld conditions comply with the design requirements of NX-3000. We therefore have the following question:

The American Society of Mechanical Engineers

345 East 47th Street
New York, NY 10017

RECEIVED
JAN 18

Subject: Section III, Division 1, NX-4420 Rules for Making Welded Joints, All Editions

Item: NI86-047*

Reference: Your letter dated September 15, 1986

Dear Sir:

Our understanding of the question in your inquiry, and our reply, are as follows:

Question: NX-4420 "Rules for Making Welded Joints" contains provisions for in-process control of welding to assure that the completed weld will comply with the design provisions of NX-3000 and with the acceptance criteria of NX-5000. When Code Stamped components and piping systems are reevaluated and it is determined that minor local deviations from the provisions of NX-4420 exist, specifically regarding weld surfaces (NX-4424), weld reinforcement (NX-4426), or size and shape of welds (NX-4427), and the N Certificate Holder can demonstrate that the existing conditions in the weld meet the design provisions of NX-3000 and it is shown that the acceptance criteria of NX-5000 have been met, does this demonstrate compliance with the provisions of Section III?

Reply: Compliance with the requirements of the Code is demonstrated by completion of the appropriate Manufacturer's Data Report and application of the ASME Symbol Stamp. Therefore, the Code does not specifically address how this situation is to be handled. However, this method of resolution meets the intent of the Code.

Very truly yours,

Kevin Ennis
Assistant Secretary, Boiler and
Pressure Vessel Committee

KE/ak

The American Society of Mechanical Engineers

345 East 47th Street
New York, NY 10017

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Reply: Yes.

Very truly yours,

Kevin Ennis
Assistant Secretary, Boiler and
Pressure Vessel Committee

KE/ak

APPENDIX D

ANALYSIS OF INTEGRAL PIPE ATTACHMENTS

APPENDIX D

ANALYSIS OF INTEGAL PIPE ATTACHMENTS

STRESS ANALYSIS METHODOLOGY FOR DEVIANT LUG-TO-PIPE WELDS

by
B. L. Harris

The evaluation of deviant welds between pipes and lugs can be thought of as an extension of the Weld Evaluation Program procedure for analysis of deviant general civil-structural welds. Satisfying the design rules of NX-3000 is adequate technical justification for disposition of non-pressure retaining deviant ASME and ANSI B31.1 welds as able to perform their intended safety function.

There are three cases of deviant lug-to-pipe welds to be considered.

The first case is for a weld with incomplete penetration at the root of the weld (see Figure 1). The stresses in the weld can be found by assuming that the weld is similar to two fillet welds. Appropriate reduction in allowable stress for the fillet weld is used for comparison of calculated stresses to determine adequacy.

The second case is for an area of incomplete fusion at the end of the weld. This weld flaw is also identified by visual examination (see Figure 2). For this case it is proposed to neglect the entire weld containing the incomplete fusion. The lug induced piping stress would be evaluated using a lug thickness equal to the remaining thickness of the nondeviant weld, dimension A of Figure 2. No reduction in allowable stress is necessary for this case because the remaining weld considered in the analysis is a full penetration weld.

The third case to consider is a combination of the first two cases. Regions of incomplete penetration and incomplete fusion are both identified by visual examination as shown in Figure 3. This case can be analyzed in the same manner as the second case. The width of lug used (dimension B of Figure 3) in the analysis is the same as the depth of the satisfactory weld. Again, no reduction of allowable stress is required since the remaining weld is a full penetration weld.

Non-destructive examination (NDE) and more analysis are required if the stresses calculated using the simplified methods discussed above exceed the allowable values. Once the flaw is characterized by NDE methods the entire weld does not have to be neglected. Suppose the region of incomplete fusion is observed (by NDE) as shown in Figure 4.

The stress analysis of the welds having stresses exceeding the allowable values can now be performed with the removal of an amount of weld material in both directions taken independently equal to the size of the defect. It is proposed to remove an area equal to the defect size by determining either an equivalent length or width across the weld which gives the correct area (see Figure 4). The stresses can now be recalculated for both cases and compared to allowable values. For simplicity of analysis the removed area may be considered to occur at the end or edge of the weld. Consideration of defect growth must be made if the equivalent area of weld defect is removed. If the stresses still exceed the allowable values the weld must be removed and replaced.

The lug induced piping stresses and weld stresses determined using the above recommended geometries and ASME code Case N-318-3 provide an adequate technical basis for compliance with the rules of NX-3000.

These welds are not part of the pressure boundary and are shown to be capable of supporting the required loading. This approach demonstrates that the deviant lug-to-pipe welds are adequate to perform their intended safety function.

APPENDIX D

ANALYSIS OF INTEGAL PIPE ATTACHMENTS

STRESS ANALYSIS METHODOLOGY FOR DEVIANT LUG-TO-PIPE WELDS

by
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The second case is for an area of incomplete fusion at the end of the weld. This weld flaw is also identified by visual examination (see Figure 2). For this case it is proposed to neglect the entire weld containing the incomplete fusion. The lug induced piping stress would be evaluated using a lug thickness equal to the remaining thickness of the nondeviant weld, dimension A of Figure 2. No reduction in allowable stress is necessary for this case because the remaining weld considered in the analysis is a full penetration weld.

The third case to consider is a combination of the first two cases. Regions of incomplete penetration and incomplete fusion are both identified by visual examination as shown in Figure 3. This case can be analyzed in the same manner as the second case. The width of lug used (dimension B of Figure 3) in the analysis is the same as the depth of the satisfactory weld. Again, no reduction of allowable stress is required since the remaining weld is a full penetration weld.

Non-destructive examination (NDE) and more analysis are required if the stresses calculated using the simplified methods discussed above exceed the allowable values. Once the flaw is characterized by NDE methods the entire weld does not have to be neglected. Suppose the region of incomplete fusion is observed (by NDE) as shown in Figure 4.

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The lug induced piping stresses and weld stresses determined using the above recommended geometries and ASME code Case N-318-3 provide an adequate technical basis for compliance with the rules of NX-3000.

These welds are not part of the pressure boundary and are shown to be capable of supporting the required loading. This approach demonstrates that the deviant lug-to-pipe welds are adequate to perform their intended safety function.

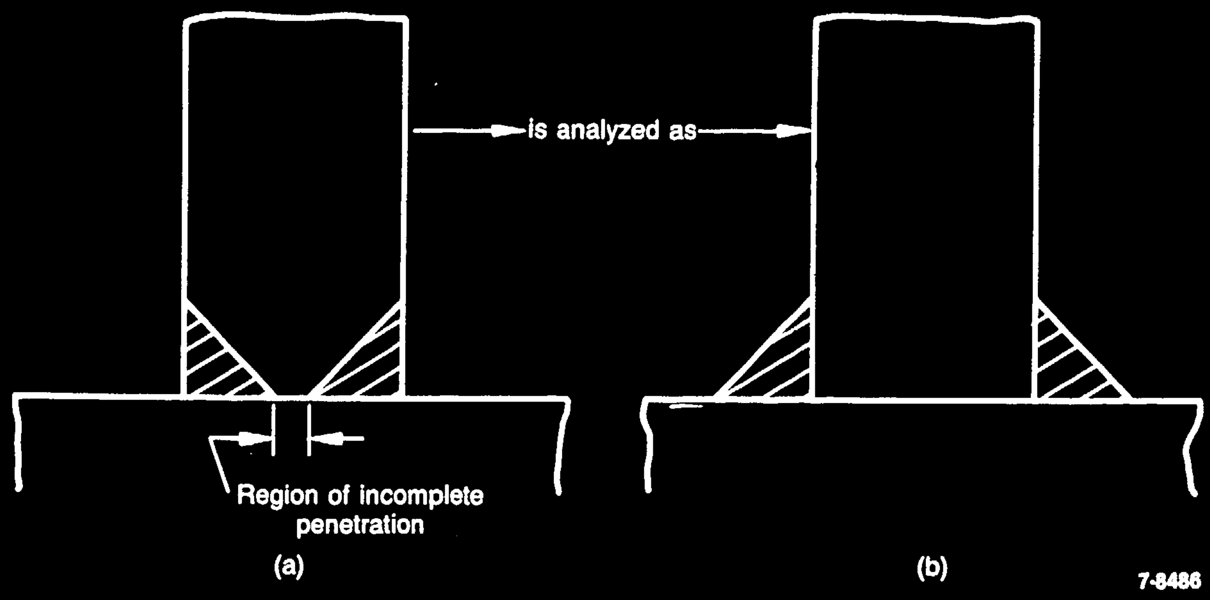


Figure D-1. Weld with incomplete penetration showing (a) actual configuration of weld and (b) assumed configuration for purpose of analysis.

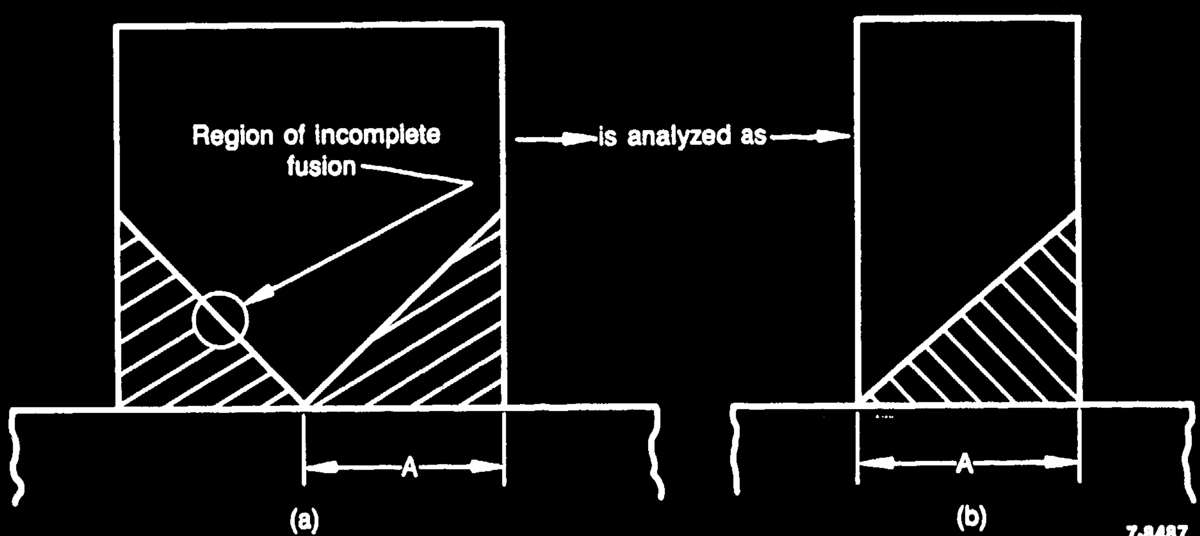


Figure D-2. Weld with region of incomplete fusion showing (a) actual configuration of weld and (b) assumed configuration for purpose of analysis.

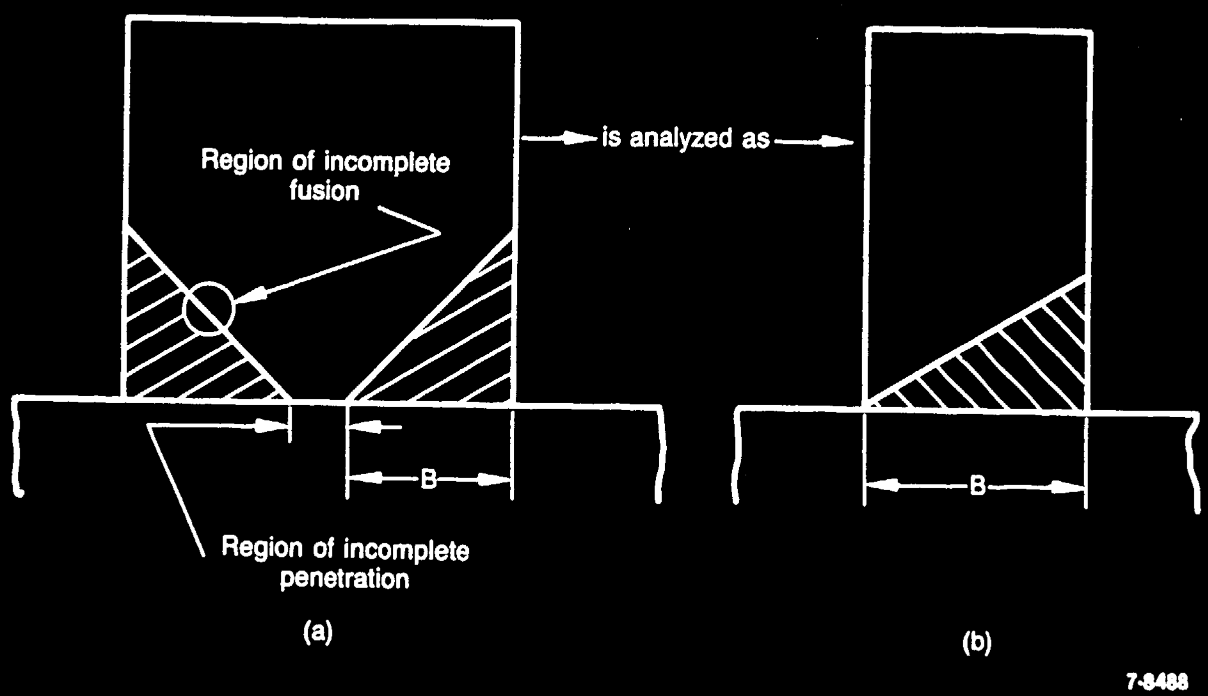


Figure D-3. Weld with both incomplete penetration and incomplete fusion showing (a) actual configuration of weld and (b) assumed configuration for purpose of analysis.

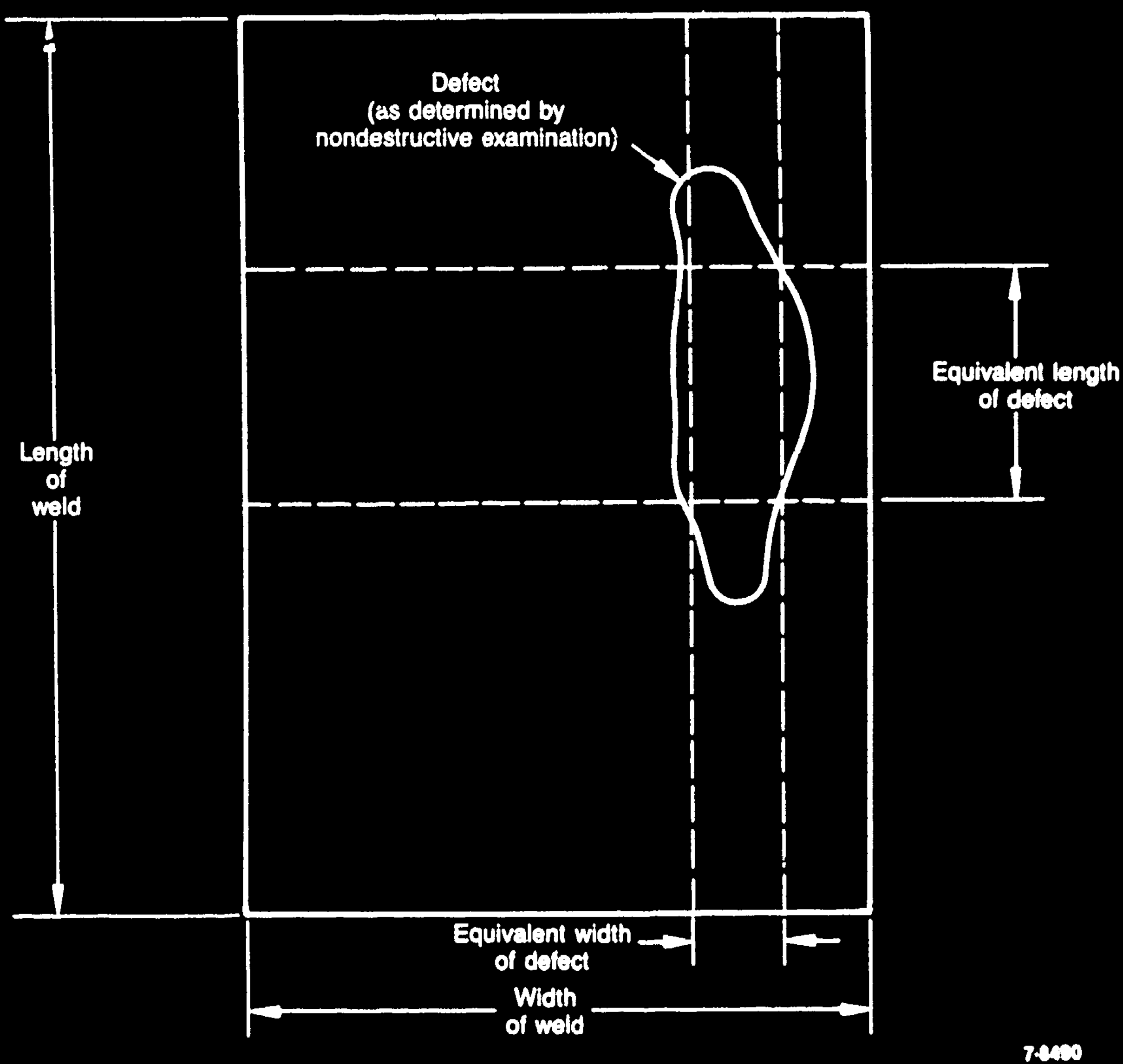


Figure D-4. Equivalent weld defect area for purpose of analysis. Defect area may be assumed to be equivalent length of defect times width of weld or equivalent width of defect times length of weld.

APPENDIX E

APPLICABLE DOE WELD EVALUATION
PROJECT STANDARD PRACTICES

APPENDIX E

APPLICABLE DOE WELD EVALUATION

PROJECT STANDARD PRACTICES

INDEX OF APPLICABLE DOE/WEP STANDARD PRACTICES

1. PURPOSE AND SCOPE

1.1 To establish Visual Testing (VT) Methods and Acceptance Criteria for the examination of welds and acquire other pertinent data at Watts Bar Plant Unit 1, Department of Energy Weld Evaluation Project.

1.2 This procedure incorporates, the VT requirements specified in the ASME Section III Division 1, ASME Section VIII Divisions 1 and 2, ANSI B31.1, ANSI B31.5, AWS D1.1, and NCIG-01 (References 4.1 through 4.6).

2. RESPONSIBILITY AND PRACTICE

2.1 The Inspection/Examination (I/E) Manager shall be responsible for compliance with this procedure.

The Level III shall be responsible for the content of this procedure and subsequent revisions.

The designated Supervisor shall be responsible to ensure that only certified personnel perform examinations to this procedure.

Personnel performing examinations to this procedure shall be certified to the requirements of Standard Practice (SP) WEP 4.1.2, and shall perform the required examinations in accordance with this procedure. This procedure shall be present during the performance of an examination.

2.2 Examination Requirement

2.2.1 Direct visual examination may usually be made when access is sufficient to place the eye within 24 inches of the surface to be examined, at an angle of not less than 30° with the surface to be examined.

2.2.2 The area under immediate examination shall be illuminated, if necessary, with a flashlight or other auxiliary lighting. Lighting shall be considered adequate when the inspector can resolve a black line 1/32 inch wide or less on an 18% neutral grey card placed on the surface being inspected.

2.2.3 Remote visual examinations may have to be substituted for direct examination in some cases. Remote visual examination may use visual aids such as mirrors, borescopes, fiber optics, cameras, or other suitable instruments. Such systems shall have a resolution capability at least equivalent to that obtainable by direct visual observation.

2.2.4 During the performance of visual examinations, the inspector shall use the appropriate examination tools.

2.2.5 A UT thickness measurement shall be taken in accordance with SP WEP 3.2.8 when the inspector deems it necessary to determine actual material thickness and other mechanical means of inspection are impractical.

2.2.6 Refer to SP WEP 3.2.16, Reference 4.11, for confirmation of cracks, arc strikes with indeterminate depth, nonrelevant indications, and, evaluation/removal of slag.

2.2.7 Inspection through paint may be performed per the Examination Package requirements. Visual Examination shall be limited to: weld size, weld profile, and weld length and location. Examination attributes related to weld quality shall be N/A'd.

2.3 Acceptance Criteria

For determination of the appropriate acceptance criteria, the inspectors shall use the acceptance criteria referenced in the examination package, which was developed according to SP WEP 3.1.8.

Appendix E, Relevant Data, shall be used for Inspector Observations only, and is not considered part of the examination.

2.4 Documentation

2.4.1 Process variables and results of the examination shall be documented on the applicable documents as defined in SP WEPs 3.1.8 and 3.2.2.

2.4.2 Attachments 1 (Form WEP 302), 2 (Form WEP 303), 3 (Form WEP 305) and/or 4 (Form WEP 328) shall be used to document examination results, as appropriate for the specific acceptance criteria.

2.4.3 As required, other relevant data shall be documented on the appropriate Weld Evaluation Project (WEP) visual forms.

3. DEFINITIONS

3.1 Inspector Observation--Specific observations which have been requested from the inspector.

4. REFERENCES

4.1 American Society of Mechanical Engineers (ASME), Nuclear Power Plant Components, Section III-Division 1, Boiler and Pressure Vessel Code, 1971 Edition through Summer 1973 Addenda.

4.2 American Society of Mechanical Engineers (ASME), Section VIII, Pressure Vessels, Divisions 1 and 2, 1971 Edition with Summer 1973 Addenda through the 1974 Edition with Summmer 1976 Addenda.

4.3 ANSI B31.1, Power Piping, American National Standard Institute Code for Pressure Piping, 1973 through Winter 1973.

4.4 ANSI B31.5-1966 (USASI B31.5-1966), Refrigeration Piping, USA Standard Code for Pressure Piping, Published by American Society of Mechanical Engineers, 1966.

4.5 AWS D1.1, Structural Welding Code, American Welding Society, Inc., 1972 through 1974 Addenda as modified by TVA Specification G29.

4.6 Visual Weld Acceptance Criteria for Structural Welding at Nuclear Power Plants, NCIG-01, May 1985, Revision 2.

4.7 Standard Practice WEP 4.1.2, "Training, Qualifying, and Certifying Personnel for Visual and Nondestructive Examinations."

4.8 Standard Practice WEP 3.1.8, "Preparation of the Examination Package."

4.9 Standard Practice WEP 3.2.2, "Reporting Deviations to TVA."

4.10 Standard Practice WEP 3.2.8, "Ultrasonic Thickness Measurement."

4.11 Standard Practice WEP 3.2.16, "Surface Conditions and Characterizing Weld/Hadware Discrepancies."

ATTACHMENT 1

Form WEP 302
Rev. 8/86a

VISUAL EXAMINATION RECORD FOR ASME/ANSI WELDS

Page __ of __

Reference Document:
Standard Practice No. ________
Revision Date ________

Examination Package No: ________
Component Identification No: ________

Attribute	Acceptance Criteria	Accept/ Reject
Cracks	1.1	
Overlap	1.1	
Undercut	1.1	
Lack of Fusion	1.1	
Incomplete Penetration	1.1	
Slag	1.1	
Visible Porosity	1.1	
Weld Spatter	1.1	
Arc Strikes	1.1	

Refer to indicated paragraph(s) of Standard Practice 3.2.3, Appendix A for acceptance criteria.

Attribute	Acceptance Criteria	Accept/ Reject
Coarse Ripples	2.1	
Grooves	2.1	
Abrupt Ridges	2.1	
Valleys	2.1	
Minimum Section Thickness	2.2	
Taper	2.3	
Maximum Offset	3.1	
Reinforcement	4.1 4.2 4.3 4.4	
Fillet/Socket Weld Size	5.1 5.2	

Relevant Data		
Inaccessible	See Appendix E	

Reviewed and Approved by: ______________________ ________
I/E Supervisor Date

ATTACHMENT 2

Form WEP 303
Rev. 8/86a

VISUAL EXAMINATION RECORD FOR AWS D1.1 WELDS
IN CATEGORY 1 STRUCTURES

Page __ of __

Examination Package No: ____________

Component Identification No: ____________

Reference Document:
Standard Practice No. ____________
Revision Date ____________

1986 SVS Used Yes ___ No ___		Accept/Reject				
Attribute	Acceptance Criteria	Weld No.	Weld No.	Weld No.	Weld No.	Weld No.
Cracks						
Lack of Fusion						
Craters						
Undercut						
Porosity						
Fillet Weld Profiles						
Undersize Welds						
Oversize Welds						
Reinforcement						
Overlap						
Piping Porosity						
Material Thickness						
Arc Strikes and Weld Spatter						
Relevent Data						
Inaccessible	See Appendix E					

Refer to indicated paragraph(s) of Standard Practice 3.2.3, Appendix B for acceptance criteria.

Reviewed and Approved by: ______________________ ____________
I/E Supervisor Date

ATTACHMENT 3

Form WEP 305
Rev. 8/86a

VISUAL EXAMINATION RECORD FOR NCIG-01 WELDS

Page __ of __

Examination Package No: ____________
Component Identification No: ____________

Reference Document:
Standard Practice No. ____________
Revision Date ____________

1986 SVS USED Yes __ No __		Accept/Reject				
Attribute	Acceptance Criteria	Weld No.	Weld No.	Weld No.	Weld No.	Weld No.
Cracks	1.2.2.1					
Weld Size	1.2.2.2					
Incomplete Fusion	1.2.2.3					
Overlap	1.2.2.4					
Underfilled Craters	1.2.2.5					
Weld Profiles	1.2.2.6					
Undercut	1.2.2.7					
Porosity	1.2.2.8					
Weld Length and Location	1.2.2.9					
Arc Strikes	1.2.2.10					
Surface Slag and Weld Spatter	1.2.2.11					
Relevant Data						
Missing Welds	See App. E					
Missing Welds Due to Configuration	See App. E					
Inaccessible	See App. E					
Weld Type	See App. E					

NDE Required Yes ______ No ______

Welders ID: ____________

Refer to indicated paragraph(s) of Standard Practice 3.2.3, Appendix C for acceptance criteria.

Reviewed and Approved by: ______________________ ____________
I/E Supervisor Date

ATTACHMENT 4

WEP Form 328
Rev. 8/86a

Page __ of __

VISUAL EXAMINATION RECORD FOR THREADED STUD WELDS

Examination Package No: ____________ Reference Document: ____________
Component Identification No: ____________ Standard Practice No: ____________
Revision Date ____________

Attribute	Acceptance Criteria	Accept/Reject			
		Weld Number	Weld Number	Weld Number	Weld Number
360° Flash	1.1				
*Inaccessible	See App. E				
		Weld Number	Weld Number	Weld Number	Weld Number
360° Flash	1.1				
*Inaccessible	See App. E				
		Weld Number	Weld Number	Weld Number	Weld Number
360° Flash	1.1				
*Inaccessible	See App. E				
		Weld Number	Weld Number	Weld Number	Weld Number
360° Flash	1.1				
*Inaccessible	See App. E				

Refer to indicated paragraph of Standard Practice 3.2.3 Appendix D for acceptance criteria.

* Relevant Data

Reviewed and Approved by: ____________________ ____________
I/E Supervisor Date

APPENDIX A

ASME SECTION III, DIVISION 1
ASME SECTION VIII, DIVISIONS 1 AND 2
ANSI B31.1 AND B31.5 PIPING WELD ACCEPTANCE CRITERIA

All welds requiring visual examination shall be examined for the following items

- o Weld defects (cracks, porosity, slag, etc.)
- o Contour and finish of the weld surface
- o Offset in final welded joints
- o Reinforcement
- o Leg and throat size for fillets.

1. Weld Defects

1.1 All welds and adjacent base material shall be free of cracks, undercut in excess of 1/32 inch (does not encroach on the required section thickness), lack of fusion, incomplete penetration (when full penetration is required), slag, visible porosity, weld spatter, and arc strikes. Overlap is unacceptable if subsequent NDE is required and the overlap condition may mask an unacceptable indication.

2. Contour and Finish of the Weld Surface

2.1 The surfaces of welds are sufficiently free from coarse ripples, grooves, abrupt ridges, and valleys to perform the required nondestructive examination without masking possible discontinuities.

2.2 Pipe Welds

The weld and adjacent surfaces shall be examined for minimum wall violations. Minimum wall thickness shall not be less than nominal minus 12.5%.

All Other Welds

The minimum wall thickness shall be as specified in the Examination Package.

EXCEPTIONS: The following components are not classified as pressure vessels. There is no minimum design section thickness. There shall be no punctures or ground areas that penetrate the full thickness of the material.

- o Reactor well
- o Spent fuel pool
- o Transfer canal
- o Fuel cast area

2.3 When components of different outside diameters, offset ends, or of different thicknesses are welded together, there shall be a gradual transition between the two surfaces. The length of the transition may include the weld. The slope of the transition shall have a length-to-offset ratio of not less than 3 to 1.

3. Maximum Allowable Offset in Double Welded Joints

3.1 The maximum offset of the finished weld shall not be greater than the applicable amount listed in Table 1, where t is the nominal thickness of the thinner section of the joint.

TABLE 1. DIRECTION OF JOINTS

Section Thickness (inch)	Longitudinal[a,b]	Circumferential[c]
Up to 1/2, inclusive	1/4t	1/4t
Over 1/2 to 3/4, inclusive	1/8 inch	1/4t
Over 3/4 to 1-1/2, inclusive	1/8 inch	3/16 inch
Over 1-1/2 to 2, inclusive	1/8 inch	1/8t
Over 2	Lesser of 1/16t or 3/8 inch	Lesser of 1/8t or 3/4 inch

a. This column also applies to joints in spherical vessels, heads, and joints between cylindrical shells and hemispherical heads.

b. In longitudinal joints, the middle lines of the adjoining thicknesses is in alignment within these tolerances.

c. This column applies to all welds made per the requirements of ASME Section III, Subsection CC, except that 1/4 inch is the maximum allowable offset.

4. Reinforcement

4.1 For double-welded butt joints, the reinforcement listed in column 1 of Table 2 shall apply separately to both inside and outside surfaces of the joint.

4.2 For single-welded butt joints, the reinforcement listed in column 2 of Table 2 shall apply to the inside surface and the reinforcement listed in column 1 shall apply to the outside surface. The reinforcement shall be measured from the higher of the abutting surfaces involved.

4.3 Weld sizes for branch connections and integral attachments shall be in accordance with the design drawings.

NOTE: Weld bevel preparation areas shall be completely consumed with weld metal unless otherwise specified by the design drawings.

4.4 Vessels, Pumps and Valves--The finished surface of welds may be flush with the base material or may have reasonably uniform crowns, the maximum on each side not to exceed the values in the appropriate column in Table 3.

TABLE 2. WELD REINFORCEMENT

Material Nominal Thickness (inch)	Maximum Reinforcement (inch)	
	Column 1	Column 2
Up to 1/8, inclusive	3/32	3/32
Over 1/8 to 3/16, inclusive	1/8	3/32
Over 3/16 to 1/2, inclusive	5/32	1/8
Over 1/2 to 1, inclusive	3/16	5/32
Over 1 to 2, inclusive	1/4	5/32
Over 2	Greater of 1/4 inch or 1/8 of weld width in inches	5/32

TABLE 3. WELD REINFORCEMENT

Nominal Thickness (inches)	Maximum Reinforcement (inches)		
	ASME III Division 2	ASME III Division 1	ASME I and VIII-1
Up to 1/2, inclusive	3/32	3/32	1/16
Over 1/2 to 1, inclusive	1/8	3/32	3/32
Over 1 to 2 , inclusive	3/16	1/8	1/8
Over 2 to 3, inclusive	--	5/32	5/32
Over 3 to 4, inclusive	--	7/32	5/32
Over 4 to 5, inclusive	--	1/4	5/32
Over 5	--	5/6	5/32

5. Leg and Throat Size for Fillets (Socket Welds)

5.1 Fillet welds may vary from convex to concave provided that the size meets the minimum requirements of Figure 1A.

5.2 The fillet weld size for socket welds shall be as shown in Figure 2A.

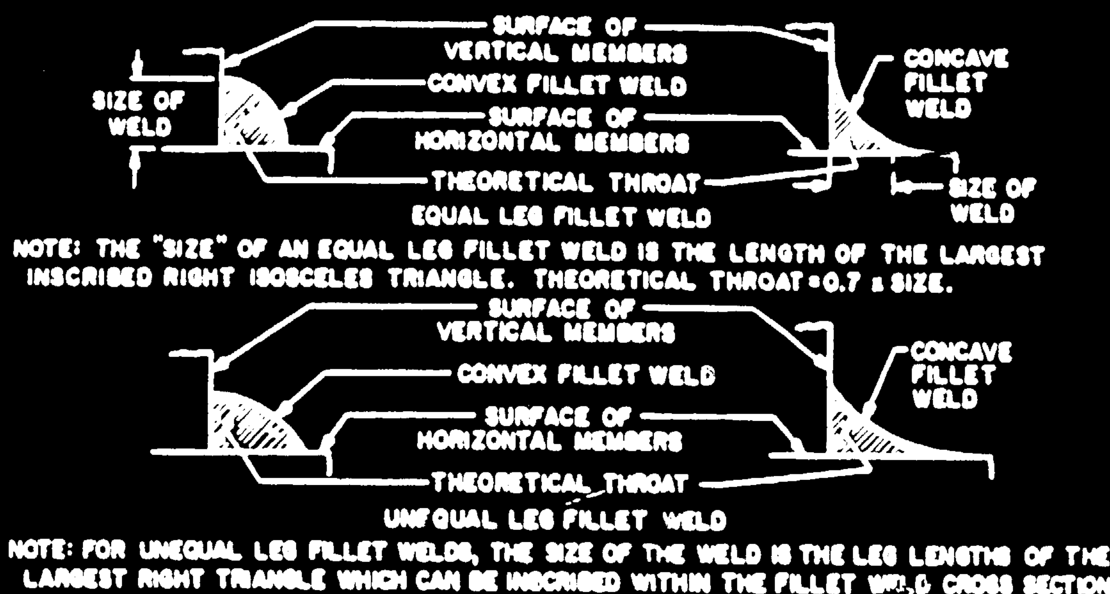
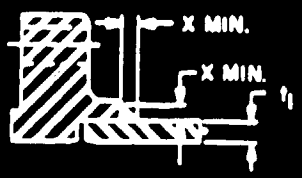


Figure 1A. Fillet weld dimensions.

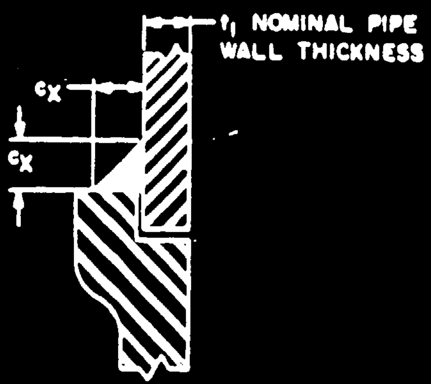
SIZE OF FILLET WELDS



SOCKET WELDING FLANGE

t_1 = NOMINAL PIPE WALL THICKNESS
X MIN. = 1.4 t_1 OR THICKNESS OF THE HUB, WHICHEVER IS SMALLER BUT NOT LESS THAN 1/8 in.

WELDING DETAILS FOR SOCKET-WELDING FLANGES



c_x MIN. = 1.09 t_1 BUT NOT LESS THAN 1/8 in.

(not permitted for connections over 2-inch nominal pipe size for Class 1 components)

Seal welds on threaded joints have all exposed threads removed entirely or the exposed threads are completely covered with weld.

Figure 2A. Fillet weld dimensions.

APPENDIX B

AWS D1.1 ACCEPTANCE CRITERIA FOR STRUCTURAL WELDS IN CATEGORY I STRUCTURES INCLUDING PIPE HANGERS, CABLE TRAY SUPPORTS, AND DUCT SUPPORTS

1. Acceptance Criteria

1.1 Welding Completed After February 13, 1981

Prior to examination, welds shall be preferably in the as-welded condition. All welds shall be free from slag, paint, rust or other extraneous material that may interfere with the examination process. A weld shall be acceptable by visual inspection if the inspection shows that:

1.1.1 The weld has no cracks.

1.1.2 Thorough fusion exists between adjacent layers of weld metal and base metal.

1.1.3 Craters are filled to the full cross-section of the weld.

1.1.4 Undercut does not exceed 1/32 inch.

1.1.5 The sum of the diameters of the piping porosity in fillet welds does not exceed 3/8 inch in any linear inch of weld and does not exceed 3/4 inch in any one-foot length of weld.

1.1.6 The face of fillet welds may be slightly convex, flat, or slightly concave. The convexity shall not exceed the value (0.1S + 0.06 inch) where S is the actual leg size of the fillet welds in inches. These requirements do not apply to outside or boxed corners.

1.1.7 A fillet weld in any single continuous weld shall be permitted to underrun the nominal fillet size required by 1/16 inch without correction, provided that the undersized portion of the weld does not exceed 10% of the length of the weld. On web-to-flange welds or girders, no underrun is permitted to the ends for a length equal to twice the width of the flange.

1.1.8 Fillet welds should be limited to 1/8 inch larger than the leg size specified. Maximum fillet weld size shall be 3/16 inch larger than specified.

1.1.9 Groove welds shall be made with slight or minimum reinforcement. Butt and corner joint reinforcement shall not exceed 1/8 inch in height and shall have a gradual transition to the adjacent base metal surface. The 1/8 inch maximum reinforcement does not apply to T joints. The contour of T joints where reinforcing fillets are not required shall have a gradual transition into both members. Fillet weld criteria of Section 1.1.7 shall apply to reinforcing fillet welds required on T joints.

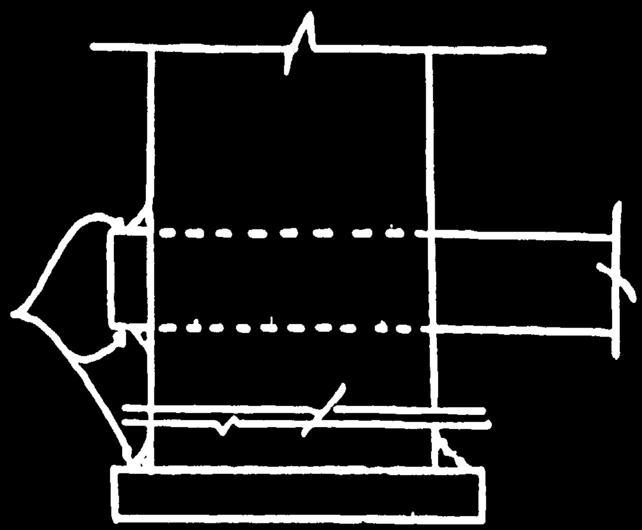
Flare bevel groove welds shall be welded out at least flush with the outside surface of the base material unless otherwise stated on the drawing.

1.1.10 All welds shall be free from overlap.

1.1.11 Complete joint penetration groove welds in butt joints shall have no piping porosity.

1.1.12 Undercut on nonstressed members as shown in Figure 1B, shall not be cause for rejection. Nonstressed members shall be specifically identified by OE.

1.1.13 Where mechanical means, such as grinding, burring, etc., were used for surface conditioning and/or corrective action to meet workmanship requirements, reduction of base material thickness will be additive to the amount of undercut. The total of the two conditions will be evaluated to the acceptance requirements for undercut.



Undercut at locations shown by arrows shall not be cause for rejection.

Figure 1B. Undercut on Nonstressed Members.

1.2 Welding Completed Prior to February 13, 1981

The requirements of Section 1.1 apply to work completed prior to February 13, 1981, except as follows:

1.2.1 Cable Tray Supports

a. Undercut on stressed members shall not exceed 1/32 inch in depth except that undercut of an additional 1/32 inch (1/16 inch total depth) and 1/4 inch length, not to exceed 10% of the run, is acceptable. All welds are to be considered in stressed members unless identified otherwise by OE.

b. Allowable minimum fillet weld sizes are shown on drawings revised under Watts Bar Nuclear ECN 2688.

c. Weld sizes specified to be 3/8 inch or less shall not be more than twice the specified size. Weld sizes specified to be greater than 3/8 inch shall not be more than 3/8 inch larger than the specified size.

d. Random weld spatter and arc strikes are acceptable if cleaned by wire brushing and are visually free of cracks.

1.2.2 Pipe Hangers

a. Weld sizes specified to be 3/8 inch or less shall not be more than twice the specified size. Weld sizes specified to be greater than 3/8 inch shall not be more than 3/8 inch larger than the specified size.

b. Random weld spatter and arc strikes are acceptable if cleaned by wire brushing and are visually free of cracks.

1.2.3 Duct Supports

a. Undercut on stressed members shall not exceed 1/32 inch in depth except that undercut of an additional 1/32 inch (1/16 inch total depth) and 1/4 inch length, not to exceed 10% of the run, is acceptable. All welds are to be considered in stressed members unless identified otherwise by OE.

b. A minimum permissible structural fillet weld size is 3/16 inch. Undersize of 1/16 inch is allowed for fillet welds over 3/16 inch in size.

c. Weld size specified to be 3/8 inch or less shall not be more than twice the specified size. Weld sizes specified to be greater than 3/8 inch shall not be more than 3/8 inch larger than the specified size.

d. Random weld spatter and arc strikes are acceptable if cleaned by wire brushing and are visually free of cracks.

1.2.4 Other Installed Work

a. Weld sizes specified to be 3/8 inch or less shall not be more than twice the specified size. Weld sizes specified to be greater than 3/8 inch shall not be more than 3/8 inch larger than the specified size.

b. Undercut on stressed members shall not exceed 1/32 inch in depth except that undercut of an additional 1/32 inch (1/16 inch total depth) and 1/4 inch length, not to exceed 10% of the run, is acceptable. All welds are to be considered in stress members unless identified other by OE.

c. Random weld spatter and arc strikes on stainless steel and carbon steel are acceptable if cleaned by wire brushing and are visually free of cracks. Weld spatter on all other materials shall be evaluated.[1]

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1. G-29 Series, TVA Process Specification for Welding Heat Treating, Nondestructive Examination, and Allied Fabrication Operations, Section C.

APPENDIX C

NCIG-01 ACCEPTANCE CRITERIA

1. ACCEPTANCE CRITERIA

1.1 Measurement Units

Table 1 identifies the smallest measurement units the Inspector will use when inspecting the listed weld attributes. When measuring and recording dimensions of the weld attributes listed in Table 1, these dimensions shall be rounded off to the nearest significant unit.

TABLE 1. MEASUREMENT UNITS

Weld Attribute	Reference Section	Smallest Measurement Unit (Significant Unit--Inches)
Fillet Weld Size	1.2.2.2	1/16
Incomplete Fusion	1.2.2.3	1/8
Weld Overlap	1.2.2.4	1/8
Undercut Depth	1.2.2.7	1/32
Surface Porosity	1.2.2.8	1/16
Weld Length	1.2.2.9	1/8 or 1/4
Weld Location	1.2.2.9	1
Slag	1.2.2.11	1/4

1.2 Acceptance Criteria

1.2.1 These Acceptance Criteria are to be used for the acceptance inspection of welds in the uncoated condition.

1.2.2 A weld shall be acceptable by visual inspection, subject to the following:

1.2.2.1 Weld Cracks--The weld shall have no cracks.

1.2.2.2 Fillet Weld Size--A fillet weld shall be permitted to be less than the size specified by 1/16 inch for 1/4 the length of the weld. Oversized fillet welds shall be acceptable if the oversized weld does not interfere with mating parts.

1.2.2.3 Incomplete Fusion--In fillet welds, incomplete fusion of 3/8 inch in any 4-inch segment, and 1/4 inch in welds less than 4 inches long, is acceptable. For groove welds, incomplete fusion is not acceptable. For fillet and groove welds, rounded end conditions that occur in welding (starts and stops) shall not be considered indications of incomplete fusion and are irrelevant.

1.2.2.4 Weld Overlap--Overlap is acceptable provided the criteria for weld size and fusion can be satisfied. When fusion in the overlap length cannot be verified, an overlap length of 3/8 inch in any 4 inch segment, and 1/4 inch in welds less than 4 inches long, is acceptable.

1.2.2.5 Underfilled Craters--Underfilled craters shall be acceptable provided the criteria for weld size are met. Craters which occur outside the specified weld length are irrelevant provided there are no cracks.

1.2.2.6 Weld Profiles

1.2.2.6.1 The faces of fillet welds may be convex, flat, or concave, provided the criteria for weld size are met.

1.2.2.6.2 The faces of groove welds may be flat or convex.

1.2.2.6.3 Convexity of fillet and groove welds are not criteria for acceptance and need not be measured.

1.2.2.6.4 The thickness of groove welds is permitted to be a maximum of 1/32 inch less than the thinner member being joined.

1.2.2.6.5 Flare bevel grooved welds shall be welded out at least flush with the outside surfaces of the base material unless otherwise stated on the drawing with the exceptions provided in Paragraph 1.2.2.6.4.

1.2.2.7 Undercut

1.2.2.7.1 For material 3/8 inch and less nominal thickness, undercut depth of 1/32 inch on one side for the full length of the weld, or 1/32 inch on one side for 1/2 the length of the weld and 1/16 inch for 1/4 the length of the weld on the same side of the member, is acceptable. For members welded on both sides where undercut exists in the same plane of a member, the cumulative lengths of undercut shall be limited to the lengths of undercut allowed on one side. Melt-through that results in a hole in the base metal is unacceptable.

1.2.2.7.2 For materials greater than 3/8 inch nominal thickness, undercut depth of 1/32 inch for the full length of the weld and 1/16 inch for 1/4 the length of the weld on both sides of the member is acceptable. When either welds or undercut exist only on one side of the member or are not in the same plane, the allowable undercut depth of 1/32 inch may be increased to 1/16 inch for the full length of the weld.

1.2.2.8 Surface Porosity--Only surface porosity whose major surface dimension exceeds 1/16 inch shall be considered relevant. Fillet and groove welds which contain surface porosity shall be considered unacceptable if:

1.2.2.8.1 The sum of diameters of random porosity exceeds 3/8 inch in any linear inch of weld or 3/4 inch in any 12 inches of weld; or

1.2.2.8.2 Four or more pores are aligned and the pores are separated by 1/16 inch or less, edge to edge.

1.2.2.9 Weld Length and Location--The length and location of welds shall be as specified on the detail drawing, except that weld lengths may be longer than specified. For weld lengths less than 3 inches, the permissible underlength is 1/8 inch and for welds 3 inches and longer the permissible underlength is 1/4 inch. Intermittent welds shall be spaced within 1 inch of the specified location.

1.2.2.10 Arc Strikes--Arc strikes and associated blemishes are acceptable provided no cracking is visually detected.

1.2.2.11 Surface Slag and Weld Spatter--Slag whose major surface dimension is 1/8 inch or less is irrelevant. Isolated surface slag that remains after weld cleaning and which does not exceed 1/4 inch in its major surface dimension, is acceptable. (Slag is considered to be isolated when it does not occur more frequently than once per weld or more than once in a 3 inch weld segment.) Spatter remaining after the cleaning operation is acceptable.

APPENDIX D

VISUAL EXAMINATION OF AWS D1.1 THREADED STUD WELDS

1. Acceptance Criteria

1.1 All studs shall show a 360° Flash.[1]

1. The expelled metal around the base of the stud is designated as flash. It is not a fillet weld such as those formed by conventional arc welding. The expelled weld metal, which is excess to the weld required for strength, is not detrimental but, is essential to provide a good weld. The stud weld flash may have none fusion on its vertical leg and overlap on its horizontal leg; and it may contain occasional small shrink fissures or discontinuities that usually form at the top of the weld flash with essentially radial or longitudinal orientation, or both, to the axis of the stud. These types of discontinuities are acceptable.

APPENDIX E

RELEVANT DATA

Relevant Data	Description	Documentation
Missing Weld[1]	Welds missing in their entirety and not a result of configuartion.	Form WEP 305[1]
Welds Missing Because of Configuration[1]	Welds missing in their enitrety because of configuration.	Form WEP 305[1]
Weld Type[1]	Weld type is not the same as called out on the design drawing or as modified by the design notes.	Form WEP 305[1]
Inaccessible[2]	When welds or portions of welds are inaccessible because of configuration.	Form WEP 302[2] Form WEP 303[2] Form WEP 305[2] Form WEP 328[2]

1. A Deviation Report (DR) shall be generated in accordance with Standard Practice 3.2.2 when this type of condition exists. The DR number shall be indicated in the appropriate block of the applicable form. If no DR is generated, N/A the block.

2. Inaccessible welds shall be processed in accordance with Standard Practice 3.2.10. The DR number shall be indicated in the "Accessible" block on the appropriate form. If no DR is generated, N/A the block.

1. PURPOSE AND SCOPE

To define guidelines to be followed by the Weld Evaluation Project Suitability for Service Evaluation Engineering group when performing reviews of Tennessee Valley Authority performed suitability-for-service evaluations of deficient welds.

2. RESPONSIBILITY AND PRACTICE

2.1 Upon receipt of the analysis packages from Tennessee Valley Authority (TVA), the Suitability for Service Evaluation Engineering (SSEE) Manager will assign the analysis package to an SSEE engineer for review.

2.2 All analysis packages reviewed per this procedure shall be given a thorough and comprehensive review to verify that:

2.2.1 Correct weld geometry and material conditions were used in the suitability-for-service (SFS) evaluation, including accounting for the weld deficiencies.

2.2.2 Design loads and load combinations, and their source, are identified.

2.2.3 Design loads are reasonable.

2.2.4 Stresses in welds are correctly and accurately calculated and combined.

a. Weld design requirements such as maximum and minimum weld size have been appropriately accounted for.

b. The effects of the weld deficiencies on connected members have been appropriately accounted for.

2.2.5 Computed stresses are evaluated using the appropriate Code allowables.

2.2.6 The SFS evaluation conclusion is appropriate.

2.3 If a new analysis for a component was performed to demonstrate SFS, the reviewer shall perform a review of the entire component analysis.

2.4 The reviewer shall review as-constructed (AC) stresses to determine SFS as described above and as-designed (AD) stresses where required for root cause and generic problem evaluation (Reference 4.1). The AD stresses will be based on the same loading used for the AC stress determination.

2.5 The reviewer is responsible for interfacing with the TVA analysis personnel and/or other SSEE group members to resolve any part of any analysis package that is not entirely clear to the reviewer. Package modifications required to satisfy the requirements of Paragraph 2.2 shall be performed by a TVA analyst and provided to the Weld Evaluation Project (WEP) SSEE reviewer for concurrence.

2.6 Once a review has been completed, Form WEP 324 (Attachment 1) shall be completed for that analysis package. The summary sheet shall then be attached to the front of the analysis package, and the package shall be submitted to the SSEE Manager.

2.7 The SSEE Manager shall review and approve each analysis package.

2.8 Any revision to Form WEP 324 after approval by the SSEE Manager shall be as follows.

2.8.1 Revisions to Form WEP 324 shall be in the form of a numerical revision. The change shall be noted by the use of a delta sign with a revision number and will be shown on all revised sheets as (1 , 2 , etc.). Document the revision on Form WEP 324 with the appropriate delta.

2.8.2 The SSEE Manager will indicate approval of the revision by initiating and dating next to the delta symbol near the approval area of Form WEP 324.

2.9 Once the SSEE Manager has approved an analysis package, it shall be transmitted to Configuration Management (CM) for storage and SSEE shall report the analysis package status to Project Administration and Control (PAC) for tracking (Reference 4.2).

2.10 Components deemed indeterminate by TVA engineering due to insufficient weld data (e.g., indeterminate depth of penetration where full penetration was not achieved) shall be removed from the group sample and replaced in accordance with SP WEP 3.1.6. Upon notification of the indeterminate condition, the SSEE Manager shall review the available data and concur if appropriate with the indeterminate status. SSEE shall notify the Component Selection Supervisor of the concurrence.

3. DEFINITIONS

3.1 Suitability-for-Service--A discrepant item is "Suitable for Service" (SFS) when it has been demonstrated by appropriate evaluations to be in compliance with the applicable codes and standards. For the WEP, a component with a discrepant weld is SFS when an appropriate engineering evaluation demonstrates that the component will adequately perform its intended safety function for all postulated design loading conditions. Where the engineering evaluation is a stress analysis accounting for the deviant condition, the calculated stresses shall satisfy the stress criteria of the applicable design code as specified in the Watts Bar Nuclear Plant Unit 1 Final Safety Analysis Report (FSAR). An overstressed weld within a component does not affect SFS of the component when the stresses in all remaining members and welds of the component are determined to be below design allowables assuming failure of the overstressed weld.

ASME Code Section III components with deviant conditions to mandatory code requirements cannot be dispositioned suitable-for-service without corrective action unless code requirements are satisfied through agreement among the owner, applicable certificate holder(s), their respective authorized inspection agencies, and appropriate jurisdictional and/or regulatory bodies.

3.2 Suitability-for-Service Evaluation--An engineering evaluation of a weld or component that appropriately accounts for the identified nonconforming condition.

4. REFERENCES

4.1 Standard Practice WEP 3.3.2, "Root Cause and Generic Problem Evaluation."

4.2 Standard Practice WEP 3.3.7, "Tracking of Examination Package Preparation, Inspection, and Analysis Data."

4.3 Standard Practice WEP 3.1.6, "Identifying Random Samples from Homogeneous Groups."

ATTACHMENT 1

Form WEP 324
Rev. 7/86

SUITABILITY FOR SERVICE
REVIEW SUMMARY SHEET

Page ___ of ___

Analysis Package/Examination Package ID: ________________

Weld ID Numbers of Nonconformance welds evaluated in this package:

____

____

____

___ Attached Analysis package has been thoroughly reviewed and in the opinion of the reviewer contains sufficient error as to invalidate the conclusions stated as to stresses being within Code Allowable Values.

___ Attached Analysis Package has been thoroughly reviewed and to the best of my knowledge, stresses have been correctly calculated and conclusions relative to stresses being within Code Allowables are correctly stated.

___ Comments and/or calculations are attached to support the review conclusion. Number of attached sheets is _____.

___ Do any of the welds require corrective action _____.

___ Summarize weld stresses on attached Weld Summary Table in terms of percent of allowable.

	Name	Signature	Date
Reviewer:	________	________	________
SSEE Manager:	________	________	________

	SSEE Manager	Date
△	________	________
△	________	________

Additional Comments: ________________

____

____

____

____

____

____

ATTACHMENT 1 (continued)

Form WEP 324
Rev. 7/86

SUITABILITY FOR SERVICE
WELD SUMMARY TABLE

Page ___ of ___

Analysis Package/Examination Package ID: ____________________

	Weld I.D.	As-Constructed Calculated Stress (% of Allowable)	As-Designed Calculated Stress (% of Allowable)
1.			
2.			
3.			
4.			
5.			
6.			
7.			
8.			
9.			
10.			
11.			
12.			
13.			
14.			
15.			

Additional Comments: ____________________

1. PURPOSE AND SCOPE

To provide instructions for review and concurrence with the Tennessee Valley Authority proposed Corrective Action Plan for hardware and/or programmatic deficiencies identified by the Weld Evaluation Project.

2. RESPONSIBILITY AND PRACTICE

2.1 Upon receipt of the proposed Corrective Action Plan (CAP; sample Attachment 1) from Tennessee Valley Authority (TVA), the Suitability-for-Service Evaluation Engineering (SSEE) Manager will assign the CAP to an SSEE engineer or designated alternate for review.

2.2 The SSEE engineer or designated alternate will perform a comprehensive review of the CAP for hardware and/or programmatic deficiencies to verify the CAP addresses the following, as applicable:

a. Description of Deficiency: A statement identifying the proposed CAP as hardware or programmatic and a description of the deficiency. This section may contain the safety significance and cause of the deficiency.

b. Boundaries of Deficiency: A description, and extent of the deficiency. For hardware deficiencies, the boundaries may be defined by component, system, location, personnel (welder or inspector), date, and any combination thereof. For programmatic deficiencies, the boundaries may be defined by procedures or organization.

c. Corrective Action: A description of proposed repair or rework required to resolve the deviant component(s) condition. Corrective action may include additional inspection and engineering evaluations in addition to, or in lieu of repair or rework. Where programmatic corrective action is required the proposed CAP shall proclude recurrence of the conditions adverse to quality.

d. Applicable Code: Identification of Code(s) to meet applicable requirements for deficiency conformance.

e. TVA Tracking Mechanism: Associated reference documents pertaining to the assessment of the CAP. Such documentation includes: Significant Condition Reports (SCR), Corrective Action Reports (CAR), 10 CFR 50.55(e) reports, and Nonconformance Reports (NCR).

2.3 During the course of the review, if any of the aforementioned criteria are indeterminate or inconclusive, the CAP will be returned to TVA for clarification.

2.4 When the CAP is determined to be acceptable in accordance with Paragraph 2.2 as applicable, the SSEE engineer will complete Form WEP 319 Attachment 2, and submit the package to the SSEE Manager for approval.

2.5 Upon approval of the Form WEP 319, the SSEE Manager will transmit the CAP to the WEP Project Manager for WEP concurrence.

2.6 Upon WEP concurrence, forward the CAP and WEP Form 319 to Configuration Management (CM). CM shall be responsible for: maintaining a copy of the CAP with Form WEP 319 and, transmitting the original CAP to TVA.

3. DEFINITIONS

Corrective action--The process of documenting, evaluating, and resolving Conditions Adverse to Quality, such as errors, omissions, test failures, inaccurate or inadequate documentation, deviation from prescribed inspection or test procedures, or any failure to meet engineering design, or procedural requirements.

4. REFERENCES

None.

STANDARD PRACTICE	Title: REVIEW OF TVA PROPOSED CORRECTIVE ACTIONS FOR WEP IDENTIFIED HARDWARE AND/OR PROGRAMMATIC DEFICIENCIES	No.: WEP 3.3.3 Rev 5 Page 3 of 4 Date:

ATTACHMENT 1

CORRECTIVE ACTION PLAN SUMMARY

WEP Group No. ________ Page ___ of ___ Date ___ Revision ___

(TVA) Prepared By: ________ Date ___
(TVA) WTG Concurrence: ________ Date ___
(EG&G) WEP Concurrence: ________ Date ___

Address the following Corrective Action Plan (CAP) items in the space remaining on this page and on additional pages as needed.

1. Description of Deficiency
2. Boundaries of Deficiency
3. Corrective Action
4. Applicable Code
5. TVA Tracking Mechanism

ATTACHMENT 2

Form WEP 319
Rev. 4/87

CORRECTIVE ACTION PLAN
REVIEW SUMMARY SHEET

WEP Group No. ____

____ The attached programmatic Corrective Action Plan has been reviewed by WEP and determined to be acceptable in accordance with the requirements of WEP SP 3.3.3.

____ The attached hardware Corrective Action Plan has been reviewed by WEP and determined to be acceptable in accordance with the requirements of WEP SP 3.3.3.

Reviewer ________________

SSEE Manager ______________

Additional Comments ______________________________

APPENDIX F

SUITABILITY FOR SERVICE EVALUATION

RELEVANT COMMUNICATIONS

APPENDIX F

SUITABILITY FOR SERVICE EVALUATION

RELEVANT COMMUNICATIONS

INDEX OF EXHIBITS

Exhibit Number	
1.	T. L. Bridges letter to K. G. Therp, "Disposition of Weld Spatter, Arc Strike, Crater Cracks, Porosity, and Overlap Weld Discrepancies," TLB-05-86, EG&G Idaho, Inc., June 30, 1986.
2.	S. J. Chang notegram to T. L. Bridges, "Safety Significance of Crater Cracks," EG&G Idaho, Inc., November 20, 1986.
3.	J. C. Standifer memorandum to L. E. Martin "Watts Bar Nuclear Plant Unit 1--Weld Reinspection Program--Applicability and Justification For Using NCIG 01 R2-Weld Inspection Criteria," P-104-SB-K, April 22, 1986.
4.	J. P. Knight ltr to D. E. Dutton, "Visual Weld Acceptance Criteria for Structural Welding at Nuclear Power Plants (VWAC) Revision 2," June 26, 1985.
5.	R. C. Weir memorandum to C.. G. Lundin, "Watts Bar Nuclear Plant (WBN)--Weld Tests--Unistrut P-1000 Material," Tennessee Valley Authority RIMS No. B45 870511 254, May 11, 1987.

EG&G Idaho

INTEROFFICE CORRESPONDENCE

Date: June 30, 1986

To: K. G. Therp

From: T. L. Bridges *T. L. Bridges*

Subject: DISPOSITION OF WELD SPATTER, ARC STRIKE, CRATER CRACKS, POROSITY, AND OVERLAP WELD DISCREPANCIES - TLB-05-86

Reference: L. E. Martin letter to K. G. Therp, dated June 18, 1986.

Attached are proposed disposition and justification for several attributes commonly found during reinspection of Watts Bar Unit 1 components. The proposed disposition has been discussed and reviewed by myself and other Weld Evaluation Project and Tennessee Valley Authority engineers and mutually agreed upon.

ss

Attachments:
As Stated

cc: W. H. Borter
A. E. Bradford
T. K. Burr
C. O. Doucette
F. C. Fogarty
C. M. Klingler
P. D. O'Leary
R. J. Wade
Central Files
T. L. Bridges File

"Providing research and development services to the government"

ATTACHMENT 1 (Revision 1)

1. Weld Spatter

Proposed Disposition - Accept as-is; no effect on suitability for service.

Justification - Weld spatter has no metallurgical significance with respect to suitability for service of the affected weld. It is not related to weld integrity and is not an indicator of weld quality. Some spatter is inevitable with most arc welding processes. Removal is typically required in order to leave the weld and base material in a condition to facilitate application and adherence of coatings. Weld spatter is not addressed in the applicable piping codes.

2. Arc Strikes

Proposed Disposition - Accept as-is on P-1 (Groups 1 & 2) and P-8 materials as listed in Table QW-422, ASME Code, Section IX. These include such pipe material as SA106 Gr B, SA105, SA312, and SA182 which comprise the majority of plant systems. Arc strikes have no effect on suitability for service on these materials and associated weld provided there is:

(1) No visually detected cracking
(2) No reduction in the base material thickness below design minimum

Justification - Arc strikes acceptable to the above criteria are a welding-related condition, not regarded as affecting function or quality of the weld. They are capable of creating, in some easily hardenable (high carbon or low alloy) materials, a heat affected zone (HAZ) of much higher hardness than the base material. These spots are considered potential initiation sites for fracture under conditions of cyclic (fatigue) loading in hardenable materials.

The austenitic stainless steel (P-8) materials are not hardenable by quenching, and so arc strikes on these materials would not result in hard spots. The plain, low carbon (P-1) materials will harden moderately from the thermal effect of welding, but the HAZ associated with arc strikes should not be appreciably harder than that resulting from a fabrication weld such as a tack weld or single pass fillet weld.

The effect on the fatigue analysis of arc strikes is negligible and therefore, their presence on P-1 or P-8 piping materials is not considered to compromise suitability for service.

3. Crater Cracks and Linear Indications Such As Lack of Fusion

Confirm the suspected crack or linear indication by liquid penetrant examination. If evaluation to the liquid penetrant acceptance criteria is acceptable, this weld area is acceptable.

DNE2 2651C
WBEP 05/14/86

ATTACHMENT 1 (Revision 1)

Justification - Treatment as suggested above meets applicable code requirements.

4. Porosity

Proposed Disposition - Porosity 1/16 inch or less in diameter observed in welds receiving only visual examination may be considered as not affecting suitability for service.

Justification - The effect of porosity on attachment welds is analagous to porosity in structural welds. The effect of porosity on weld strength has been found to be insignificant in amounts up to 5 percent of weld volume.[1] In pressure boundary welds, the 1/16-inch criterion is consistent with the rules for relevancy applicable to MT and PT examination. Both structural and pressure integrity are established by hydrostatic tests.

5. Overlap

Proposed Disposition - Overlap existing within the weld or at weld edges may be considered acceptable for service provided either of the following conditions are met:

(1) Fusion at the root of the overlap can be visually confirmed.
(2) The condition does not result in a rejectable indication when MT or PT examination is performed.

Justification - The technical significance of overlap is that it may be associated with lack of fusion or may interfere with performance of NDE. The condition is not specifically addressed in applicable codes. If fusion can be observed and any required NDE can be performed, the presence of overlap will not affect suitability for service.

[1] Welding Research Council Bulletin 222 "The Significance of Weld Discontinuities - A Review of Current Literature" by C. D. Lundin.

EG&G Idaho NOTEGRAM We have the highest standards for service.

FORM EG&G 460A (Rev. 05-84)

Date November 20, 1986

To: T. L. Bridges | From: S. J. Chang S J Chang

Org. | Org. EG&G Weld Evaluation Project

Address | Address

SUBJECT:SAFETY SIGNIFICANCE OF CRATER CRACKS

Occasional existence of weld crater cracks has been observed by WEP weld inspection at Watts Bar Nuclear Plant, Unit 1 (WBNP-1). They are shallow and located at ends of the welds. From the results of recent articles (Ref. 1 & 2) on defects in welds, we can conclude that weld fracture as a result of the presence of crater cracks is not likely for design loading conditions not including fatigue loading.

According to the articles, ductile materials with short surface cracks would yield prior to fracture for axial loadings at room temperature. Structural welds at WBNP-1 are made with E7018 weld filler material. The yield strength and fracture toughness of the welds satisfy the conditions as required in the articles. Therefore, crater cracks would not propagate before the welds yield. Futhermore, the yield strength of welds is above that for the mild steel members. For the majority of the cases, the base structure will yield before yielding of the weld filler material. This provides adequate assurance that the crater crack does not affect weld failure provided other design requirements are satisfied.

Reference 1: Weldability of Steels, by R. D. Stout and W. D. Doty, Weld Research Council, New York, 1978.

2: Fundamentals of Weld Discontinuities and Their Significance, by C. D. Lundin, Welding Research Council Bulletin 295, Welding Research Council, New York, 1984.

lm

cc: G. R. Archibald
T. L. Bridges
F. C. Fogarty
K. G. Therp
E. A. Wright
S. J. Chang File

UNITED STATES GOVERNMENT

Memorandum

TENNESSEE VALLEY AUTHORITY

B26 '86 0422 016

TO : L. E. Martin, Assistant of Manager of Nuclear Operations Office, LP 5N 25-C

FROM : J. C. Standifer, Project Engineer, Watts Bar Engineering Project, P-104 SB-K

DATE : APR 22 1986

SUBJECT: WATTS BAR NUCLEAR PLANT UNIT 1 - WELD REINSPECTION PROGRAM - APPLICABILITY AND JUSTIFICATION FOR USING NC1G 01 R2 - WELD INSPECTION CRITERIA

Per the Weld Evaluation Project's request, this is to confirm that for the welds at WBN, which were installed in accordance with Construction Specification G-29C, fatigue life was not a governing design consideration.

J. C. Standifer

WDL:CTE

cc: J. G. Adair, DNE Onsite WBN IOB
R. O. Barnett, W9 D224 C-K
J. W. Coan, W9 C135 C-K
D. E. Martin, 3-132 SB-K
R. G. Pratt, P-10? SB-K
W. D. Leslie, 3-108 SB-K
RIMS, SL 26 C-K

OE02-2300C
WBEP 04/11/86

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

JUN 2 6 1985

Mr. Douglas E. Dutton, Chairman
Nuclear Construction Issues Group
Southern Company Services
P. O. Box 2625
Birmingham, Alabama 35202

Dear Mr. Dutton:

Subject: Visual Weld Acceptance Criteria for Structural Welding at Nuclear Power Plants (VWAC) Revision 2

The staff has completed review of the subject document prepared by the Nuclear Construction Issues Group. We have concluded that VWAC Revision 2 represents a technically acceptable approach for visual inspection of structural weldments of nuclear power plants that are under the purview of American Welding Society Standard D1.1 or other non-ASME class structures. VWAC is, in our opinion, not applicable to inservice inspections that are required by Section XI of the ASME Code.

Applicants and licensees wishing to commit to the VWAC must document their commitment in the form of an amendment to the Safety Analysis Report for each power plant. The staff's processing of these amendments can be expected to be expeditious if no significant exceptions are taken to VWAC Revision 2.

We believe it particularly important that uniform training be provided to QC inspectors in the implementation of VWAC Revision 2 to assure consistency of application. The NRC staff, particularly regional inspectors, should be provided opportunities to review your training program and to observe the conduct of the training.

If you have any questions regarding this matter, please do not hesitate to contact us.

Sincerely,

James P. Knight, Acting Director
Division of Engineering
Office of Nuclear Reactor Regulation

cc: V. Stello
H. R. Denton
J. M. Taylor

TVA 64 (OS-9-65) (OP-WP-5-85)

UNITED STATES GOVERNMENT

Memorandum

TENNESSEE VALLEY AUTHORITY

B45 870511 254

TO : C. G. Lundin, Welding Program Manager, WTG-ECTG, Trailer 14, Watts Bar

FROM : R. C. Weir, Acting Chief Nuclear Engineer, W10 C126 C-K

DATE : MAY 11 1987

SUBJECT: WATTS BAR NUCLEAR PLANT (WBN) - WELD TESTS - UNISTRUT P-1000 MATERIAL

References:

1. Memorandum from W. H. Childres to C. E. Roberts dated October 29, 1986 (B46 861030 001)
2. My memorandum to you dated March 12, 1987 (B45 870312 251)
3. Memorandum from W. H. Childres to C. E. Roberts dated April 23, 1987 (B46 870424 002)

This memorandum is to provide, for your information, a summary of the most recent Unistrut weld tests and results of those tests.

<u>Background</u>

Test welds involving Unistrut P-1000 material were made and destructively tested in October 1986. Those tests involved two weld configurations commonly used in support applications: (a) Unistrut welded to a flat surface, and (b) Unistrut welded to itself in back-to-back configuration. Results of those tests were reported in reference 1. Reference 2 provided commentary and conclusions derived from the test results.

Although the purpose of the tests was unrelated to the Weld Evaluation Project (WEP), the results were made available to them for possible use in resolution of related welding issues. During discussion of the tests with WEP personnel, it was learned that some welds involving Unistrut had been rejected by their inspectors for an underfilled condition.

A review of inspection records and hardware for six such welds selected at random showed that all cases involved Unistrut P-1000 welded to 2" x 2" square tubing (longitudinal axes of both members parallel). Observation of the hardware showed the underfilled condition to occur when the weld toe against the Unistrut terminated on the corner radius of the Unistrut. WEP criteria requires the weld to be at least flush with the side wall of the Unistrut.

C. G. Lundin

MAY 11 1987

WATTS BAR NUCLEAR PLANT (WBN) - WELD TESTS - UNISTRUT P-1000 MATERIAL

To determine physical properties of underfilled welds of this configuration, additional mockups were welded at WBN in March 1987. Also included in these tests was a variation of the Unistrut-to-plate specimens tested previously. In this variation, the reinforcing fillet was made to 1/16" x 1/8" size with the shorter leg being against the base plate. This weld profile had been observed on production welds but was not duplicated in the original tests.

Results of the second test series are reported in reference 3. A summary of the test program and discussion of the results follows.

Test Summary

Fifteen specimens were welded at WBN for destructive testing at Singleton Lab. Thirteen specimens were of the Unistrut P-1000 to 2" x 2" x 1/4" wall tube steel configuration. Two were of the Unistrut-to-plate configuration with 1/16" x 1/8" reinforcing fillets. Unistrut-to-tube specimens were welded with both the shielded metal arc (SMAW) and gas tungsten arc (GTAW) processes. With each process, welds were made in both the full and underfilled condition. SMAW specimens were made with 3/32" and 1/8" diameter electrodes. GTAW specimens included welds made with 1/16", 3/32", and 1/8" diameter filler metal. Welds were made in the downhand (flat) position using welding currents determined to facilitate the desired condition. Welding was performed by James Buchanan (WBN-WTG).

Welded specimens were prepared at Singleton Lab for measurement of weld throat and underfill (as applicable) and for tensile tests. Except for one reference specimen, tensile test fixturing was designed to inhibit failure by deformation of the Unistrut lips and to promote failure by fracture of the weld or base material. For the reference specimen, tensile load was carried through a standard Unistrut 1/2" diameter spring-loaded nut attached to the specimen. This test established the limiting strength of a typical mechanical connection to the Unistrut channel.

Discussion of Results

1. Test results indicate the capacity of a mechanical (bolted) connection to the Unistrut to be approximately 9,300 pounds in direct tension. Failure in this case occurs by deformation of the Unistrut lips, allowing the captive nut to pull out. In actual installations, the ultimate strength of the mechanical connection may be lower, as limited by the properties of the attaching bolt or clamp device.

DNE1 - NEB - 4670Q

2. Failure of all tensile specimens in which lip deformation was successfully inhibited by test fixturing, occurred at loads in excess of 9,300 pounds. Average load at failure of these specimens, including those with underfilled welds, was in excess of 11,000 pounds per inch of welded connection. All underfilled specimens failed at values in excess of 11,000 pounds.

3. Test results do not indicate a correlation between the degree of underfill (up to the maximum of 0.094" measured in these tests) and either the weld effective throat or the tensile strength of the specimens.

4. Welds with effective throats as small as 0.075" will develop ? the Unistrut base material. This observation is consistent with results of previous tests (reference 1).

5. Based on observations made during welding of the underfilled test specimens, it is believed that they are representative of the worst conditions that could be expected on production welds. Attempts to produce greater underfill by means of lower welding current and/or increased travel speed resulted in gross lack of fusion.

6. Tensile test results reported in reference 3, and discussed in paragraphs 2., 3., and 4. above, relate to the properties of only one linear inch of Unistrut welded (both sides) to the structural backing. This represents a conservative basis for evaluation of the weld capacity of plant installations in that the load applied through a bolted connection to the Unistrut is normally carried by more than a single inch of welded connection per bolt.

Original Signed by
R. M. Jessee
R. C. Weir

JDW:SJB
cc: RIMS, SL 26 C-K
H. B. Bounds, C102 IOB, Watts Bar
P. D. Metcalf, C115 IOB, Watts Bar

This was prepared principally by J. D. White, extension 7900.

SENT MAY 12 1987

DNE1 - NEB - 4670Q