PACIFIC GAS AND ELECTRIC COMPANY

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JAMES D. SHIFFER
VICE PRESIDENT
NUCLEAR POWER GENERATION

November 26, 1986

PGandE Letter No.: DCL-86-342

Mr. John B. Martin, Regional Administrator
U. S. Nuclear Regulatory Commission, Region V
1450 Maria Lane, Suite 210
Walnut Creek, CA 94596-5368

Re: Docket No. 50-275, OL-DPR-80
Docket No. 50-323, OL-DPR-82
Diablo Canyon Units 1 and 2
Proposed Revision to FSAR Update, Chapter 17

Dear Mr. Martin:

Enclosed are proposed changes to Chapter 17 of the Diablo Canyon Power Plant (DCPP) Final Safety Analysis Report (FSAR) Update for your review and approval. Upon approval, these changes will be incorporated into the appropriate FSAR Update revision.

Pursuant to 10 CFR 50.54(a)(3), this submittal identifies proposed changes to the Quality Assurance Program description of Chapter 17 (Enclosure 1). The change is identified by a "10 CFR 50.54" next to the change bar in the right margin. Enclosure 1 would replace Table 17.2 of DCPP Units 1 and 2 FSAR Update.

Change No. 1

The present Table 17.2 (Enclosure 2) contains Regulatory Guide 1.58, Revision 1, September 1980, which invokes ASME Boiler and Pressure Vessel Code Section XI. This section requires recertification of Level III NDE personnel by examination every 3 years. The intent of the proposed change is to make use of ASME Code Case N-356, "Certification Period for Level III NDE Personnel Section XI, Divisions 1, 2, and 3," approved by ASME on July 16, 1982, to extend the certification period of Level III NDE personnel to 5 years. The use of this code case at Clinton Power Station Unit 1 was approved by the Nuclear Regulatory Commission Staff on April 11, 1983 (Enclosure 3). This proposed change would also make use of the 1980 edition of SNT-TC-1A, in lieu of the 1975 edition referenced by Regulatory Guide 1.58, Revision 1. The subject code case has been previously determined to be acceptable by the Commission and has been approved for general use, as indicated in Enclosure 3.

IE01
1/1

Change No. 2

This change will revise Table 17.2 to include reference to NCIG-01, Revision 2, May 7, 1985, "Visual Weld Acceptance Criteria for Structural Welding at Nuclear Power Plants," (Enclosure 4) and NCIG-03, Revision 0, July 23, 1985, "Training Manual for Inspectors of Structural Welds at Nuclear Power Plants Using the Acceptance Criteria of NCIG-01" (Enclosure 5).

These standards have been developed by the Nuclear Station Issues Group (NSIG -- formerly the Nuclear Construction Issues Group, NCIG). NCIG-01 has been approved by the NRC for generic use by letter dated June 26, 1985 (Enclosure 6).

If no comments on the above-mentioned changes are received by January 25, 1987, PGandE will assume these changes are acceptable and commence revision of the appropriate documents.

Kindly acknowledge receipt of this material on the enclosed copy of this letter and return it in the enclosed addressed envelope.

Sincerely,

W. Raymond
for J. D. Shiffer

Enclosures

cc: L. J. Chandler
M. M. Mendonca
B. Norton
H. E. Schierling
S. A. Varga
CPUC
Diablo Distribution

1091S/0048K/RWM/029

ENCLOSURE 1

DCPP UNITS 1 & 2 FSAR UPDATE

TABLE 17.2

CURRENT REGULATORY REQUIREMENTS AND PGandE COMMITMENTS
PERTAINING TO THE QUALITY ASSURANCE PROGRAM

The Quality Assurance Program described in the Quality Assurance Manual for Nuclear Power Plants complies with the requirements set forth in the Code of Federal Regulations. In addition, it complies with the regulatory documents and industry standards listed below. Changes to this list are not made without the review and concurrence of the Quality Assurance Manager.

Reg. Guide	Date	Standard No.	Rev.	Title/Subject	Comments/Reservations
(S.G.) 28	6/72	ANSI N45.2	1971	Quality Assurance Program Requirements for Nuclear Power Plants	
1.37	3/73	ANSI N45.2.1	1973	Quality Assurance Requirements for Cleaning Fluid Systems and Associated Components of Water-Cooled Nuclear Power Plants	
1.38	5/77	ANSI N45.2.2	1972	Quality Assurance Requirements for Packaging, Shipping, Receiving, Storage, and Handling of Items for Water-Cooled Nuclear Power Plants	
1.39	9/77	ANSI N45.2.3	1973	Housekeeping Requirements for Water-Cooled Nuclear Power Plants	Housekeeping zones established at the power plants differ from those described in the standard; however, PGandE is in compliance with the intent of the standard.

Reg. Guide	Date	Standard No.	Rev.	Title/Subject	Comments/Reservations
1.30	8/72	ANSI N45.2.4	1972	Quality Assurance Requirements for the Installation, Inspection, and Testing of Instrumentation and Electric Equipment	
1.94	4/76	ANSI N45.2.5	1974	Quality Assurance Requirements for Installation, Inspection, and Testing of Structural Concrete and Structural Steel During the Construction Phase of Nuclear Power Plants.	
1.29	9/78	--	--	Seismic Design Classification	
1.58	9/80	ANSI N45.2.6	1978	Qualification of Nuclear Power Plant Inspection, Examination and Testing Personnel	ANSI N45.2.6 applies to individuals conducting independent QC inspections, examinations, and tests. ANSI N18.1 applies to personnel conducting inspections and tests of items or activities for which they are responsible (e.g., plant surveillance tests, maintenance tests, etc.). ASME Code Case N-356 applies to Level III NDE personnel certifications for ASME Section XI, Division 1. The code case extends Level III NDE personnel qualifications from three to five years. NDE personnel shall be qualified and certified in accordance with SNT-TC-1A 1980 Edition. 10 CFR 50.54

TABLE 17.2

Reg. Guide	Date	Standard No.	Rev.	Title/Subject	Comments/Reservations
1.116	5/77	ANSI N45.2.8	1975	Quality Assurance Requirements for Installation, Inspection, and Testing of Mechanical Equipment and Systems	
1.88	10/76	ANSI N45.2.9	1974	Collection, Storage, and Maintenance of Nuclear Power Plant Quality Assurance Records	Except PGandE will comply with the 2-hour rating of Section 5.6 of ANSI N45.2.9 issued July 15, 1979.
1.74	2/74	ANSI N45.2.10	1973	Quality Assurance Terms and Definitions	
1.64	6/76	ANSI N45.2.11	1974	Quality Assurance Requirements for the Design of Nuclear Power Plants	Except PGandE will allow the designer's immediate supervisor to perform design verification in exceptional circumstances and with the controls as described in NUREG-0800, Revision 2, July 1981.
1.144	1/79	ANSI N45.2.12	1977	Auditing of Quality Assurance Programs for Nuclear Power Plants	
1.123	7/77	ANSI N45.2.13	1976	Quality Assurance Requirements for Control of Procurement of Items and Services for Nuclear Power Plants	
1.146	8/80	ANSI N45.2.23	1978	Qualification of Quality Assurance Program Audit Personnel for Nuclear Power Plants	

Reg. Guide	Date	Standard No.	Rev.	Title/Subject	Comments/Reservations
1.33	2/78	ANSI N18.7	1976	Quality Assurance Program Requirements (Operation)	
1.8	9/75	ANSI N18.1	1971	Personnel Selection and Training	
	2/79	ANSI/ANS 3.1	1978	Personnel Selection and Training	Within three years of commercial operation of Unit 1.
4.15	12/77	--	--	Quality Assurance for Radiological Monitoring Programs (Normal Operations) - Effluent Streams and the Environment	
BTP APCSB 9.5-1 Appendix A	5/76	--	--	Guidelines for Fire Protection for Nuclear Power Plants	Supplemented by SER, Supplement 13, April 1981, that endorses 10 CFR 50, Appendix R, Section III, Parts G, J, and O. Application of Appendix R, Section III, Parts G, J, and O is clarified and modified by SER Supplement 23, June 1984.
1.26	2/76	--	--	Quality Group Classifications and Standards for Water, Steam, and Radioactive Waste Containing Components of Nuclear Power Plants	Design and construction of Diablo Canyon Power Plant started in 1965 and most of the work cannot comply with the specific requirements of Regulatory Guide 1.26, February 1976. The intent of the Reg. Guide has been followed as shown by comparing the Reg. Guide with Tables 3.2-2 and 3.2-3 in the FSAR.

TABLE 17.2

Reg. Guide	Date	Standard No.	Rev.	Title/Subject	Comments/Reservations
--	--	NCIG-01	5/85	Visual Weld Acceptance Criteria for Structural Welding at Nuclear Power Plants	
--	--	NCIG-03	7/85	Training Manual for Inspection of Structural Weld at Nuclear Power Plants Using the Acceptance Criteria of NCIG-01	

10 CFR 50.54

ENCLOSURE 2

DCPP UNITS 1 & 2 FSAR UPDATE

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DCPP UNITS 1 & 2 FSAR UPDATE

TABLE 17.2

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1.123	7/77	ANSI N45.2.13	1976	Quality Assurance Requirements for Control of Procurement of Items and Services for Nuclear Power Plants	
1.146	8/80	ANSI N45.2.23	1978	Qualification of Quality Assurance Program Audit Personnel for Nuclear Power Plants	
1.33	2/78	ANSI N18.7	1976	Quality Assurance Program Requirements (Operation)	

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ENCLOSURE 3

ENCLOSURE

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

APR 11 1983

Docket No.: 50-461

Mr. George Wuller
Supervisor - Licensing
Illinois Power Company
500 South Street
Decatur, Illinois 62525

Dear Mr. Wuller:

Subject: Use of ASME Code Cases N-341 and N-356

The Mechanical Engineering Branch has completed its review of your request for authorization to use ASME Code Cases N-341 and N-356 for application at the Clinton Power Station as identified in your letter (U-0625) dated March 28, 1983.

Code Case N-341, "Certification of Level III NDE Examiner Section III, Division 1 and 2", and Code Case N-356, "Certification Period for Level III NDE Personnel Section XI, Division 1, 2, and 3", are acceptable code cases and are approved by the Commission for general use and may be used at the Clinton Power Station for Unit 1. Use of these code cases should be documented in the FSAR.

Sincerely,

A. Schwencer

A. Schwencer, Chief
Licensing Branch No. 2
Division of Licensing

cc: See next page

NPG LICENSING
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ENCLOSURE 4

Enclosure 4

NCIG-01
05/07/85
Rev. 2

VISUAL WELD ACCEPTANCE CRITERIA

FOR STRUCTURAL WELDING

AT NUCLEAR POWER PLANTS

43pp

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TABLE OF CONTENTS (cont.)

PREFACE

This document has been prepared and issued under the auspices of the NUCLEAR CONSTRUCTION ISSUES GROUP (NCIG). NCIG was formed by several utilities for the purpose of developing a common approach to the resolution of issues at nuclear power plant construction sites. The first issue considered by NCIG was in the area of acceptance criteria for and inspection of welds in certain supports and structures. This document contains NCIG's resolution of that issue.

SECTION 1.0

INTRODUCTION

1.0 INTRODUCTION

1.1 This document provides Acceptance Criteria for visual inspection of structural welds in nuclear power plants. The development of such acceptance criteria by the owner and the Engineer(1) falls within the provisions of the AISC Specification(2) and AWS D1.1(3). This provision is clarified in the 1985 edition of AWS D1.1. A new paragraph 1.1.1.1 has been added which states:

> "1.1.1.1 The fundamental premise of the Code is to provide general stipulations adequate to cover any situation. Acceptance criteria for production welds different from those specified in the Code may be used for a particular application provided they are suitably documented by the proposer and approved by the Engineer. These alternate acceptance criteria can be based upon evaluation of suitability for service using past experience, experimental evidence or engineering analysis considering material type, service load effects, and environmental factors."

In addition, the commentary for this new paragraph reads:

> "C1.1.1.1 The workmanship criteria provided in Section 3 of the Code are based upon knowledgeable judgment of what is achievable by a qualified welder. The criteria in Section 3 should not be considered as a boundary of suitability for service. Suitability for service analysis would lead to widely varying workmanship criteria unsuitable for a standard code. Furthermore, in some cases, the criteria would be more liberal than what is desirable and producible by a qualified welder. In general, the appropriate quality acceptance criteria and whether or not a deviation is harmful to the end use of the product should be the Engineer's decision. When modifications are approved, evaluation of suitability for service using modern fracture mechanics techniques, a history of satisfactory service, or experimental evidence is

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(1) See paragraph 1.2 for a definition of the Engineer, as used in this document.

(2) American Institute of Steel Construction, "Specification for Design, Fabrication and Erection of Structural Steel for Buildings."

(3) American Welding Society, "Structural Welding Code - Steel, D1.1."

recognized as a suitable basis for alternate acceptance criteria for welds."

1.2 Engineer's Responsibility The Engineer, as used in this document, is the individual or the organization designated by the owner as being responsible for the design of the structure being welded or inspected. The owner may fulfill the role of the Engineer for the design and inspection of any structure, in accordance with the provisions of the owner's Quality Assurance Program.

Before the provisions of this document are used for structures which have already been designed, the Engineer shall review this document to assure applicability to the structures for which it will be used. Before application, the Engineer shall determine that the provisions of this document are consistent with the engineering considerations used for the original design.

The Engineer shall specify the structures to which these Acceptance Criteria will be applied.

It is not the intent of this document to preclude the development and use of other visual weld acceptance criteria. The Engineer may specify alternative acceptance criteria; this may be done based on the provisions of paragraph 1.1.1.1 of the 1985 edition of AWS D1.1, with documented justification and appropriate project approvals.

1.3 After the Engineer accepts this document for use, it may be used to supplement specifications for design and construction as appropriate.

1.4 The application and distribution of these Acceptance Criteria and Inspection Guidelines shall be controlled in accordance with applicable document control procedures.

1.5 The workmanship provisions of AWS D1.1 are not modified by the Acceptance Criteria presented in this document and are to be implemented by the fabricator or erector during production.

1.6 Section 2.0 of this document contains a Scope statement, specifies applicable materials, weld Acceptance Criteria, and measurement units; Section 3.0 provides Inspection Guidelines for use in applying these Acceptance Criteria; Section 4.0 contains engineering evaluations for Acceptance Criteria.

SECTION 2.0

ACCEPTANCE CRITERIA

2.0 ACCEPTANCE CRITERIA

2.1 Introduction

2.1.1 This Section contains Acceptance Criteria for use when inspecting welds in nuclear power plant structures and supports that have been designed and fabricated to the requirements of the AISC Specification and AWS D1.1.

2.1.2 The provisions of this document do not apply to ASME Code(1) stamped work.

2.2 Scope

2.2.1 This document is intended to be used with design and construction specifications for nuclear power plants where the structures have already been designed, fabricated, and/or erected, and for new work.

2.2.2 This document is applicable to welded construction for safety and non-safety related structures, including seismically loaded structures, where fatigue(2) is not the governing design consideration. Examples of typical structures to which these criteria apply include, but are not necessarily limited to, steel components such as:

2.2.2.1 Main building framing members and connecting members;

2.2.2.2 Supports for equipment, components and piping(3), cable trays and conduit, and HVAC ducts;

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(1) American Society of Mechanical Engineers Boiler and Pressure Vessel Code, Section III, Nuclear Components.

(2) For the purposes of this document, structures whose design is governed by fatigue are those structures for which an analysis is required for cyclic service and whose endurance limit must be considered in the design. At a nuclear power plant, most supports and pipe hangers, which might be designed considering seismic loads, are not governed by fatigue design limits.

(3) Excluding component supports stamped in accordance with the ASME Code Section III, Subsection NF.

2.2.2.3 Miscellaneous steel including bracing and stiffeners; embedments; stairways and handrails, doors and door frames, windows and window frames, gratings, covers, etc.

2.2.3 This document and its provisions may be used for the inspection and acceptance of welds in other structures and systems not specifically addressed in 2.2.2, provided the provisions of Sections 1.2 and 2.3 are met.

2.3 Materials

2.3.1 This document is applicable to the inspection of the following structural steels:

Material Number 1, Groups Number 1 and 2, as listed in Table C2 of AWS B2.1. (These materials include those structural steels also listed in Table 4.1.1 of AWS D1.1 as Groups I and II; P Number 1, Groups 1 and 2, as listed in Table QW-422 of Section IX of the ASME Code; and S Number 1, Groups 1 and 2 as listed in Table 1 of ASME Code Case N-71-12.)

2.4 Measurement Units

Table 2-1 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 2-1, these dimensions shall be rounded off to the nearest significant unit.

Table 2-1

Weld Attribute	Reference Section	Smallest Measurement Unit (Significant Unit - Inches)
Fillet Weld Size	2.5.2.2	1/16
Incomplete Fusion	2.5.2.3	1/8
Weld Overlap	2.5.2.4	1/8
Undercut Depth	2.5.2.7	1/32
Surface Porosity	2.5.2.8	1/16
Weld Length	2.5.2.9	1/8 or 1/4
Weld Location	2.5.2.11	1/4

2.5 Acceptance Criteria

2.5.1 These Acceptance Criteria are to be used for the acceptance inspection of welds in the uncoated condition. These criteria may also be used for subsequent inspections after the welds have been coated, with the concurrence of the Engineer.

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

2.5.2.1 Weld Cracks The weld shall have no cracks.

2.5.2.2 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.

2.5.2.3 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.

2.5.2.4 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.

2.5.2.5 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.

2.5.2.6 Weld Profiles

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

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

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

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

2.5.2.7 Undercut

2.5.2.7.1. 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.

2.5.2.7.2 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.

2.5.2.8 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:

2.5.2.8.1 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

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

2.5.2.9 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.

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

2.5.2.11 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.

SECTION 3.0

INSPECTION GUIDELINES

3.0 INSPECTION GUIDELINES

These Inspection Guidelines are to be used for visual inspection of structural welds made in accordance with the provisions of AWS D1.1. These guidelines provide background information and instructions to assist the Inspector in evaluating weld attributes. Measuring techniques and guidance on the accuracy, frequency, and locations for measuring welds are discussed. It is important for the Inspector to understand weld size tolerances and significant measurement units in order to preclude rejection of adequate welds.

Effective implementation of the Acceptance Criteria requires that all Inspectors evaluating any weld use the same inspection techniques, acceptance criteria, and measurement accuracy. The Inspector's duties, inspection philosophy, and inspection guidelines are presented with this goal in mind.

3.1 The Inspector

3.1.1 As used herein, the Inspector is that person performing acceptance inspections of completed welds.

3.1.2 The Inspector using these Acceptance Criteria is to perform inspections in accordance with the guidelines provided in this document. Section 6 of AWS D1.1 addresses some inspection provisions for structural welding, but they are applicable to the in-process welding control of the project.

3.2 General Inspection Requirements

3.2.1 Weld inspection and tests are performed as necessary prior to assembly, during assembly, during welding, and after welding to ensure that materials and workmanship meet the requirements of contract documents. It is the responsibility of the contractor to assure that the workmanship standards and in-process controls of AWS D1.1 are met as appropriate.

3.2.2 In nuclear construction, in-process workmanship may be monitored and audited by the Quality Control group as required by the constructor's Quality Assurance Program. The Acceptance Criteria of this document are to be used to determine the adequacy of completed structural welds.

3.2.3 The inspection of structural welds to the Acceptance Criteria of this document shall be documented in accordance with project requirements. The marking of welds during in-process work is not required as part of the acceptance inspections addressed by this document.

3.3 Inspection Philosophy

3.3.1 The workmanship provisions of Section 3 of AWS D1.1 are necessary for in-process quality control purposes. The determination of whether corrective action is necessary to assure good workmanship during production shall be made in accordance with the in-process welding control of the project.

3.3.2 Inspections subsequent to the acceptance inspection are intended to evaluate and verify that previous inspections were competently performed and to demonstrate compliance with design requirements. They are not intended to upgrade or downgrade the level of workmanship or impose more stringent criteria or examination methods.

3.4 Inspection Principles

The following identifies general inspection principles that will enable Inspectors to consistently inspect welds to verify compliance with the Acceptance Criteria.

3.4.1 Each weld attribute shall be inspected and evaluated independently. It is not necessary to consider cumulative effects.

3.4.2 Acceptance inspections shall be performed promptly after welding has been completed so that deficiencies, if any, may be identified and resolved in a timely manner.

3.4.3 Visual inspection of welds is normally performed on the as-welded surface after the weld cleaning operation.

3.4.4 Measuring devices should be graduated in increments compatible with the applicable significant unit, e.g., 1/16 inch increments, rather than decimals. When taking or recording measurements, measurements should be rounded off to the nearest significant unit.

3.4.5 Lighting, natural or artificial, shall be of sufficient intensity and placement to illuminate the area being examined. Lighting shall be considered adequate when, for example, the Inspector can resolve a black line 1/32 inch wide or less on an 18 percent neutral gray card placed on the surface to be inspected. Backlighting is not required. Visual inspection may be aided by using a flashlight.

3.4.6 Applicable drawings for the structure shall be reviewed prior to inspection, and referred to during inspection, as necessary.

3.4.7 These Acceptance Criteria are to be used for the acceptance inspection of welds in the uncoated condition. These criteria may also be used for subsequent inspections after the welds have been coated, with the concurrence of the Engineer. Subsequent inspections related to suspected weldment cracking may require the removal of the coating or the use of appropriate magnetic particle inspection.

3.5 Weld Attribute Descriptions, Acceptance Criteria and Inspection Guidelines

This Section includes a definition or description of each weld attribute to be inspected, identifies the weld Acceptance Criteria to be applied, and provides specific inspection guidelines.

3.5.1 Weld Cracks

3.5.1.1 Description of Weld Cracks: Weld cracks are discontinuities characterized by a sharp tip and high ratio of length and depth to opening displacement.

3.5.1.2 Acceptance Criteria: The weld shall have no cracks.

3.5.1.3 Inspection Guidelines: Weld cracks shall be identified by visually examining the weld and heat affected zone. Visually detected cracks shall be identified for repair. The use of magnification devices for detection of cracks by visual examination is not required. However, additional lighting, such as a flashlight, or magnifiers may be appropriate for further investigation of suspected cracks.

3.5.2 Fillet Weld Size

3.5.2.1 Description of Fillet Weld Undersize: Fillet weld undersize occurs when the amount of weld metal deposited results in a size that is significantly less than specified.

The undersize condition may occur in the legs or the throat of fillet welds, as shown in Figure 3-1.

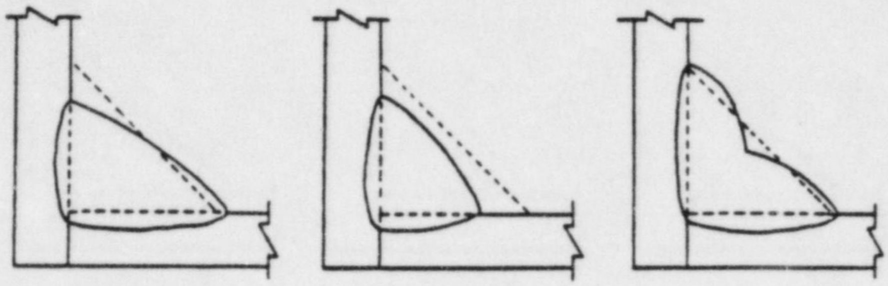

Figure 3-1

3.5.2.2 Acceptance Criteria: 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.

3.5.2.3 Inspection Guidelines: The Inspector shall measure weld size using appropriate measuring devices. Potentially undersize areas are the most appropriate locations for measuring weld size. Such areas can usually be determined by viewing the weld length. Areas of the weld that appear to be significantly undersized should be examined based on the requirements of the Acceptance Criteria.

Scales or fillet weld gages may be used for measuring the size of welds. Measurement increments of 1/16 inch are appropriate for these gages. The Inspector has the responsibility for assuring that the weld meets the Acceptance Criteria for size, but continuous measurement of size over the full length of the weld is not mandatory and weld size measurements should be rounded off to the nearest 1/16 inch.

3.5.3 Incomplete Fusion

3.5.3.1 Description of Incomplete Fusion: Incomplete fusion is a condition in which coalescence of weld metal and base metal (or previous passes of filler metal) did not occur.

3.5.3.2 Acceptance Criteria: 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.

3.5.3.3 Inspection Guidelines: Inspection for incomplete fusion shall be performed by visually examining the weld. The wetting and flow of weld metal at the fusion line is the best indication of fusion. Incomplete fusion in fillet welds which does not exceed 3/8 inch in any 4 inch segment of weld or 1/4 inch in welds less than 4 inches long is acceptable. Visually detected incomplete fusion in groove welds is not acceptable.

Indications of incomplete fusion at the start and stop of a weld which are observed only at the weld root are not indicative of the fusion in the main run of the weld. (See Figure 3-2.) This apparent incomplete fusion is the result of transient conditions and should be considered acceptable. These brief transients affect only a very short portion of the weld and are not a cause for rejection because the main run of the weld is not affected. Measurements of incomplete fusion length should be rounded off to the nearest 1/8 inch.

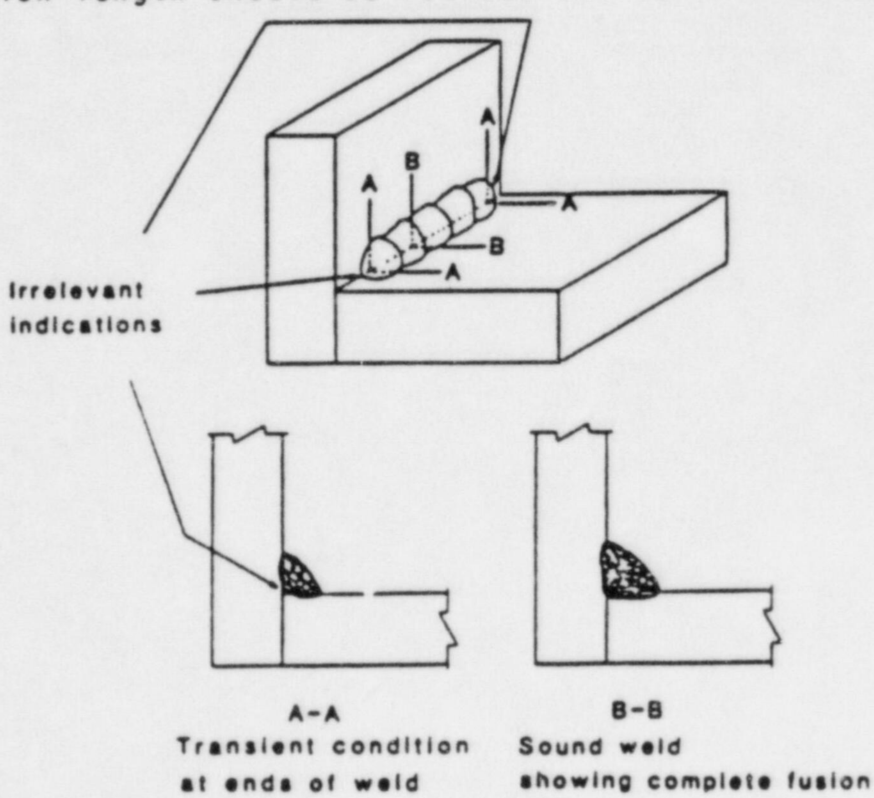

Figure 3-2

3.5.4 Weld Overlap

3.5.4.1 Description of Weld Overlap: Weld overlap is the protrusion or rollover of weld metal over the adjacent base metal at the toe of the weld.

Fillet and Groove Weld overlap is shown in Figure 3-3.

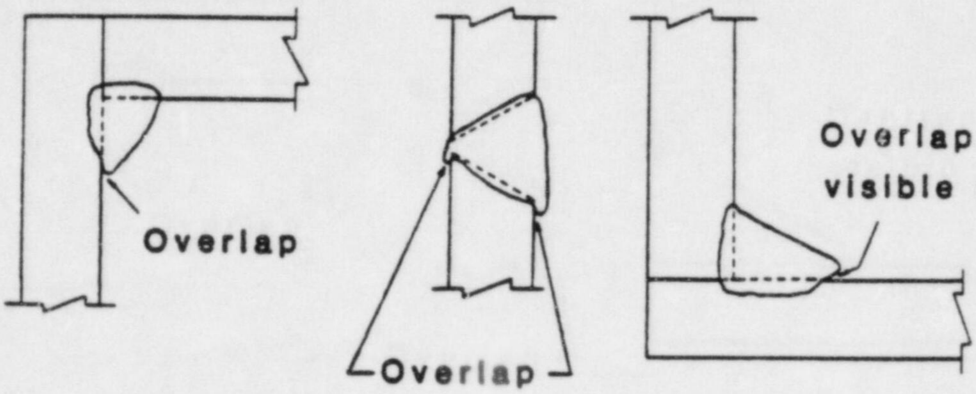

Figure 3-3

3.5.4.2 Acceptance Criteria: 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.

3.5.4.3 Inspection Guidelines: The area of any overlap should be inspected to assure weld size and fusion requirements are met. Generally, in an overlap condition, if incomplete fusion occurs, it will be short in length. The wetting and flow of weld metal at the fusion line is the best indication of fusion. Portions of individual weld ripples or weave patterns which overlap are not a concern when there is fusion on each side. Where fusion cannot be verified, the unverified length should not exceed 3/8 inch in any 4 inch segment or 1/4 inch in welds less than 4 inches long. Overlap in excess of 3/8 inch (or 1/4 inch) length is acceptable when both fusion and weld size can be verified. Measurements of overlap length should be rounded off to the nearest 1/8 inch.

3.5.5 Underfilled Craters

3.5.5.1 Description of Underfilled Craters: A crater is a depression at the termination of a weld bead. Underfilled craters are small areas in which the nominal weld size has not been achieved.

3.5.5.2 Acceptance Criteria: 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.

3.5.5.3 Inspection Guidelines: The length of the weld should be visually examined to locate the craters. Craters are to be evaluated using the acceptance criteria for undersized welds. Craters should be visually inspected for cracks.

3.5.6 Weld Profiles

3.5.6.1 Descriptions Applicable to Weld Profiles:

Description of Convexity and Concavity:

Convexity is the maximum distance from the face of a convex fillet weld perpendicular to a line joining the weld toes. Concavity is the maximum distance from the face of a concave fillet weld perpendicular to a line joining the weld toes.

Description of Groove Weld Reinforcement:

Groove weld reinforcement is the weld metal added in excess of the quantity needed to fill the weld joint. It increases the joint thickness.

3.5.6.2 Acceptance Criteria:

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

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

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

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

3.5.6.3 Inspection Guidelines: Fillet weld convexity is controlled during the welding process and need not be measured as part of the acceptance inspection. Concavity is acceptable provided the requirements for weld size are met.

Groove weld reinforcement is controlled during the welding process and need not be measured as part of the acceptance inspection.

When evaluating groove weld thickness, the 1/32 inch undersize allowance is a maximum value. It is equivalent to rounding off to the nearest 1/16 inch; that is, if the thickness of a groove weld is 1/32 inch or less than the specified thickness, it is acceptable; if it is more than 1/32 inch less than the specified thickness, it is to be rejected.

3.5.7 Undercut

3.5.7.1 <u>Description of Undercut</u>: Undercut appears as a groove melted into the base metal adjacent to the toe or root of a weld and is an area left unfilled by weld metal. Undercut may occur in any length from a fraction of an inch to the full length of the weld.

Fillet and groove weld undercut is shown in Figure 3-4.

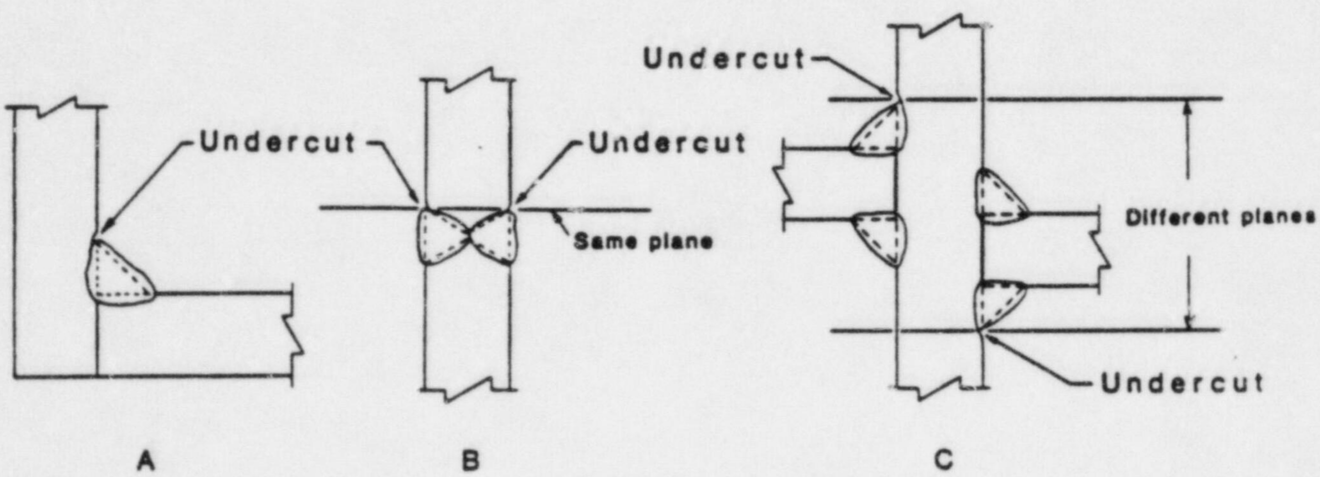

Figure 3-4

3.5.7.2 <u>Acceptance Criteria</u>:

3.5.7.2.1. 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.

3.5.7.2.2 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.

3.5.7.3 Inspection Guidelines: The criteria for determining the acceptance of undercut are depth and length. The method to be used for determining acceptable depth is primarily visual. Potentially rejectable areas may be evaluated using a scale, comparative sample, or suitable gage to determine the depth of undercut. Melt-through is unacceptable.

These Acceptance Criteria allow undercut for the full length of the weld on one side of a member. However if undercut exists for the full length, it may be indicative of a welding process control problem, and should be brought to the attention of appropriate personnel.

The acceptance criteria refer to situations where undercut may exist on both sides of the member and in the same plane. Sketch A of Figure 3-4 illustrates undercut on only one side of a member. Sketch B shows undercut on both sides of a member and in the same plane. Sketch C is an example of undercut on both sides of a member but not in the same plane. In Sketch B, the total length of undercut is determined by adding together the length of undercut on each side of the member; for material 3/8 inch and less nominal thickness the total length of undercut should not exceed the length of undercut that would be allowed if there was undercut on only one side of the member. In Sketch C, the undercut on one side is not in the same plane as the undercut on the opposite side of the member and therefore, the length of undercut at each location is to be evaluated independently.

Undercut depth is to be estimated to the nearest 1/32 inch and undercut length is to be estimated to determine compliance with the length of undercut criteria. There are significant margins in these criteria so that it is not necessary to sum isolated intermittent undercut (i.e., 1/4 inch here, 5/8 inch there) to develop the total length of undercut.

3.5.8 Surface Porosity

3.5.8.1 Description of Surface Porosity: Porosity consists of discontinuities formed by gas entrapment during solidification.

Porosity appears on the surface of welds as circular voids. The voids are caused by gas in the molten weld material which collects in discrete bubbles. The bubbles, moving toward the weld surface while it is still molten, form voids which are trapped as the metal solidifies. Gas bubbles merge and varying void sizes result. This type of porosity is frequently referred to as "pin holes" when the porosity extends to the weld surface.

3.5.8.2 Acceptance Criteria: 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:

3.5.2.8.1 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

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

3.5.8.3 Inspection Guidelines: Porosity voids are generally less than 1/16 inch in diameter. Thus, relatively few are relevant. Very seldom should it be necessary to use any measuring device, but when there is concern, a 1/16 inch wire and a tape or scale are adequate.

Estimating the number of random voids which appear to be over 1/16 inch in diameter within one inch and twelve inch spans will usually provide adequate information for weld acceptance.

When evaluating potentially rejectable aligned porosity, a 1/16 inch diameter wire can be used to measure both the size of the pores and the edge to edge spacing of the pores. If the size of a pore is 1/16 inch or less it is irrelevant and need not be counted; if the spacing between any two relevant pores exceeds 1/16 inch, those pores are irrelevant for the purpose of evaluating aligned porosity.

3.5.9 Weld Length and Location

3.5.9.1 Description of Weld Length and Location: Weld length and location are an expression of the design and detail drawing requirements specifying the length of welds and the physical location of welds on the structure.

3.5.9.2 Acceptance Criteria: 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.

3.5.9.3 Inspection Guidelines: Welds should be visually inspected to determine that they are in the locations shown on the design drawings. Weld length should be measured to the tolerances designated in the drawings. When the design drawings do not provide tolerances for weld length and location, an underlength of 1/8 inch is acceptable for welds less than 3 inches and 1/4 inch for welds 3 inches or longer. Welds may be longer than specified.

Welds are usually designated as full length of the member or continuous. When the length of a weld is specified, it usually applies to intermittent welding, such as, "3 inches long at 12 inches center-to-center," or, "6 inches long at 12 inches center-to-center." The total sum of the lengths of the intermittent welds is more important than the actual length of the individual intermittent welds. Either way, a 1/8 inch or 1/4 inch tolerance, as applicable to segment length, is acceptable if no other tolerance is given.

Intermittent welds may be located within 1 inch of the designated location.

Measurements shall be rounded off to the nearest 1/16 inch for size; to the nearest 1/8 or 1/4 inch for length; and to the nearest inch for location of intermittent welds.

3.5.10 Arc Strikes

3.5.10.1 Description of Arc Strikes: An arc strike is an area of base metal struck by inadvertent arcing from the welding electrode, which may cause a small amount of base metal melting in the impingement region. Arc strikes sometimes cause a discoloration of the base metal.

3.5.10.2 Acceptance Criteria: Arc strikes and associated blemishes are acceptable provided no cracking is visually detected.

3.5.10.3 Inspection Guidelines: No special inspection is required for detection of arc strikes. Arc strikes are usually found near the weld and the Inspector should review them while performing inspections for other weld attributes. Arc strikes and the associated blemishes should be visually examined for cracks.

3.5.11 Surface Slag and Weld Spatter

3.5.11.1 Description of Surface Slag and Weld Spatter: Surface slag is the nonmetallic residue remaining from the reactions occurring in the arc and weld pool during welding. Spatter consists of metal particles expelled during fusion welding that do not form a part of the weld. Slag and spatter are removed during the cleaning operation by brushing, grinding, chipping, or other suitable means.

3.5.11.2 Acceptance Criteria: 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.

3.5.11.3 Inspection Guidelines: Inspection for surface slag and weld spatter should be performed by visually examining the length of the weld and adjacent base metal areas. Any areas not meeting the acceptance criteria should be cleaned again and re-examined. (Cleaning required for subsequent processing, such as painting or NDE, is not addressed here.)

3.6 Significant Measurement Units

3.6.1 Measurement units are identified in Table 2-1.

3.6.2 It is not appropriate to mix or interchange fractional and decimal dimensions or tolerances. For example, undercut must not be measured in terms of hundredths or thousandths of an inch. When acceptance limits are given in fractions of an inch, all measuring tools must also be graduated in fractions of an inch. Decimal gages are only to be used when dimensions or tolerances are explicitly specified in decimals.

3.7 Equivalency

These Acceptance Criteria have been developed based on the effect that discontinuities may have on the reduction of cross-sectional area. The Acceptance Criteria for some discontinuities (such as weld size, incomplete fusion, weld overlap, undercut and surface porosity) provide limits based on both depth or surface dimensions and length. It is intended that the Engineer may provide for acceptance of welds on an equivalency basis; for example, in material 3/8 inch or less, in nominal thickness, undercut depth that exceeds 1/32 inch may be acceptable up to 1/16, if the length of undercut is proportionately less. Equivalency is meant as a means for the Engineer to evaluate a weld condition documented by the Inspector as not meeting the acceptance criteria.

The Inspector must base his acceptance of welds on the criteria specified and provided by the Engineer.

SECTION 4.0

COMMENTARY

4.0 COMMENTARY

4.1 Criteria Evaluation

This Section contains engineering evaluations of the Acceptance Criteria given in Section 2.0. In general, it is important to recognize that the engineering design of structures and weld connections is based on conservatively estimated loads. The allowable stresses for materials given in Codes are also conservative. Code allowable stresses have been chosen by applying a "safety factor" or "design factor" to compensate for design and analysis techniques and assumptions, fabrication tolerances, inspection techniques, variables in material properties, and other unknowns. For these reasons, there is no need to modify allowable stresses or design techniques when implementing the Acceptance Criteria of this document.

Because fatigue is not a concern for the structures addressed in this document, the evaluation of the Acceptance Criteria is primarily based on an allowable reduction of area consistent with construction Codes and Standards. Welding Research Council Bulletin 222, "The Significance of Weld Discontinuities" reports that geometrical discontinuities are influential in static behavior only to the extent they reduce cross-sectional area.

4.1.1 Weld Cracks

4.1.1.1 Acceptance Criteria: The weld shall have no cracks.

4.1.1.2 Discussion: Visually detected cracks in welds are unacceptable.

4.1.2 Fillet Weld Size

4.1.2.1 Acceptance Criteria: 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.

4.1.2.2 Discussion: Undersized fillet welds could cause increased stress in the throat of the weld and a subsequent reduction of the load carrying capacity of the weld. Therefore it is appropriate to review the increase in stress due to the allowable reduction of weld size.

Evaluation of the Acceptance Criteria for a 3/16 inch fillet weld results in a potential reduction in shear area of about

8%. (See paragraph 4.3 for a sample calculation of the effect on shear area due to undersized welds.)

This evaluation is based on the assumption that both legs are reduced equally, whereas the condition generally found is that one leg is reduced and the other is not. In addition, no consideration is given for either convexity or penetration, both of which may increase the weld shear area. Also, no credit is taken for actual weld metal strength, which is generally about 10% greater than specified.

4.1.3 Incomplete Fusion

4.1.3.1 Acceptance Criteria: 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.

4.1.3.2 Discussion: Incomplete fusion describes a weld zone region within which the desired coalescence of base metal and weld metal did not take place due to the absence of complete melting. An important aspect of structural welding is the welding procedure and the performance test which all welders must execute satisfactorily. These are the industry accepted primary safeguards for prevention of unacceptable incomplete fusion.

The use of an acceptance criterion which allows an incomplete fusion length of 3/8 inch in any 4 inch segment is equivalent to a maximum potential reduction of load carrying area of less than 10% (9.4%). Furthermore, the 9.4% calculated reduction in the strength of any 4 inch segment of a fillet weld that contains a 3/8 inch length of incomplete fusion (where fusion cannot be readily verified) is based on the assumption of no weld fusion for the width of the indication and the full depth of the weld. This is considered to be an extremely conservative assumption because the condition is local and usually affects only a minor portion of one weld bead; that is, the condition does not affect the full depth of the weld. Such indications (i.e., short lengths of visually detected incomplete fusion), when further investigated, generally exhibit a high percentage of complete fusion.

Indications of incomplete fusion at the starts and stops of welds are usually observed only at the weld root and are not indicative of the fusion in the main run of the weld, provided fusion is evident at the weld toes. (See Figure 3-2.) This apparent incomplete fusion is the result of transient conditions and is acceptable. These brief transients affect only a very short portion of the weld at the start and stop, and are not a cause for rejection because the main run of the weld is not affected.

4.1.4 Weld Overlap

4.1.4.1 Acceptance Criteria: 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.

4.1.4.2 Discussion: Weld overlap or rollover may occur intermittently or as a continuous condition. Short lengths of localized or intermittent overlap at weld ripples, weld weaves or at bead starts is not a concern when the adjacent portions of a weld are fused to the base material. Fusion to the base metal is a function of the arc energy and the heat content of the molten weld pool. Neither of these factors change rapidly enough to adversely affect fusion in a short length. A short length of overlap is evidence of a localized variation in welding technique that alters the weld surface appearance, but not the underlying weld deposit.

Overlap of 3/8 inch in any 4 inch segment results in a maximum potential reduction of load carrying capacity of the weld of less than 10% (9.4%). The basis and assumptions for this calculated reduction of 9.4% due to overlap are the same as those for incomplete fusion. (See paragraph 4.1.3.2.) Thus, the evaluation of the Acceptance Criteria for overlap is consistent with the evaluation for incomplete fusion. This is desirable, because at times there is difficulty in distinguishing between overlap and incomplete fusion. With equivalent acceptance criteria, any difference is immaterial.

4.1.5 Underfilled Craters

4.1.5.1 Acceptance Criteria: 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.

4.1.5.2 Discussion: Weld craters are slightly underfilled areas sometimes found at weld stops. A crater may constitute a short length of weld undersize. The justification for undersized fillet welds is given in Section 4.1.2.

4.1.6 Weld Profiles

4.1.6.1 Acceptance Criteria:

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

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

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

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

4.1.6.2 Discussion: Fillet weld convexity and groove weld reinforcement do not adversely affect weldments for these structural applications, but removal is not necessarily beneficial to suitability for service, and could create other problems.

The undersize allowance of up to 1/32 inch for groove welds is consistent with the requirements of AWS D1.1, paragraph 3.6.3 for flush butt joints and is equivalent to rounding off to the nearest 1/16 inch.

4.1.7 Undercut

4.1.7.1 Acceptance Criteria:

4.1.7.1.1. 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.

4.1.7.1.2 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.

4.1.7.2 Discussion: Weld undercut is caused by melting away of base metal at the toe of a fillet weld or groove weld. Thus, undercut is best characterized as a broad shallow discontinuity rather than a crack-like defect. Undercut is a base metal condition rather than weld metal condition.

For some structures, undercut limitations have been based upon concern for fatigue loading and other factors which by scope definition are not a concern for the service conditions being covered by these Acceptance Criteria.

Undercut develops when base metal is melted and flows under the effects of gravity and/or surface tension, without being replaced by weld filler metal. Melting and flow cause the defect to have a shallow, broad contour, as limited by the molten metal surface tension and viscosity. The broad shallow nature of undercut will permit stress redistribution in that area.

Because fatigue is not a concern for the structures addressed in this document, undercut allowance is properly based on potential reduction of area. There is significant technical support for this approach in addressing the acceptability of undercut. Principal reference in this regard is Welding Research Council Bulletin 222, "The Significance of Weld Discontinuities." Bulletin 222 reports that geometrical discontinuities are influential in static behavior only to the extent that they reduce the cross-sectional area.

The NCIG undercut criteria were evaluated considering the effect of undercut on the net load carrying base metal area. Table 4-1 shows the effect of the undercut allowed by the Acceptance Criteria of this document on area reduction for several thicknesses of material. (See Section 4.3 for a sample calculation for the effect of undercut.)

Figure 8.15.1.5 of AWS D1.1 specifies permissible undercut values for various thicknesses of materials and principal tensile stress conditions. Table 4-1A provides a comparison of the percent reduction in area allowed based on the NCIG Acceptance Criteria and the requirements of AWS D1.1 for various material thicknesses.

TABLE 4-1

EFFECT OF UNDERCUT ON
REDUCTION OF CROSS SECTION

Material Thickness (Inches)	Allowable Undercut (Depth and Length)	Maximum Area Change (%)
3/16	1/32 for L (one side) or 1/32 for L/2 + 1/16 for L/4 (one side)	16.7
1/4	(same as for 3/16")	12.5
5/16	(same as for 3/16")	10.0
3/8	(same as for 3/16")	8.3
7/16	1/16 for L/4 + 1/32 for 3L/4 (both sides)	17.9
5/8	(same as for 7/16")	12.5

L is the full weld length.

TABLE 4-1A

COMPARISON OF THE EFFECT OF UNDERCUT
ON PERCENT REDUCTION OF AREA

Material Thickness	NCIG	AWS D1.1		
		No Calculated Stress	Stress Parallel to Undercut	Stress Perpendicular to Undercut
3/16"	16.7	24.9	12.4	12.4
1/4"	12.5	28.0	18.7	9.3
5/16"	10.0	28.0	22.4	7.5
3/8"	8.3	27.8	18.7	6.2
7/16"	17.9	23.0	16.0	5.3
5/8"	12.5	20.0	11.2	3.7

From the above comparison, the reduction of area based on the NCIG acceptance criteria for undercut is comparable to the reduction of area permitted by AWS D1.1.

4.1.8 Surface Porosity

4.1.8.1 Acceptance Criteria: 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:

4.1.8.1.1 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

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

4.1.8.2 Discussion: Steel weld metal porosity is usually caused by improper cleaning of the base metal or contamination of the weld metal, and additionally, by inadequate shielding of the welding arc. Porosity is created when the molten steel solidifies before all the gas has issued from the liquid weld metal.

Numerous publications indicate that the presence of porosity in amounts of 5% to 7% has an insignificant influence on weld strength in non-fatigue stress applications, and that 10% porosity does not diminish weld metal strength below the minimum specified values. If the porosity is assumed to extend through the full depth of the weld, the 3/4 inch in 12 inches represents 6% of a weld, therefore there is a significant margin before porosity becomes a concern. Since this is surface porosity, the effect is really insignificant.

The conclusion that porosity less than 1/16 inch in diameter is irrelevant is consistent with the provisions of ASME Section III, Subsection NF, paragraph NF-5360(a); the criteria for aligned porosity is consistent with paragraph NF 5360(a)(4).

4.1.9 Weld Length and Location

4.1.9.1 Acceptance Criteria: 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.

4.1.9.2 Discussion: Welds have been rejected when their length is slightly more or less than specified on construction drawings. The purpose of verifying that welds are of proper length and location is to assure that the welds are capable of transmitting loads through the structure in accordance with the design.

Welds are most often designated on drawings as being the full length of the member or continuous around the member. Specific weld lengths are designated for intermittent welding. The total sum of the lengths of the intermittent welds is more important than the actual length of the individual intermittent welds. Intermittent welds that are longer than specified increase total weld length, reduce stress, and are acceptable.

For the minimum allowable intermittent fillet weld length of 1-1/2 inch, the 1/8 inch permitted underlength results in an area reduction of about 8%. A similar reduction, about 8%, occurs for the 1/4 inch permitted underlength applied to a 3 inch weld. This effect decreases with increasing weld length, being less than 5% for welds over 5 inches in length. This reduction of area is consistent with the reductions of area allowed for other weld attributes. (See Section 4.3 for a sample calculation of the effect of weld underlength.)

In general, welds should be located as shown on drawings. However, for welds of specific length, such as intermittent welds, a linear offset in location by as much as 1 inch is not considered to be significant because the load will still be properly transmitted through the structure.

4.1.10 Arc Strikes

4.1.10.1 Acceptance Criteria: Arc strikes and associated blemishes are acceptable provided no cracking is visually detected.

4.1.10.2 Discussion: Arc strikes are caused by inadvertent arcing between the welding electrode and the base metal, causing a small amount of base metal melting in the arc impingement region. More than ordinary attention is sometimes given arc strike areas because of potential hardness and the possibility of cracking.

For the structural steels to which this document applies, the maximum hardness of the arc strike region is limited by the relatively low carbon equivalents of the materials. Recently published work[1] has shown that cracking does not occur in arc strikes on materials of this class, and concludes that since uncorrected arc strikes do not affect the strength of the material, they should not be of concern when the design is not governed by fatigue. The article states one of the problems suspected to be associated with arc strikes is the possibility of cracking occurring as a result of the rapid heating and cooling of the material. The results documented in the article demonstrate that the suspected cracking does not occur.

The article also discusses potential encroachment on required thickness by arc strikes and concludes that such encroachment on the required thickness by arc strikes is unlikely.

4.1.11 Surface Slag and Weld Spatter

4.1.11.1 Acceptance Criteria: 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 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.

4.1.11.2 Discussion: Sometimes removal of all slag from completed welds requires extraordinary effort since occasional tightly adhering slag in small areas requires the use of pneumatic chisels or grinders to completely remove the slag. This usually results in a less presentable surface and removal may cause more harm than good. It is good practice to remove surface slag by wire brushing or chipping hammers, but there are limits as to what can be accomplished with such tools. It is not considered a necessity to remove small tightly adherent areas of slag since it has no effect on the weld. The amount of slag permitted by the Acceptance Criteria should not mask any significant condition of concern.

The basic purpose for removing weld spatter is to clean the area so it can be properly inspected and painted. Tightly adhering weld spatter is not harmful to the weld or base metal.

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(1) Van Malssen, S.H., "The Effects of Arc Strikes on Steels Used in Nuclear Construction," Welding Journal, July 1984.

4.2 Cumulative Effects

4.2.1 Eleven attributes are considered in this document. The cumulative effect that deficiencies in any one of these attributes may, or may not have, on any other attribute is summarized in Table 4-2. It is concluded that it is not necessary to consider cumulative effects when evaluating welds in these types of structures and therefore each weld attribute should be inspected and evaluated independently.

4.2.2 The justification for not considering the cumulative effects of any of the potentially negative combinations that are possible, follows:

4.2.2.1 Both base metal and weld metal strength are significantly higher than minimum specified values.

4.2.2.2 Small size welds are rarely loaded to allowable stress limits.

4.2.2.3 Convexity and reinforcement do not reduce the load carrying capacity of the weld.

4.2.2.4 These structures are designed using conservative load definitions, load combinations, analytical techniques, and design methods.

4.2.2.5 Designers round-up to the next larger fillet weld size in 1/16 in. increments.

4.2.2.6 Member sizes and material thicknesses are selected by the designer based on manufacturer's standards or material availability. As a result, these structures are usually fabricated using material that exceeds the size or thickness needed to satisfy design requirements for area or load carrying capability.

4.2.3 Weld Underlength and Fillet Weld Undersize It is possible that these attributes could combine to decrease the load capacity of a weld. However, underlength is a consideration that is generally applicable only to intermittent welds and such welds are not common in these types of structures.

TABLE 4-2

COMMENTS APPLICABLE TO CUMULATIVE EFFECTS

Weld Attributes	Comment
Weld Cracks	Not allowed, therefore not cumulative.
Fillet Weld Undersize	Could combine with weld underlength (refer to Section 4.2.3 for Discussion).
Incomplete Fusion	Local condition which does not produce a general reduction in strength.
Weld Overlap	Local condition which does not produce a general reduction in strength.
Underfilled Craters	Weld size restrictions must be met; therefore not cumulative.
Weld Profiles:	
Convexity and Groove Weld Reinforcement	Do not result in a reduction in weld or material strength or area.
Concavity	Weld size restrictions must be met; therefore not cumulative.
Undercut	This is a base metal condition which does not affect the weld.
Surface Porosity	Porosity does not adversely affect weld strength and therefore is not cumulative.
Weld Length	Could combine with fillet weld undersize (refer to Section 4.2.3 for Discussion).
Arc Strikes	Could result in minor reduction in base metal area, but is not a cumulative effect with other base metal considerations.
Surface Slag and Weld Spatter	Do not reduce weld strength or area.

On a worst case basis, if a fillet weld specified to be 3/16 inch by 3 inches long was undersized and underlength but met the Acceptance Criteria for both of these attributes, the total reduction in throat area compared to the throat area of the weld as specified, would be approximately 16 percent, which is reasonable on the basis of the conservatisms stated in 4.2.2. (See Section 4.3 for a sample calculation of percent reduction in throat area.)

4.2.4 Fillet Weld Undersize and Undercut Fillet weld undersize is a condition which may affect the load carrying capability of the weld and undercut is a condition in the base material adjacent to the weld. The two effects do not occur at the same point and are not cumulative. The failure plane for a structure with fillet welds is through the weld. This failure plane is not in line with nor in close proximity to any plane affected by undercut. Thus the two attributes cannot combine nor bear upon one another.

4.2.5 Incomplete Fusion or Weld Overlap and Other Weld Attributes The 9.4% calculated reduction in the strength of a 4 inch segment of a fillet weld that contains a 3/8 inch length of incomplete fusion or weld overlap (where fusion cannot be readily verified) is based on the assumption of no weld fusion for the width of the indication and the full depth of the weld. This is considered to be an extremely conservative assumption because the condition is local and usually affects only a minor portion of one weld bead; that is, the condition does not affect the full depth of the weld. Such indications (i.e., short lengths of visually detected incomplete fusion or weld overlap), when further investigated, generally exhibit complete fusion. Because the assumed condition is extremely rare, it is not necessary to consider the cumulative effect of either incomplete fusion or weld overlap with any other deficiency (such as weld underlength or weld undersize) when inspecting welds in these types of structures.

4.2.6 Other Weld Attributes The other attributes are either not related or are clearly independent of each other.

4.3 Sample Calculations

4.3.1 Sample Calculation for the Combined Effect of Weld Underlength and Undersize

For a 3/16" X 3" long fillet weld that meets NCIG criteria for length and size:

Theoretical throat area:

$$= (S)(L)(.707)$$

$$= (3/16)(3)(0.707) = 0.398 \text{ in.}^2$$

Actual throat area:

$$= (S)(L')(.707) - (s)(L')(\%L')(.707)$$

$$= (3/16)(2\text{-}3/4)(.707) - (1/16)(2\text{-}3/4)(0.25)(.707)$$

$$= 0.365 - 0.030$$

$$= 0.335 \text{ in.}^2$$

$$\text{Area reduction} = \frac{0.398 - 0.335}{0.398}$$

$$= 0.158 \text{ or approximately } 16\%^{(1)}$$

Where:

S = Specified Weld Size
L = Specified Weld Length
L' = Permissible Weld Length = L-1/4"
s = Permissible Undersize = 1/16"
%L' = % of Weld Length that may be Undersize = 25%

(1) A calculation to determine the reduction in weld metal area along the heat affected zone (weld leg) would obviously yield an identical result. This same observation can be made for the results given in 4.3.3 and 4.3.4.

4.3.2 Sample Calculation for the Effect of Undercut in 5/8 Inch Material

$$\text{Area Reduction} = \frac{(2)(u)(L/4) + (2)(u')(3L/4)}{(t)(L)}$$

$$= \frac{(2)(1/16)(L/4) + (2)(1/32)(3L/4)}{(5/16)(L)}$$

$$= \frac{0.031 + 0.047}{0.625}$$

$$= 0.125 \text{ or } 12.5\%$$

Where:

t = Base Metal Thickness

L = Specified Weld Length

u = Permissible undercut depth for L/4

u' = Permissible undercut depth for 3L/4

4.3.3 Sample Calculation for the Effect of Undersize in a 3/16 Inch Fillet Weld

$$\text{Area Reduction} = \frac{(s)(L/4)(.707)}{(S)(L)(.707)}$$

$$= \frac{(1/16)(L/4)(.707)}{(3/16)(L)(.707)}$$

$$= \frac{(0.0156)}{(0.1875)}$$

$$= 0.083 \text{ or } 8.3\%$$

Where:

s = Permissible Undersize

S = Specified Weld Size

L = Specified Weld Length

4.3.4 Sample Calculations for the Effect of Weld Underlength

For an intermittent fillet weld specified to be 1-1/2 inches long that meets the NCIG criteria for length:

Theoretical throat area:

$$= (S)(L)(.707)$$

$$= (S)(1.5)(.707)$$

$$= 1.061(S)\ in.^2$$

Actual throat area:

$$= (S)(L')(.707)$$

$$= (S)(1.5 - 0.125)(.707)$$

$$= 0.972(S)\ in.^2$$

$$\text{Area reduction} = \frac{1.061 - 0.972}{1.061}$$

$$= 0.083 \text{ or } 8.3\%$$

Where:

S = Specified Weld Size

L = Specified Weld Length

L' = Permissible Weld Length

For an intermittent weld specified to be 5 inches long that meets the NCIG criteria for length:

Theoretical throat area:

$$= (S)(5)(.707)$$

$$= 3.535(S)\ in.^2$$

Actual throat area:

$$= (S)(5 - 0.25)(.707)$$

$$= 3.358(S)\ in.^2$$

$$\text{Area reduction} = \frac{3.535 - 3.358}{3.535}$$

$$= 0.050 \text{ or } 5\%$$

ENCLOSURE 5