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**Commentary
on
Structural Welding
Code**

Aluminum



AMERICAN WELDING SOCIETY

ANSI/AWS D1.2A-83

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American National Standards Institute
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Commentary on Structural Welding Code —Aluminum

Prepared by
AWS Structural Welding Committee

Under the Direction of
AWS Technical Activities Committee

Approved by
AWS Board of Directors

AMERICAN WELDING SOCIETY, INC.
550 North LeJeune Rd., Miami, FL 33126

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American Welding Society, 550 North LeJeune Rd., P.O. Box 351040, Miami, FL 33135

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<i>J. R. Stitt</i>	J. R. Stitt, P.E.
<i>L. Tall*</i>	Florida International University
<i>J. D. Theisen</i>	Exxon Company, USA

*Advisory Member

**Resigned July 1982

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<i>D. D. Rager, Vice Chairman</i>	Reynolds Metals Company
<i>G. A. Alison, Secretary</i>	Aluminum Association
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<i>L. A. Colarossi</i>	Pittsburgh-Des Moines Corporation
<i>H. F. Crick</i>	Brown & Root, Incorporated
<i>P. B. Dickerson</i>	Alcoa Laboratories
<i>M. F. Godfrey</i>	Consultant
<i>M. Holt*</i>	Consultant
<i>G. S. Gresham</i>	Reynolds Metals Company
<i>R. A. Kelsey</i>	Alcoa Laboratories
<i>C. E. Hartbower</i>	Consultant
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<i>P. J. Sullivan</i>	Massachusetts Department of Public Works
<i>W. Sunderland</i>	New Jersey Department of Transportation
<i>A. A. Trinidad</i>	Andrews and Clark
<i>L. E. Hoffman</i>	Union Metal Manufacturing Company

*Deceased June 1981

Foreword

This Commentary on AWS D1.2, Structural Welding Code - Aluminum, has been prepared to generate better understanding in the application of the Aluminum Code to welding in aluminum construction.

Since the Aluminum Code is written in the form of a specification, it cannot present background material or discuss the Committee's intent; it is the function of this commentary to fill that need.

Suggestions for application as well as clarification of the Aluminum Code requirements are offered with specific emphasis on sections that may be less familiar to the user.

The fundamental premise of the Aluminum Code is to provide general stipulations applicable to any situation and to leave sufficient latitude for the exercise of engineering judgement. The Aluminum Code represents the collective experience of the Committee. Although some provisions may seem overly conservative, they have been based on sound engineering practice.

The Committee believes that a commentary is the most suitable means to provide clarification as well as proper interpretation of many of the Aluminum Code requirements. Obviously, the size of the commentary had to impose some limitations with respect to the extent of coverage.

This commentary is not intended to provide a historical background of the development of the Aluminum Code, nor is it intended to provide a detailed resume of the studies and research data reviewed by the Committee in formulating the provisions of the Aluminum Code.

Generally, the Code does not treat such design considerations as loading and the computation of stresses for the purpose of proportioning the load-carrying members of the structure and their connections. Such considerations are assumed to be covered elsewhere, such as the Aluminum Association's Specification for Aluminum Structures, or similar documents.

The Committee has endeavored to produce a useful document suitable in language, form, and coverage for welding in aluminum construction. The Aluminum Code provides a means for establishing welding standards for use in design and construction by the owner or his designated representative. The Aluminum Code incorporates provisions for regulation of welding that are considered necessary for public safety.

The Committee recommends that the owner or owner's representative be guided by this commentary in application of the Aluminum Code to the structure to be welded. The commentary is not intended to supplement Aluminum Code requirements, but only to provide a useful document for interpretation and application of the Aluminum Code; the Commentary provisions are not binding.

Comments or inquiries pertaining to this Commentary or to the Aluminum Code are welcome. They should be addressed to: Secretary, Structural Welding Committee, American Welding Society.

Commentary on Structural Welding Code— Aluminum

1. General Provisions

Note: All references to numbered paragraphs, tables, and figures, unless otherwise indicated, refer to paragraphs, tables, or figures in AWS D1.2 Structural Welding Code—Aluminum. References to paragraphs, tables, or figures in this commentary are prefixed with a C. For example, 8.8.1 is in AWS D1.2, while C8.8.1 is in this Commentary.

1.1 Application

The Structural Welding Code, hereinafter referred to as the Code, provides welding requirements for the construction of aluminum structures. It is intended to be complementary with any general code or specification for design and construction of aluminum structures.

Although the provisions of the Code are generally applicable to any aluminum structure, owners, architects, and engineers using the Code for structures should recognize that not all of its provisions may be applicable or suitable to their particular structures. However, any modifications of the Code deemed necessary by these authorities should be clearly referenced in the contractual agreement between the owner and the contractor.¹

1.2 Base Metal

The ANSI H35.2-1982 specifications provide for dimensional tolerances. Base metal used for structural applications is usually furnished based on these requirements. The Engineer should recognize this, and any

special dimensional requirements should be specified in the information furnished to the bidders.

1.3 Welding Processes

Certain gas metal arc and gas tungsten arc welding procedures in conjunction with certain related types of joints have a long record of proven satisfactory performance. These welding procedures and joints are designated as recommended; they may not be used without tests or qualification (see Section 5).

1. As used in this commentary, contractor designates the party responsible for performing the welding under the Code. The term is used collectively to mean contractor, fabricator, erector, manufacturer, etc.

Recommended provisions are given in Section 2, Design; Section 3, Workmanship; and Section 4, Technique. Section 4 includes welding procedures, with specific reference to preheat, filler metals, and other pertinent requirements. Additional requirements for recommended joints in tubular construction are given in Section 10.

2. Design of Welded Connections

2.1.3 The Engineer preparing contract design drawings cannot specify the depth of groove (S) without knowing the welding process and the position of welding. The Code is explicit in stipulating that only the effective throat (E) is to be specified on design drawings for partial joint penetration groove welds (2.1.3.1). This allows the contractor to produce the effective throat by assigning a depth of preparation to grooves shown on shop drawings as related to his choice of welding process and position of welding.

The root penetration will generally depend on the angle subtended at the root of the groove in combination with the root opening, the welding position, and the welding process.

2.5 Partial Joint Penetration Groove Welds

A partial joint penetration groove weld has an unwelded portion at the root of the weld. This condition may also exist with a groove weld in a single-welded joint without backing and with a groove weld in a double-welded joint without back gouging. Therefore, the Code places the same application limits on these welds as for partial joint penetration groove welds.

The unwelded portions are no more harmful than those in fillet welded joints. These unwelded portions constitute a significant stress concentration when fatigue loading is applied transversely to the joint.

However, when the load is applied longitudinally, there is no appreciable reduction in fatigue strength. Irrespective of the rules governing the service application of these particular groove welds, the eccentricity of shrinkage forces in relation to the center of gravity of the joint members will result in angular distortion on cooling after welding. This same eccentricity will also tend to cause rotation in transfer of axial load transversely across the joint. Therefore, means must be applied to restrain or preclude such rotation, both during fabrication and in service.

2.7 Details of Fillet Welds

The Code specifies the minimum fillet weld size and requires that this size be made in a single pass. This provision is intended to insure sufficient heat input during welding to reduce the possibility of cracking in the weld metal on cooling, especially in a restrained joint. The minimum size applies if it is greater than the size required to carry design loads.

3. Workmanship

3.1 General

3.1.3 Experience has shown that a welder cannot produce optimum results when working in an environment where the temperature is lower than 32° F (0° C). Reference is made in 3.1.3, 4.13.3, and 4.17.3 relative to the use of a heated structure or shelter to protect the welder and the area being welded, from inclement weather conditions. The environmental conditions inside the structure or shelter do not alter the preheat or interpass temperature requirements for base metals stated elsewhere in the Code.

3.2 Preparation of Base Metal

3.2.1.1 Grinding of aluminum for edge preparation is generally not recommended; however, the Code recognizes that it is necessary in some instances. In these instances, care must be taken not to contaminate the base metal by embedding abrasive particles in the aluminum surface.

3.2.1.2 When plasma arc cuts are made on heat-treatable alloys, 1/8 in. (3.2 mm) of base metal shall be removed by machining, except as allowed in 10.6.3.

3.2.3 Visual Inspection and Repair of Plate Cut Edges. The repair procedures for discontinuities in plate cut edges may not be adequate where tension is applied in the through-thickness direction of the base metal. For other directions of loading, this article permits some lamination type discontinuities in the base metal. Experience and tests have shown that laminations parallel to the direction of tensile stresses do not generally adversely affect the load-carrying capacity of a structural member.

3.2.5 In buildings and tubular structures, the Code permits a smaller re-entrant corner radius than is permitted for bridges. The smaller radius is necessary for some standard bolted or riveted connections. The unacceptable condition defined in the last sentence of 3.2.5 is illustrated in Fig. C3.2.5.

3.2.7 Heat-shrink techniques used to correct moderate variations from specified dimensions shall be employed only within the limitations outlined in 3.7.5.

3.3 Assembly

3.3.1 Typical sketches of the application of the alignment requirements for abutting parts to be joined by welds in butt joints are shown in Fig. C3.3.1 (A) and (B).

3.3.4 Except for the root opening in lap joints and the separation between a backing and base metal, a root opening of 1/16 in. (1.6 mm) maximum is permitted for fillet welding base metal not exceeding 3 in. (76 mm) in thickness. For base metal over 3 in. (76 mm), the maximum permissible root opening is 5/16 in. (7.9 mm). These root openings are necessitated by the allowable mill tolerances and inability to bring thick parts into closer alignment. The Code presupposes straightening of members prior to assembly or an application of external load mechanism to force and keep the members in alignment during assembly.

These root openings may require backing, either as a backing weld or other types of backing capable of supporting molten weld metal. It should be realized that upon release of any external jacking loads, additional stresses may act upon the welds. Any root opening 1/16 in. (1.6 mm) or greater in size requires an increase in size of fillet by the size of the root opening.

3.3.7 Tack welds must comply with the same workmanship, preheat, etc., and quality criteria required for finished welds, except as allowed in 10.7.1.

3.5 Dimensional Tolerances

3.5.1.3 The cambering of structural members is used to eliminate the appearance of sagging or to match elevation of adjacent building components when the member is fully loaded.

3.5.1.6 The combined warpage and tilt (Δ) of the flange of welded beams and girders is measured, as shown in Fig. C3.5.1.6.

3.6 Weld Profiles

3.6.1 Acceptable and unacceptable weld profiles are shown in Fig. 3.6; unacceptable profiles are shown with modification in Table 10.10.1 for Class I structures.

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3.7 Repairs

3.7.2 The Code permits the contractor to either repair or remove and replace an unacceptable weld. It is not the intent of the Code to give the Inspector authority to specify the mode of correction.

3.7.4 Application of localized heat is permitted for straightening members; however, this must be done carefully so as not to exceed temperature limitations that would adversely affect the properties of the aluminum base metal.

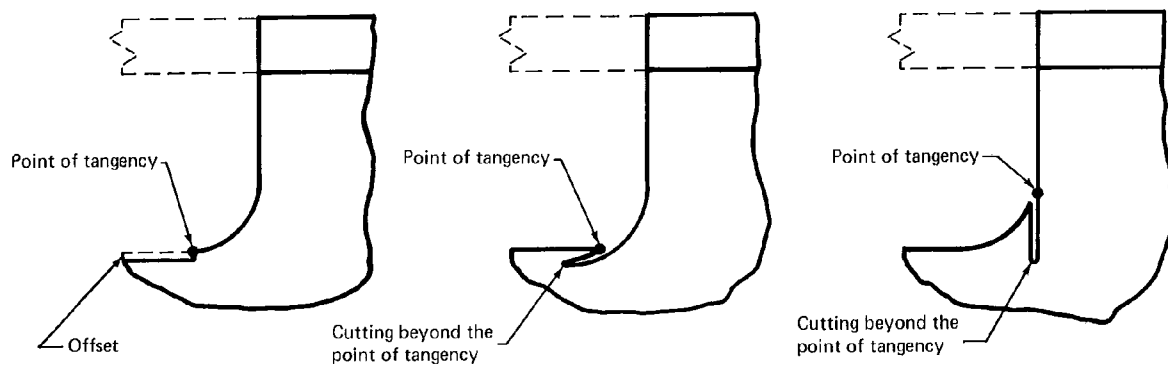


Fig. C3.2.5—Examples of unacceptable cutting beyond the point of tangency
Note: Any cutting beyond the point of tangency is unacceptable

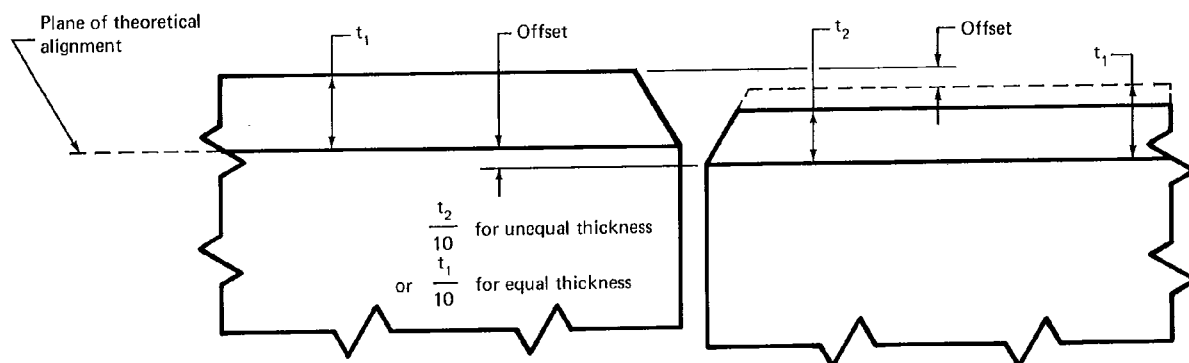


Fig. C3.3.1(A)—Permissible offset in abutting members. An offset not exceeding 10 percent of the thickness of the thinner part joined, but in no case more than 1/8 in. (3.2 mm), may be permitted as a departure from the theoretical alignment.

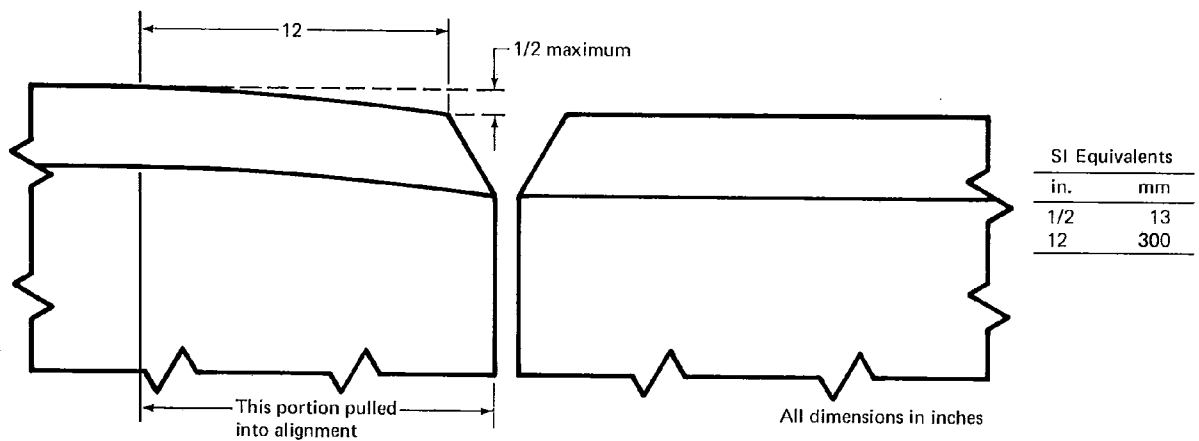


Fig. C3.3.1(B)—Correction of misaligned members. In correcting misalignment that exceeds the permissible allowance, the parts shall not be drawn to a slope greater than 1/2 in. (12.7 mm) in 12 in. (305 mm).

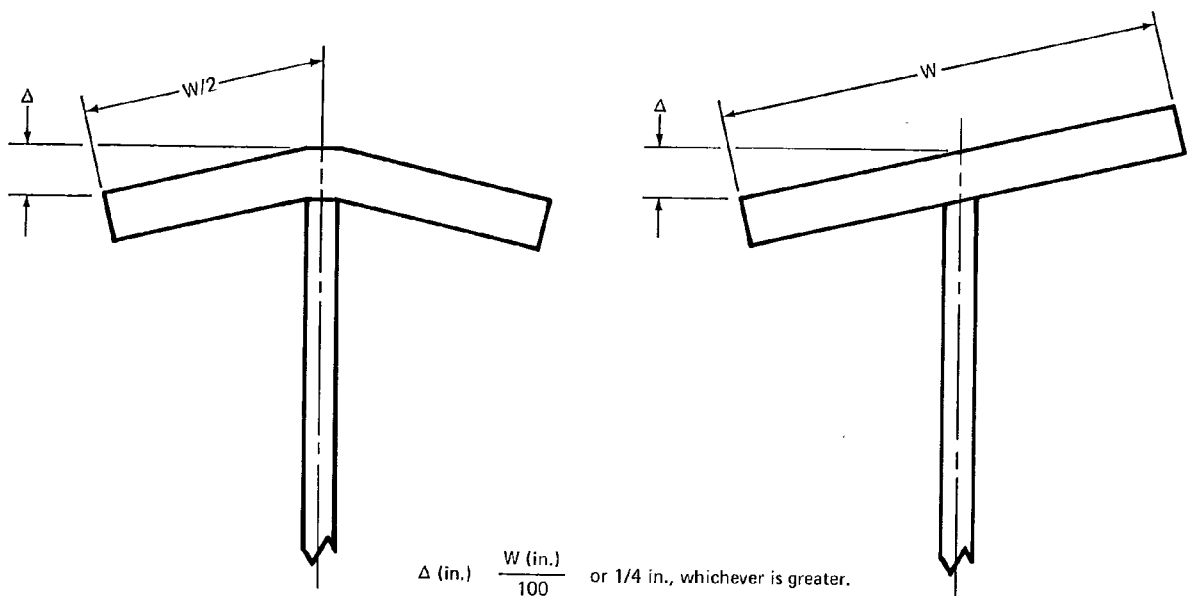


Fig. C3.5.1.6—Measurement of flange warpage and tilt

4. Technique

4.1 Material Requirements. Recommended combinations of base metals and filler metals are shown in Table 1.2.2.1.

4.2 Welding Processes. Welding processes covered by the Code are limited to the gas metal arc (GMAW) process and the gas tungsten arc (GTAW) process.

4.6 Arc Strikes. Arc strikes result in heating and very

rapid cooling. When located outside the intended weld area, they may result in localized cracking and may serve as potential sites for initiating fracture.

4.11 Thermal Stress-Relief Treatment. When stress-relief of a welded assembly is required, the limitations listed in this paragraph and in Table 3.7.5 shall apply. These limitations do not apply to artificial aging of heat-treatable alloys.

5. Qualification of Procedures and Personnel

Part A General Requirements

5.2 Qualification of Welding Procedures

5.2.2 Many aluminum alloys used in structural applications are heat treatable. During welding, certain areas of the heat-affected zone are subjected to temperatures that cause a partial annealing of the base metal. The extent of this partial annealing is dependent upon the welding conditions affecting the heat input. Thus, these variations in heat input can drastically alter the load carrying capacity of the welded structures. Therefore, all procedures approved for use under this Code shall be qualified by test.

The Engineer is encouraged to accept properly documented evidence of previously qualified procedures. If the Engineer specifically intends to require requalification of procedures, it should be clearly stated in the contract documents, so that the contractor can make a proper estimate of costs.

5.3 Qualification of Welders, Welding Operators and Tackers

5.3.1 Welders, welding operators, and tackers should have a minimum of three months of successful experience welding on aluminum alloys. In lieu of such experience, they should be instructed in the welding of aluminum and its alloys.

Since tack welds sometimes become a part of the final weld, the importance of tackers' receiving instruction in welding aluminum is stressed.

5.4 Qualification Responsibility

All contractors are responsible for their final product. Therefore, it is their responsibility to comply with the qualification requirements of the Code relative to welding procedures, welders, welding operators, and tackers. Properly documented welding procedures and personnel qualification tests conducted by the contractor in accordance with this Code are generally acceptable to the Engineer for the contract.

Part B Types of Tests, Test Methods and Acceptance Criteria

The types of tests, test methods, and acceptance criteria for each specific requirement are found in this part of the Code. It alerts the user to the types of tests required for procedure and performance qualification and to see the types and limits of discontinuities that each type of test is designed to detect.

5.7 Types of Tests

This section describes tests, the procedures for conducting them, and the basis for acceptance. Figure 5.10.2 describes procedures for testing groove welds, and Fig. 5.11 describes procedures for conducting fillet weld tests.

Part C Procedure Qualification

This part sets forth the requirements for qualifying a welding procedure. The Code recognizes that the approved aluminum alloys are weldable and that certain conditions will be applicable to many of them.

5.14 Limits of Qualified Positions for Procedures

Table 5.14 summarizes the requirements for the positions that are qualified by each qualification test. The test positions qualified are based on the experience and skill required to make a welded joint.

5.16 Limitation of Variables

Some degree of departure from the variables stated in the welding procedure specification is recognized as permissible without requiring verification. Departures from a welding procedure that affect predictable results are referred to as essential variables and are considered to be items that will affect the mechanical or chemical properties, or both, of the weldment. The limits set forth in

this section are based on the combined experience of the members of the subcommittee on welded aluminum structures.

5.17 Tests—Procedure Qualifications

5.17.3 Test Specimens: Number, Type and Preparation. Tables 5.17.3.1, 5.17.3.2, and 5.17.3.3 summarize the requirements for the number and type of test specimens and the range of thickness qualified. A test weld plate thickness of 1 in. (25 mm) or over qualifies a procedure for unlimited maximum thickness. The 1 in. (25 mm) thickness has been shown generally to reflect the influence of weld metal chemical composition, heat input, and preheat and interpass temperature on the weld metal and heat-affected zone properties.

Table 5.17.3 summarizes the procedure qualifications for (A) complete joint penetration groove welds; (B) partial joint penetration groove welds; and (C) fillet welds.

The procedure qualification for pipe and tubing is divided into Class I and Class II structures based on the criteria outlined in Section 10 of the Code. Class I structures deal with the welding of castings, and provisions are made in this table to qualify these procedures. Conditions for large diameter job-size pipe or tubing are found in the section of the table dealing with Class II tubular structures.

All partial joint penetration groove welds and all test weld plates with fillet welds (except option No. 2) require a macroetch test to determine the effective throat of the weld being tested.

Part D *Performance Qualification*

5.19 General

The welder, welding operator, or tacker qualification

test is specifically designed to determine their ability to produce sound welds in any given test weld. After successfully completing the performance qualification tests, the welder, welding operator, or tacker should be considered to have minimum acceptable qualifications.

Knowledge of the base metal is beneficial to the welder, welding operator, or tacker in producing a sound weldment; therefore, it is recommended that before welding aluminum wrought alloys or aluminum castings, welders, welding operators, or tackers be given instructions as to the properties of these base metals, except where they have had prior experience in welding aluminum products.

5.22, 5.23, and 5.24 Limitations of Variables

The ability of a welder to produce a sound weld is considered by the Code to be dependent on certain essential variables. These are listed in subparagraphs of 5.22 for welders, under 5.23 for welding operators, and 5.24 for tackers.

Table 5.23.3 lists the number and type of specimens and range of thickness qualified for welder and welding operator qualification. Performance qualification for pipe and tubing is divided into Class I and Class II structures to recognize the use of castings in Class I structures. Tackers qualify by performing one of the designated fillet weld tests.

5.26 Retests

If a specimen from the test weld fails a specific test, an immediate testing of two additional specimens from the same test weld or an additional test weld is allowed under the Code. If it is apparent that additional training is necessary, a complete retest at such time as this training has been accomplished is allowed by the Code.

6. Inspection

Part A **General Requirements**

AWS D1.2 parallels the AWS D1.1 on the basic premise of contractual obligations when providing products and services. Those who submit competitive bids or otherwise enter into a contract to provide materials and workmanship for structural weldments in accordance with the provisions of the Code assume an obligation to furnish the products as specified in the contract documents and are fully responsible for product quality.

6.1 General

In this section, the term *fabrication/erection inspection* is separated from verification inspection. These broader terms are used to avoid confusion with the terms quality control and quality assurance as used by some industries (e.g., nuclear). It was advantageous to use more general terms that place greater emphasis on timely inspection. The contractor is solely responsible for the ordering of materials, and assembly and welding of the structural weldments.

6.1.1 This paragraph describes the responsibility of the contractor for fabrication/erection inspection and testing, which is basically the quality control responsibility described in other contract documents. The owner has the right, but generally not the responsibility, to provide independent inspection to verify that the product meets specified requirements. This inspection may be done independently by the owner or his representative or, when provided in the contract, verification inspection may be waived or it may be stipulated that the contractor shall perform both the inspection and the verification.³

3. When this is done, fabrication/erection inspection (quality control) and verification inspection (quality assurance) remain separate functions. Verification inspection should be performed independently by personnel whose primary responsibility is not production inspection.

6.2 Inspection of Materials

This Code provision is all-encompassing. It requires inspection of materials and review of materials certification and mill test reports. It is important that this work be done in a timely manner so that unacceptable materials are not used or incorporated in the work.

6.3 Inspection of Welding Procedure Qualification and Equipment

The requirements of 6.3.1 and 6.3.2, should be completed before welding is begun on weldments required by the contract documents. Qualification for each weldment should always be done before welding is started, but qualification for all weldments does not have to be completed before welding with qualified procedures can be started.

6.4 Inspection of Welder, Welding Operator, and Tacker Qualifications

6.4.1 It is important that the Inspector determine that all welders are qualified before they begin welding on the project. If discovered after welding has begun, lack of welder qualification documentation may cause serious delays in the acceptance of weldments.

6.4.2 The Inspector must regularly appraise the quality of welds produced by welders, welding operators, and tackers. Individuals producing unacceptable welds should be required to produce satisfactory test welds of the type causing difficulties. Complete requalification may not always be necessary. Only qualified welders producing acceptable welds may be employed in the work.

6.4.3 Welders who cannot provide evidence that they have used the welding process for which they were qualified within the preceding six months is required to take appropriate tests to become requalified. Since active welders can maintain certification as long as they continue to do good work, it is essential that the Inspector regularly evaluate the quality of the welds produced by each welder, welding operator, and tacker.

6.5 Inspection of Work and Records

The Inspector shall determine from inspection of the work prior to assembly, during assembly, during welding, and after welding (see 6.1.1) that all requirements of the Code are met. Inspectors shall identify the work they have inspected and accepted or rejected. The method of identification should not be destructive to the weldment. Die stamping of welds is not recommended, since die stamp marks may form sites for crack initiation. It is essential that the Inspector keep accurate records documenting his basis for accepting or rejecting weldments.

6.6. Obligation of the Contractor

6.6.1 The contractor is responsible for the product acceptability. The contractor shall conduct inspection to the extent necessary to ensure conformance with the Code, except as provided in 6.6.5.

6.6.2 If the Verification Inspector finds deficiencies in materials and workmanship, regardless of whether the Verification Inspector is a representative of the owner or an employee of the contractor, the contractor shall be responsible for all necessary repairs or replacements.

6.6.4 and 6.6.5 When nondestructive testing is specified in the information furnished to bidders, the contractor shall take necessary steps to ensure that the nondestructive testing acceptance criteria prescribed by the Code are met. When nondestructive testing other than visual inspection is not specified, the owner shall be responsible for all associated costs of testing and surface preparation plus the repair of defects not reasonably expected to be discovered during visual inspection. Since there is a limit to the defects that might reasonably be expected to be found in visual inspection of welds, welds that contain defects that are considered beyond reasonable weld quality standards and which appear to result from gross nonconformance to this Code shall be repaired or replaced at the contractor's expense in accordance with 3.7.2.

6.7 Nondestructive Testing

In addition to visual inspection, which is always necessary to achieve compliance with Code requirements, three nondestructive testing (NDT) methods are provided for in the Code. They are: (1) radiographic testing (RT); (2) ultrasonic testing (UT); and (3) dye penetrant testing (PT). Radiographic and ultrasonic testing are used to detect both surface and internal discontinuities. Dye penetrant testing is used to detect discontinuities open to the surface. Other NDT methods may be used upon agreement between owner and contractor.

6.7.1 It is essential that the contractor know in advance the categories of welds that will be subject to nondestructive tests, the testing procedure to be used, and the level of acceptance. Unless otherwise provided in the contract, the quality criteria for the acceptance of welds are stated in 8.8, 9.8, 10.10 and 10.15.

It is not necessary to write in the contract documents

exactly which weld or what portions of specific welds will be examined by a specific test method. A general description of weld test requirements may be specified, e.g., "All welds in complete joint penetration butt joints in tension flanges of girders shall be radiographed."

If the location of tension flange butt joints is not obvious, their location should be designated on the plans.

When spot checking is specified, e.g., 10% of all fillet welds, it should not be taken to imply that the contractor be notified prior to welding which specific welds or portion of welds shall be tested. It is a basic premise of the specifications that if spot tests are made, there should be a sufficient number of test locations to give a reliable indication of weld quality.

There are different acceptance criteria for buildings, bridges, and tubular structures. The basic difference in acceptance criteria for each of these structures is based upon the difference between static and dynamic loading.

When fatigue crack growth is anticipated, acceptable initial weld flaw sizes must of necessity be small. All criteria are established in an attempt to preclude weld failure during the anticipated service life of the weldment.

6.7.6 Only individuals who qualify to SNT-TC-1A NDT Level II may perform nondestructive tests without supervision. Level III individuals may also perform NDT tests, provided they meet the requirements of NDT Level II.

NDT Level III Engineers and technicians are generally supervisors and may not be actively engaged in the actual work of testing. Since there is no performance qualification test for individuals qualified to NDT Level III, all individuals providing testing services under the Code must be qualified to Level II, which has specific performance qualification requirements.

Part B *Radiographic Testing of Groove* *Welds in Butt Joints*

6.8 General

6.8.1 The procedures and standards set forth in this section are primarily designed for the radiographic inspection of complete joint penetration groove welds. Typical geometries for structural welds and design requirements for these structures were taken into account in the preparation of the specification.

6.8.2 Since this section does not provide for the radiographic testing of welds in pipe or tubular structures, variations are permitted based upon agreement between the contractor and the owner. The provisions of Section 10 shall apply to radiographic testing of welds in pipe and tubular structures.

6.9 Extent of Testing

6.9.1 It is important that joints to be radiographed be clearly described in the information furnished to bidders

as explained in Part A of this Commentary.

6.9.4 The Code requires that if rejectable discontinuities are found in one spot and again in either of the additional required spot radiographs, the remainder of the weld shall be radiographed to determine the extent of any remaining defects.

6.10 Radiographic Procedure

6.10.1 A single source of radiation is specified to avoid confusion or blurring of the radiographic image. Radiographic sensitivity is judged solely on the quality of the penetrameter image(s), as specified in both ASTM and ASME standard provisions.

6.10.2 Ionizing radiation and chemicals used in radiographic inspection can present serious health hazards. All safety regulations must be complied with.

6.10.3 When the owner wishes weld surfaces to be ground flush or otherwise smoothed in preparation for radiographic testing, it should be so stated in the contract documents. The owner and the contractor should attempt to agree in advance on which weld surface irregularities will not need to be ground unless surface irregularities interfere with interpretation of the radiograph. It is extremely difficult and often impossible to separate internal discontinuities from surface discontinuities when reviewing radiographs in the absence of information describing the weld surface. When agreement can be reached on weld surface preparation prior to radiography, rejections and delays will generally be reduced.

6.10.3.1 Weld tabs, (extension bars and run-off plates) are generally removed prior to radiographic inspection so that the radiograph will represent the weld as finished and placed in service. Contraction cracks are commonly found in the weld at the interface between weld tabs and the edge of the plate or shape joined by the weld. These cracks are hard to identify in the radiograph under the best conditions. It is considered necessary to remove the weld tabs before attempting to radiograph the boundaries of the welded joint.

6.10.3.3 When weld reinforcement or backing, or both, are not removed, shims placed under the penetrameters are required so that the penetrameter image may be evaluated on the average total thickness of aluminum (weld metal, backing, reinforcement) exposed to radiation.

6.10.4 Provisions of this section are to assure the use of fine grain film and to avoid coarseness in the image that

may result from the use of fluorescent screens.

6.10.5 The source of radiation is centered with respect to the portion of the weld being examined to avoid as much geometric distortion as possible.

6.10.5.1 This paragraph is provided to limit geometric unsharpness⁴ that causes distortion and blurring of the radiographic image.

6.10.5.2 and 6.10.5.3 These sections are intended to limit geometric distortion of the object as shown in the radiograph. An exception is made for panoramic exposures.

6.10.6 The maximum permissible voltage for radiographic inspection depends on the material thickness, when X-ray units are used. These units may be used on all radiographic inspection, provided they have adequate penetrating ability.

Aluminum has a lower radiographic density than steel, and the resulting poor radiation contrast and sensitivity with isotope sources limit their use. Iridium 192 is approved as a radiographic source only when aluminum exceeds 2.5 in. (63 mm) thickness. Cobalt 60 is not an approved source.

Care should be taken to ensure that the effective size of the radiograph source is small enough to preclude excessive geometric unsharpness.⁴

6.10.7, 6.10.7.1, and 6.10.7.2 Since radiographs sensitivity and the acceptability of radiographs are based upon the image of the required penetrameters, care is taken in describing the manufacture and use of the required penetrameters. Penetrameters are placed as shown in Fig. 6.10.7.

Penetrameters may only be placed on the source side, unless otherwise approved by the Engineer. Failure to place the penetrameters on the source side during the radiographic exposure, without prior approval of the Engineer, shall be cause for rejection of the radiographs.

6.10.8 Welds shall be radiographed and the film indexed by methods that will ensure continuous inspection of the weld within the limits specified.

6.10.8.1 Backscattered radiation can cause general fogging and produce artifacts in the radiograph. The method described in this section will identify backscattered radiation so that corrective steps can be taken.

6.10.9 Radiographic inspection is designed to inspect all of the weld zone. Defects in the weld metal or the adjacent heat-affected zones can produce weld failure. Film widths shall be sufficient to inspect all portions of the weld joint and have sufficient room for weld identification.

6.10.10 Quality radiographs with the appropriate penetrameter sensitivity are the only indicators of proper radiographic inspection.

6.10.11 It is the intent of the specification to use radiographic films within the full limits of the useful film density. An effort is made in this Code to avoid the necessity of making multiple exposures or using films of more than one exposure speed when examining welded joints expected to be routinely encountered.

6.10.12 This section describes all information required

4. Geometric unsharpness is defined as the fuzziness or lack of definition in a radiographic image resulting from the source size, object-to-film distance, and source-to-object distance. Geometric unsharpness may be expressed mathematically as: $U_g = F(L_1 - L_o)/L_o$. Where U_g is the geometric unsharpness, F is the size of the x-ray tube focal spot or the diameter of the gamma source, L_1 is the source-to-film distance, L_o is the source-to-object distance, and $L_1 - L_o$ is the object-to-film distance.

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to identify the radiograph and also provides methods for matching the radiograph to the weld joint, so that weld repairs, when necessary, may be made without repetitive or unnecessary metal removal. Radiograph identification marks and location identification marks shall be used to locate defects and to verify that unacceptable discontinuities have been repaired as demonstrated by the subsequent radiograph of the repair.

6.11 Acceptability of Welds

The provisions of Sections 8.8.2, 9.8.2, and 10.15.2 prescribe the radiographic quality of welds for buildings, bridges, and tubular structures, respectively.

6.12 Examination, Report, and Disposition of Radiographs

6.12.2 Since more accurate film viewing is possible when the eyes of the viewer are not subjected to light from portions of the radiograph not under examination, a suitable, variable intensity illuminator with spot review or masked spot review capability is required. The ability to adjust the light intensity reduces eye discomfort and enhances visibility of weld discontinuities. Subdued light in the viewing area allows the reviewer's eyes to adjust to see small discontinuities in the radiographic image. Film review in complete darkness is not advisable since the contrast between darkness and the intense light from portions of the radiograph with low density cause discomfort and loss of accuracy.

Film densities within the range of 2.5 to 3.5, as described in 6.10.11, are preferred. The illuminator must have sufficient capacity to properly illuminate radiographs with densities up to 4.0. In general, within the limits of density approved by the Code, the greater the film density, the greater the radiographic sensitivity.

6.12.3 and 6.12.4. After the radiographic inspection technician and the fabrication/erection Inspector have reviewed and approved both the radiographs and the report interpreting them, the radiographic examination report shall be submitted to the verification Inspector for a separate review on behalf of the owner. All radiographs, including those showing unacceptable quality prior to repair, shall, unless otherwise provided in the contract documents, become the property of the owner. The contractor shall not discard radiographs or reports under the provisions of the Code until the owner has been given, and has acknowledged, prior notice in writing.

The term *a full set of radiographs* as used in 6.12.4 means one radiograph of acceptable weld quality from each radiographic exposure required for complete radiographic inspection, plus one radiograph of any unacceptable weld quality prior to repair from each radiographic exposure. If the contractor elects to load more than one film in each cassette to produce an extra radiograph for his own use or to avoid possible delays

due to film artifacts, the extra radiographs are, unless otherwise specified, the property of the contractor.

Part C

Ultrasonic Testing of Groove Welds

6.13 General

Ultrasonic testing (UT) of aluminum weldments is recognized as an acceptable non-destructive testing method. Ultrasonic testing is regularly being used on aluminum welds to provide information about the location, size, and orientation of discontinuities.

This method is not treated in detail in the Aluminum Code because of the lack of consensus, at this time, about formulating a simple procedure giving satisfactory results. **6.13.1** When ultrasonic testing is included in the contract documents, not only the extent of testing, but also the testing procedures and the acceptance criteria shall be specified.

There are existing standards and codes that provide applicable information for ultrasonic testing. These include: ASTM E164, *Standard Recommended Practice for Ultrasonic Contact Examination of Weldments*; and Section V of *ASME Boiler and Pressure Vessel Code, Non-Destructive Examination*.

6.13.2 The provisions for maintaining and retaining records on welds subjected to ultrasonic testing parallel those for radiographic testing. Likewise, unless otherwise specified in the contract documents, the records become the property of the owner.

Part D

Dye-Penetrant Examination of Welds

6.14.2 The provisions set forth in this section are adaptable to all types of welds, the heat-affected zone, and the adjacent base metal for detecting discontinuities open to the surface.

6.14.3 Dye-penetrant testing is limited to the testing of completed welds because of the difficulty often encountered in removing all traces of the dye-penetrant and developer from intermediate passes in multi-pass welds. Retained penetrant materials can cause weld porosity when subsequent passes are made.

6.15 Extent of Testing

6.15.1 It is important that joints to be dye-penetrant inspected be clearly described in the information furnished to bidders as explained in Part A of this Commentary.

6.16 Dye-Penetrant Inspection Procedure

It is important that standard procedures, as described

in this section, be carefully followed. The sensitivity and accuracy of the test can be affected by incorrect procedures.

Acceptance or rejection of the weld must be established by the verification Inspector before dye-penetrant evidence of discontinuities is removed. All penetrant and developer must be removed before any welding repairs

are made on discontinuities.

6.18 Record of Inspection

The provisions for maintaining and retaining records on welds subjected to dye-penetrant inspection parallel those for radiographic testing. Likewise, unless otherwise specified in the contract documents, the records become the property of the owner.

7. Strengthening and Repairing Existing Structures

7.2 Materials

One essential requirement in strengthening and repairing existing structures is the identification of the base metal.

Obviously, when welding is anticipated, weldability of the aluminum alloys in the existing structure is of primary importance. Together with the mechanical properties of the base metal it will provide information essential for establishment of safe and sound welding procedures. Only then will realistic data be available for reliable cost estimates. Should poor weldability make such cost economically prohibitive, other means of joining should be considered by the Engineer.

Mechanical properties are normally determined by tension testing from a representative sample taken from the existing structure.

If the chemical composition has to be established by test, then it will be advisable to take samples from the greater thicknesses as these are more indicative of the extremes in composition.

7.3 Design

Repair and strengthening of existing structures differ from new construction inasmuch as the operations will need to be executed with the structure or the structural element under some condition of working stress.

There is presently little guidance with respect to welding of structural members under stress. Hence, each given situation must be evaluated on its own merits, and sound

engineering judgement must be exercised as to the optimum manner in which repair or strengthening should be accomplished.

Economy is the obvious underlying consideration when deciding whether a member should be repaired or entirely replaced. However, the cost estimate supporting the decision to be made must be related not only to material and labor, but also should include the returns from an uninterrupted use of the member or, conversely, the loss due to its time out of service.

Generally, in the case of dynamically loaded structures, sufficient data regarding past service is not available to estimate the remaining fatigue life. If such is the case, an inspection program designed to locate possible fatigue cracks in stable growth prior to their becoming critical is a reasonable alternative.

The only practical methods of extending the expected fatigue life of a member in a given service is to reduce the stress or stress range, or to provide joint geometry less susceptible to fatigue failure.

7.5 Special

In 7.5.1, it stipulates that the extent of cross-sectional heating must be considered by the Engineer when determining whether dynamic stresses may be carried by the member during welding.

The significance of this provision lies in the fact that the properties of heat-treated and work hardened aluminum alloys are influenced by heat, and their weldability varies considerably.

8. Non-Tubular Statically Loaded Structures

Part A General Requirements

8.1 Application

The provisions of Section 8, like those of most building codes, assume static loading under service conditions. However, in situations where a significant number of repetitions of a substantial stress range is likely to occur in service so as to constitute fatigue loading, the provisions of non-tubular dynamically loaded structures are recommended.

8.2 Base Metal

Aluminum alloys specifically approved for non-tubular statically loaded structures are listed in 8.2.

8.2.3 When an alloy not listed is considered for use, a special welding investigation is required to confirm the weldability of a specific composition and heat-treated or work-hardened condition.

Part B Allowable Stresses

8.4 Allowable Stresses

Allowable stresses in heat-treated and work-hardened structural alloys may vary with the alloy and the extent of the heat-affected zone.

For allowable stresses for the various available alloys, the user of the Code is referred to the documents listed in Appendix A, in particular to the *Specifications for Aluminum Structures* issued by the Aluminum Association.

Part C Workmanship

8.5 Dimensional Tolerances

8.5.1 The flatness tolerances for webs with intermediate stiffeners on both sides are somewhat more liberal than those for interior bridge girders (see 9.5.1.2). The tolerance given for intermediate stiffeners, placed only on one side of the web, is the same for either dynamic or static loading and is the same as that for interior bridge girders.

8.6 Temporary Welds

Because of the effects of heat on the aluminum structural alloys, it is essential that temporary welds, not incorporated in the final welds, be identified and approved by the Engineer.

8.8 Quality of Welds

8.8.1 **Visual Inspection.** These requirements make visual inspection of all welds mandatory and contain the acceptance criteria.

9. Non-Tubular Dynamically Loaded Structures

Part A General Requirements

9.1 Application

Sections 1 through 6 are supplemented by the specific requirements of this section to provide a structure capable of serving for a finite period under dynamic and repeated or cyclical loads. Design constraints, except those specifically related to welding and given in this section, should be those of the applicable general specification.

9.2 Base Metal

All the aluminum alloys that are generally used in welded non-tubular dynamically loaded structures are included in the list.

9.2.3 When an alloy not listed is considered for use, a special welding investigation is required to confirm the weldability of a specific composition and heat-treated or work-hardened condition.

Part B Allowable Stresses

9.4 Allowable Stresses

Allowable stresses in heat-treated and work-hardened structural alloys vary with the alloy and the extent of the heat-affected zone.

For allowable stresses for the various available alloys, the user of the Code is referred to the documents listed

in Appendix A, in particular to the *Specifications for Aluminum Bridge and Other Highway Structures* issued by the Aluminum Association.

Part C Workmanship

9.5 Dimensional Tolerances

Permissible tolerances for variations from flatness of bridge girder webs are given in the Code separately for interior and fascia girders. The stricter tolerance for fascia girders is based only on appearance, as there is no structural requirement for the difference. Even the fascia girder distortion permitted will be somewhat noticeable. The fascia tolerances are considered satisfactory for most requirements. If more stringent tolerances are needed for appearance, they should be included in the contract documents, but some distortion is unavoidable.

9.5.1.3 Web distortions of twice the amount permitted for interior or fascia girder panels are permitted if the installation of field bolted splice plates will reduce the distortion to the level otherwise permitted. To avoid the possibility of costly field correction, the contractor should determine by a shop assembly that the bolted splice plate will reduce the distortion to acceptable limits.

9.8 Quality of Welds

The quality requirements set forth in 9.8 are more stringent than those required by 8.8. All weldments are subject to mandatory visual inspection by the contractor.

10. Tubular Structures

Part A *General Requirements*

10.1 Application

The requirements of Section 10 are intended to be generally applicable to a wide variety of tubular structures. However, welded tubular construction involves new terminology and a sufficient number of unique requirements for design detailing, workmanship, and inspection to fill a separate section of the Code.

The Committee recognized while in using a general format in the *Structural Welding Code—Aluminum*, similar to that of *Structural Welding Code—Steel*, the types of structures made from aluminum likely would not be of the magnitude of offshore drilling platforms. Further, the Committee also recognized that the workmanship requirements differ greatly among tubular structures. For these reasons, this Code establishes two classes of tubular structures with different workmanship requirements. Unless otherwise specified, Class I structures are those identified in *Standard Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals*, published by AASHTO (Appendix A). All other structures are Class II. There are also certain support structures in the AASHTO Specifications which should be given special consideration because of their configuration and loadings.

Additionally, the joint configurations shown in Figs. 10.5.1 and 10.5.2 are intended to only apply to Class II structures. This is because the typical Class I structure most often utilizes fillet welds with member sizes that vary from approximately 3/4 in. NPS to 12 in. NPS.

10.2 Base Metal

The aluminum alloys listed in 10.2 of the Code include those considered suitable for non-tubular statically and dynamically loaded structures, as well as tubular structures.

While any base metal listed in 1.2.1 may be used for Class I or Class II structures, material availability would likely dictate the specification of the 3000, 5000, and 6000 wrought alloys and 356 and 443 cast alloys.

10.2.3 When an alloy not listed is considered for use, a special welding investigation is required to confirm the weldability of a specific composition and heat-treated or work-hardened condition.

Part B *Allowable Stresses*

10.4 Allowable Stresses

The Committee recognizes that several specifications exist that specify allowable stresses for aluminum structures. In most cases, these specifications reference the allowable stresses as given in *Specifications for Aluminum Structures—Construction Manual Series, Section I* (see Appendix A). Regardless of the specification used, the Engineer should be aware that the allowable stresses should reflect the difference in strength of welded aluminum versus unwelded aluminum; allowable stresses in heat-treated and work-hardened structural alloys will vary with the alloy and the extent of the heat affected zone.

Part C *Details of T-, Y-, and K-Connections*

10.5 Tubular Branch Connections

The definitions of the various types of connections are as shown. The intended application of these joint details is for Class II structures.

Part D *Workmanship—Class I Structures*

10.6 Dimensional Tolerances

Due to the nature of the types of structures covered by the *Standard Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals*, dimensional tolerances for Class I structures should be specified by the Engineer. This is because the tolerances vary greatly between users. Therefore, the provisions of 3.5 would not be applicable.

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10.7 Finishing Cut Edges

Plasma arc cuts as described in this paragraph have been successfully used by fabricators for many years. The most common application is for cutting handhole openings for

luminaire supports. Other successful applications include cutting for connections of intersecting tubes for cantilevered sign support structures. For this reason, the Committee agreed that plasma arc cutting would be permissible for Class I structures.