January 12, 1998

TECHNICAL SPECIFICATION FOR THE WELDING OF SUBMODULES

Atlas Tilecal collaboration

Document responsible: M.Nessi, V. Romanov , V. Guarino

1 Introduction

This document is a summary of the Welding Process Specification (WPS). The WPS conforms to the AWS D1.1-98 Structural Welding Code and is included in Appendix 1. All welding of the submodules are to be welded to this WPS.

Each submodule will have two types of bars welded on it. The submodules with weld bars are shown in Figure 1. These bars will initially be tack welded on the submodule immediately after the stacking of the submodule and the 16 to 24 hour cure of the structural epoxy. The tack welding will occur with the submodule on the stacking fixture. The submodule will subsequently be removed from the stacking fixture and placed in fixturing that will allow ready access to the bars so that full welds can be completed.

2 Drawings

The welds shall be in accordance to the drawing ATLLEMS-00010. Details of the welds are shown in Figure 2.

3 Standards

Welding shall be in accordance to the procedures described in this documentation and the AWS D1.1-98 Structural Welding Code.

4 Welding Process

The welding process is completely described in the WPS included in Appendix 1. All welded is expected to conform to this WPS.

The welding process shall be manual, Gas tungsten Arc Welding (TIG). The base material of the stacked plates and weld bars is low carbon steel. The stacked plates are nominally AISI 1010 and the bars are FE 360.

The surfaces of the material shall be free of dirt, rust, paint, epoxy, oil, or grease. Cleaning may be accomplished with carbon or stainless wire brushes followed by an Acetone wash and Alcohol rinse. Parts shall be completely dry prior to welding. Once parts are squeezed together, no evidence of epoxy shall exist on the joint face. If epoxy extrudes into the joint face it must be removed by wire brushing.

The filler material to be used shall be either:

ER70S-2 Diameter 3/32" or 1/16"
Din 8559 SG2 Diameter 1.6mm

5 Tack Welding

Tack welding shall be initially done on the submodules while they are still on the stacking fixture. Tack welding shall be intermittently done on each side of each bar in all four corners of the submodule by alternating sides of the bars and then sides of the submodule. Tack from the center of the joint out. A minimum of four tacks, 12mm minimum long and a minimum of 30% of total joint thickness shall be used.

6 Final Welding

Final welding shall be done in accordance to the WPS included in Appendix 1 and which is summarized below.

Final welding shall occur in two passes per weld. Bars shall be fully welded by alternating sides of the module between passes.

It is recommended that the following welding parameters be used:

- Position of weld groove shall be horizontal and flat
- No pre-heat of material
- Shielding gas will be Argon with a 99.99% mixture.
- The gas flow rate will be 17 to 25 CFH
- Direct current with a straight non-pulsing polarity
- 150-275 amps and 15-21 volts
- Tungsten electrode will be 3/32" diameter EWTH2

7 Weld Repairs

Weld repairs shall be done in accordance with the WPS included in Appendix 1 and summarized below.

Welders qualified by Atlas must make any repairs. Repairs to cracks, or lack of fusion must be fully excavated to the original base metal and that excavation must be verified free from defects by visual inspection at not less than 10X magnification.

8 Welder Qualification

Welder qualification shall be done in accordance to the WPS included in Appendix 1 and summarized below.

The persons who will be performing the submodule welding at each institution shall be qualified by producing two different types of weld samples. The first weld sample is shown in Figure 3 and is subjected to non-destructive testing. After welding this sample shall be inspected as per section 6.1.4 and 6.9 of the AWS D1.1-98 Structural Welding Code. This code is included in Appendix 2. Next, this weld sample will be sectioned at the mid point, polished and etched with a suitable etchant to reveal the profile of the weld joint. Each face of the section shall meet Section 4.8.4.1 of AWS D1.1-98 Structural Weld Code which is included in Appendix 3.

The second sample is shown in Figure 4 and will be subjected to destructive testing. After welding this sample shall be inspected as per paragraph 6.1.4 and 6.9 of the AWS D1.1-98 Structural Welding Code. This code is included in Appendix 2. Pulling it apart in tension will then destructively test this sample. Failure of this weld shall not occur at less than 20,000 lbs. load.

If either test sample fails to meet the above stated requirements a complete re-test of the welder, is required.

9 Weld Inspection

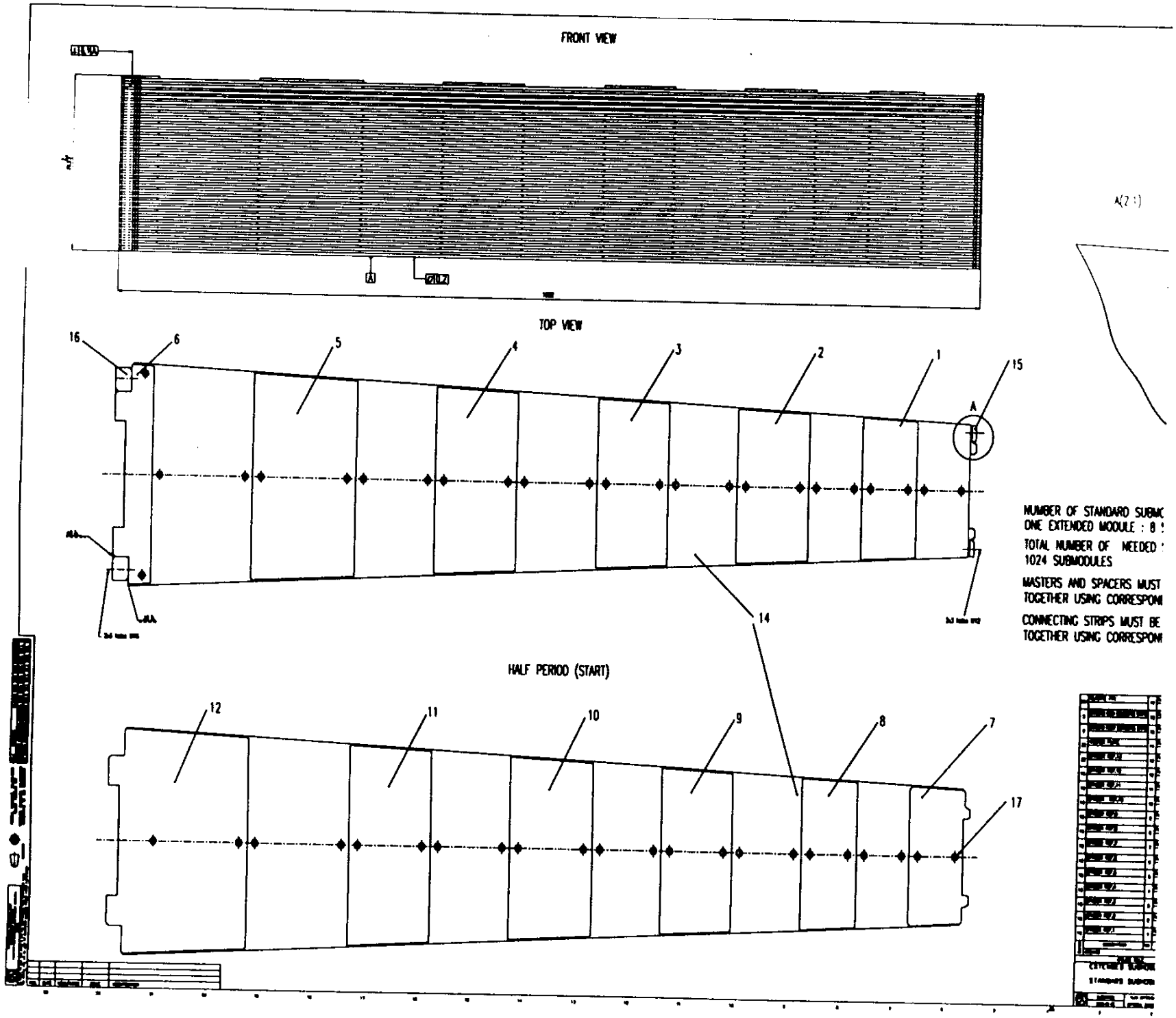
Weld inspection shall be done in accordance to the WPS included in Appendix 1 and summarized below.

A magnification of no less than 10X will be used to determine the following inspection criteria:

- That the weld has no cracks
- That thorough fusion shall exist between adjacent layers of weld metal and between weld metal and base metal.
- All craters shall be filled to the full cross section of the weld.
- Weld inspection shall begin immediately after the completed welds have cooled to ambient temperature.

- The undercut shall not exceed .25mm.
- There shall be no visible porosity in the weld.
- The welds shall be made with the minimum of face reinforcement and shall conform to the profile requirements shown in Figure 5.

Submodule and Weld Bars



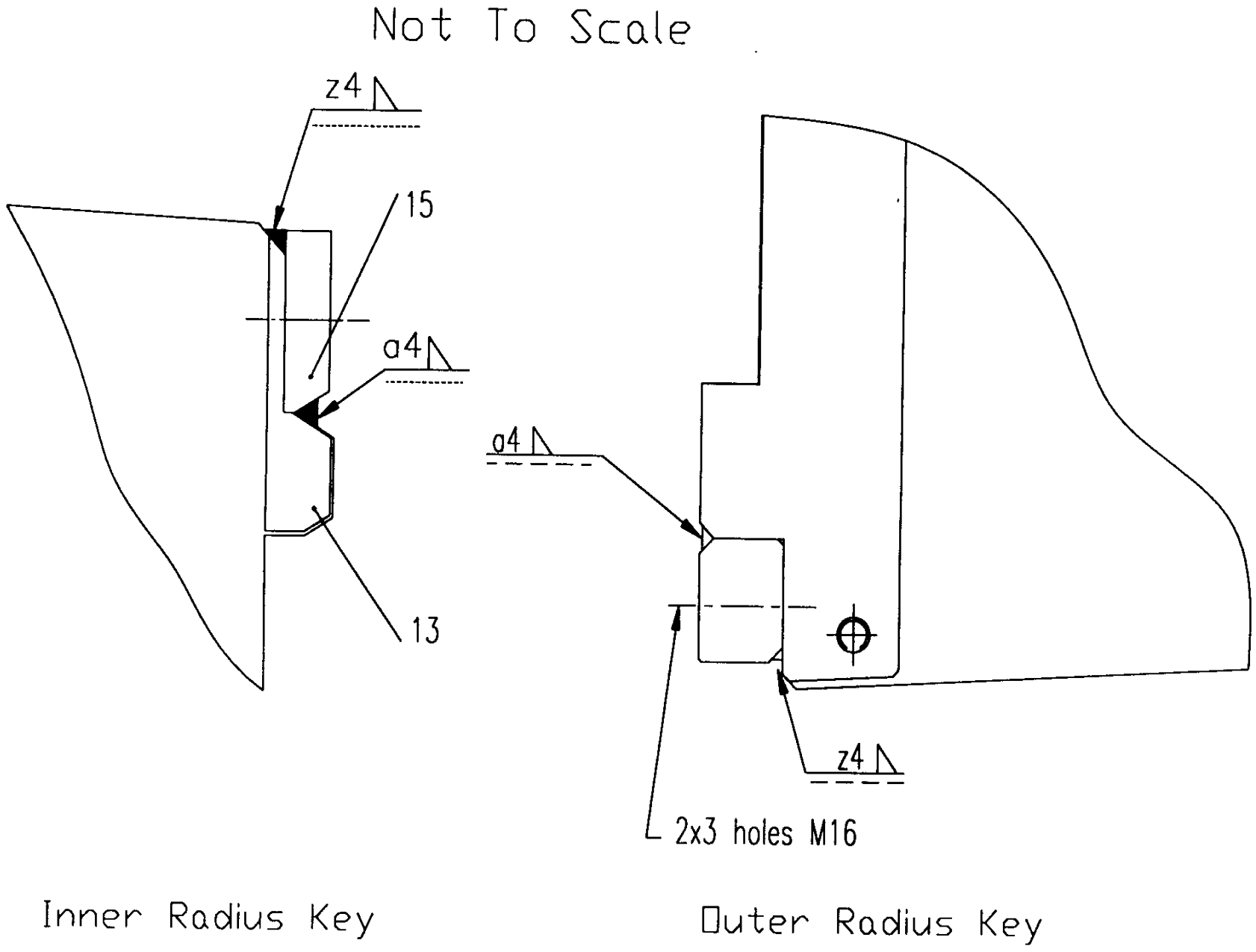


Figure 2
Detail of Welds

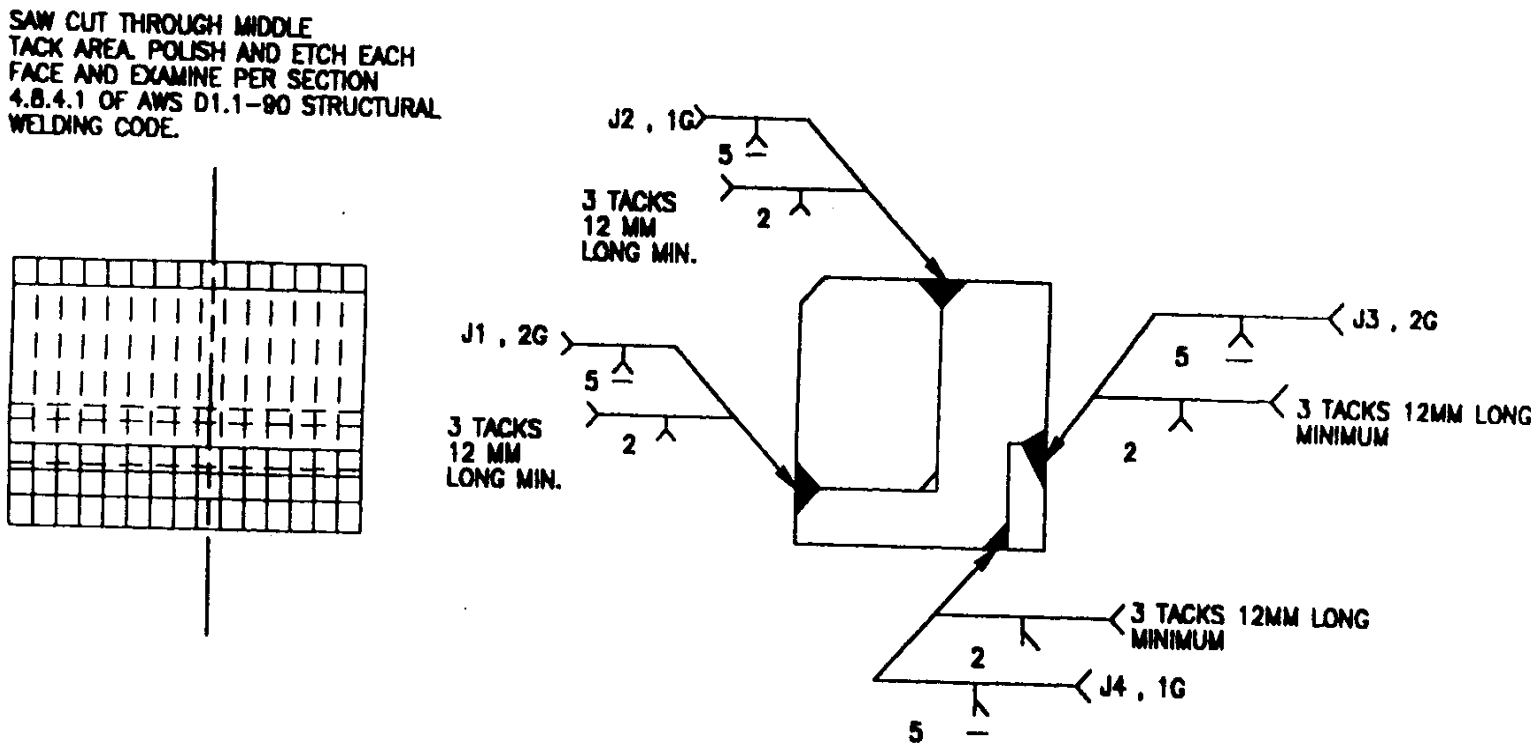
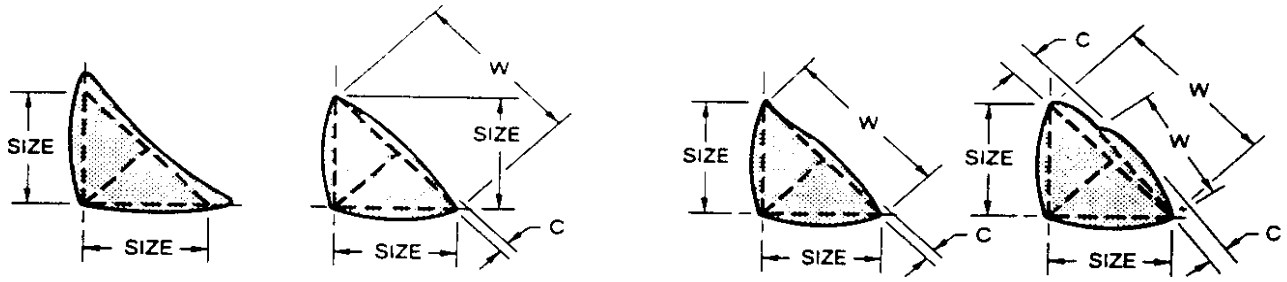


FIGURE 10.1 SHEET 2 OF 2
WELDING AND EVALUATION DETAIL
ANL-CS-2013

Figure 3
First Weld Sample

Figure 5
Required Weld Profile

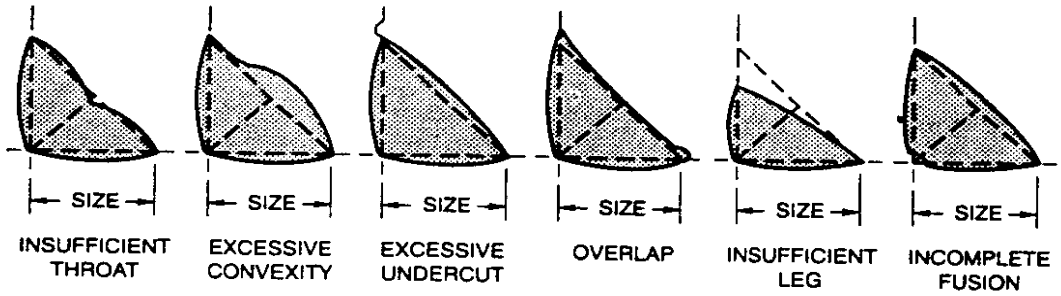


(A) DESIRABLE FILLET WELD PROFILES

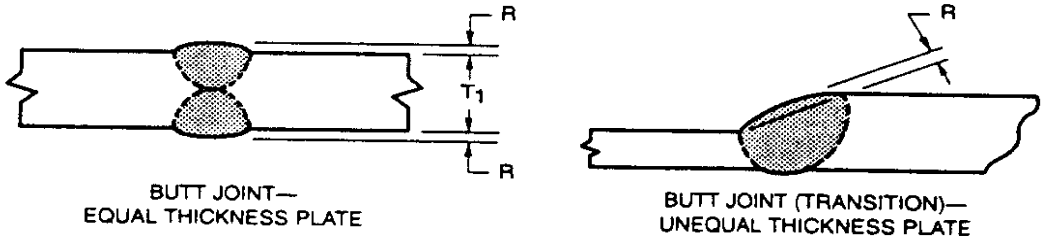
(B) ACCEPTABLE FILLET WELD PROFILES

NOTE: CONVEXITY, C, OF A WELD OR INDIVIDUAL SURFACE BEAD WITH DIMENSION W SHALL NOT EXCEED THE VALUE OF THE FOLLOWING TABLE:

WIDTH OF WELD FACE OR INDIVIDUAL SURFACE BEAD, W	MAX CONVEXITY, C
W ≤ 5/16 in. (8 mm)	1/16 in. (1.6 mm)
W > 5/16 in. TO W < 1 in. (25 mm)	1/8 in. (3 mm)
W ≥ 1 in.	3/16 in. (5 mm)

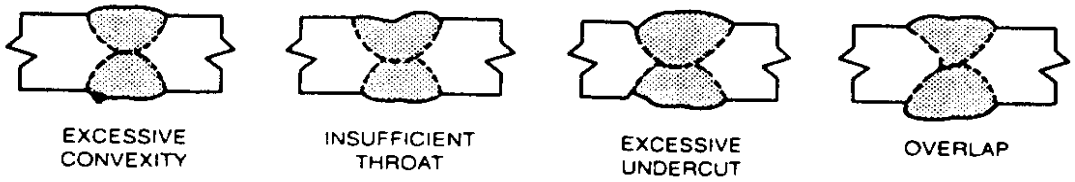


(C) UNACCEPTABLE FILLET WELD PROFILES



NOTE: REINFORCEMENT R SHALL NOT EXCEED 1/8 in. (3 mm). SEE 5.24.4.

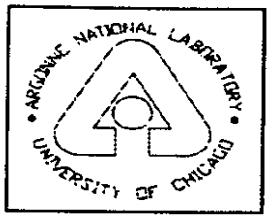
(D) ACCEPTABLE GROOVE WELD PROFILE IN BUTT JOINT



(E) UNACCEPTABLE GROOVE WELD PROFILES IN BUTT JOINTS

Figure 5.4—Acceptable and Unacceptable Weld Profiles (see 5.24)

Appendix 1
Welding Procedure Specification



ARGONNE NATIONAL LABORATORY
9700 SOUTH CASS
ARGONNE, ILLINIOS 60439

CENTRAL SHOPS DEPARTMENT

WELDING PROCEDURE SPECIFICATION
ANL-CS 2013 REVISION 1
REVISED MAY 18, 1999

ATLAS SUBMODULE WELDING
G.T.A.W. CARBON STEEL

PREPARED BY:

WILLIAM F. TOTER
WELDING ENGINEER

6/18/99

CENTRAL SHOPS DEPARTMENT
WELD PROCEDURE AMENDMENT LISTING

ANL PROCEDURE NO. ANL-CS-2013

AMENDMENT NO./ DATE	DESCRIPTION	APPROVED
1. 5/18/99	Added 1/16 filler metal Increased amperage and voltage range Miscellaneous grammatical changes	

CS-85 (3-74)

1.0 General Description and Application:

This specification covers the Welding of the ATLAS Sub module. Welding Procedure Qualification and Welder Performance Qualification shall be performed in accordance with this specification, and the applicable referenced sections of AWS D1.1 Structural Welding Code.

2.0 References:

2.1 ANSI/AWS D1.1-98 Structural Welding Code - Steel.
2.2 ANSI/AWS A2.4-98 Standards Symbols for Welding Brazing, and Nondestructive Examination.
2.3 AWS A3.0-80 Welding Terms and Definitions.
2.4 Technical Specification Supply of Laminated Steel Sheets as Absorber for the Atlas Tile Hadron Calorimeter.

3.0 Base Metal:

Base metal shall comply with the Argonne "Technical Specification" for the "Supply of Laminated Steel Sheets as absorber for the ATLAS Tile Hadron Calorimeter" (Fe360).

4.0 Cleaning:

The Base Metal and faying surfaces shall be free of dirt, rust, paint, epoxy, oil or grease. Cleaning may be accomplished with carbon or stainless steel wire brushes followed by an acetone wash and alcohol rinse. Parts shall be completely dry prior to welding. Once parts are squeezed together, no evidence of adhesive shall exist on the joint face. If adhesive extrudes into the joint face it must be removed by wire brushing.

5.0 Welding Process:

The welding process shall be manual, Gas Tungsten Arc Welding.

6.0 Welding Procedure Specification:

The Welding Procedure Specification is ANL-CS-2013-001 attached. Prior to the start of welding, qualification test coupons shall be run in accordance with Section 10.0 of this procedure.

7.0 Welding Sequence:

7.1 Tack welds shall be made by Welders qualified per Section 10.0 of this specification, and shall be performed in accordance with ANL-CS-2013.

7.2 Tack welding shall be intermittently done on each side of each bar in all four corners of the module by alternating sides of the bars then sides of the module assembly. Tack from the center of the joint out. A minimum of four tacks, 12mm minimum long and a minimum of 30% of total joint thickness shall be used .

7.3 Once the module is completely tack welded, each joint shall be welded 100% on each bar. Bars shall be welded by alternating sides of the module.

8.0 Inspection:

Each weld shall be 100% visually inspected per Sections 6.1.4 and 6.9 of AWS D1.1-98 for statically loaded nontubular sections.

9.0 Repairs:

9.1 Any repairs must be made by welders qualified per Section 10.0 of this procedure.

9.2 Repairs to cracks, or lack of fusion must be fully excavated to the original base metal, and that excavation must be verified free from defects by visual inspection at not less than 10X magnification.

10.0 Qualification:

10.1 Welding procedure and Welder must be qualified by producing two sample welds per figure 10.1 attached. Qualification of the procedure and welder must be done at Argonne National Laboratory, in Argonne Illinois.

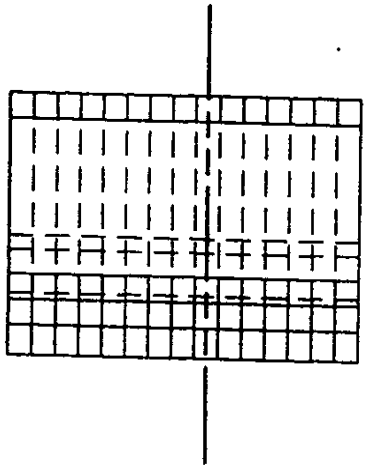
10.2 Each weld sample shall be visually inspected per paragraph 6.1.4 and 6.9 of AWS D1.1-90 Structural Welding Code.

10.3 Each weld sample must be sectioned at the midpoint, polished and etched with a suitable etchant to reveal the profile of the weld joint. Each face of the section shall meet Section 4.8.4.1 of AWS D1.1-90 Structural Welding Code.

10.4 Samples that fail, must result in a complete re-test of the procedure, and/or welder.

10.5 The results of qualification test must be available for review by Argonne National Laboratory or its designee when required.

SAW CUT THROUGH MIDDLE TACK AREA. POLISH AND ETCH EACH FACE AND EXAMINE PER SECTION 4.8.4.1 OF AWS D1.1-90 STRUCTURAL WELDING CODE.



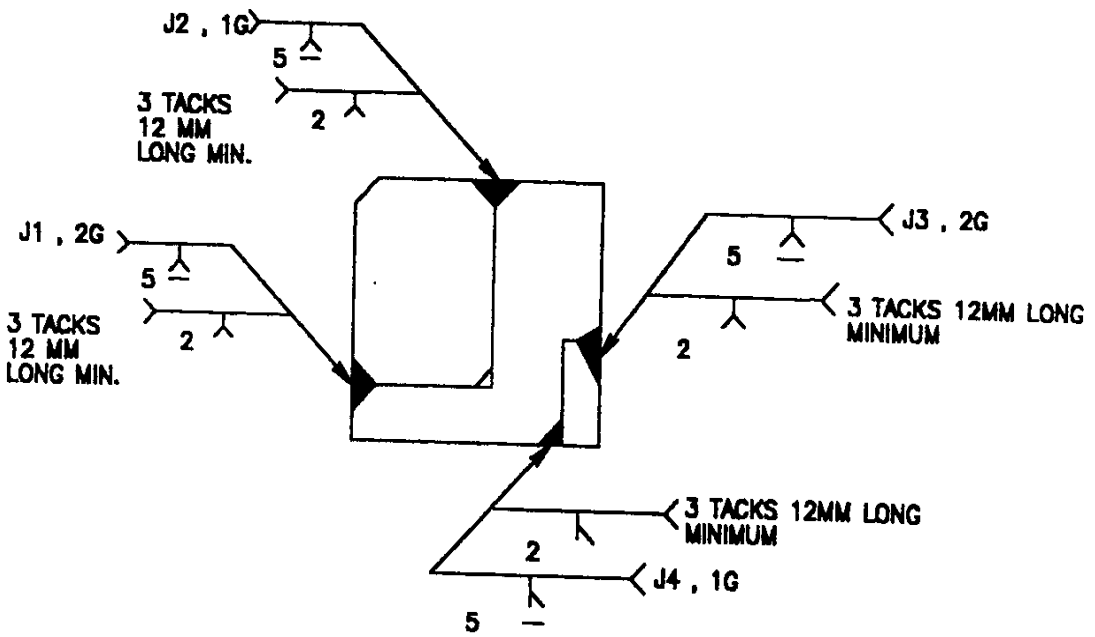


FIGURE 10.1 SHEET 2 OF 2
WELDING AND EVALUATION DETAIL
ANL-CS-2013

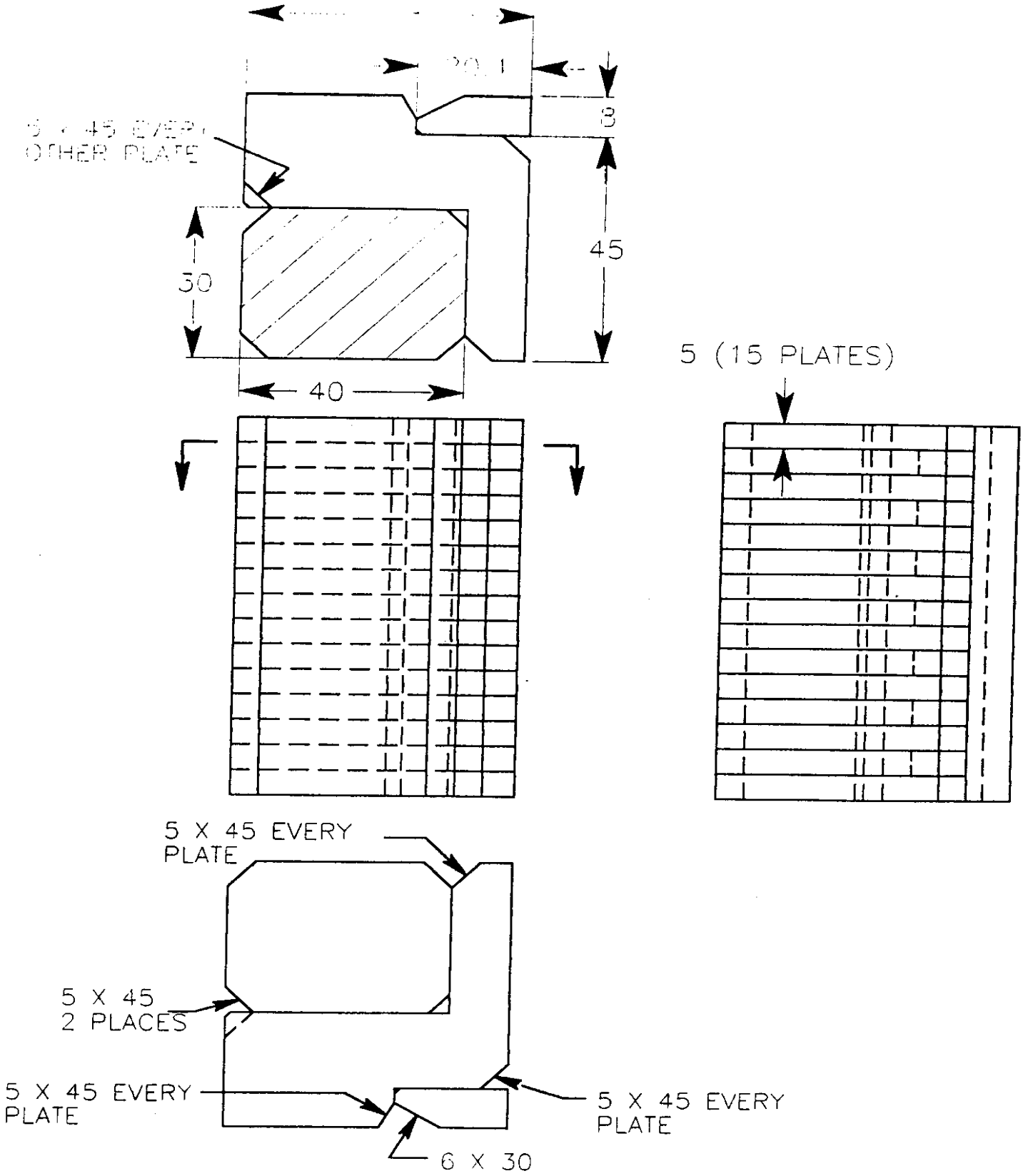


FIGURE 10.1 SHEET 1 OF 2
MACHINING AND ASSEMBLY DETAIL
ANL–CS–2013

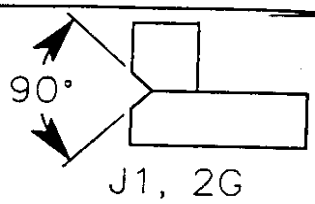
ARGONNE NATIONAL LABORATORY
9700 South Cass Avenue, Argonne, IL 60439

ARGONNE NATIONAL LAB
WELDING PROCEDURE SPECIFICATION

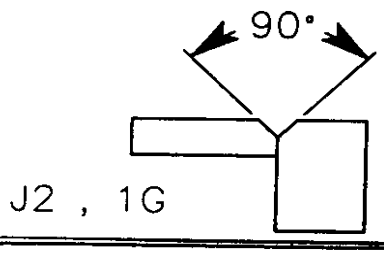
Welding Procedure Specification No. ANL-CS-2013-001 Date 7-28-97
Revision No. 1 Date 5/18/99 Supporting PQRNo.(s) None
Welding Process(es) 1) G.T.A.W. Type 1) Manual
2) (Manual, Auto, Semi)

JOINTS (QW-402)
Joint Design Partial Penetration Single 'V'
Backing (Yes) X (No)
Backing Material (Type) Root: Base Metal/Remainder Deposited Metal
Retainer: Yes No X
If yes type: Non-metallic
Metallic (non-fusing)

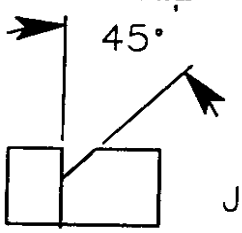
DETAILS



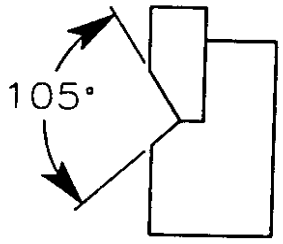
J1, 2G



J2 , 1G



J4 , 1G



J3 , 2G

BASE METALS (QW-403)
P No Grp To P No Grp
Specification type and grade Fe360
to specification type and grade Fe360
OR
Chem. Analysis and Mech Prop
to Chem. Analysis and Mech Prop
Thickness Range
Base Metal Groove 3/16-3 Fillet 3/16-3
Deposited Weld Metal Groove --- Fillet ---
Pipe Dia. Range Groove --- Fillet ---
Other

FILLER METALS (QW-404)
Spec. No. (SFA) 5.18
AWS No. (Class) ER70S-2
F-No. 6
A-No. 1
Size of Filler Metals 3/32 Dia.+ 1/16 Dia.
Deposited Weld Metal ---
Thickness Range: ---
Groove ---
Fillet ---
Electrode-Flux (Class) N/A
Flux Trade Name N/A
Consumable Insert None
Other

Each base metal-filler metal combination should be recorded individually.

WPS ANL-CS-2013-001

POSITIONS (QW-405)
Positions of Groove: Horizontal and Flat
Welding Progression: Up _____ Down _____
Positions(s) of Fillet _____

POSTWELD HEAT TREATMENT (QW-407)
Temperature Range: None
Time Range: N/A
Other _____

PREHEAT (QW-408)
Preheat Temp. Min.: Ambient 32°F min temp for welding
Interpass Temp. Max.: Not measured
Preheat Maintenance _____

GAS (QW-408)

	Gas(es)	Percent Composition (Mixture)	Flow Rate
Shielding	Argon	99.99	17-25 CFH
Trailing	None		
Backing	None		

ELECTRICAL CHARACTERISTICS (QW-409)
Current AC or DC: Direct Polarity: Straight Non-Pulsing
AMPS (Range): 150 - 275 a Volts (Range): 15-21 V
Tungsten Electrode Size and Type: 3/32 Dia. EWTH2
Model of Mar Transfer for GMAW: N/A
Electrode Wire Feed Speed Range: N/A

TECHNIQUE (QW-410)
String or Weave Bead: String and Weave. Weave not to exceed 1/4"
Orifice or Gas Cup Size: #6 or #7
Initial Interpass Cleaning (Brushing, Grinding, etc.): Acetone wash, alcohol rinse, wire brush, no adhesive is allowed in the weld joint.
Method of Back Gouging: None
Oscillation: N/A
Contact Tube to Work Distance: N/A
Multiple or Single Pass (per side): Multipass
Multiple or Single Electrodes: Single Electrode
Travel Speed (Range): As required
Peening: None
Other _____

Weld Layers	Process	Filler Metal Class	Filler Metal Dia.	Current Type Polar.	Current Amp. Range	Volt Range	Travel Speed Range	Other (Power Source)
1-Final	GTAW	ER70S-2	3/32 or 1/16	DCSP	150-275a	15-21V	As required	

Appendix 2
AWS D1.1-98
Sections 6.1.4, 6.9

6. Inspection

Part A
General Requirements

6.1 Scope

Section 6 contains all of the requirements for the Inspector's qualifications and responsibilities, acceptance criteria for discontinuities, and procedures for nondestructive testing (NDT).

6.1.1 Information Furnished to Bidders. When nondestructive testing other than visual is to be required, it shall be so stated in the information furnished to the bidders. This information shall designate the categories of welds to be examined, the extent of examination of each category, and the method or methods of testing.

6.1.2 Inspection and Contract Stipulations. For the purpose of this code, fabrication/erection inspection and testing, and verification inspection and testing are separate functions.

6.1.2.1 Fabrication/Erection. This type of inspection and test shall be performed as necessary prior to assembly, during assembly, during welding, and after welding to ensure that materials and workmanship meet the requirements of the contract documents. Fabrication/erection inspection and testing are the responsibilities of the contractor unless otherwise provided in the contract documents.

6.1.2.2 Verification Inspection. This type of inspection and testing shall be performed and their results reported to the owner and contractor in a timely manner to avoid delays in the work. Verification inspection and testing are the prerogatives of the owner who may perform this function or, when provided in the contract, waive independent verification, or stipulate that both inspection and verification shall be performed by the contractor.

6.1.3 Definition of Inspector Categories

6.1.3.1 Fabrication/Erection Inspector. This inspector is the duly designated person who acts for, and in behalf of, the contractor on all inspection and quality matters within the scope of the contract documents.

6.1.3.2 Verification Inspector. This inspector is the duly designated person who acts for, and in behalf of, the owner or engineer on all inspection and quality matters within the scope of the contract documents.

6.1.3.3 Inspector(s). When the term inspector is used without further qualification as to the specific inspector category described above, it applies equally to inspection and verification within the limits of responsibility designated in 6.1.2.

6.1.4 Inspector Qualification Requirements

6.1.4.1 Bases for Qualification. Inspectors responsible for acceptance or rejection of material and workmanship shall be qualified. The basis of Inspector qualification shall be documented. If the Engineer elects to specify the basis of inspector qualification, it shall be so stated in contract documents.

The acceptable qualification bases are the following:

(1) Current or previous certification as an AWS Certified Welding Inspector (CWI) in accordance with the provisions of AWS QC1, *Standard and Guide for Qualification and Certification of Welding Inspectors*, or

(2) Current or previous qualification by the Canadian Welding Bureau (CWB) to the requirements of the Canadian Standard Association (CSA) Standard W178.2, *Certification of Welding Inspectors*, or

(3) An engineer or technician who, by training or experience, or both, in metals fabrication, inspection and testing, is competent to perform inspection of the work.

6.1.4.2 Term of Effectiveness. The qualification of an Inspector shall remain in effect indefinitely, provided the Inspector remains active in inspection of welded steel fabrication, unless there is specific reason to question the Inspector's ability.

6.1.4.3 Assistant Inspector. The Inspector may be supported by Assistant Inspectors who may perform specific inspection functions under the supervision of the Inspector. Assistant Inspectors shall be qualified by training and experience to perform the specific functions

to which they are assigned. The work of Assistant Inspectors shall be regularly monitored by the Inspector, generally on a daily basis.

6.1.4.4 Eye Examination. Inspectors and Assistant Inspectors shall have passed an eye examination with or without corrective lenses to prove: (1) near vision acuity of Snellen English, or equivalent, at no less than 12 in. (305 mm); and (2) far vision acuity of 20/40, or better. Eye examination of all inspection personnel is required every three years or less if necessary to demonstrate adequacy.

6.1.4.5 Verification Authority. The Engineer shall have authority to verify the qualification of Inspectors.

6.1.5 Inspector Responsibility. The Inspector shall ascertain that all fabrication and erection by welding is performed in accordance with the requirements of the contract documents.

6.1.6 Items to be Furnished to the Inspector. The Inspector shall be furnished complete detailed drawings showing the size, length, type, and location of all welds to be made. The Inspector shall also be furnished the portion of the contract documents that describes material and quality requirements for the products to be fabricated or erected, or both.

6.1.7 Inspector Notification. The Inspector shall be notified in advance of the start of operations subject to inspection and verification.

6.2 Inspection of Materials

The Inspector shall make certain that only materials conforming to the requirements of this code are used.

6.3 Inspection of WPSs and Equipment

6.3.1 WPS. The Inspector shall verify that all WPSs have been approved by the Engineer in conformance with 4.1.1.

6.3.2 Welding Equipment. The Inspector shall inspect the welding equipment to be used for the work to make certain that it conforms to the requirements of 5.11.

6.4 Inspection of Welder, Welding Operator, and Tack Welder Qualifications

6.4.1 Determination of Qualification. The Inspector shall permit welding to be performed only by welders, welding operators, and tack welders who are qualified in accordance with the requirements of section 4, or shall make certain that each welder, welding operator, or tack welder has previously demonstrated such qualification under other acceptable supervision and approved by the Engineer in conformance with 4.1.2.1.

6.4.2 Retesting Based on Quality of Work. When the quality of a qualified welder's, welding operator's, or tack welder's work appears to be below the requirements of this code, the Inspector may require that the welder, welding operator, or tack welder demonstrate an ability to produce sound welds by means of a simple test, such as the fillet weld break test, or by requiring complete requalification in accordance with section 4.

6.4.3 Retesting Based on Certification Expiration. The Inspector shall require requalification of any qualified welder or welding operator who has not used the process (for which they are qualified) for a period exceeding six months. See 4.1.3.1.

6.5 Inspection of Work and Records

6.5.1 Size, Length, and Location of Welds. The Inspector shall make certain that the size, length, and location of all welds conform to the requirements of this code and to the detail drawings and that no unspecified welds have been added without approval.

6.5.2 WPS. The Inspector shall make certain that only WPSs are employed which meet the provisions of section 3 or section 4.

6.5.3 Electrode Classification and Usage. The Inspector shall make certain that electrodes are used only in the positions and with the type of welding current and polarity for which they are classified.

6.5.4 Scope of Examinations. The Inspector shall, at suitable intervals, observe joint preparation, assembly practice, the welding techniques, and performance of each welder, welding operator, and tack welder to make certain that the applicable requirements of this code are met.

6.5.5 Extent of Examination. The Inspector shall examine the work to make certain that it meets the requirements of this code. Other acceptance criteria, different from those specified in the code, may be used when approved by the Engineer. Size and contour of welds shall be measured with suitable gages. Visual inspection for cracks in welds and base metal and other discontinuities should be aided by a strong light, magnifiers, or such other devices as may be found helpful.

6.5.6 Inspector Identification of Inspections Performed. Inspectors shall identify with a distinguishing mark or other recording methods all parts or joints that they have inspected and accepted. Any recording method which is mutually agreeable may be used. Die stamping of cyclically loaded members is not permitted without the approval of the Engineer.

spection is specified in the information furnished to bidders, it shall be the contractor's responsibility to ensure that all specified welds meet the quality requirements of section 6, Part C, whichever is applicable.

Particle Testing

Welds that are subject to magnetic particle and liquid penetrant testing, in addition to visual inspection, shall

6.5.7 Maintenance of Records. The Inspector shall keep a record of qualifications of all welders, welding operators, and tack welders; all WPS qualifications or other tests that are made; and such other information as may be required.

Part B
Contractor Responsibilities

6.6 Obligations of the Contractor

6.6.1 Contractor Responsibilities. The contractor shall be responsible for visual inspection and necessary correction of all deficiencies in materials and workmanship in accordance with the requirements of this code.

6.6.2 Inspector Requests. The contractor shall comply with all requests of the Inspector(s) to correct deficiencies in materials and workmanship as provided in the contract documents.

6.6.3 Engineering Judgment. In the event that faulty welding, or its removal for rewelding, damages the base metal so that in the judgment of the Engineer its retention is not in accordance with the intent of the contract documents, the contractor shall remove and replace the damaged base metal or shall compensate for the deficiency in a manner approved by the Engineer.

6.6.4 Specified Nondestructive Testing Other Than Visual. When nondestructive testing other than visual inspection is specified in the information furnished to bidders, it shall be the contractor's responsibility to ensure that all specified welds meet the quality requirements of section 6, Part C, whichever is applicable.

6.6.5 Nonspecified Nondestructive Testing Other Than Visual. If nondestructive testing other than visual inspection is not specified in the original contract agreement but is subsequently requested by the owner, the contractor shall perform any requested testing or shall permit any testing to be performed in conformance with 6.14. The owner shall be responsible for all associated costs including handling, surface preparation, nondestructive testing, and repair of discontinuities other than those listed in 6.9, whichever is applicable, at rates mutually agreeable between owner and contractor. However, if such testing should disclose an attempt to defraud or gross nonconformance to this code, repair work shall be done at the contractor's expense.

Part C
Acceptance Criteria

6.7 Scope

Acceptance criteria for visual and nondestructive inspection of tubular connections and statically and cyclically loaded nontubular connections are described in Part C. The extent of examination and the acceptance criteria shall be specified in the contract documents or information furnished to the bidder.

6.8 Engineer's Approval for Alternate Acceptance Criteria

The fundamental premise of the code is to provide general stipulations applicable to most situations. 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.

6.9 Visual Inspection

All welds shall be visually inspected and shall be acceptable if the criteria of Table 6.1 are satisfied.

6.10 Liquid Penetrant and Magnetic Particle Testing

Welds that are subject to magnetic particle and liquid penetrant testing, in addition to visual inspection, shall be evaluated on the basis of the applicable requirements for visual inspection. The testing shall be performed in conformance with 6.14.4 or 6.14.5, whichever is applicable.

6.11 Nondestructive Testing

Except as provided for in 6.18, all NDT methods including equipment requirements and qualifications, personnel qualifications, and operating methods shall be in accordance with section 6, Inspection. Acceptance criteria shall be as specified in this section. Welds subject to nondestructive testing shall have been found acceptable by visual inspection in accordance with 6.9.

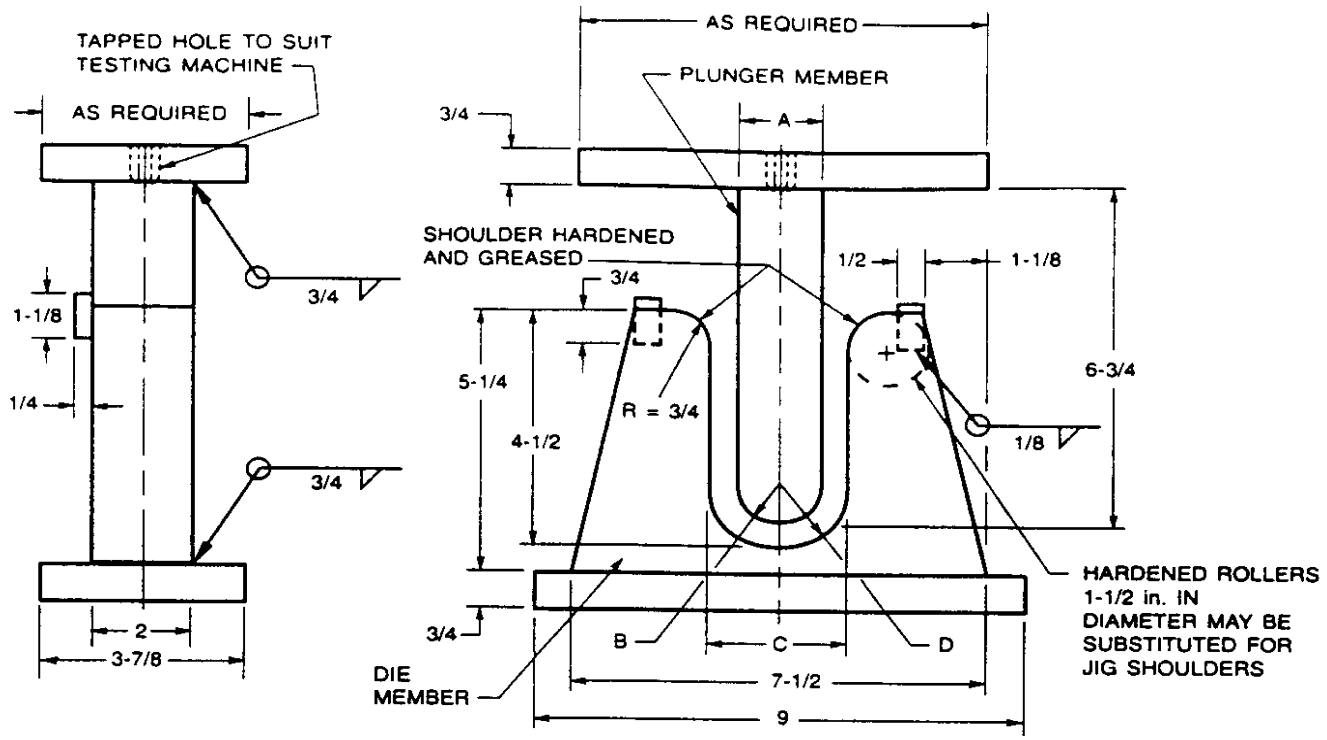
For welds subject to nondestructive testing in accordance with 6.10, 6.11, 6.12.3, and 6.13.3, the testing may begin immediately after the completed welds have cooled to ambient temperature. Acceptance criteria for ASTM A514, A517, and A709 Grade 100 and 100W steels shall be based on nondestructive testing performed not less than 48 hours after completion of the welds.

Table 6.1
Visual Inspection Acceptance Criteria[1] (see 6.9)

Discontinuity Category and Inspection Criteria	Statically Loaded Nontubular Connections	Cyclically Loaded Nontubular Connections	Tubular Connections (All Loads)
(1) Crack Prohibition The weld shall have no cracks	X	X	X
(2) Weld/Base-Metal Fusion Thorough fusion shall exist between adjacent layers of weld metal and between weld metal and base metal.	X	X	X
(3) Crater Cross Section All craters shall be filled to the full cross section of the weld, except for the ends of intermittent fillet welds outside of their effective length.	X	X	X
(4) Weld Profiles Weld profiles shall be in conformance with 5.24.	X	X	X
(5) Time of Inspection Visual inspection of welds in all steels may begin immediately after the completed welds have cooled to ambient temperature. Acceptance criteria for ASTM A514, A517, and A709 Grade 100 and 100 W steels shall be based on visual inspection performed not less than 48 hours after completion of the weld.	X	X	X
(6) Underrun A fillet weld in any single continuous weld shall be permitted to underrun the nominal fillet size specified by 1/16 in. (1.6 mm) without correction, provided that the undersize portion of the weld does not exceed 10% of the length of the weld. On web-to-flange welds on girders, no underrun is permitted at the ends for a length equal to twice the width of the flange.	X	X	X
(7) Undercut (A) For material less than 1 in. (25.4 mm) thick, undercut shall not exceed 1/32 in. (1 mm), except that a maximum 1/16 in. (1.6 mm) is permitted for an accumulated length of 2 in. (50 mm) in any 12 in. (305 mm). For material equal to or greater than 1 in. thick, undercut shall not exceed 1/16 in. for any length of weld.	X		
(B) In primary members, undercut shall be no more than 0.01 in. (0.25 mm) deep when the weld is transverse to tensile stress under any design loading condition. Undercut shall be no more than 1/32 in. (1 mm) deep for all other cases.		X	X
(8) Porosity (A) Complete joint penetration groove welds in butt joints transverse to the direction of computed tensile stress shall have no visible piping porosity. For all other groove welds and for fillet welds, the sum of the visible piping porosity 1/32 in. (1 mm) or greater in diameter shall not exceed 3/8 in. (10 mm) in any linear inch of weld and shall not exceed 3/4 in. (19 mm) in any 12 in. (305 mm) length of weld.	X		
(B) The frequency of piping porosity in fillet welds shall not exceed one in each 4 in. (100 mm) of weld length and the maximum diameter shall not exceed 3/32 in. (2 mm). Exception: for fillet welds connecting stiffeners to web, the sum of the diameters of piping porosity shall not exceed 3/8 in. (10 mm) in any linear inch of weld and shall not exceed 3/4 in. (19 mm) in any 12 in. (305 mm) length of weld.		X	X
(C) Complete joint penetration groove welds in butt joints transverse to the direction of computed tensile stress shall have no piping porosity. For all other groove welds, the frequency of piping porosity shall not exceed one in 4 in. (100 mm) of length and the maximum diameter shall not exceed 3/32 in. (2 mm)		X	X

1. An "X" indicates applicability for the connection type; a shaded area indicates non-applicability.

Appendix 3
AWS D1.1-98
Section 4.8.4.1



specified or actual base metal yield strength, psi	A in.	B in.	C in.	D in.
50 000 & under	1-1/2	3/4	2-3/8	1-3/16
over 50 000 to 90 000	2	1	2-7/8	1-7/16
90 000 & over	2-1/2	1-1/4	3-3/8	1-11/16

Note: Plunger and interior die surfaces shall be machine-finished.

Figure 4.15—Guided Bend Test Jig (see 4.8.3)

Specimens with corner cracks exceeding 1/4 in. (6 mm) with no evidence of slag inclusions or other fusion type discontinuities shall be disregarded, and a replacement test specimen from the original weldment shall be tested.

4.8.3.4 Reduced-Section Tension Specimens (See Figure 4.14). Before testing, the least width and corresponding thickness of the reduced section shall be measured. The specimen shall be ruptured under tensile load, and the maximum load shall be determined. The cross-sectional area shall be obtained by multiplying the width by the thickness. The tensile strength shall be obtained by dividing the maximum load by the cross-sectional area.

4.8.3.5 Acceptance Criteria for Reduced-Section Tension Test. The tensile strength shall be no less than the minimum of the specified tensile range of the base metal used.

4.8.3.6 All-Weld-Metal Tension Specimen (See Figure 4.18). The test specimen shall be tested in accordance with ASTM A370, *Mechanical Testing of Steel Products*.

4.8.4 Macroetch Test. The weld test specimens shall be prepared with a finish suitable for macroetch examination. A suitable solution shall be used for etching to give a clear definition of the weld.

4.8.4.1 Acceptance Criteria for Macroetch Test. For acceptable qualification, the test specimen, when inspected visually, shall conform to the following requirements:

(1) Partial joint penetration groove welds: the actual weld size shall be equal to or greater than the specified weld size, (E).

(2) Fillet welds shall have fusion to the root of the joint, but not necessarily beyond.

(3) Minimum leg size shall meet the specified fillet weld size.

(4) The partial joint penetration groove welds and fillet welds shall have the following:

(a) no cracks

(b) thorough fusion between adjacent layers of weld metals and between weld metal and base metal

(c) weld profiles conforming to specified detail, but with none of the variations prohibited in 5.24

(d) no undercut exceeding 1/32 in. (1 mm)

4.8.5 Retest. If any one specimen of all those tested fails to meet the test requirements, two retests for that particular type of test specimen may be performed with specimens cut from the same WPS qualification material. The results of both test specimens must meet the test requirements. For material over 1 1/2 in. (38.1 mm) thick, failure of a specimen shall require testing of all specimens of the same type from two additional locations in the test material.

4.9 Complete Joint Penetration (CJP) Groove Welds for Nontubular Connections

See Table 4.2(1) for the requirements for qualifying a WPS of a CJP weld on nontubular connections. See Figures 4.9–4.11 for the appropriate test plate.

4.9.1.1 Corner or T-Joints. Test specimens for groove welds in corner or T-joints shall be butt joints having the same groove configuration as the corner or T-joint to be used on construction, except the depth of groove need not exceed 1 in. (25 mm).

4.10 Partial Joint Penetration (PJP) Groove Welds for Nontubular Connections

4.10.1 Type and Number of Specimens to be Tested. The type and number of specimens that must be tested to qualify a WPS are shown in Table 4.3. A sample weld shall be made using the type of groove design and WPS to be used in construction, except the depth of groove need not exceed 1 in. (25 mm). For the macroetch test required below, any steel of Groups I, II, and III of Table 3.1 may be used to qualify the weld size on any steels or combination of steels in those groups. If the partial joint penetration groove weld is to be used for corner or T-joints, the butt joint shall have a temporary restrictive plate in the plane of the square face to simulate the T-joint configuration. The sample welds shall be tested as follows:

4.10.2 Weld Size Verification by Macroetch. For WPSs which conform in all respects to section 4, three macroetch cross-section specimens shall be prepared to demonstrate that the designated weld size (obtained from the requirements of the WPS) are met.

4.10.3 Verification of Complete Joint Penetration Groove WPS by Macroetch. When a WPS has been qualified for a complete joint penetration groove weld and is applied to the welding conditions of a partial joint penetration groove weld, three macroetch cross-section tests specimens are required to demonstrate that the designated weld size is achieved as a minimum.

4.10.4 Other WPS Verifications by Macroetch. If a WPS is not covered by either 4.10.2 or 4.10.3, or if the welding conditions do not meet a prequalified status, or if these have not been used and tested for a complete joint penetration weld in a butt joint, then a sample joint shall be prepared and the first operation is to make a macroetch test specimen to determine the weld size of the joint. Then, the excess material is machined off on the bottom side of the joint to the thickness of the weld size. Tension and bend test specimens shall be prepared and tests performed, as required for complete joint penetration groove welds (see 4.9).

4.10.5 Flare-Groove Welds. The effective weld sizes for qualified flare-groove welds are determined by the following:

(1) When required by the Engineer, test sections shall be used to verify that the effective weld size is consistently obtained.

(2) For a given set of WPS conditions, if the contractor has demonstrated consistent production of larger effective weld sizes than those shown in Table 2.1, the contractor may establish such larger effective weld sizes by qualification.

(3) Qualification required by (2) shall consist of sectioning the radiused member, normal to its axis, at midlength and ends of the weld. Such sectioning shall be made on a number of combinations of material sizes representative of the range used by the contractor in construction or as required by the Engineer.

4.11 Fillet Weld Qualification Requirements for Tubular and Nontubular Connections

4.11.1 Type and Number of Specimens. The type and number of specimens that must be tested to qualify a fillet weld WPS are shown in Table 4.4