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# AEROSPACE MATERIAL SPECIFICATION

Submitted for recognition as an American National Standard



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## Qualification of Aircraft, Missile and Aerospace Fusion Welders

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## 1. SCOPE:

### 1.1 Purpose:

This standard establishes the procedure for qualification of welders and welding operators engaged in the welding of aircraft, missiles, other aerospace equipment, and their parts and accessories by fusion welding processes. This standard is applicable to aircraft, missile, and aerospace ground support equipment or other welding, when included in the contracting documents or when invoked in the absence of a specified welder qualification document.

### 1.2 Welder and welding operator assignments:

1.2.1 Welder: Welders may weld all joints by manual and semi-automatic welding for which they are qualified by producing acceptable test welds, as defined in Sections 4 and 5. In addition, welders may weld all joints by machine and automatic welding within the same limitations as for the acquired welder qualification.

1.2.2 Welding operator: Welding operators may weld all joints by machine and automatic welding for which they are qualified by producing acceptable test welds, as defined in Sections 4 and 5.

## 2. APPLICABLE DOCUMENTS:

The following publications, of the issue in effect on the date of invitation for bids or request for proposal, form a part of this specification to the extent specified herein.

### 2.1 U.S. Government Publications:

Available from DODSSP, Subscription Services Desk, Building 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094.

MIL-STD-410 Nondestructive Testing Personnel Qualification and Certification  
MIL-STD-453 Inspection, Radiographic

### 2.2 ASTM Publications:

Available from ASTM, 100 Barr Harbor, West Conshohocken, PA 19428-2959.

ASTM DS-56 Unified Numbering System for Metals and Alloys (Same as SAE HS1086)

### 2.3 SAE Publications:

Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

SAE HS1086 Unified Numbering System for Metals and Alloys (Same as ASTM DS-56)

## 2.4 AWS Publications:

Available from American Welding Society, 550 N.W. LaJeune Road, Miami, FL 33126.

|           |                                                                       |
|-----------|-----------------------------------------------------------------------|
| AWS A3.0  | Welding Terms and Definitions                                         |
| AWS B3.0  | Welding Procedure and Performance Qualification                       |
| AWS D1.1  | Structural Welding Code                                               |
| AWS D10.9 | Qualification of Welding Procedures and Welders for Piping and Tubing |

## 3. DEFINITIONS:

### 3.1 Welding terminology:

The welding terminology of "Welding Terms and Definitions" AWS A3.0, shall be used in the interpretation of this standard. Some of these items and additional terms are defined below.

- 3.1.1 As-welded: The condition of weld metal, welded joints, and weldments after welding but prior to any subsequent thermal, mechanical, or chemical treatments.
- 3.1.2 Automatic welding: Welding with equipment which performs the welding operation without adjustment of the controls of a welding operator. The equipment may or may not perform the loading and unloading of the work.
- 3.1.3 Backing: A material (base metal, weld metal, carbon, or granular material) placed at the root of a weld joint for the purpose of supporting molten weld metal.
- 3.1.4 Base metal: The metal to be welded, soldered, or cut.
- 3.1.5 Blank: Part of a test weld removed for the preparation of a bend test specimen or a metallographic specimen.
- 3.1.6 Butt joint: A joint between two members aligned approximately in the same plane.
- 3.1.7 Complete fusion: Fusion that has occurred over the entire base metal surfaces intended for welding and between all layers and weld beads.
- 3.1.8 Complete joint penetration: Joint penetration in which the weld metal completely fills the groove and is fused to the base metal throughout its total thickness.
- 3.1.9 Defect: A discontinuity or discontinuities which by nature or accumulated effect render a part or product unable to meet minimum applicable acceptance standards or specifications. This term designated rejectability.
- 3.1.10 Depth of fusion: The distance that fusion extends into the base metal or previous pass from the surface melted during welding.

- 3.1.11 Discontinuity: An interruption of the typical structure of a weldment, such as a lack of homogeneity in the mechanical, metallurgical, or physical characteristics of the material or weldment. A discontinuity is not necessarily a defect.
- 3.1.12 Filler metal: The metal to be added in making a welded, brazed, or soldered joint.
- 3.1.13 Fusion zone: The areas of base metal melted as determined on the cross section of a weld.
- 3.1.14 Heat-affected zone: That portion of the base metal which has not been melted, but whose mechanical properties or microstructure have been altered by the heat of welding, brazing, soldering, or cutting.
- 3.1.15 Joint: The junction of members or the edges of members which are to be joined or have been joined.
- 3.1.16 Machine welding: Welding with equipment which performs the welding operation under the constant observation and control of a welding operator. The equipment may or may not perform the loading and unloading of the work.
- 3.1.17 Manual welding: A welding operation performed and controlled completely by hand.
- 3.1.18 Semiautomatic arc welding: Arc welding with equipment which controls only the filler metal feed. The advance of the welding is manually controlled.
- 3.1.19 Test weld: A joint made by a welder for purposes of welder qualification.
- 3.1.20 Welder: One who performs a manual or semiautomatic welding operation.
- 3.1.21 Welder certification: Certification in writing that a welder has produced welds meeting prescribed standards.
- 3.1.22 Welding machine: Equipment used to perform the welding operation. For example, spot welding machine, arc welding machine, seam welding machine, etc.
- 3.1.23 Welding operator: One who operates machine or automatic welding equipment.
- 3.2 Symbols and terms:
- Sheet refers to both sheet and plate, where appropriate.
  - Tube refers to both tube and pipe, where appropriate.
  - The lower case letter, t, indicates base metal thickness for either sheet or tube wall.
  - Mathematical symbols used before numbers mean:
    - < less than
    - > more than
    - ≤ equal to or less than
    - ≥ equal to or more than.

#### 4. GENERAL REQUIREMENTS:

##### 4.1 Qualification requirements:

To achieve qualified status, welders and welding operators shall demonstrate their skill by producing acceptable test welds in accordance with 4.1.1. No test welds are required for those welds which will not be required in production welding.

##### 4.1.1 Welders: The correlation between test welds and production welds shall be based on the following factors.

- a. Welding process (see 5.1).
- b. Base metal composition (see 5.2).
- c. Base metal thickness (see 5.3).
- d. Welding position (see 5.4).
- e. Base metal form, sheet or tube (see 5.5).
- f. Type of weld, groove or fillet (see 5.5).
- g. Other welding conditions (see 5.6).

##### 4.1.2 Welding operators: The correlation between test welds and production welds shall be based on only the first three factors given in 4.1.1.

##### 4.2. Minimum requirements:

The requirements of this standard are minimum. Other requirements may be added by the contractor, but may not be substituted for the requirements of this standard.

##### 4.3 Physical requirements:

The contractor shall establish reasonable and appropriate physical requirements for welders and welding operators. It will be accepted that those whose corrected vision in each eye for long distance is better than 20/30 and for 16 inches distance permits reading of Joeger No. 2 type will ordinarily satisfy vision needs for welding.

##### 4.4 Identification:

The contractor shall assign a unique number or other identification to each welder or welding operator upon qualification.

##### 4.5 Test records:

The contractor shall complete a test record containing the essential information required as evidence of the welder or welding operator qualification. These records shall be retained for the period of time specified in the contract or, if no retention time is specified, the period of record retention shall be for the duration of qualification.

- 4.5.1 Test record forms: Suggested test record forms are given in Figure 1 and in the following documents.
- a. Structural Welding Code, AWS D1.1
  - b. Qualification of Welding Procedures and Welders for Piping and Tubing, AWS D10.9.
- 4.6 Requalification: A welder or welding operator shall be requalified every five years to the same requirements as an original qualification. Requalification is also required when either of the following two conditions are present.
- 4.6.1 A welder or welding operator has not welded with a given welding process for a period of three months; except that this period shall be extended to six months if the welder has welded with another process of Table I.
- 4.6.2 There is a specific reason to question the ability of a welder or welding operator to meet the requirements for qualification in a given welding process.
- 4.7 Alternate requalification: As an alternate to the requirements of 4.6.1, requalification to the same requirements as an original qualification may be accomplished at two year intervals, in lieu of the three month and six month restrictions.
5. DETAILED REQUIREMENTS:
- 5.1 Welding process: For welders and welding operators, a test weld made with a given welding process of Table I qualifies only that welding process. This standard does not apply to welding processes not included in Table I.
- 5.2 Base metals: For welders and welding operators, a test weld made in a base metal included in one of the ten base metal groups of Table II qualifies only that base metal group, except as modified by 5.2.1 and 5.2.2 and as illustrated in Table III. The specific base metals included in each of the base metal groups of Table II, are given in the Appendix of this standard. Since the base metal groups are intended only for the purpose of qualification, some of the base metal groups contain base metals whose composition does not conform to the nominal description of the base metal group.

### QUALIFICATION TEST RECORD

Name \_\_\_\_\_ Id. \_\_\_\_\_ SS No. \_\_\_\_\_  
 Joint welding procedure \_\_\_\_\_ Welder  Welding operator

### TEST WELD

Base metal description \_\_\_\_\_ Group No. \_\_\_\_\_  
 Welding process \_\_\_\_\_ Single weld  Double weld   
 Current AC  DC  Backing Yes  No   
 Vertical Down  Up  Penetration Complete  Partial

|              | Position                                                                                                        | Dimension, inch     |
|--------------|-----------------------------------------------------------------------------------------------------------------|---------------------|
| Sheet groove | 1G <input type="checkbox"/> 2G <input type="checkbox"/> 3G <input type="checkbox"/> 4G <input type="checkbox"/> | t _____             |
| Tube groove  | 1G <input type="checkbox"/> 2G <input type="checkbox"/> 5G <input type="checkbox"/>                             | O. D. _____ t _____ |
| Sheet fillet | 1F <input type="checkbox"/> 2F <input type="checkbox"/> 3F <input type="checkbox"/> 4F <input type="checkbox"/> | t _____             |
| Tube fillet  | 1F <input type="checkbox"/> 2F <input type="checkbox"/> 4F <input type="checkbox"/> 5F <input type="checkbox"/> | O. D. _____ t _____ |

### TEST RESULTS

Visual Pass  Fail   
 Radiographic NA  Pass  Fail   
 Bend NA  Pass  Fail   
 Metallographic NA  Pass  Fail

### QUALIFIED

Base Metal Group No. \_\_\_\_\_ Single weld  Double weld   
 Current AC  DC  Backing With  Without   
 Vertical Down  Up  Penetration Complete  Partial

|              | Position                                                                                                        | t, inch | O. D., inch |       |       |
|--------------|-----------------------------------------------------------------------------------------------------------------|---------|-------------|-------|-------|
|              |                                                                                                                 | Min.    | Max.        | Min.  | Max.  |
| Sheet groove | 1G <input type="checkbox"/> 2G <input type="checkbox"/> 3G <input type="checkbox"/> 4G <input type="checkbox"/> | _____   | _____       | _____ | _____ |
| Tube groove  | 1G <input type="checkbox"/> 2G <input type="checkbox"/> 5G <input type="checkbox"/>                             | _____   | _____       | _____ | _____ |
| Sheet fillet | 1F <input type="checkbox"/> 2F <input type="checkbox"/> 3F <input type="checkbox"/> 4F <input type="checkbox"/> | _____   | _____       | _____ | _____ |
| Tube fillet  | 1F <input type="checkbox"/> 2F <input type="checkbox"/> 4F <input type="checkbox"/> 5F <input type="checkbox"/> | _____   | _____       | _____ | _____ |

The above named individual is qualified in accordance with MIL-STD-1595A within the above limits for the welding process used for this test weld.

Date of test weld \_\_\_\_\_ Signed by \_\_\_\_\_  
Qualifier

FIGURE 1. Suggested test record form.

TABLE I. Fusion welding processes.

|                                   |
|-----------------------------------|
| Oxyfuel welding (OFW)             |
| Shielded metal arc welding (SMAW) |
| Submerged arc welding (SAW)       |
| Gas tungsten arc welding (GTAW)   |
| Gas metal arc welding (GMAW)      |
| Flux cored arc welding (FCAW)     |
| Plasma arc welding (PAW)          |
| Electron beam welding (EBW)       |

TABLE II. Base metal groups.

| Group | Nominal description                        |
|-------|--------------------------------------------|
| Ia    | Carbon and low alloy steels                |
| Ib    | Alloy steels                               |
| IIa   | Stainless steels                           |
| IIb   | Precipitation hardening stainless steels   |
| IIIa  | Nickel and nickel-base alloys              |
| IIIb  | Precipitation hardening nickel-base alloys |
| IV    | Aluminum and aluminum-base alloys          |
| V     | Magnesium-base alloys                      |
| VI    | Titanium and titanium-base alloys          |
| VII   | Cobalt-base alloys                         |

- 5.2.1 Qualification in a base metal group with a "b" designator also qualifies for base metal numbers with the same roman numeral designator and an "a" designator. See Table III.

TABLE III. Base metal groups qualified by test weld.

| Test weld | Qualified  |
|-----------|------------|
| Ia        | Ia         |
| Ib        | Ia, Ib     |
| IIa       | IIa        |
| IIb       | IIa, IIb   |
| IIIa      | IIIa       |
| IIIb      | IIIa, IIIb |
| IV        | IV         |
| V         | V          |
| VI        | VI         |
| VII       | VII        |

- 5.2.2 For welders and welding operators, a separate qualification is required for each base metal not included in the Appendix, except as modified in 5.2.2.1.
- 5.2.2.1 Exception: A base metal not included in the Appendix, with welding characteristics similar to a given base metal group of the Appendix, may be qualified with any base metal of the given base metal group. The preparing activity shall be notified by the organization qualifying a welder or welding operator under the provisions of this paragraph, with DD Form 1426 or a letter, of the two base metals involved and the chemical composition of the base metal not included in the Appendix.
- 5.3 Base metal thickness: The qualification limits, with regard to base metal thickness (sheet thickness or tube wall thickness), are given below for welders and welding operators. These limits apply to both groove welds and fillet welds.
- 5.3.1 A test weld with a base metal thickness of  $t$  shall qualify welds with a thickness range of  $0.67t$  to  $4t$ ; except that, when the test weld thickness is equal to or greater than 1 inch, the qualification range is  $0.67t$  to unlimited.
- 5.3.2 Two test welds, each with members of equal thickness, shall qualify welds with all intermediate thicknesses, in addition to the thickness qualifications of 5.3.1.
- 5.4 Welding position:
- 5.4.1 Welders: The welding positions qualified by a given test weld position, to be found at the left of Table IV, are denoted by an X in the table. The welding positions are illustrated in Figures 2 through 5.
- 5.4.2 Welding operators: A test weld made in any welding position qualifies for all welding positions.

- 5.5 Base metal form and weld type:
- 5.5.1 Welders: The base metal forms and weld types qualified by a given test weld, to be found at the left of Table IV, are denoted by an X in the table, with the exceptions given below.
- 5.5.1.1 Qualification for fillet welds in base metal equal to or less than 0.063 inch in thickness requires a fillet test weld. Groove test welds do not qualify for fillet welds in this thickness range.
- 5.5.1.2 A tube test weld shall qualify only for tubes of an outside diameter equal to or greater than the outside diameter of the test weld.
- 5.5.2 Welding operators: A test weld of any base metal form and of any weld type shall qualify for all base metal forms and all weld types. A tube test weld of any outside diameter shall qualify for tubes of any outside diameter.
- 5.6 Other welding conditions: In addition to the welding process, base metal composition, base metal thickness, welding position, base metal form and type of weld; other welding conditions which require a correlation between the test weld and the production welds are given in Table V.
- 5.6.1 Welders: The welding conditions qualified by the given test weld conditions, to be found at the left of Table V, are denoted by an X in the table. The current type restrictions apply only to the GTAW process. For all other processes, a test weld made with either ac or dc current qualifies for welds made with either current type.
- 5.6.2 Welding operators: The welding condition restrictions of Table V do not apply to the qualification of welding operators.
- 5.7 Test welds: One test weld shall be required for each combination of welding conditions, given in 4.1.1 and 4.1.2, being qualified. Test welds shall be made in accordance with a written joint welding procedure.
- 5.7.1 Groove test weld in sheet: The test weld is a butt joint in sheet as described in Figure 6.

TABLE IV. Welding position, base metal form, and weld type qualified by test weld

| Test Weld |           | Position | Qualified position |    |                      |    |        |    |                      |    |    |    |    |    |    |    |    |   |
|-----------|-----------|----------|--------------------|----|----------------------|----|--------|----|----------------------|----|----|----|----|----|----|----|----|---|
| Form      | Weld type |          | Sheet              |    |                      |    | Tube   |    |                      |    |    |    |    |    |    |    |    |   |
|           |           |          | Groove             |    | Fillet <sup>1/</sup> |    | Groove |    | Fillet <sup>1/</sup> |    |    |    |    |    |    |    |    |   |
|           |           | 1G       | 2G                 | 3G | 4G                   | 1F | 2F     | 3F | 4F                   | 1G | 2G | 5G | 6G | 1F | 2F | 4F | 5F |   |
| Sheet     | Groove    | 1G       | X                  |    |                      |    | X      | X  |                      |    | X  |    |    |    | X  |    |    |   |
|           |           | 2G       | X                  | X  |                      |    | X      | X  |                      |    | X  | X  |    |    | X  |    |    |   |
|           |           | 3G       | X                  |    | X                    |    | X      | X  | X                    |    | X  |    |    |    | X  |    |    |   |
|           |           | 4G       | X                  |    |                      | X  | X      | X  | X                    |    | X  |    |    |    | X  |    |    |   |
| Sheet     | Fillet    | 1F       |                    |    |                      |    | X      |    |                      |    |    |    |    |    | X  |    |    |   |
|           |           | 2F       |                    |    |                      |    | X      | X  |                      |    |    |    |    |    | X  | X  |    |   |
|           |           | 3F       |                    |    |                      |    | X      | X  | X                    |    |    |    |    |    | X  |    |    |   |
|           |           | 4F       |                    |    |                      |    | X      | X  |                      | X  |    |    |    |    | X  | X  | X  |   |
| Tube      | Groove    | 1G       | X                  |    |                      |    | X      | X  |                      |    | X  |    |    |    | X  | X  |    |   |
|           |           | 2G       | X                  | X  |                      |    | X      | X  |                      |    | X  | X  |    |    | X  | X  |    |   |
|           |           | 5G       | X                  |    | X                    | X  | X      |    | X                    | X  | X  |    | X  |    | X  |    | X  | X |
|           |           | 6G       | X                  | X  | X                    | X  | X      | X  | X                    | X  | X  | X  | X  | X  | X  | X  | X  | X |
| Tube      | Fillet    | 1F       |                    |    |                      |    | X      |    |                      |    |    |    |    |    | X  |    |    |   |
|           |           | 2F       |                    |    |                      |    | X      | X  |                      |    |    |    |    |    | X  | X  |    |   |
|           |           | 4F       |                    |    |                      |    | X      | X  |                      | X  |    |    |    |    | X  | X  | X  |   |
|           |           | 5F       |                    |    |                      |    | X      | X  | X                    | X  |    |    |    |    | X  | X  | X  | X |

<sup>1/</sup> A groove test weld does not qualify for fillet welds in base metal equal to or less than 0.063 inch in thickness (see 5.5.1.1).

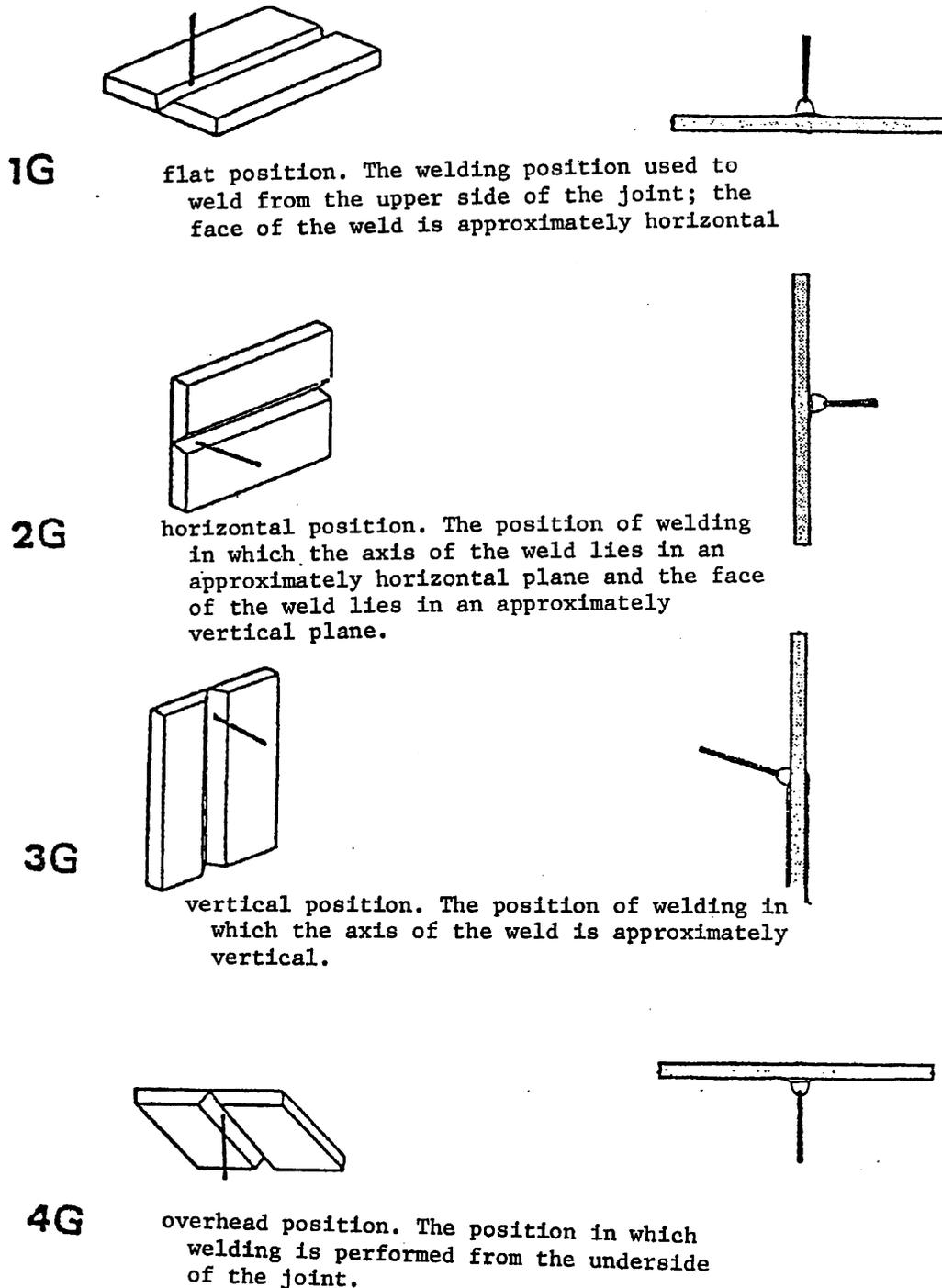
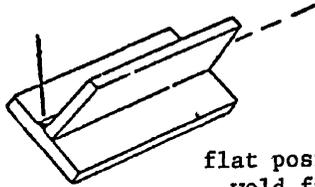
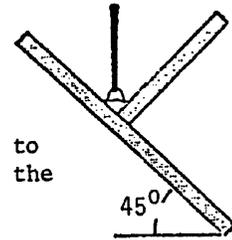


FIGURE 2. Groove weld in sheet: positions 1G, 2G, 3G, and 4G.

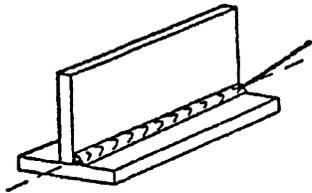
1F



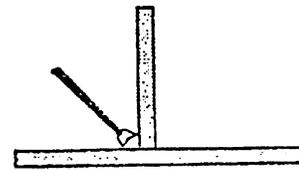
flat position. The welding position used to weld from the upper side of the joint; the face of the weld is approximately horizontal.



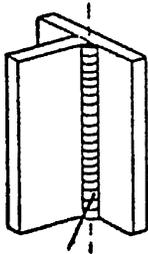
2F



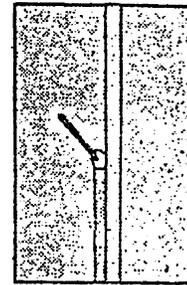
horizontal position. The position in which welding is performed on the upper side of an approximately horizontal surface and against an approximately vertical surface.



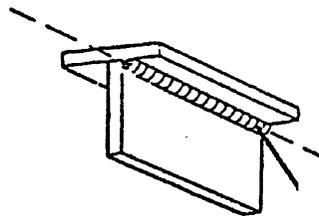
3F



vertical position. The position of welding in which the axis of the weld is approximately vertical.



4F



overhead position. The position in which welding is performed from the underside of the joint.

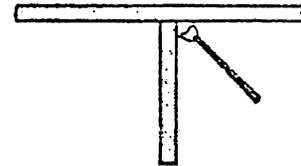
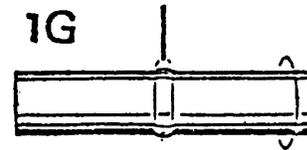
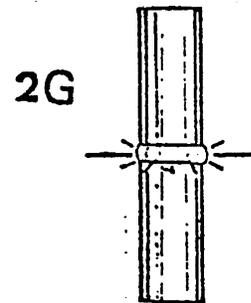


FIGURE 3. Fillet weld in sheet: positions 1F, 2F, 3F, and 4F.

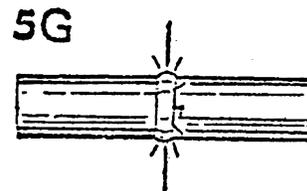
horizontal rolled position. The position of a pipe joint in which the axis of the pipe is approximately horizontal, and welding is performed in the flat position by rotating the pipe.



vertical position. The position of a pipe joint in which welding is performed in the horizontal position and the pipe is not rotated during welding.



horizontal fixed position. The position of a pipe joint in which the axis of the pipe is approximately horizontal and the pipe is not rotated during welding.



inclined position. The position of a pipe joint in which the axis of the pipe is approximately at an angle of  $45^\circ$  to the horizontal and the pipe is not rotated during welding.

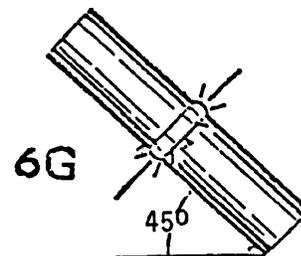
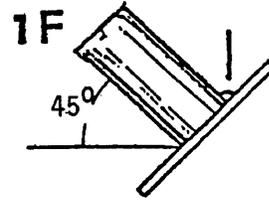
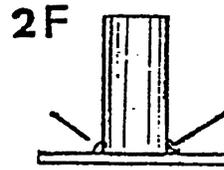


FIGURE 4. Groove weld in tube: positions 1G, 2G, 5G, and 6G.

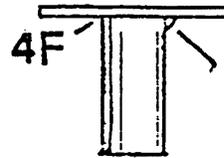
flat position. The welding position used to weld from the upper side of the joint; the face of the weld is approximately horizontal and the pipe is rotated during welding.



horizontal position. The position in which welding is performed on the upper side of an approximately horizontal surface and against an approximately vertical surface and the pipe is not rotated during welding.



overhead position. The position in which welding is performed from the underside of the joint and the pipe is not rotated during welding.



multiple position. The position in which the axis of the pipe is approximately horizontal and the pipe is not rotated during welding.

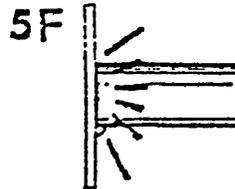


FIGURE 5. Fillet weld in tube: positions 1F, 2F, 4F, and 5F.

TABLE V. Welding conditions qualified by test weld.

| Test weld                 | Qualified |         |             |        |                      |                     |                            |    |
|---------------------------|-----------|---------|-------------|--------|----------------------|---------------------|----------------------------|----|
|                           | Backing   |         | Groove weld |        |                      |                     | Current type <sup>1/</sup> |    |
|                           | With      | Without | Single      | Double | Complete penetration | Partial Penetration | ac                         | dc |
| With backing              | X         |         |             |        |                      |                     |                            |    |
| Without backing           | X         | X       |             |        |                      |                     |                            |    |
| Single welded groove weld |           |         | X           | X      |                      |                     |                            |    |
| Double welded groove weld |           |         |             | X      |                      |                     |                            |    |
| Complete penetration weld |           |         |             |        | X                    | X                   |                            |    |
| Partial penetration weld  |           |         |             |        |                      | X                   |                            |    |
| ac welding                |           |         |             |        |                      |                     | X                          |    |
| dc welding                |           |         |             |        |                      |                     |                            | X  |

<sup>1/</sup> Applicable only to GTAW process (see 5.6.1).

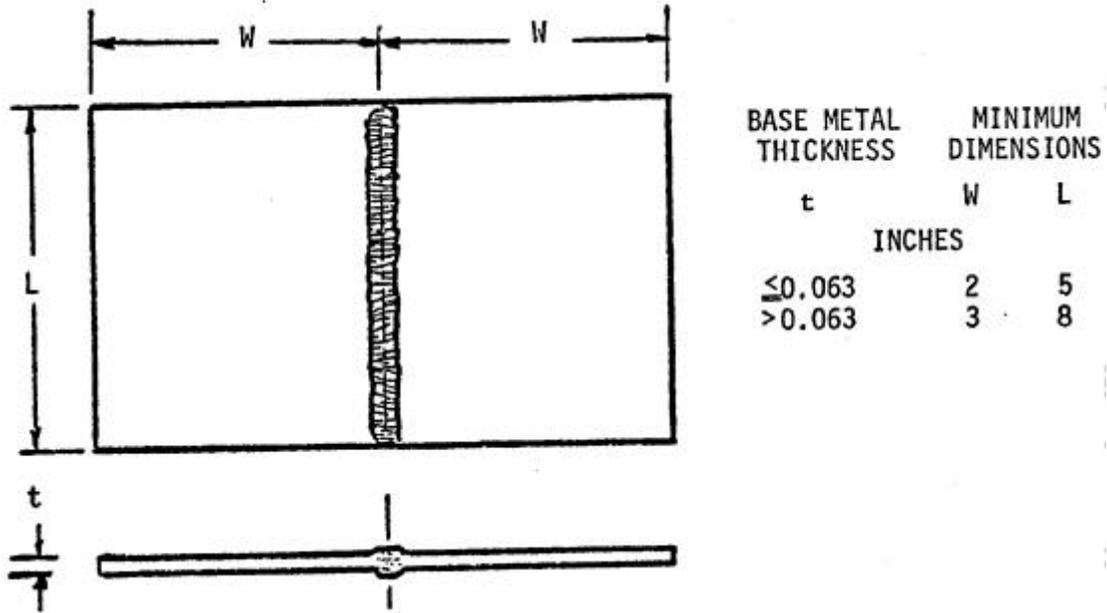
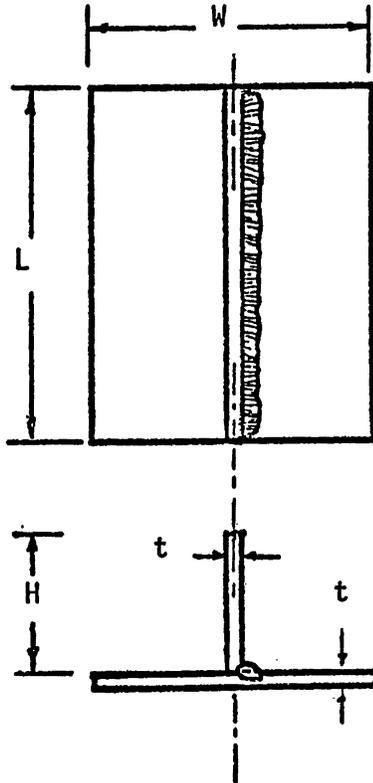


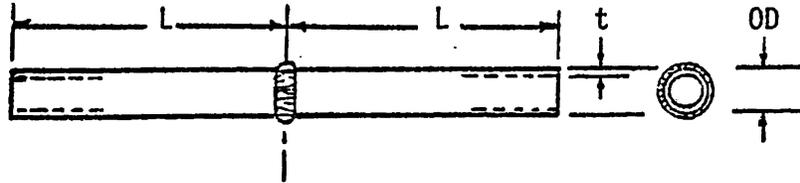
FIGURE 6. Groove test weld in sheet.



| BASE METAL<br>THICKNESS<br>t | MINIMUM<br>DIMENSIONS |   |   |
|------------------------------|-----------------------|---|---|
|                              | W                     | L | H |
| INCHES                       |                       |   |   |
| ≤ 0.063                      | 4                     | 5 | 2 |
| > 0.063                      | 4                     | 8 | 3 |

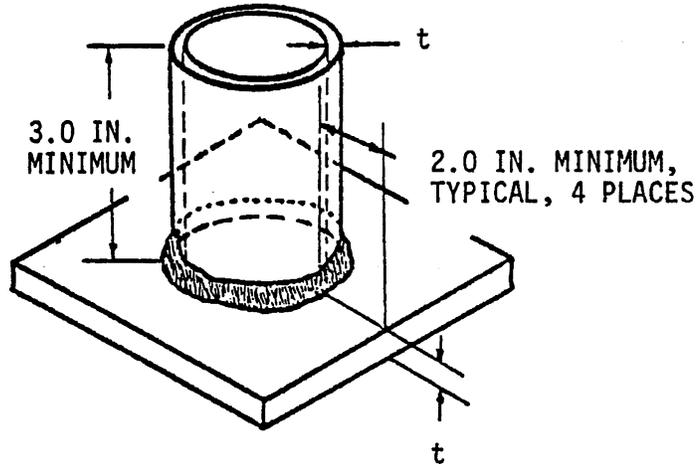
NOTE: Where the members differ in thickness more than 10 percent of the thicker, the cap sheet shall be the thicker.

FIGURE 7. Fillet test weld in sheet.



| BASE METAL<br>WALL THICKNESS | MINIMUM<br>DIMENSIONS |
|------------------------------|-----------------------|
| t                            | L                     |
| INCHES                       |                       |
| ≤ 0.063                      | 2                     |
| > 0.063                      | 3                     |

FIGURE 8. Groove test weld in tube.



NOTE: Where the members differ in thickness equal to or more than 10 percent of the thicker member, the sheet shall be the thicker member.

FIGURE 9. Fillet test weld in tube.

- 5.7.2 Fillet test weld in sheet: The test weld is a T-joint in sheet as described in Figure 7.
- 5.7.3 Groove test weld in tube: The test weld is a butt joint in tube as described in Figure 8.
- 5.7.4 Fillet test weld in tube: The test weld is a tube to sheet joint as described in Figure 9.
- 5.7.5 Special applications: When none of the test welds described above are applicable to a given production weld, a more limited welder or welding operator qualification may be achieved with a test weld consisting of the given production weld or a test weld representative of the given production weld.
- 5.7.5.1 Qualification limitations: The qualification is limited to the welding conditions of the test weld with regard to welding process, base metal composition, base metal thickness, welding position, base metal form, type of weld and the other welding conditions of 5.6.
- 5.7.5.2 Acceptance criteria: The required inspection, examination, bend testing, and acceptance criteria shall be consistent with 5.9 through 5.14.
- 5.8 Inspection, examination, and bend testing requirements:
- 5.8.1 Visual inspection: Visual inspection is required for all test welds and shall be completed with the test weld in the as-welded condition.
- 5.8.2 Radiographic inspection: Radiographic inspection is required for all groove welds, except that bend testing may be used as an alternate under the following conditions.
- The base metal is not included in Table VI.
  - The base metal is included in the Appendix.
  - The members of the test weld differ in thickness by less than 10 percent of the thicker member.
  - For tube welds, the outside diameter is equal to or more than 2 inches or the wall thickness is equal to or more than 0.250 inch.
- 5.8.3 Bend testing: Bend testing is required for all fillet welds with a base metal thickness of more than 0.063 inch, except that metallographic examination may be used as an alternate to bend testing. Bend testing of groove welds may be used as an alternate to radiographic inspection as described in 5.8.2.

TABLE VI. Base metals for which bend testing is not applicable.

| Base metal group | Unified number                                                                                                                 | Common description                                                                                                                                                                                        |
|------------------|--------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Ia               | NA<br>K92810                                                                                                                   | 9Ni-4Co steel<br>18Ni maraging steel                                                                                                                                                                      |
| Ib               | A11                                                                                                                            |                                                                                                                                                                                                           |
| IIa              | K63198<br>K63199<br>R30155<br>R30590<br>S15500<br>S17400<br>S35000<br>S35500<br>S41800<br>S42000<br>S42200<br>S45000<br>S45500 | 19-9 DL<br>19-9 DX<br>N155<br>S590<br>15-5PH stainless steel<br>17-4PH stainless steel<br>AM350 PH stainless steel<br>AM355 PH stainless steel<br>Greek Ascoloy<br>420<br>422<br>Custom 450<br>Custom 455 |
| IIb              | A11                                                                                                                            |                                                                                                                                                                                                           |
| IIIb             | A11                                                                                                                            |                                                                                                                                                                                                           |
| IV               | A03560<br>A92014<br>A92219                                                                                                     | 356<br>2014<br>2219                                                                                                                                                                                       |
| V                | A11                                                                                                                            |                                                                                                                                                                                                           |
| VI               | R54620<br>R56210<br>R56260<br>R56620<br>R58640<br>NA<br>NA                                                                     | Ti-6Al-2Sn-4Zr-2Mo<br>Ti-6Al-2Cb-1Ta-1Mo<br>Ti-6Al-2Sn-4Zr-6Mo<br>Ti-6Al-6V-2Sn<br>Ti-3Al-8V-6Cr-4Mo-4Zr<br>Ti-6Al-2Sn-2Zr-2Cr-2Mo<br>Ti-15V-3Cr-3Mo-3Sn                                                  |
| VII              | A11                                                                                                                            |                                                                                                                                                                                                           |

- 5.8.4 Metallographic examination: Metallographic examination is required for all fillet welds with a base metal thickness of equal to or less than 0.063 inch. Metallographic examination may be used as an alternate to bend testing for fillet welds with a base metal thickness of more than 0.063 inch.
- 5.8.5 Summary: The required inspection, examination, and bend testing of test welds are summarized in Table VII.
- 5.9 Visual inspection procedure: Visual inspection shall be completed with the test weld in the as-welded condition.
- 5.9.1 Weld length: The center 4-inch length of welds in sheet of equal to or less than 0.063 inch thickness, the center 6-inch length of welds in sheet of more than 0.063 inch thickness, and the entire weld in tubes shall be inspected.
- 5.9.2 Magnification: Inspection shall be performed at a magnification of 3X for welds in base metal with a thickness of equal to or less than 0.063 inch and without magnification for more than 0.063 inch.
- 5.10 Radiographic inspection procedure: Radiographic inspection shall be completed with the test weld in the as-welded condition, except as modified by MIL-STD-453.
- 5.10.1 Weld length: The same length of weld as given in 5.9.1 shall be inspected.
- 5.10.2 Radiography standard: Radiography shall be performed in accordance with MIL-STD-453.
- 5.10.3 Radiographer qualification: Radiographers shall be qualified in accordance with MIL-STD-410.
- 5.11 Preparation of bend specimens: Blanks for bend specimens may be removed from the test weld by any means of cutting, provided that any crack or heat affected zone caused by cutting is removed by mechanical means.
- 5.11.1 Groove welds in sheet:
- Blanks for bend specimens shall be removed from test welds at the locations shown in Figure 10.
  - The bend specimen type and dimensions for sheet are given in Table VIII. Each specimen type identified in Column 3 of Table VIII is illustrated in Figure 11.

TABLE VII. Required inspection, examination, and bend testing of test welds.

| Weld type    | Base metal |                   | Visual | Radio graphic | Bend           |                  |                    | Metallographic |                  |                    |                         |
|--------------|------------|-------------------|--------|---------------|----------------|------------------|--------------------|----------------|------------------|--------------------|-------------------------|
|              | Form       | Thickness t, inch |        |               | Applica-bility | Figure reference | Specimens required | Applica-bility | Figure reference | Specimens required | Cross sections required |
| 1            | 2          | 3                 | 4      | 5             | 6              | 7                | 8                  | 9              | 10               | 11                 | 12                      |
| Groove Sheet |            | $\leq 0.063$      | A11    | A11 1/        | 1/             | 10 & 11          | 1                  | None           |                  |                    |                         |
|              |            | $> 0.063$         | A11    | A11 1/        | 1/             | 10 & 11          | 2                  | None           |                  |                    |                         |
| Groove Tube  |            | $\leq 0.063$      | A11    | A11           | None           |                  |                    | None           |                  |                    |                         |
|              |            | $> 0.063$         | A11    | A11 1/        | 1/             | 12 & 13          | 2                  | None           |                  |                    |                         |
| Fillet Sheet |            | $\leq 0.063$      | A11    | None          | None           |                  |                    | A11            | 19               | 4                  | 8                       |
|              |            | $> 0.063$         | A11    | None          | A11 2/         | 14               | 1                  | 2/             | 19               | 4                  | 8                       |
| Fillet Tube  |            | $\leq 0.063$      | A11    | None          | None           |                  |                    | A11            | 20               | 4                  | 8                       |
|              |            | $> 0.063$         | A11    | None          | A11 2/         | 15               | 2                  | 2/             | 20               | 4                  | 8                       |

1/ Bend testing may be used as an alternate to radiographic inspection as described in 5.8.2.  
 2/ Metallographic examination may be used as an alternate to bend testing.

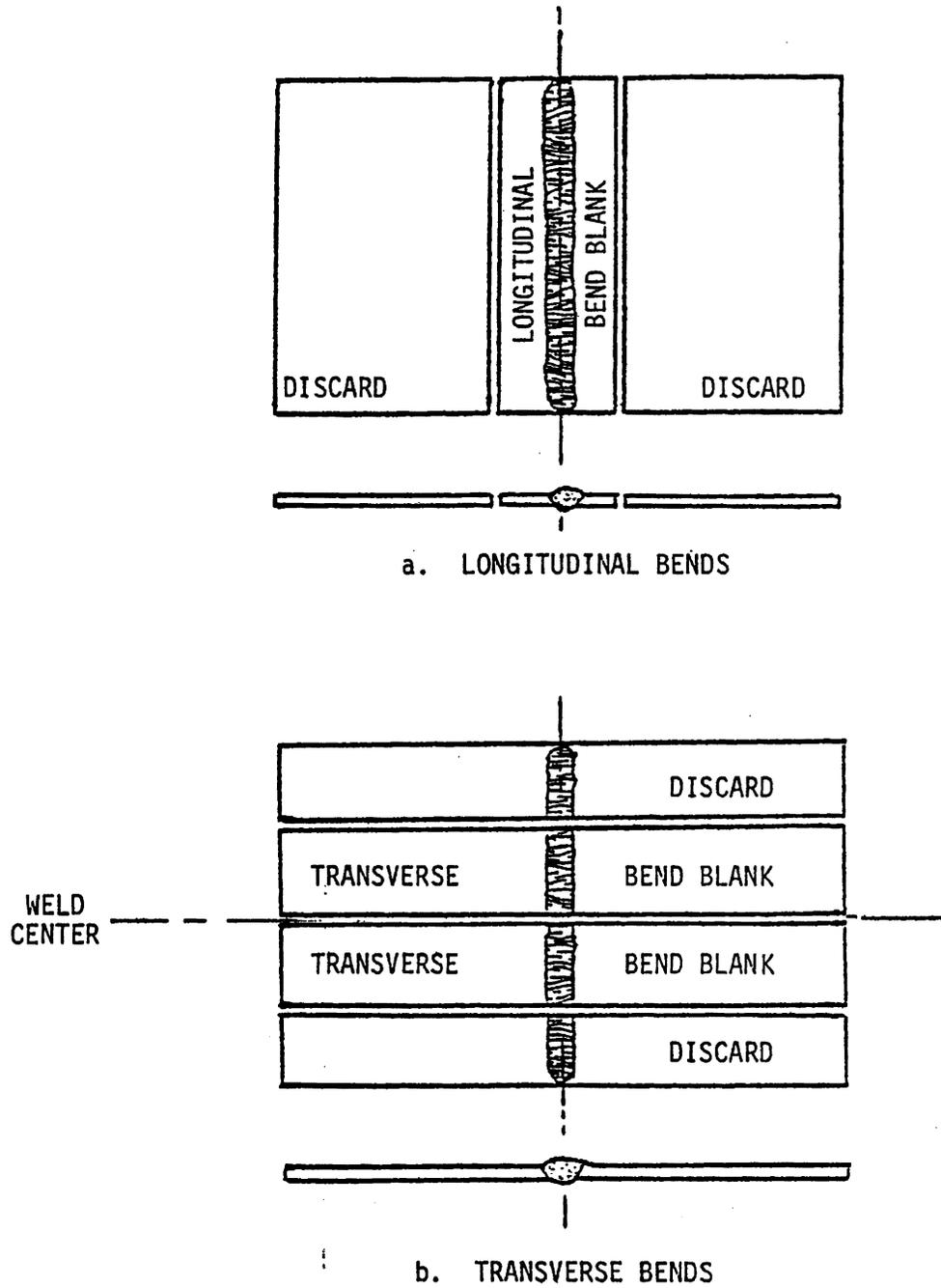
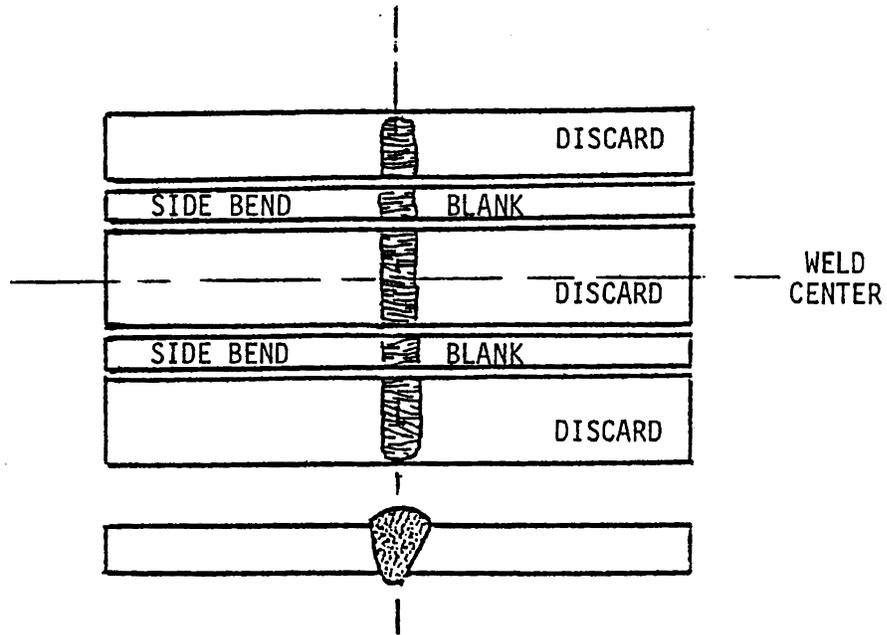


FIGURE 10. Blank locations for bend specimens in groove-welded sheet.



c. SIDE BENDS

NOTE: Discard pieces from b to be of equal width.  
Discard pieces from c to be of equal width.

FIGURE 10. Blank locations for bend specimens in groove-welded sheet. Continued.

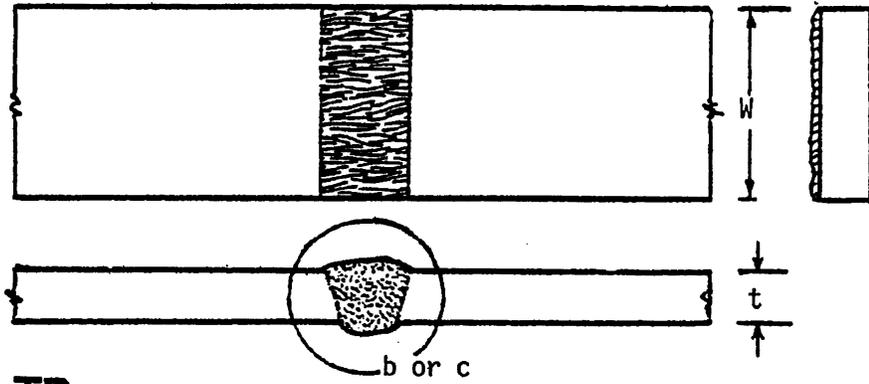
TABLE VIII. Bend specimens for groove welds in sheet.

| Base metal             |           | Bend test specimen         |                  |           |           |           |      |
|------------------------|-----------|----------------------------|------------------|-----------|-----------|-----------|------|
| Thickness<br>t<br>inch | No.       | Type<br>shown in<br>Fig.11 | Dimensions, inch |           |           |           |      |
|                        |           |                            | t <sub>1</sub>   |           | L<br>Min. | W         |      |
|                        |           |                            | Min.             | Max.      |           | Min.      | Max. |
| 1                      | 2         | 3                          | 4                | 5         | 6         | 7         | 8    |
| ≤ 0.063                | A11       | LB-a                       | t                | <u>1/</u> | 5         | 1.00      | 1.05 |
| > 0.063-<br>0.125      | A11       | TB-b & TB-c                | 0.9t             | t         | 6         | 1.50      | 1.55 |
| > 0.125-<br>0.375      | <u>2/</u> | TB-b & TB-c                | 0.115            | 0.135     | 6         | 1.50      | 1.55 |
|                        | Others    | TB-b & TB-c                | 0.9t             | t         | 6         | 1.50      | 1.55 |
| > 0.375-<br>0.750      | <u>2/</u> | TB-b & TB-c<br>or<br>SB-d  | 0.115            | 0.135     | 6         | t         | t    |
|                        | Others    | TB-b & TB-c<br>or<br>SB-d  | 0.350            | 0.400     | 6         | 1.50      | 1.55 |
|                        |           |                            | 0.350            | 0.400     | 6         | t         | t    |
| > 0.750                | <u>2/</u> | SB-d                       | 0.115            | 0.135     | 6         | <u>3/</u> | t    |
|                        | Others    | SB-d                       | 0.350            | 0.400     | 6         | <u>3/</u> | t    |

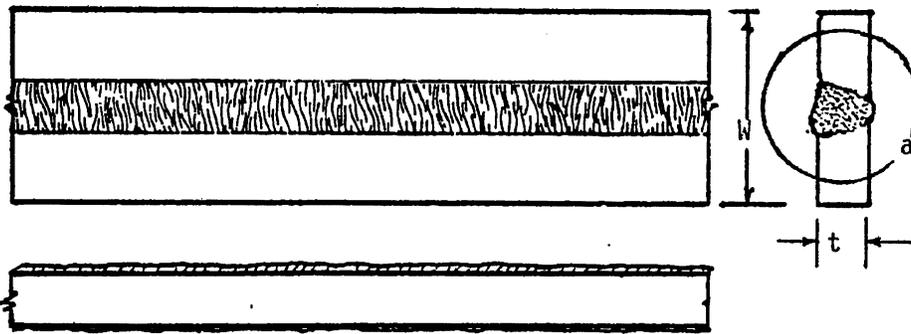
1/ The weld face and root surfaces shall be dressed to produce smooth surfaces with a maximum weld metal thickness variation of 10 percent.

2/ A96061 and A96063 of Base Metal Group IV.

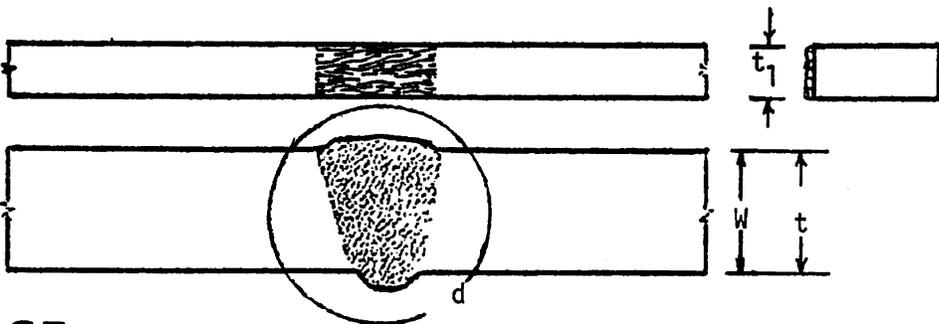
3/ For base metal thicknesses of >0.750 to 1.50 inch, W is equal to t. For base metal thicknesses of >1.50 inch specimens may be cut into approximately equal strips between 0.75 and 1.50 inch wide for testing, or the specimens may be bent at full width.



**TB** TRANSVERSE BEND

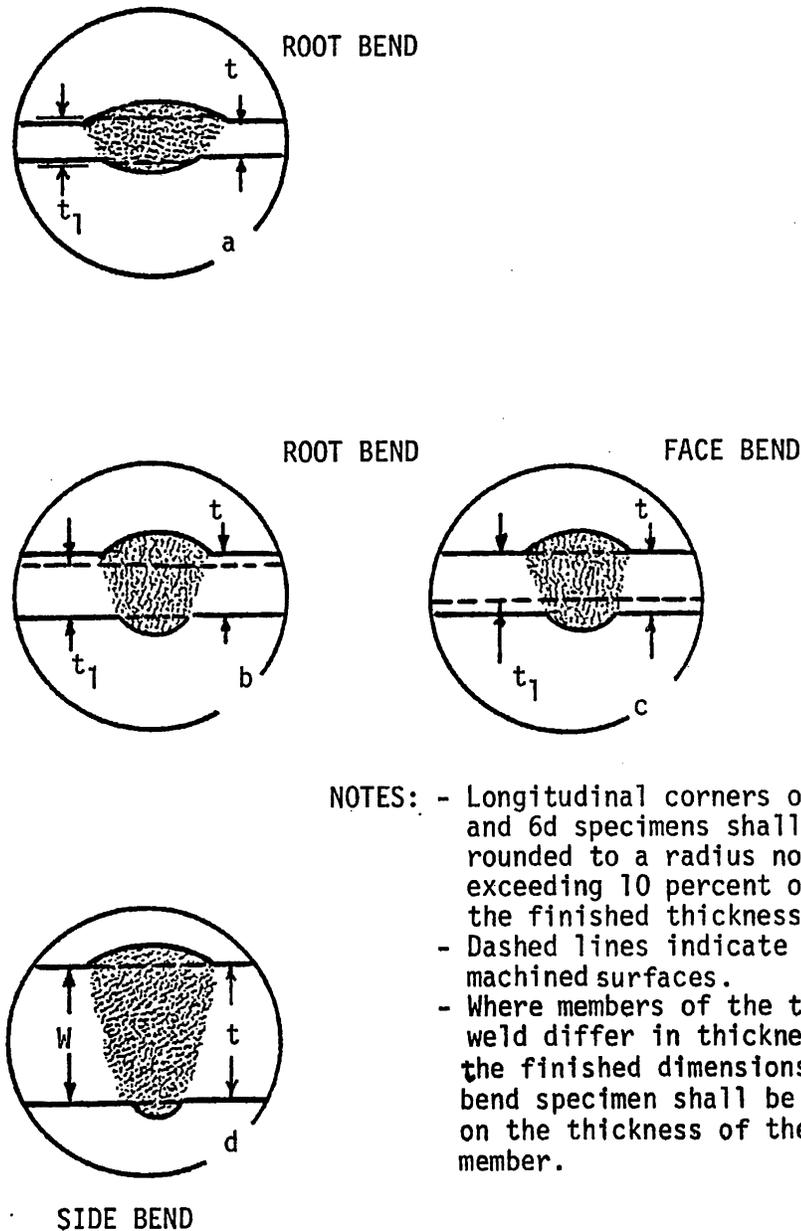


**LB** LONGITUDINAL BEND



**SB** SIDE BEND

FIGURE 11. Bend specimens in groove-welded sheet.



- NOTES: - Longitudinal corners of 6b, 6c, and 6d specimens shall be rounded to a radius not exceeding 10 percent of the finished thickness.
- Dashed lines indicate machined surfaces.
- Where members of the test weld differ in thickness, the finished dimensions of the bend specimen shall be based on the thickness of the thicker member.

FIGURE 11. Bend specimens in groove-welded sheet. Continued.

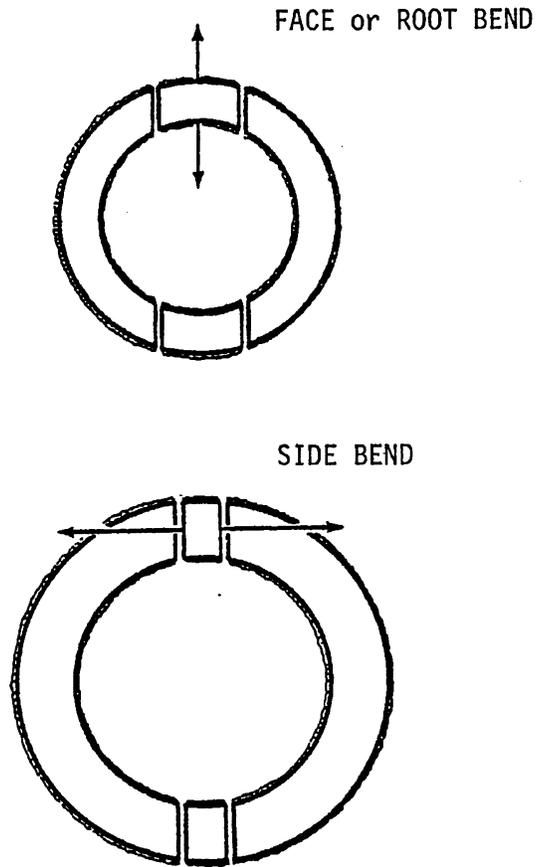


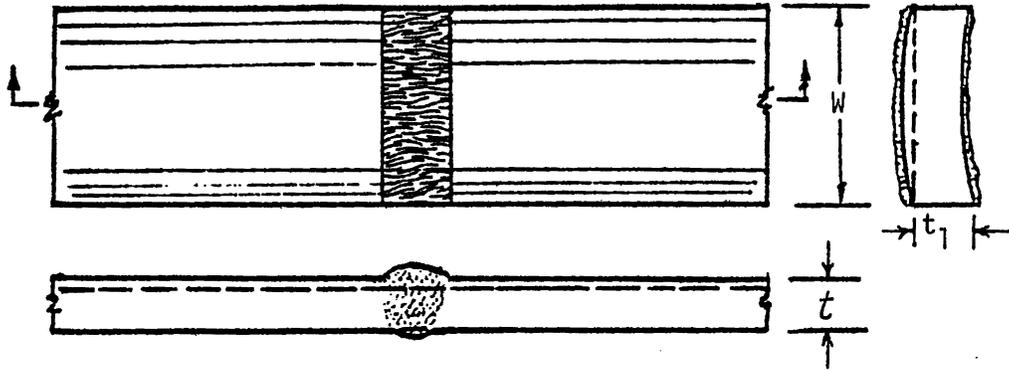
FIGURE 12. Blank locations for bend specimens in groove-welded tube.

- 5.11.2 Groove welds in tube:
- Blanks for bend specimens shall be removed from test welds at the locations shown in Figure 12.
  - The bend specimen type and dimensions for tube are given in Table IX. Each specimen type identified in Column 4 of Table IX is illustrated in Figure 13.
- 5.11.3 Fillet welds in sheet: Blanks for bend specimens shall be removed from the test weld at the location shown in Figure 14.
- 5.11.4 Fillet welds in tube: Blanks for bend specimens shall be removed from the test weld at the locations shown in Figure 15.
- 5.12 Bend testing procedure: Testing may be performed with the bend specimen either in the as-welded or any heat-treated condition.
- 5.12.1 Groove welds:
- 5.12.1.1 Base metal thickness of more than 0.063 inch: Bend specimens shall be bent in the wrap-around bend test fixture illustrated in Figure 16. After clamping the bend specimen firmly in place, the roller (planetary cylinder) shall be advanced slowly through an arc of 180 degrees from its starting location directly below the fixed mandrel (cylinder with radius A). Root bend specimens shall be placed with the weld root out toward the roller and face bend specimens shall be placed with the weld face out toward the roller.
- 5.12.1.2 Alternate method for base metal thickness of more than 0.063 inch: Bend specimens shall be bent in the ram-and-die bend test fixture illustrated in Figure 17. After placing the bend specimen across the die shoulders, with the center of the weld at the center of the die opening for transverse bend and side bend specimens, the specimen shall be forced into the die cavity by applying a load to the ram until the curvature of the specimen will now allow a wire of 0.12 inch diameter to be inserted between the specimen and the die cavity. Root bend specimens shall be placed with the weld face against the ram and face bend specimens shall be placed with the weld root against the ram.
- 5.12.1.3 Base metal thickness of equal to or less than 0.063 inch: Bend specimens with a base metal thickness of equal to or less than 0.063 inch shall be tested in a manner similar to that described in 5.12.1.1, except that the roller is not used. The free end of the bend specimen is gripped with pliers and slowly wrapped around the fixed mandrel. Specimens shall be placed with the weld face against the fixed mandrel.

TABLE IX. Bend specimens for groove welds in tube.

| Tube                     |                           |                      | Bend test specimen        |                         |           |           |       |
|--------------------------|---------------------------|----------------------|---------------------------|-------------------------|-----------|-----------|-------|
| Outside diameter<br>inch | Wall thickness<br>t, inch | Base metal<br>number | Type shown in<br>Fig.13   | Dimensions, inch        |           |           |       |
|                          |                           |                      |                           | t                       |           | W         |       |
|                          |                           |                      |                           | Min.                    | Max.      | Min.      | Max.  |
| 1                        | 2                         | 3                    | 4                         | 5                       | 6         | 7         | 8     |
| < 2                      | A11                       |                      |                           | Radiographic inspection |           |           |       |
| 2-5                      | <0.250                    |                      |                           | Radiographic inspection |           |           |       |
|                          | $\geq 0.250$ -<br>0.375   | <u>1/</u>            | TB-e & TB-f               | 0.115                   | 0.135     | 0.750     | 0.800 |
|                          |                           | Others               | TB-e & TB-f               | <u>2/</u>               | <u>2/</u> | 0.750     | 0.800 |
|                          | <0.375-<br>0.750          | <u>1/</u>            | TB-e & TB-f<br>or<br>SB-g | 0.115                   | 0.135     | 0.750     | 0.800 |
|                          |                           | Others               | TB-e & TB-f<br>or<br>SB-g | <u>3/</u>               | <u>3/</u> | 0.750     | 0.800 |
|                          | >0.750                    | <u>1/</u>            | SB-g                      | 0.115                   | 0.135     | t         | t     |
| Others                   |                           | SB-g                 | 0.350                     | 0.400                   | t         | t         |       |
| > 5                      | <0.250                    |                      |                           | Radiographic inspection |           |           |       |
|                          | $\geq 0.250$ -<br>0.375   | <u>1/</u>            | TB-e & TB-f               | 0.115                   | 0.135     | 1.50      | 1.55  |
|                          |                           | Others               | TB-e & TB-f               | <u>2/</u>               | <u>2/</u> | 1.50      | 1.55  |
|                          | >0.375-<br>0.750          | <u>1/</u>            | TB-e & TB-f<br>or<br>SB-g | 0.115                   | 0.135     | 1.50      | 1.55  |
|                          |                           | Others               | TB-e & TB-f<br>or<br>SB-g | <u>3/</u>               | <u>3/</u> | 1.50      | 1.55  |
|                          | >0.750                    | <u>1/</u>            | SB-g                      | 0.115                   | 0.135     | <u>4/</u> | t     |
| Others                   |                           | SB-g                 | 0.350                     | 0.400                   | <u>4/</u> | t         |       |

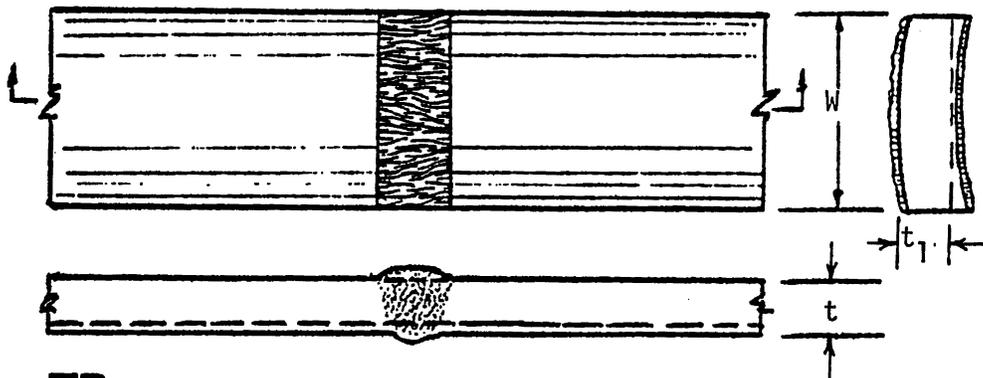
- 1/ A96061 and A96063 of Base Metal Group IV.
- 2/ The maximum  $t_1$  is the thickness resulting from dressing of the curved surface to a plane. The minimum  $t_1$  is 0.9 times the maximum.
- 3/ The maximum  $t_1$  is the thickness resulting from dressing the curved surface to a plane, or 0.400 in., whichever is the lesser. In the first case, the minimum  $t_1$  is 0.9 times the maximum. In the second case, the minimum  $t_1$  is 0.350 in.
- 4/ For wall thicknesses of > 0.750 to 1.50 in.,  $W$  is equal to  $t$ . For wall thicknesses of > 1.50 in., specimens may be cut into approximately equal strips between 0.75 and 1.50 in. wide for testing, or the specimens may be bent at full width.



**TB**

NOTE: The thickness of the transverse root bend specimen is measured at the specimen edge.

a. TRANSVERSE ROOT BEND

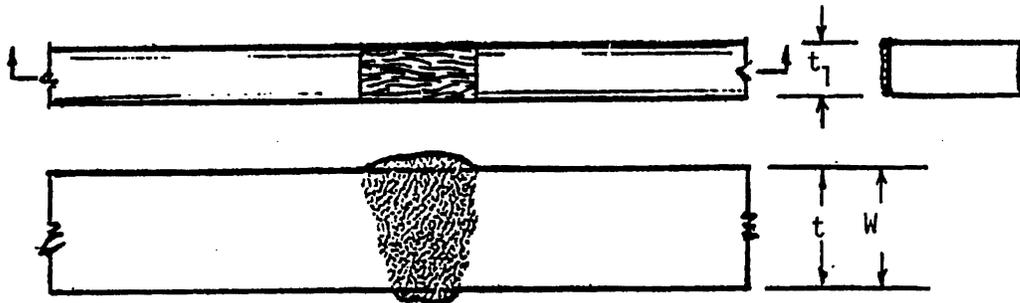


**TB**

NOTE: The thickness of the transverse root bend specimen is measured at the specimen center.

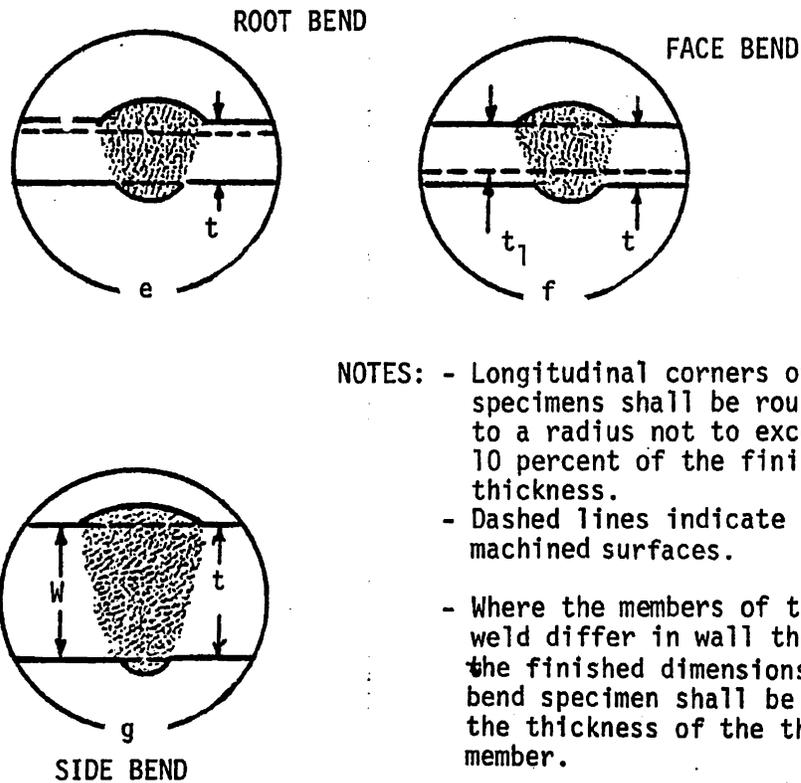
b. TRANSVERSE FACE BEND

FIGURE 13. Bend specimens in groove-welded tube.



SB

c. SIDE BEND



- NOTES:
- Longitudinal corners of all specimens shall be rounded to a radius not to exceed 10 percent of the finished thickness.
  - Dashed lines indicate machined surfaces.
  - Where the members of the test weld differ in wall thickness, the finished dimensions of the bend specimen shall be based on the thickness of the thicker member.

d. BEND SPECIMEN SECTION DETAILS

FIGURE 13. Bend specimens in groove-welded tube. Continued.

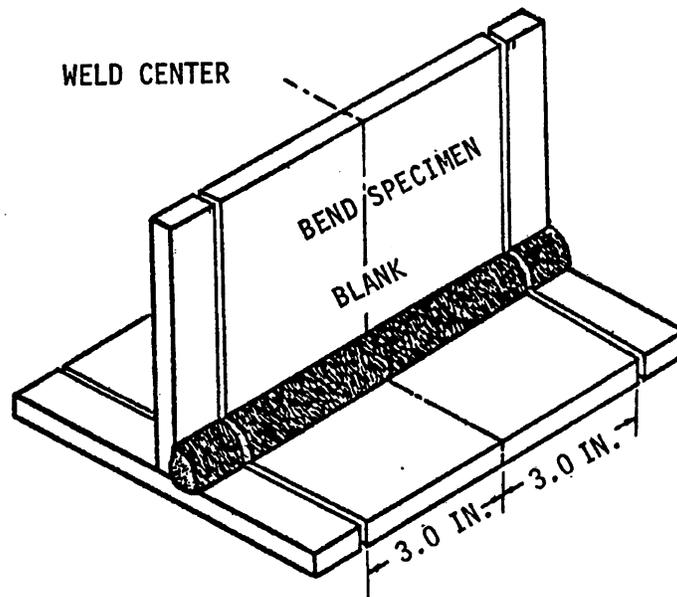
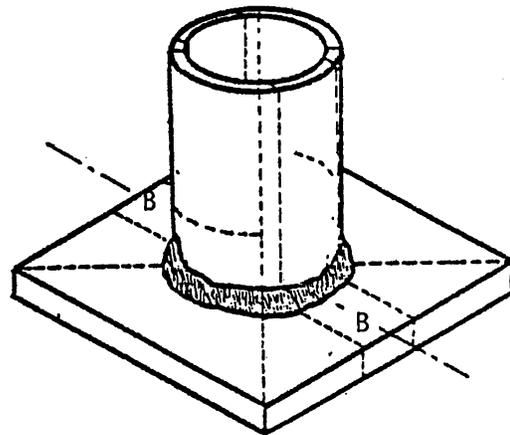
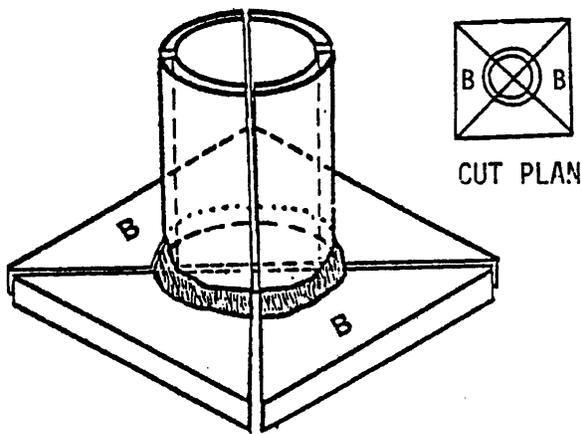
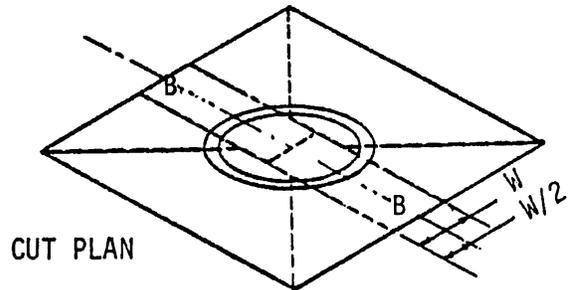


FIGURE 14. Blank location for bend specimens in fillet-welded sheet.

B = BEND SPECIMEN BLANK

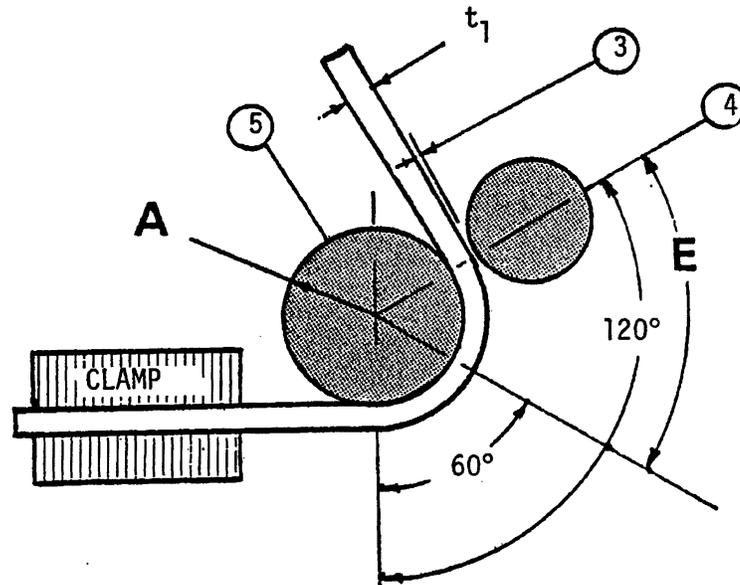


a. For tubes <1.5 in. in outside diameter, OD

b. For tubes  $\geq 1.5$  in. in outside diameter, OD

| OD         | W    |
|------------|------|
| INCHES     |      |
| 1.5 to 3.0 | 0.75 |
| > 3.0      | 1.50 |

FIGURE 15. Blank location for bend specimens in fillet-welded tube.

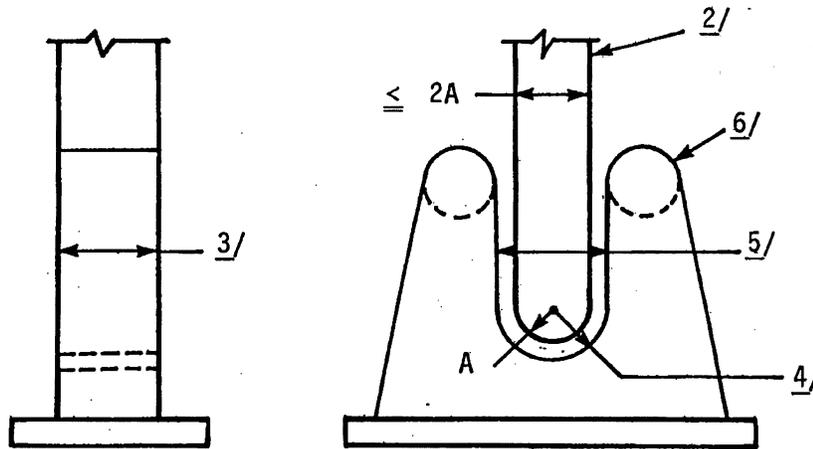


$A = Ft_1$ , where  $A$  is the bend radius  
 $F$  is the bend factor  
 $t_1$  is the bend specimen thickness

## NOTES:

1. Dimensions not shown are the option of the designer. An essential consideration is to have adequate rigidity for the applied loads.
2. For transverse weld bend specimens, the center of the weld shall be located within angle E.
3. This clearance dimension shall be a maximum of 0.06 inch plus  $0.1 t_1$ .
4. This roller shall be free to rotate about its cylindrical axis and shall have a minimum diameter of 0.75 inch. The minimum roller width shall be  $W$  plus 0.25 inch.
5. This fixed mandrel may or may not be free to rotate about its cylindrical axis and shall have a minimum width of  $W$  plus 0.25 inch.

FIGURE 16. Wrap-around bend test fixture.



$A = Ft_1$ , where  $A$  is the bend radius  
 $F$  is the bend factor  
 $t_1$  is the bend specimen thickness

NOTES:

- 1/ Dimensions not shown are the option of the designer. An essential consideration is to have adequate rigidity for the applied loads.
- 2/ The length of the ram shall be sufficient to reach the bottom of the die cavity. The ram shall be fitted with an appropriate base and provision shall be made for attachment to the testing machine.
- 3/ The minimum width of the die cavity and the ram shall be equal to  $W$  plus 0.25 in.
- 4/ The maximum radius of the die cavity shall be equal to  $A$  plus  $1.1t_1$  plus 0.06 in. The minimum depth shall be 2 in. The die shall be fitted with an appropriate base and provision shall be made for maintaining the ram centered in the die cavity.
- 5/ This dimension shall be twice the radius of the die cavity.
- 6/ Either hardened and greased shoulders or hardened rollers, free to rotate, shall be used. The minimum radius shall be  $5t_1$  or 0.75 in., whichever is less.

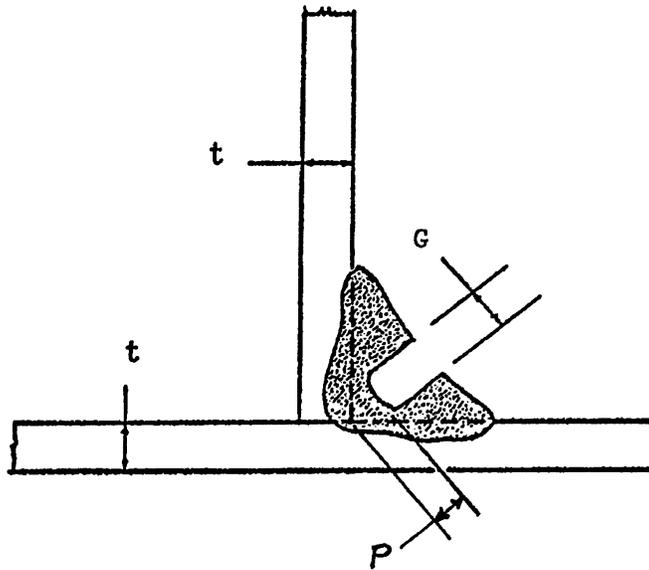
FIGURE 17. Ram-and-die bend test fixture.

- 5.12.1.4 Bend radius: The bend radius (A) to be used with a given bend specimen thickness and a given base metal may be found in Table X. Other ranges of bend specimen thickness and bend radius may be used, provided that the bend factor does not exceed the range of F to 1.1F. (See equation of Figure 16.)
- 5.12.2 Fillet welds:
- 5.12.2.1 Loading: The stem of the bend specimen shall be loaded parallel to the cap sheet, so that the root of the weld is in tension. The load shall be slowly increased until the specimen fractures in the weld.
- 5.12.2.2 Weld fracture: Where it is necessary to ensure fracture in the weld, the weld face shall be grooved as shown in Figure 18. For fillet welds in tube, the groove shall be cut before the bend specimen blanks are removed from the test weld.
- 5.13 Metallographic examination: Blanks for metallographic specimens shall be removed from test welds in accordance with Figures 19 and 20.
- 5.13.1 Cutting: Removal from the test weld may be by any means of cutting, provided that any crack or heat affected zone caused by cutting is removed by mechanical means.
- 5.13.2 Trimming: Extraneous metal may be trimmed from the blanks, either before or after removal from the test weld, to obtain a metallographic specimen of convenient size, provided that the entire weld and heat affected zone at the designated cross section remains in the metallographic specimen.
- 5.13.3 Cross sections: Each of the cut weld cross sections, designated in Figures 19 and 20, of the metallographic specimens shall be smoothed by fine abrasive or file and etched with a suitable reagent to clearly reveal the weld macrostructure for examination at a magnification of 5X.
- 5.14 Acceptance criteria:
- 5.14.1 Visual inspection:
- 5.14.1.1 Groove welds: Groove welds in sheet or tube which have any of the following defects are unacceptable:
- Any type of crack.
  - Incomplete joint penetration.
  - Underfill.

TABLE X. Bend specimen thickness and bend radius.

| Bend<br>Radius<br>A<br>Inch <sup>2/</sup> | Bend specimen thickness <sup>1/</sup> |                  |                            |             |                            |             |
|-------------------------------------------|---------------------------------------|------------------|----------------------------|-------------|----------------------------|-------------|
|                                           | Unified number                        |                  |                            |             |                            |             |
|                                           | R54520<br>R54810<br>R56320<br>R56400  | A96061<br>A96063 | R50400<br>R50550<br>R52400 | R50250      | A95083<br>A95086<br>A95456 | Others      |
|                                           | F = 12 <sup>3/</sup>                  | F = 8            | F = 5                      | F = 4       | F = 3                      | F = 2       |
|                                           | ≥ <                                   | ≥ <              | ≥ <                        | ≥ <         | ≥ <                        | ≥ <         |
| 0.070                                     |                                       |                  |                            |             |                            | 0.031 0.035 |
| 0.079                                     |                                       |                  |                            |             |                            | 0.035 0.039 |
| 0.088                                     |                                       |                  |                            |             |                            | 0.039 0.044 |
| 0.099                                     |                                       |                  |                            |             | 0.029 0.033                | 0.044 0.050 |
| 0.111                                     |                                       |                  |                            |             | 0.033 0.037                | 0.050 0.056 |
| 0.125                                     |                                       |                  |                            |             | 0.037 0.042                | 0.056 0.062 |
| 0.140                                     |                                       |                  |                            | 0.031 0.035 | 0.042 0.047                | 0.062 0.070 |
| 0.157                                     |                                       |                  |                            | 0.035 0.039 | 0.047 0.052                | 0.070 0.078 |
| 0.176                                     |                                       |                  | 0.031 0.035                | 0.039 0.044 | 0.052 0.059                | 0.078 0.088 |
| 0.198                                     |                                       |                  | 0.035 0.040                | 0.044 0.049 | 0.059 0.066                | 0.088 0.099 |
| 0.222                                     |                                       |                  | 0.040 0.044                | 0.049 0.055 | 0.066 0.074                | 0.099 0.111 |
| 0.249                                     |                                       |                  | 0.044 0.050                | 0.055 0.062 | 0.074 0.083                | 0.111 0.124 |
| 0.279                                     |                                       | 0.031 0.035      | 0.050 0.056                | 0.062 0.070 | 0.083 0.093                | 0.124 0.140 |
| 0.313                                     |                                       | 0.035 0.039      | 0.056 0.063                | 0.070 0.078 | 0.093 0.104                | 0.140 0.157 |
| 0.351                                     |                                       | 0.039 0.044      | 0.063 0.070                | 0.078 0.088 | 0.104 0.117                | 0.157 0.176 |
| 0.394                                     | 0.029 0.033                           | 0.044 0.049      | 0.070 0.079                | 0.088 0.099 | 0.117 0.131                | 0.176 0.197 |
| 0.442                                     | 0.033 0.037                           | 0.049 0.055      | 0.079 0.088                | 0.099 0.111 | 0.131 0.147                | 0.197 0.221 |
| 0.496                                     | 0.037 0.041                           | 0.055 0.062      | 0.088 0.099                | 0.111 0.124 | 0.147 0.165                | 0.221 0.248 |
| 0.557                                     | 0.041 0.046                           | 0.062 0.070      | 0.099 0.111                | 0.124 0.139 | 0.165 0.186                | 0.248 0.279 |
| 0.625                                     | 0.046 0.052                           | 0.070 0.078      | 0.111 0.125                | 0.139 0.156 | 0.186 0.208                | 0.279 0.312 |
| 0.701                                     | 0.052 0.058                           | 0.078 0.088      | 0.125 0.140                | 0.156 0.175 | 0.208 0.234                | 0.312 0.351 |
| 0.787                                     | 0.058 0.066                           | 0.088 0.098      | 0.140 0.157                | 0.175 0.197 | 0.234 0.262                | 0.351 0.393 |
| 0.883                                     | 0.066 0.074                           | 0.098 0.110      | 0.157 0.177                | 0.197 0.221 | 0.262 0.294                |             |
| 0.991                                     | 0.074 0.083                           | 0.110 0.124      | 0.177 0.198                | 0.221 0.248 | 0.294 0.330                |             |
| 1.111                                     | 0.083 0.093                           | 0.124 0.139      | 0.198 0.222                | 0.248 0.278 | 0.330 0.370                |             |
| 1.247                                     | 0.093 0.104                           | 0.139 0.156      | 0.222 0.249                | 0.278 0.312 | 0.370 0.416                |             |
| 1.399                                     | 0.104 0.117                           | 0.156 0.175      | 0.249 0.280                | 0.312 0.350 |                            |             |
| 1.570                                     | 0.117 0.131                           | 0.175 0.196      | 0.280 0.314                | 0.350 0.392 |                            |             |
| 1.761                                     | 0.131 0.147                           | 0.196 0.220      | 0.314 0.352                |             |                            |             |
| 1.976                                     | 0.147 0.165                           | 0.220 0.247      | 0.352 0.395                |             |                            |             |
| 2.218                                     | 0.165 0.185                           | 0.247 0.277      |                            |             |                            |             |
| 2.488                                     | 0.185 0.207                           | 0.277 0.311      |                            |             |                            |             |
| 2.782                                     | 0.207 0.233                           | 0.311 0.349      |                            |             |                            |             |
| 3.132                                     | 0.233 0.261                           | 0.349 0.392      |                            |             |                            |             |
| 3.515                                     | 0.261 0.293                           |                  |                            |             |                            |             |
| 3.943                                     | 0.293 0.329                           |                  |                            |             |                            |             |
| 4.425                                     | 0.329 0.369                           |                  |                            |             |                            |             |
| 4.965                                     | 0.369 0.414                           |                  |                            |             |                            |             |

- 1/ The body of the table contains the bend specimen thickness ( $t_1$ ) in inches.
- 2/ The tolerance on bend radius A is  $\pm 0.001$  in. or  $\pm 1\%$ , whichever is the larger.
- 3/ F = Bend factor



NOTES:  $G$  shall be a maximum of  $0.5 t$   
or  $0.25$  inch, whichever is less.

$P$  shall be no less than  $0.5 t$ .

FIGURE 18. Slotted fillet weld.

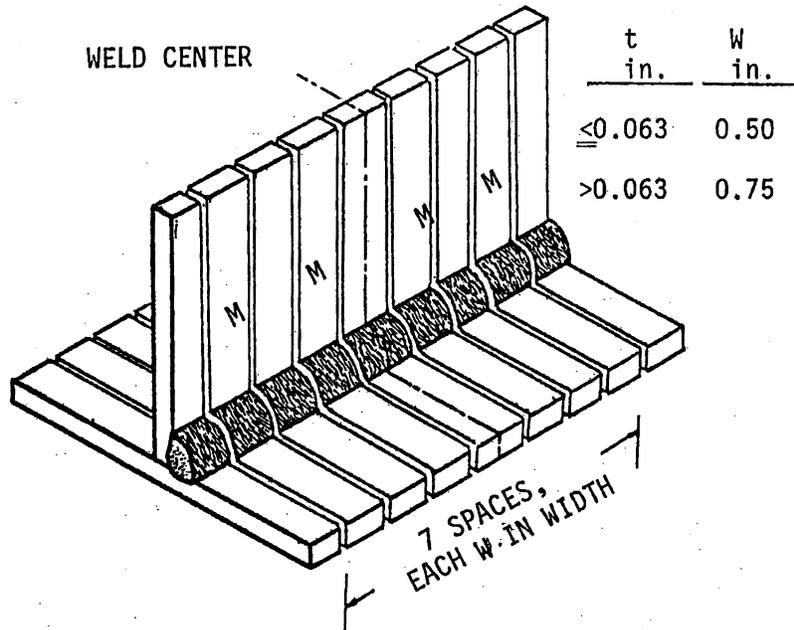


FIGURE 19. Blank locations for metallographic specimens in fillet-welded sheet.

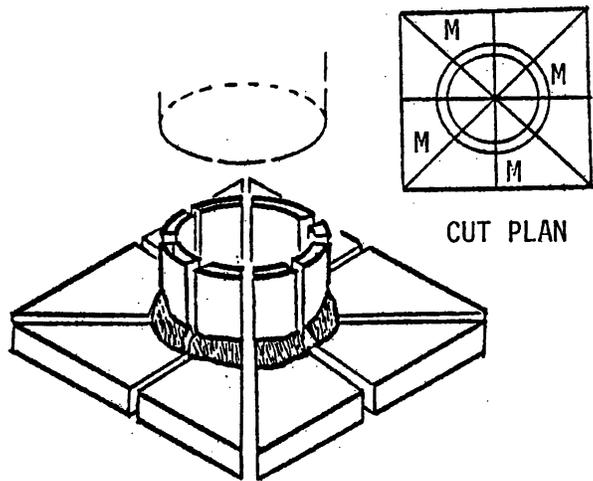


FIGURE 20. Blank locations for metallographic specimens in fillet-welded tube.

## 5.14.1.1 (Continued):

- d. Overlap.
- e. For test welds with a base metal thickness of more than 0.063 inch, undercut at any location in excess of 0.05 t or 0.032 inch, whichever is the lesser.
- f. Mismatch at any location in excess of 10 percent of the base metal thickness or 0.12 inch, whichever is the lesser, except that a mismatch up to 25 percent is allowed for a base metal thickness of equal to or less than 0.063 inch.
- g. Reinforcement of the weld face or the weld root in excess of that shown in Table XI.

## 5.14.1.2 Fillet welds: Fillet welds in sheet or tube which have either of the following defects are unacceptable:

- a. Any type of crack.
- b. Overlap.

## 5.14.1.3 Base metal thickness of more than 0.063 inch: Fillet welds in sheet or tube with a base metal thickness of more than 0.063 inch, which have any of the following defects, are unacceptable:

- a. Undercut at any location in excess of 0.1 t or 0.063 inch, whichever is the lesser.
- b. Fusion evident at any sheet or tube surface opposite the weld bead.
- c. For base metal thickness equal to or less than 1 inch, a leg size less than t. For a base metal thickness of more than 1 inch, the minimum leg size shall be 1 inch. Where the members of the test weld differ in thickness, the minimum leg size shall be based on the thinner member.
- d. For base metal thickness equal to or less than 1 inch, a leg size in excess of 3 t, or t plus 0.25 inch, whichever is the lesser. For a base metal thickness more than 1 inch, the maximum leg size shall be 1.25 inch. Where the members of the test weld differ in thickness, the maximum leg size shall be based on the thinner member.
- e. A ratio of the leg of larger size to the leg of smaller size greater than 1.5 at any location.
- f. For a convex weld, at any location a convexity in excess of 0.1 times the average leg size at that location.
- g. For a concave weld, a theoretical throat size of less than 0.5 t at any location. Where the members of the test weld differ in thickness, the minimum theoretical throat size shall be based on the thinner member.

TABLE XI. Maximum allowable weld reinforcement.

| Base metal thickness $t$ , in. | Maximum allowable weld reinforcement <sup>1/</sup> |                                   |                                                                 |                                                                            |
|--------------------------------|----------------------------------------------------|-----------------------------------|-----------------------------------------------------------------|----------------------------------------------------------------------------|
|                                | Face                                               |                                   | Root                                                            |                                                                            |
|                                | Base metal group                                   | Any location                      | Base metal group                                                | Any location                                                               |
| $\leq 0.063$                   | A11                                                | 0.020 inch + $t$<br>or 0.050 inch | IV and V<br><br>Ia, Ib, IIa, IIb,<br>IIIa, IIIb, VI,<br>and VII | 0.030 inch + $t$<br>or 0.070 inch<br><br>0.020 inch + $t$<br>or 0.050 inch |
| $> 0.063$                      | A11                                                | 0.8 $t$<br>or 0.25 inch           | IV and V<br><br>Ia, Ib, IIa, IIb,<br>IIIa, IIIb, VI,<br>and VII | $t$<br>or 0.25 inch<br><br>0.8 $t$<br>or 0.25 inch                         |

<sup>1/</sup> The applicable maximum is the smaller of the two values given in the body of the table.

## 5.14.2 Radiographic inspection:

## 5.14.2.1 Interpretation of indications:

- a. A linear indication is defined as one whose maximum dimension is more than three times its minimum dimension.
- b. Non-linear indications with major and minor dimensions shall be evaluated as an equivalent circle with estimated average diameter. This estimated diameter shall be the size used in determining the acceptability of the indication, and the area corresponding to this estimated diameter shall be used in calculating the area of an indication.
- c. Tungsten inclusions shall be counted as porosity.
- d. In a test weld with a base metal thickness of equal to or less than 0.063 inch, disregard all indications of less than 0.002 inch size. In a test weld with a base metal thickness of more than 0.063 inch, disregard all indications of less than 0.005 inch or 0.02 t size, whichever is greater.

## 5.14.2.2 Unacceptable indications: Test welds, whose radiograph of the inspected length shows any of the following indications, are unacceptable:

- a. Any type of crack.
- b. Incomplete joint penetration, except as indicated in 5.14.2.2c.
- c. Internal linear indications in excess of those shown in Table XII.
- d. Porosity in excess of that shown in Table XIII. Examples of the allowable maximum total porosity area and the maximum pore size are shown in Figure 21.

TABLE XII. Maximum linear indications.

| Linear indication                            | Indication length <sup>1/</sup> |                                  |
|----------------------------------------------|---------------------------------|----------------------------------|
|                                              | Base metal thickness, inch      |                                  |
|                                              | ≤ 0.063                         | > 0.063                          |
| Length of any indication                     | 2 t                             | t or 0.38 inch <sup>2/</sup>     |
| Accumulated length in any 1 inch weld length | 2 t                             | t or 0.38 inch <sup>2/</sup>     |
| Average length                               | t                               | 0.5 t or 0.18 inch <sup>2/</sup> |

<sup>1/</sup> Where the members of the test weld differ in thickness, t is the thickness of the thicker member.

<sup>2/</sup> The applicable maximum is the smaller of the two values.

TABLE XIII. Maximum allowable porosity.

| Porosity                                             | Porosity size, area, or amount |                              |
|------------------------------------------------------|--------------------------------|------------------------------|
|                                                      | Base metal thickness <u>1/</u> |                              |
|                                                      | $\leq 0.063$ <u>2/</u>         | $> 0.063$ <u>3/</u>          |
| Any pore                                             | 0.6 t                          | 0.4 t or 0.18 inch <u>4/</u> |
| Pores of $> 0.3$ t                                   | 8 pores                        | NA                           |
| Pores of $> 0.2$ t or $> 0.12$ inch <u>4/</u>        | NA                             | 12 pores                     |
| Total porosity area                                  | $0.10 t \text{ inch}^2$        | $0.10 \text{ inch}^2$        |
| Cluster porosity area in any 1/2 inch of weld length | $0.04 t \text{ inch}^2$        | $0.025 t \text{ inch}^2$     |
| Aligned porosity area <u>5/</u>                      | $0.02 t \text{ inch}^2$        | $0.015 t \text{ inch}^2$     |

1/ Where the members of the test weld differ in thickness, t is the thickness of the thicker member.

2/ These values apply to a 4 inch weld length. For groove welds in tube, the values shall be adjusted in proportion to the tube circumference.

3/ These values apply to a 6 inch weld length. For groove welds in tube, the values shall be adjusted in proportion to the tube circumference.

4/ The applicable maximum is the lesser of the two values.

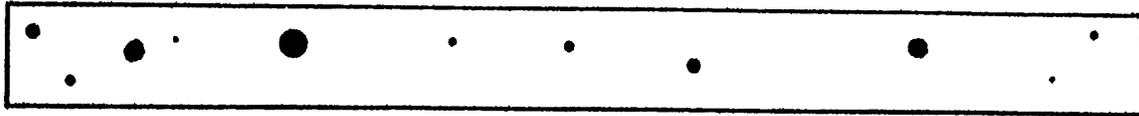
5/ Aligned porosity is defined as a group of more than 3 pores within 1/2 inch of weld length, and which may be intersected by a straight line.



- a. Base metal thickness: 0.032 inch  
Represents 1 inch of weld length at 5X magnification



- b. Base metal thickness: 0.063 inch  
Represents 2 inches of weld length at 3X magnification

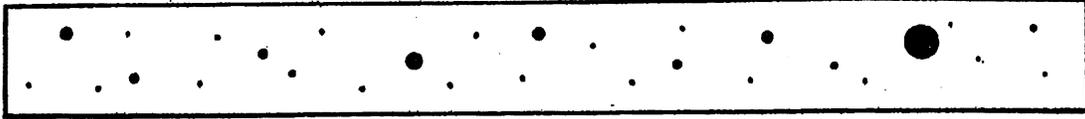


- c. Base metal thickness: 0.125 inch  
Represents 2 inches of weld length at 3X magnification

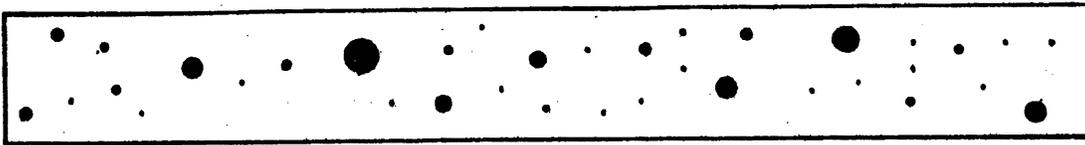


- d. Base metal thickness: 0.250 inch  
Represents 6 inches of weld length at no magnification

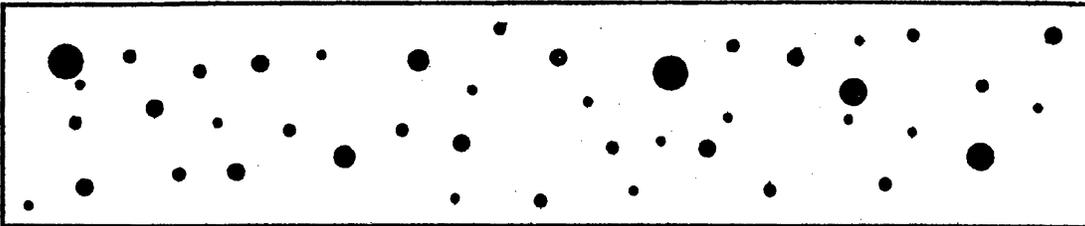
FIGURE 21. Allowable maximum total porosity area and maximum pore size.



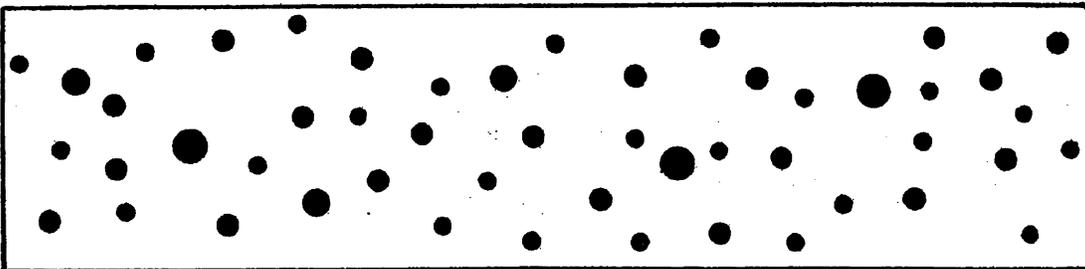
- e. Base metal thickness: 0.50 inch  
Represents 6 inches of weld length at no magnification



- f. Base metal thickness: 1.00 inch  
Represents 6 inches of weld length at no magnification



- g. Base metal thickness: 2.00 inches  
Represents 6 inches of weld length at no magnification



- h. Base metal thickness: 4.00 inches  
Represents 6 inches of weld length at no magnification

FIGURE 21. Allowable maximum total porosity area and maximum pore size. Continued.

### 5.14.3 Bend specimens:

- 5.14.3.1 Groove welds: Groove welds bend specimens having open defects exceeding  $t$  or 0.12 inch, whichever is the lesser, on the convex surface are not acceptable. Cracks occurring on the corners shall not be considered, unless it is evident that they result from weld defects.
- 5.14.3.2 Fillet welds: Fillet weld bend specimens which exhibit less than complete fusion to the root of the joint are not acceptable. The left-hand fillet of Figure 22 illustrates this condition prior to bending. The right-hand fillet illustrates minimum acceptable root fusion.

### 5.14.4 Metallographic examination:

#### 5.14.4.1 Interpretation of defects:

- a. A linear defect is defined as one whose maximum dimension is more than three times its minimum dimension.
- b. Non-linear defects with major and minor dimensions shall be evaluated as of an equivalent estimated average circle. The estimated diameter shall be the size used in determining the acceptability of the defect, and the area corresponding to this estimated diameter shall be used in calculating the area of a defect.
- c. Tungsten inclusions shall be counted as porosity.
- d. In a test weld with base metal thickness of equal to or less than 0.063 inch, disregard all defects of less than 0.002 inch size.
- e. In a test weld with a base metal thickness of more than 0.063 inch, disregard all defects of less than 0.005 inch or  $0.02 t$  size, whichever is greater.

#### 5.14.4.2 Fillet weld defects: Fillet welds which have any of the following defects are unacceptable:

- a. A crack which intersects the weld face.
- b. A crack at the weld root which exceeds 0.2 times the actual throat size or 0.12 inch, whichever is the lesser.
- c. Incomplete fusion at the weld face.
- d. Overlap.
- e. Undercut at any cross section in excess of  $0.1 t$  or 0.063 inch, whichever is the lesser.

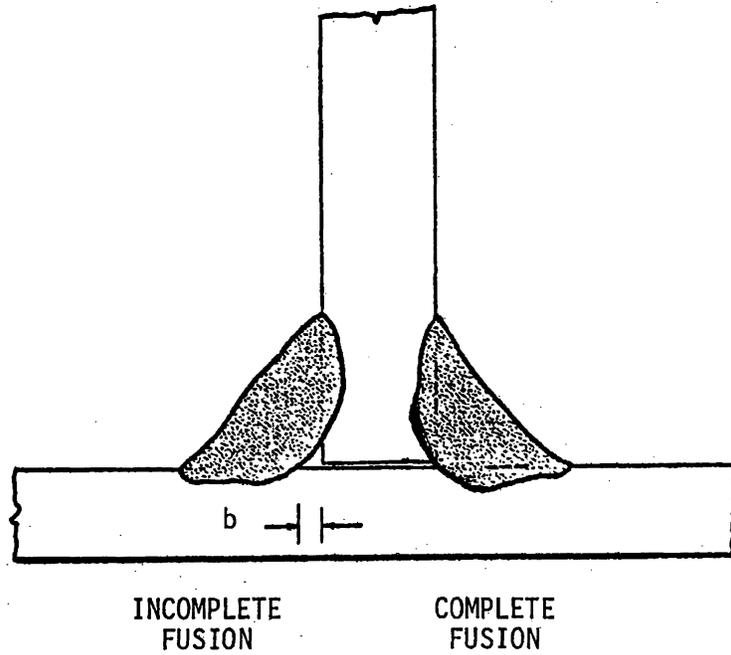


FIGURE 22. Complete and incomplete fusion in fillet welds.

## 5.14.4.2 (Continued):

- f. For base metal thickness of equal to or less than 1.00 inch, a leg size less than  $t$ . For a base metal thickness of more than 1.00 inch, the minimum leg size shall be more than 1 inch. Where members of the test weld differ in thickness, the minimum leg size shall be based on the thinner member.
- g. A ratio of the leg of larger size to the leg of smaller size greater than 1.5 at any cross section.
- h. For a convex weld, at any cross section a convexity in excess of 0.1 times the average of the two leg sizes.
- i. For a concave weld, an actual throat size of less than  $0.5 t$  at any cross section. Where the members of the test weld differ in thickness, the minimum actual throat shall be based on the thinner member.
- j. Any linear defect in excess of 0.3 times the actual throat size or 0.12 inch, whichever is the lesser.
- k. A total porosity area, on any cross section, greater than 0.05 times the area of the weld metal.

## 5.14.4.3 Base metal thickness of equal to or less than 0.063 inch: Fillet welds in sheet or tube with a base metal thickness of equal to or less than 0.063 inch, which have any of the following defects, are unacceptable:

- a. Weld metal at a sheet or tube surface opposite the weld bead and extending more than  $t$  beyond the sheet or tube surface; at any cross section.
- b. A leg size larger than  $6 t$  or  $t$  plus 0.18 inch, whichever is the lesser. Where members of the test weld differ in thickness the maximum leg size shall be based on the thinner member.
- c. Incomplete fusion, at either weld leg, as shown in Figure 22, with a dimension  $b$  in excess of 0.3 times the actual throat size.
- d. An individual pore size in excess of  $0.6 t$ , where  $t$  is the thickness of the thicker member of the test weld.

## 5.14.4.4 Base metal thickness more than 0.063 inch: Fillet welds in sheet or tube with a base metal thickness of more than 0.063 inch, which have any of the following defects, are unacceptable:

- a. Fusion evident at any sheet or tube surface opposite the weld bead.
- b. A leg size larger than  $3 t$  or  $t$  plus 0.25 inch, whichever is the lesser. Where members of the test weld differ in thickness, the maximum leg size shall be based on the thinner member.
- c. Less than complete fusion to the root of the joint, as illustrated in Figure 22.
- d. An individual pore size in excess of  $0.4 t$  or 0.18 inch, whichever is the lesser. Where the members of the test weld differ in thickness,  $t$  shall be based on the thickness of the thicker member.

PREPARED UNDER THE JURISDICTION OF AMS COMMITTEE "B"

## APPENDIX

## SPECIFIC BASE METALS OF BASE METAL GROUPS

## 10. GENERAL:

## 10.1 Scope:

The classification of metals by base metal groups for welder and welding operator qualification is given in this Appendix. The base metals are identified by the Unified Number of the Unified Numbering System for Metals and Alloys and by the common description.

## 10.2 This Appendix is a mandatory part of this Standard.

## Base Metal Group Ia. Carbon and Alloy Steels

| <u>Unified Number</u> | <u>Common Description</u> | <u>Unified Number</u> | <u>Common Description</u> |
|-----------------------|---------------------------|-----------------------|---------------------------|
| G10050                | Carbon steel              | G15220                | Carbon steel              |
| G10060                | Carbon steel              | G15240                | Carbon steel              |
| G10080                | Carbon steel              | G15270                | Carbon steel              |
| G10090                | Carbon steel              | J02502                | Carbon steel              |
| G10100                | Carbon steel              | J02503                | Carbon steel              |
| G10110                | Carbon steel              | J02504                | Carbon steel              |
| G10120                | Carbon steel              | J02505                | Carbon steel              |
| G10130                | Carbon steel              | J02506                | Low alloy steel           |
| G10150                | Carbon steel              | J03002                | Carbon steel              |
| G10160                | Carbon steel              | J03003                | Carbon steel              |
| G10170                | Carbon steel              | J03004                | Carbon steel              |
| G10180                | Carbon steel              | J03011                | Carbon steel              |
| G10190                | Carbon steel              | J11522                | Low alloy steel           |
| G10200                | Carbon steel              | J11549                | Low alloy steel           |
| G10210                | Carbon steel              | J12072                | Low alloy steel           |
| G10220                | Carbon steel              | J12080                | Carbon steel              |
| G10230                | Carbon steel              | J12082                | Low alloy steel           |
| G10250                | Carbon steel              | J12092                | Carbon steel              |
| G10260                | Carbon steel              | J12522                | Low alloy steel           |
| G10290                | Carbon steel              | J12524                | Low alloy steel           |
| G10300                | Carbon steel              | J13005                | Low alloy steel           |
| G10330                | Carbon steel              | J13047                | Low alloy steel           |
| G10340                | Carbon steel              | J21890                | Low alloy steel           |
| G10350                | Carbon steel              | J22000                | Low alloy steel           |
| G10370                | Carbon steel              | J22091                | Low alloy steel           |
| G10380                | Carbon steel              | J31550                | Low alloy steel           |
| G10390                | Carbon steel              | J42045                | Alloy steel               |
| G10400                | Carbon steel              | J82090                | Alloy steel               |

## Base Metal Group Ia. Carbon and Alloy Steels (continued)

| <u>Unified Number</u> | <u>Common Description</u> | <u>Unified Number</u> | <u>Common Description</u> |
|-----------------------|---------------------------|-----------------------|---------------------------|
| K01200                | Carbon steel              | K02700                | Carbon steel              |
| K01201                | Carbon steel              | K02701                | Carbon steel              |
| K01501                | Carbon steel              | K02702                | Carbon steel              |
| K01502                | Carbon steel              | K02703                | Carbon steel              |
| K01504                | Carbon steel              | K02704                | Carbon steel              |
| K01506                | Carbon steel              | K02705                | Carbon steel              |
| K01601                | Carbon steel              | K02707                | Carbon steel              |
| K01700                | Carbon steel              | K02800                | Carbon steel              |
| K01701                | Carbon steel              | K02801                | Carbon steel              |
| K01800                | Carbon steel              | K02802                | Carbon steel              |
| K01801                | Carbon steel              | K02803                | Carbon steel              |
| K01802                | Carbon steel              | K02804                | Carbon steel              |
| K01805                | Carbon steel              | K02900                | Carbon steel              |
| K01806                | Carbon steel              | K03000                | Carbon steel              |
| K01807                | Carbon steel              | K03002                | Carbon steel              |
| K01808                | Carbon steel              | K03003                | Carbon steel              |
| K02000                | Carbon steel              | K03004                | Carbon steel              |
| K02001                | Carbon steel              | K03005                | Carbon steel              |
| K02003                | Low alloy steel           | K03006                | Carbon steel              |
| K02004                | Carbon steel              | K03007                | Carbon steel              |
| K02005                | Carbon steel              | K03008                | Carbon steel              |
| K02007                | Carbon steel              | K03009                | Carbon steel              |
| K02008                | Carbon steel              | K03010                | Carbon steel              |
| K02100                | Carbon steel              | K03011                | Carbon steel              |
| K02101                | Carbon steel              | K03012                | Carbon steel              |
| K02102                | Carbon steel              | K03013                | Carbon steel              |
| K02104                | Carbon steel              | K03100                | Carbon steel              |
| K02200                | Carbon steel              | K03101                | Carbon steel              |
| K02201                | Carbon steel              | K03102                | Carbon steel              |
| K02202                | Carbon steel              | K03103                | Carbon steel              |
| K02203                | Carbon steel              | K03200                | Carbon steel              |
| K02300                | Carbon steel              | K03300                | Carbon steel              |
| K02400                | Carbon steel              | K03501                | Carbon steel              |
| K02401                | Carbon steel              | K03502                | Carbon steel              |
| K02402                | Carbon steel              | K03503                | Carbon steel              |
| K02403                | Carbon steel              | K03504                | Carbon steel              |
| K02404                | Carbon steel              | K03505                | Carbon steel              |
| K02500                | Carbon steel              | K03506                | Carbon steel              |
| K02500                | Carbon steel              | K03507                | Carbon steel              |
| K02501                | Carbon steel              | K04001                | Carbon steel              |
| K02502                | Carbon steel              | K04700                | Carbon steel              |
| K02503                | Carbon steel              | K05001                | Carbon steel              |
| K02504                | Carbon steel              | K05200                | Carbon steel              |
| K02505                | Carbon steel              | K07501                | Carbon steel              |
| K02506                | Carbon steel              | K11224                | Low alloy steel           |
| K02600                | Carbon steel              | K11267                | Low alloy steel           |
| K02601                | Carbon steel              | K11422                | Low alloy steel           |

## Base Metal Group Ia. Carbon and Alloy Steels (continued)

| <u>Unified Number</u> | <u>Common Description</u> | <u>Unified Number</u> | <u>Common Description</u> |
|-----------------------|---------------------------|-----------------------|---------------------------|
| K11430                | Carbon steel              | K12021                | Low alloy steel           |
| K11501                | Carbon steel              | K12022                | Low alloy steel           |
| K11510                | Carbon steel              | K12023                | Low alloy steel           |
| K11511                | Low alloy steel           | K12032                | Low alloy steel           |
| K11522                | Low alloy steel           | K12039                | Low alloy steel           |
| K11523                | Low alloy steel           | K12040                | Low alloy steel           |
| K11526                | Low alloy steel           | K12042                | Low alloy steel           |
| K11535                | Low alloy steel           | K12043                | Low alloy steel           |
| K11538                | Low alloy steel           | K12044                | Low alloy steel           |
| K11540                | Low alloy steel           | K12045                | Low alloy steel           |
| K11541                | Low alloy steel           | K12047                | Low alloy steel           |
| K11547                | Low alloy steel           | K12054                | Low alloy steel           |
| K11552                | Low alloy steel           | K12122                | Low alloy steel           |
| K11562                | Low alloy steel           | K12143                | Low alloy steel           |
| K11564                | Low alloy steel           | K12202                | Low alloy steel           |
| K11567                | Low alloy steel           | K12203                | Low alloy steel           |
| K11572                | Low alloy steel           | K12211                | Low alloy steel           |
| K11576                | Low alloy steel           | K12320                | Low alloy steel           |
| K11578                | Low alloy steel           | K12520                | Low alloy steel           |
| K11591                | Low alloy steel           | K12521                | Low alloy steel           |
| K11597                | Low alloy steel           | K12524                | Low alloy steel           |
| K11625                | Low alloy steel           | K12529                | Low alloy steel           |
| K11630                | Low alloy steel           | K12539                | Low alloy steel           |
| K11646                | Low alloy steel           | K12542                | Low alloy steel           |
| K11662                | Low alloy steel           | K12554                | Low alloy steel           |
| K11682                | Low alloy steel           | K12609                | Low alloy steel           |
| K11683                | Low alloy steel           | K12700                | Low alloy steel           |
| K11695                | Low alloy steel           | K12765                | Alloy steel               |
| K11742                | Low alloy steel           | K12766                | Alloy steel               |
| K11757                | Low alloy steel           | K12822                | Low alloy steel           |
| K11789                | Low alloy steel           | K13502                | Low alloy steel           |
| K11803                | Low alloy steel           | K20622                | Low alloy steel           |
| K11820                | Low alloy steel           | K20747                | Low alloy steel           |
| K11847                | Low alloy steel           | K21509                | Low alloy steel           |
| K11856                | Low alloy steel           | K21590                | Low alloy steel           |
| K11872                | Low alloy steel           | K21604                | Low alloy steel           |
| K12000                | Low alloy steel           | K21650                | Low alloy steel           |
| K12003                | Low alloy steel           | K21703                | Low alloy steel           |
| K12010                | Low alloy steel           | K21903                | Low alloy steel           |
| K12020                | Low alloy steel           | K22035                | Low alloy steel           |

## Base Metal Group Ia. Carbon and Alloy Steels (continued)

| <u>Unified Number</u> | <u>Common Description</u> | <u>Unified Number</u> | <u>Common Description</u> |
|-----------------------|---------------------------|-----------------------|---------------------------|
| K22036                | Low alloy steel           | K42544                | Alloy steel               |
| K22103                | Low alloy steel           | K51255                | Alloy steel               |
| K22375                | Low alloy steel           | K51545                | Alloy steel               |
| K31509                | Low alloy steel           | K61595                | Alloy steel               |
| K31545                | Low alloy steel           | K71340                | Alloy steel               |
| K31718                | Low alloy steel           | K81340                | Alloy steel               |
| K31918                | Low alloy steel           | K81590                | Alloy steel               |
| K32018                | Low alloy steel           | K90941                | Alloy steel               |
| K32025                | Low alloy steel           | K92810                | 18Ni maraging steel       |
| K41245                | Alloy steel               | K93601                | Alloy steel               |
| K41545                | Alloy steel               | NA                    | 9Ni-4Co steel             |
| K41583                | Alloy steel               |                       |                           |

## Base Metal Group Ib. Alloy Steels

| <u>Unified Number</u> | <u>Common Description</u> | <u>Unified Number</u> | <u>Common Description</u> |
|-----------------------|---------------------------|-----------------------|---------------------------|
| G41300                | 4130                      | K24728                | D6AC                      |
| G41350                | 4135                      | K44315                | 300M                      |
| G41400                | 4140                      | T20811                | H11                       |
| G43400                | 4340                      |                       |                           |
| G86300                | 8630                      |                       |                           |

## Base Metal Group IIa. Stainless Steels

| <u>Unified Number</u> | <u>Common Description</u> | <u>Unified Number</u> | <u>Common Description</u> |
|-----------------------|---------------------------|-----------------------|---------------------------|
| J91150                | Stainless steel           | S31008                | 310S                      |
| J91151                | Stainless steel           | S31500                | Stainless steel           |
| J91540                | Stainless steel           | S31600                | 316                       |
| J92500                | Stainless steel           | S31603                | 316L                      |
| J92600                | Stainless steel           | S31609                | 316H                      |
| J92710                | Stainless steel           | S31651                | 316N                      |
| J92800                | Stainless steel           | S31700                | 317                       |
| J92900                | Stainless steel           | S31703                | 317L                      |
| J93400                | Stainless steel           | S32100                | 321                       |
| J93402                | Stainless steel           | S32109                | 321H                      |
| J94202                | Stainless steel           | S32900                | 329                       |
| J95150                | Stainless steel           | S33100                | Stainless steel           |
| K63198                | 19-9 DL                   | S34700                | 347                       |
| K63199                | 19-9 DX                   | S34709                | 347H                      |
| K64299                | 29-9                      | S34800                | 348                       |
| R30155                | N155                      | S34809                | 348H                      |
| R30590                | S590                      | S35000                | AM350 PH stainless steel  |
| S15500                | 15-5 PH stainless steel   | S35500                | AM355 PH stainless steel  |
| S16800                | Stainless steel           | S38100                | Stainless steel           |
| S17400                | 17-4 PH stainless steel   | S40300                | 403                       |
| S20100                | 201                       | S40500                | 405                       |
| S20200                | 202                       | S40900                | 409                       |
| S20910                | Stainless steel           | S41000                | 410                       |
| S21600                | 216                       | S41008                | 410S                      |
| S21603                | 216L                      | S41040                | Stainless steel           |
| S21900                | 21-6-9                    | S41460                | Stainless steel           |
| S21904                | 21-6-9 LC                 | S41461                | Stainless steel           |
| S24000                | Stainless steel           | S41800                | Greek Ascoloy             |
| S30100                | 301                       | S42000                | 420                       |
| S30200                | 302                       | S42200                | 422                       |
| S30215                | 302B                      | S42900                | 429                       |
| S30400                | 304                       | S43000                | 430                       |
| S30403                | 304L                      | S43035                | Stainless steel           |
| S30409                | 304H                      | S44300                | 443                       |
| S30451                | 304N                      | S44400                | Stainless steel           |
| S30452                | Stainless steel           | S44600                | 446                       |
| S30500                | 305                       | S44625                | Stainless steel           |
| S30800                | 308                       | S45000                | Custom 450                |
| S30900                | 309                       | S45500                | Custom 455                |
| S30908                | 309S                      | NA                    | 16-25-6                   |
| S31000                | 310                       |                       |                           |

## Base Metal Group IIb. Precipitation Hardening Stainless Steels

| <u>Unified Number</u> | <u>Common Description</u> | <u>Unified Number</u> | <u>Common Description</u> |
|-----------------------|---------------------------|-----------------------|---------------------------|
| K66286                | A286 stainless steel      | S15700                | PH 15-7Mo stainless steel |
| K66545                | W545                      | S17700                | 17-7PH stainless steel    |
| S13800                | PH 13-8Mo stainless steel |                       |                           |

## Base Metal Group IIIa. Nickel and Nickel-Base Alloys

| <u>Unified Number</u> | <u>Common Description</u> | <u>Unified Number</u> | <u>Common Description</u> |
|-----------------------|---------------------------|-----------------------|---------------------------|
| N02200                | Nickel 200                | N08330                | RA330                     |
| N02201                | Nickel 201                | N08800                | Incoloy 800               |
| N04400                | Monel 400                 | N08810                | Incoloy 800H              |
| N06002                | Hasteloy X                | N08825                | Incoloy 825               |
| N06007                | Hasteloy G                | N08904                | Fe-Ni-Cr alloy            |
| N06455                | Hasteloy C4               | N10001                | Hasteloy B                |
| N06600                | Inconel 600               | N10002                | Hasteloy C                |
| N06625                | Inconel 625               | N10003                | Hasteloy N                |
| N06975                | Hasteloy G2               | N10276                | Hasteloy 276              |
| N08020                | Carpenter Cb3             | N10665                | Hasteloy B2               |
| N08320                | Haynes 20 Mod             |                       |                           |

## Base Metal Group IIIb. Precipitation Hardening Nickel-Base Alloys

| <u>Unified Number</u> | <u>Common Description</u> | <u>Unified Number</u> | <u>Common Description</u> |
|-----------------------|---------------------------|-----------------------|---------------------------|
| N05500                | Monel K500                | N07750                | Inconel X750              |
| N06601                | Inconel 601               | N09706                | Inconel 706               |
| N07001                | Waspaloy                  | N09901                | Incoloy 901               |
| N07041                | Rene 41                   | NA                    | Rene 77                   |
| N07252                | M252                      | NA                    | Rene 80                   |
| N07500                | Udimet 500                | NA                    | Udimet 700                |
| N07718                | Inconel 718               |                       |                           |

## Base Metal Group IV. Aluminum and Aluminum-Base Alloys

| <u>Unified Number</u> | <u>Common Description</u> | <u>Unified Number</u> | <u>Common Description</u> |
|-----------------------|---------------------------|-----------------------|---------------------------|
| A03560                | 356                       | A95086                | 5086                      |
| A91060                | 1060                      | A95154                | 5154                      |
| A91100                | 1100                      | A95254                | 5254                      |
| A92014                | 2014                      | A95454                | 5454                      |
| A92219                | 2219                      | A95456                | 5456                      |
| A93003                | 3003                      | A95652                | 5652                      |
| A93004                | 3004                      | A96061                | 6061                      |
| A95052                | 5052                      | A96063                | 6063                      |
| A95083                | 5083                      |                       |                           |

## Base Metal Group V. Magnesium-Base Alloys

| <u>Unified Number</u> | <u>Common Description</u> | <u>Unified Number</u> | <u>Common Description</u> |
|-----------------------|---------------------------|-----------------------|---------------------------|
| M10100                | AM100A                    | M13210                | HM21A                     |
| M11311                | AZ31B                     | M13310                | HK31A                     |
| M11610                | AZ61A                     | M13312                | HM31A                     |
| M11800                | AZ80A                     | M13320                | HZ32A                     |
| M11910                | AZ91A                     | M14141                | LA141A                    |
| M11920                | AZ92A                     | M16620                | ZH62A                     |
| M12330                | EZ33A                     | M18220                | QE22A                     |

## Base Metal Group VI. Titanium and Titanium-Base Alloys

| <u>Unified Number</u> | <u>Common Description</u> | <u>Unified Number</u> | <u>Common Description</u> |
|-----------------------|---------------------------|-----------------------|---------------------------|
| R50250                | Titanium                  | R56260                | Ti-6Al-2Sn-4Zr-6Mo        |
| R50400                | Titanium                  | R56320                | Ti-3Al-2.5V               |
| R50550                | Titanium                  | R56400                | Ti-6Al-4V                 |
| R52400                | Titanium                  | R56620                | Ti-6Al-6V-2Sn             |
| R54520                | Ti-5Al-2.5Sn              | R58640                | Ti-3Al-8V-6Cr-4Mo-4Zr     |
| R54620                | Ti-6Al-2Sn-4Zr-2Mo        | NA                    | Ti-6Al-2Sn-2Zr-2Cr-2Mo    |
| R54810                | Ti-8Al-1Mo-1V             | NA                    | Ti-15V-3Cr-3Mo-3Sn        |
| R56210                | Ti-6Al-2Cb-1Ta-1Mo        |                       |                           |

## Base Metal Group VII. Cobalt-Base Alloys

| <u>Unified<br/>Number</u> | <u>Common Description</u> | <u>Unified<br/>Number</u> | <u>Common Description</u> |
|---------------------------|---------------------------|---------------------------|---------------------------|
| R30006                    | Stellite 6                | R30031                    | Stellite 31               |
| R30021                    | Stellite 21               | R30188                    | HS188                     |
| R30023                    | Stellite 23               | R30605                    | L605                      |
| R30027                    | Stellite 27               | R30816                    | S816                      |
| R30030                    | Stellite 30               |                           |                           |