BOMBARDIER
Toronto Site
PROPRIETARY INFORMATION

PPS 37.10

PRODUCTION PROCESS STANDARD

REQUIREMENTS FOR FUSION WELDS

Issue 19
- This standard supersedes PPS 37.10, Issue 18.
- Vertical lines in the left hand margin indicate changes over the previous issue.
- Direct PPS related questions to michael.wright@aero.bombardier.com or (416) 375-4365.
- This PPS is effective as of the distribution date.

Prepared By:	*Michael Wright*	(Michael Wright)	July 13, 2015
	PPS Group		
Approved By:	*Ken Quon*, for	(L.K. John)	July 14, 2015
	Materials Technology		
	Anthony Assivero, for	(D. Dawe)	July 21, 2015
	Quality		

Table of Contents

Sections **Page**

Tables

Figures

1 Scope

1.1 This Production Process Standard (PPS) specifies the procedure and requirements for fusion welds of aluminum, ferrous, nickel and titanium alloys.

1.1.1 This PPS complements the engineering drawings that specify its use as an authorized instruction. The procedure specified in this PPS must be followed to ensure compliance with all applicable specifications. In general, if this PPS conflicts with the engineering drawing, follow the engineering drawing. The requirements specified in this PPS are necessary to fulfil the engineering design and reliability objectives.

1.1.2 Refer to PPS 13.26 for the subcontractor provisions applicable to this PPS.

1.1.3 Procedure or requirements specified in a Bombardier BAPS, MPS, LES or P. Spec. **do not** supersede the procedure or requirements specified in this PPS.

2 Hazardous Materials

2.1 Before receipt at Bombardier (Toronto Site), all materials must be approved and assigned Material Safety Data Sheet (MSDS) numbers by the Bombardier (Toronto Site) Environment, Health and Safety Department. Refer to the manufacturer's MSDS for specific safety data on any of the materials specified in this PPS. If the MSDS is not available, contact the Bombardier (Toronto Site) Environment, Health and Safety Department.

3 References

3.1 General

3.1.1 Unless a specific issue is indicated, the issue of the reference documents specified in this section in effect at the time of manufacture shall form a part of this specification to the extent indicated herein.

3.2 Bombardier (Toronto Site) Specifications

3.2.1 PPS 6.01 - Fabrication of Rigid Fluid Lines.

3.2.2 PPS 6.12 - Pressure Testing Hydraulic Components, Fuel and Bleed Air Lines.

3.2.3 PPS 13.26 - General Subcontractor Provisions.

3.2.4 PPS 13.39 - Bombardier Toronto Engineering Process Manual.

3.2.5 PPS 20.01 - Magnetic Particle Inspection.

3.2.6 PPS 20.03 - Fluorescent Penetrant Inspection.

3.2.7 PPS 20.10 - Radiographic Inspection.

3.2.8 PPS 37.03 - Fusion Welding of Aluminum Alloys.

3.2.9 PPS 37.04 - Fusion Welding of Ferrous and Nickel Alloys.

3.2.10 PPS 37.05 - Fusion Welding of Titanium

3.2.11 PPS 37.06 - Testing and Approval of Aircraft Welders.

3.2.12 PPS 37.09 - Special Welding Procedure.

3.3 Bombardier Aerospace Specifications

3.3.1 BAERD GEN-012 - Non-Destructive Testing - Certification of Personnel.

4 Materials, Equipment and Facilities

4.1 Unless otherwise specified in this section, use only the materials specified; use of superseding or alternative materials is not allowed.

4.2 Weld parts using the materials and equipment specified in the applicable welding PPS.

4.3 Facilities performing fusion welding of aluminum, ferrous, nickel or titanium alloys must meet the facility requirements specified in PPS 37.03, PPS 37.04, PPS 37.05 or PPS 37.09, as applicable.

5 Procedure

5.1 Weld parts using the procedure specified in the applicable welding PPS. Do not repair weld parts more than two times in any one location.

5.2 Upon completion of a fusion welding operation, the welder must apply his identification stamp against each applicable welding operation on the Shop Order. If 2 or more welders have worked on a batch of parts of the same part number, each welder must apply his identification stamp against the welding operation on the Shop Order.

6 Requirements

6.1 If possible, perform the tests specified in Table 1 after the completion of all fusion welding operations. If the completion of all fusion welding operations makes these tests impossible, perform the tests after the last fusion welding operation which still allows accessibility.

Table 1 - Test Applicability

Weld Class (Note 1)	Test Applicability			
	Visual	**Magnetic Particle or Fluorescent Penetrant** (Note 2)	**Radiographic** (Note 4)	**Pressure Test**
A	100%	100%	100%	100% to welded parts that will carry fluid
B	100%	100%	N/A (Note 5)	
C	100%	N/A (Note 3)		

Notes
1. For parts that have been repaired, perform all the tests required for the next higher weld class (i.e., perform the tests required for Class B welds on repaired Class C welds and perform the tests required for Class A welds on repaired Class B welds).
2. Magnetic particle inspect magnetic ferrous alloy parts according to PPS 20.01; fluorescent penetrant inspect non-ferrous alloy and non-magnetic ferrous alloy parts according PPS 20.03. There shall be no evidence of lack of fusion or arc strike (localized coalescence outside the weld zone). Refer to Table 3 and Table 4 for the limitations on other defects.
3. Perform magnetic particle or fluorescent penetrant inspection on Class C welds only if doubt exists as to the nature or extent of defects disclosed by visual examination.
4. Perform radiographic inspection according to PPS 20.10.
5. Perform radiographic inspection on Class B or Class C welds only if doubt exists as to the nature or extent of defects disclosed by visual examination.

6.2 Acceptable welds must meet the following visual requirements. If it is difficult to determine whether or not a defect is within acceptable limits through visual examination, verify the measurements by radiographic examination according to PPS 20.10.

- Each weld must be uniform in width and appearance and blend smoothly into the base metal. Except for fillet welds, welds must be convex. For fillet welds only, the weld should be flat to concave (although **slight** convexity is also acceptable).
- There must be no evidence of cracks, undercuts, overlaps, suck back, lack of fusion, or arc strike when the weld is viewed at 10X magnification. For Class B and C welds only, it is acceptable to fill in welds showing indications of suck back (loss of metal thickness), as shown in Figure 9, with filler metal to restore the original metal thickness.
- Butt welds must have complete weld joint penetration, approximately as shown in Figure 1 and the weld reinforcement must be within the limits specified in Table 2. Evidence of either excessive or incomplete penetration is not acceptable.
- Surface porosity, inclusions or other metallic discontinuities must be within the limits specified in Table 3.
- Fillet welds may show indications of melt through, as shown in Figure 9, provided that the build up of material does not exceed the thickness of the thinner member (“T”) and that the melt through does not interfere with mating parts.
- The flanges of edge welded standing flanges must be fused completely down, approximately as shown in Figure 4.

Table 2 - Maximum Allowable Weld Reinforcement in Butt Welds

BASE METAL THICKNESS (T)	MAXIMUM ALLOWABLE REINFORCEMENT			
	WELD FACE		WELD ROOT	
	BASE METAL GROUP	LIMIT AT ANY LOCATION	BASE METAL GROUP	LIMIT AT ANY LOCATION
0.063" and under	All	(T + 0.020") or 0.050", whichever is less	IV and V	(T + 0.030") or 0.070", whichever is less
			Ia, Ib, IIa, IIb, IIIa, IIIb, VI, and VII	(T + 0.020") or 0.050", whichever is less
over 0.063"	All	0.8T or 0.25", whichever is less	IV and V	T or 0.25", whichever is less
			Ia, Ib, IIa, IIb, IIIa, IIIb, VI, and VII	0.8T or 0.25", whichever is less

Table 3 - Defect Limits for Visual Examination of Welds

DEFECT		CLASS OF WELD		
		A	B	C
Surface porosity	Maximum individual size	0.25T or 0.030", whichever is less	0.33T or 0.060", whichever is less	0.5T or 0.090", whichever is less
	Minimum spacing	8 times the size of the larger adjacent defect	4 times the size of the larger adjacent defect	2 times the size of the larger adjacent defect
	Maximum accumulated length in any 3" of weld	T or 0.12", whichever is less	1.33T or 0.24", whichever is less	2T or 0.36", whichever is less
Craters	Maximum depth	0.20T or 0.030", whichever is less	0.20T or 0.050", whichever is less	0.20T or 0.050", whichever is less
	Maximum length	T	T	2T
Surface cracks (see Figure 7)		None Allowed		
Underfill and/or concavity in butt welds		None Allowed (Note 2)		

Notes
1. "T" is the base metal thickness of the thinner weld member.
2. Fillet welds of either single or multiple beads shall be flat to concave, although slight convexity shall not be cause for rejection. All other types of welds shall be convex.

Table 4 - Defect Limits for Radiographic and Metallographic Examination of Welds

DEFECT		CLASS OF WELD		
		A	**B**	**C**
Undercut (Note 2)	Maximum depth for full length of weld	0.002"	0.015T or 0.002", whichever is greater	0.025T or 0.002", whichever is greater
	Maximum depth for individual defects	0.07T or 0.030", whichever is less	0.10T or 0.050", whichever is less	0.20T or 0.070", whichever is less
	Maximum accumulated length in any 3" of weld	0.20"	0.60"	1.00"
Sub-surface porosity and inclusions	Maximum individual size	0.33T or 0.060", whichever is less (Note 4)	0.50T or 0.090", whichever is less	Not applicable
	Minimum spacing	4 times the size of the larger adjacent defect	2 times the size of the larger adjacent defect	
	Maximum accumulated length in any 3" of weld	1.33T or 0.24", whichever is less	2T or 0.36", whichever is less	
Craters	Maximum length	T	T	2T
	Maximum depth	0.20T or 0.030", whichever is less	0.20T or 0.050", whichever is less	
Maximum acceptable incomplete root penetration (fillet welds only) (Note 5)		0.20T or 0.030", whichever is less	0.20T or 0.050", whichever is less	
Suck back		None Allowed	For Class B and C welds only, it is acceptable to fill in welds showing indications of suck back (loss of metal thickness) with filler metal to restore the original metal thickness.	
Cracks		None Allowed		
Underfill and/or concavity in butt welds		None Allowed (Note 3)		

Notes
1. "T" is the base metal thickness of the thinner weld member.
2. The maximum depth of undercut at the corner of a fillet weld shall be 2X the specified limit.
3. Fillet welds of either single or multiple beads shall be flat to concave, although slight convexity is acceptable. All other types of welds shall be convex.
4. For aluminum and magnesium alloys, the maximum allowable individual size shall be 0.5T or 0.060", whichever is less.
5. The maximum length of any one indication shall be 2T.

6.3 If radiographic examination is specified in Table 1 or verification of visual examination is required, radiographically examine the weld according to PPS 20.10 to ensure that the following requirements are met:

- The weld bead and the parent metal adjacent to the weld must be free of cracks. See Figure 7 for a definition of crack types.
- Refer to Table 4 for the maximum acceptable limits for porosity, undercuts, craters, incomplete penetration and other metallic discontinuities. Tungsten inclusions shall be considered porosity. Porosity shall be evaluated as an equivalent sized circle with an estimated average diameter. The estimated diameter shall be used in calculating the area of the defect.
- Welds exhibiting lack of fusion are unacceptable.
- Incomplete root penetration in butt welds is not acceptable.

6.4 For welded parts that will carry fluids, pressure test according to PPS 6.01 or PPS 6.12, as applicable.

6.5 If the nature or extent of a defect disclosed by radiographic examination warrants destruction of the part, section, polish and examine the weld at a minimum of 10X magnification for evidence of porosity, cracks, undercuts, overlaps, craters, lack of fusion or other metallic discontinuities and incomplete root penetration as specified in Table 4. In fillet welds, joint penetration (as determined by etching and examining the sample at 10X magnification) must be at least 10% of the parent metal thickness. In butt welds, there must be complete joint penetration, indications of melt through, and a convex root surface.

7 Safety Precautions

7.1 The safety precautions specified herein are specific to Bombardier Toronto to meet Canadian Federal and Provincial government environmental, health and safety regulations. It is recommended that other facilities consider these safety precautions; however, suppliers, subcontractors and partners are responsible for ensuring that their own environmental, health and safety precautions satisfy the appropriate local government regulations.

7.2 Observe general shop safety precautions when performing the procedure specified herein.

7.3 Follow the safety precautions specified in the applicable welding PPS.

8 Personnel Requirements

8.1 All fusion welders of aircraft or engine parts must meet the personnel requirements specified by PPS 37.03, PPS 37.04 or PPS 37.05, as applicable and be certified according to PPS 37.06. Refer parts welded by a welder who does not hold a current certification for the applicable class and type of weld to MRB for disposition.

8.2 This PPS has been categorized as a “Controlled Critical Process” by PPS 13.39. Refer to PPS 13.39 for additional personnel requirements.

8.3 Personnel responsible for performing radiographic examination must be certified according to PPS 20.10.

9 Additional Information

9.1 Classification of weld joints are as specified on the engineering drawing. Refer to Table 5 for the cross reference between current and superseded weld classifications. Contact Liaison Engineering in all cases where the engineering drawing does not specify the class of weld.

Table 5 - Weld Classification Cross Reference

CURRENT	SUPERSEDED
Class A	Class 1, Type A
Class B	Class 1, Type B and Class 2
Class C	Class 1, Type C and Class 3

9.2 Refer to Figures 1 through 9 for illustrations of welding terms.

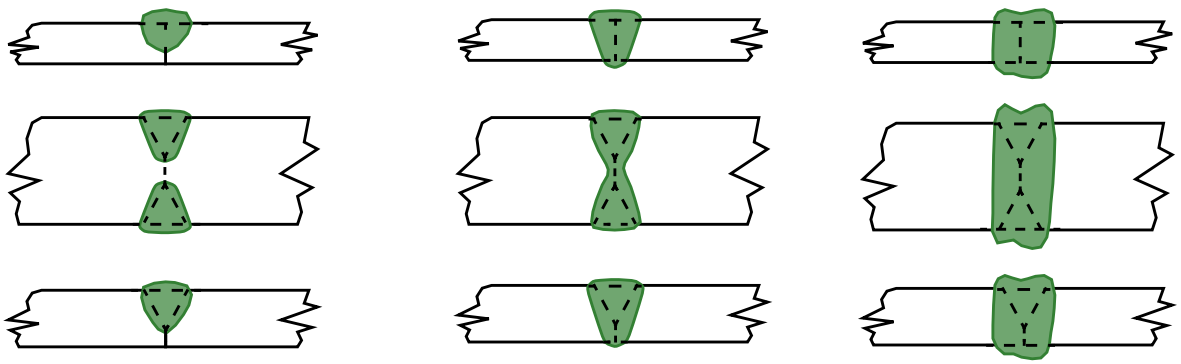
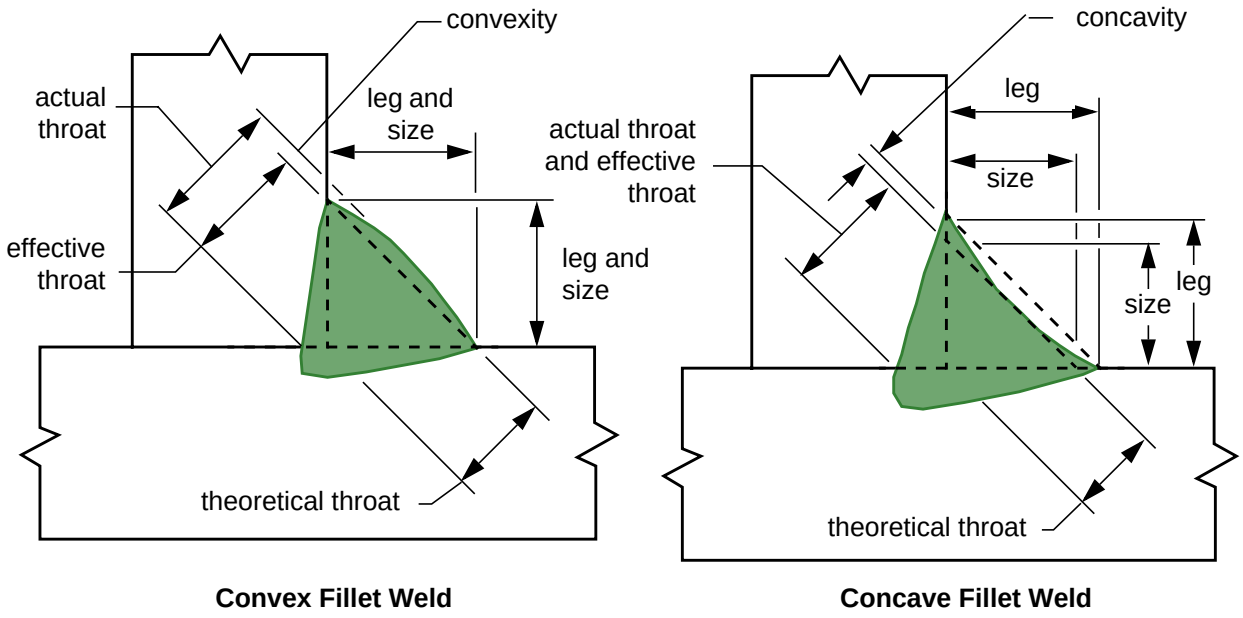


Figure 1 - Weld Joint Penetration



Convex Fillet Weld **Concave Fillet Weld**

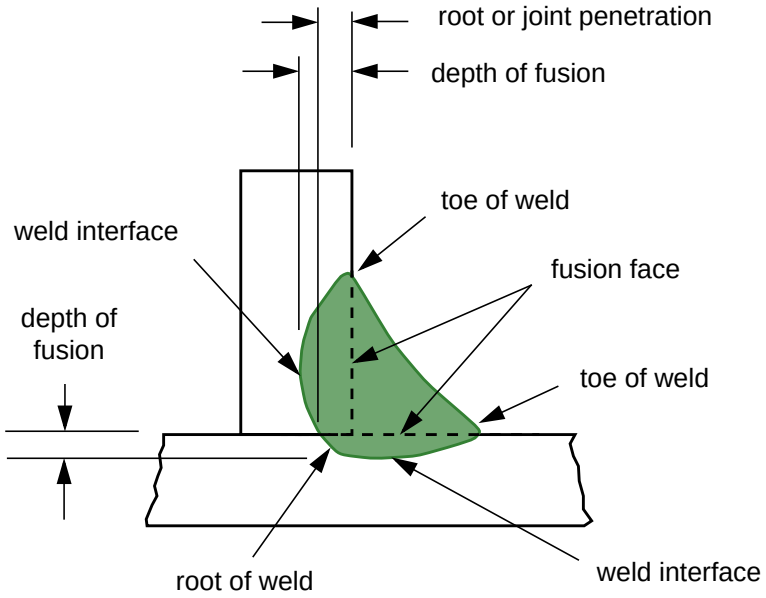


Figure 2 - Fillet Weld Terms

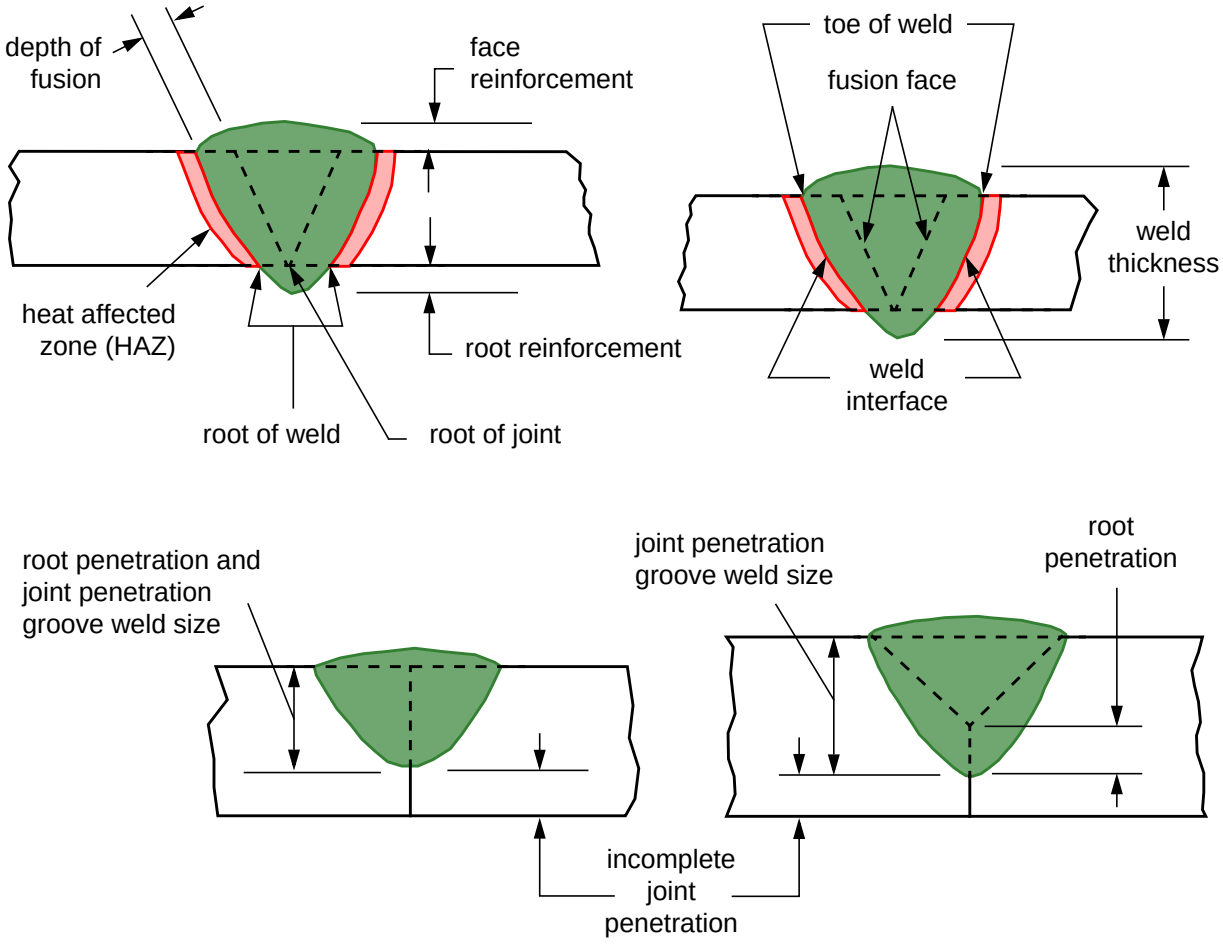


Figure 3 - Butt Weld Terms

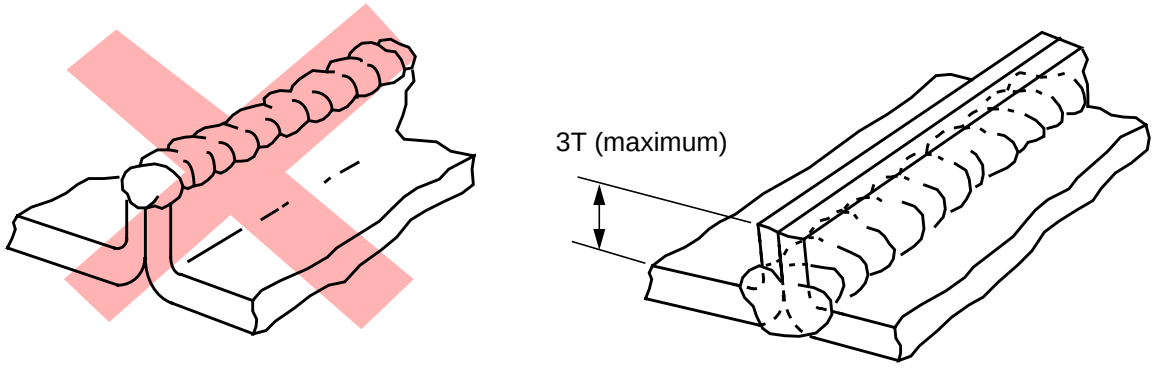


Figure 4 - Standing Edge Weld

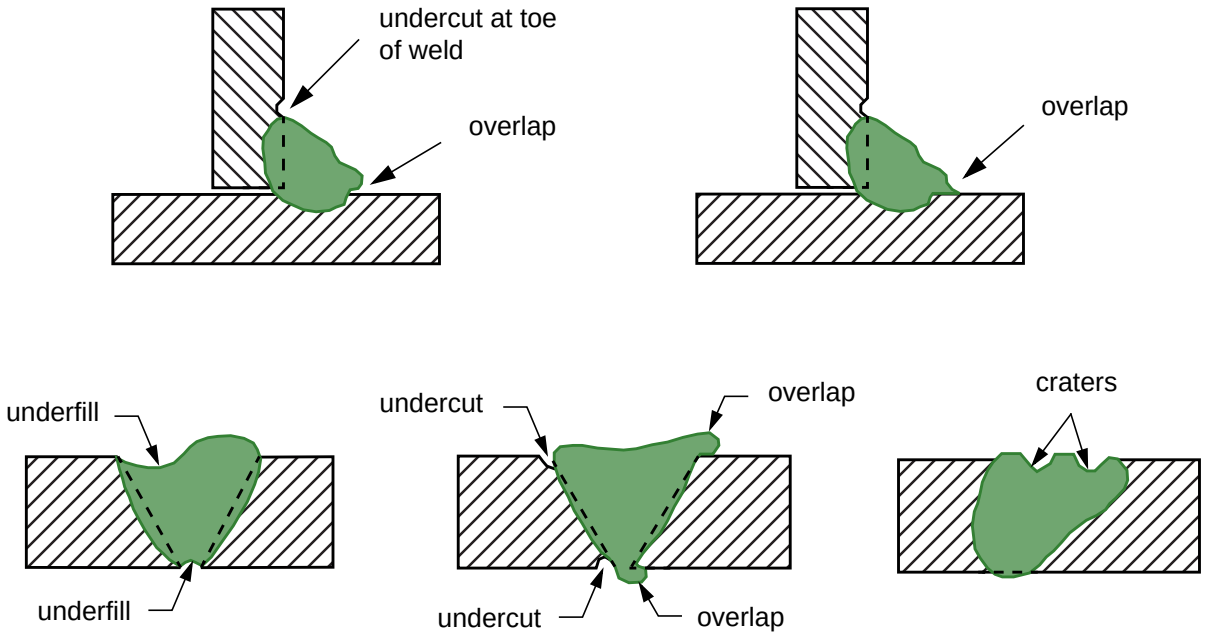


Figure 5 - Undercut, Underfill, Overlap, and Craters

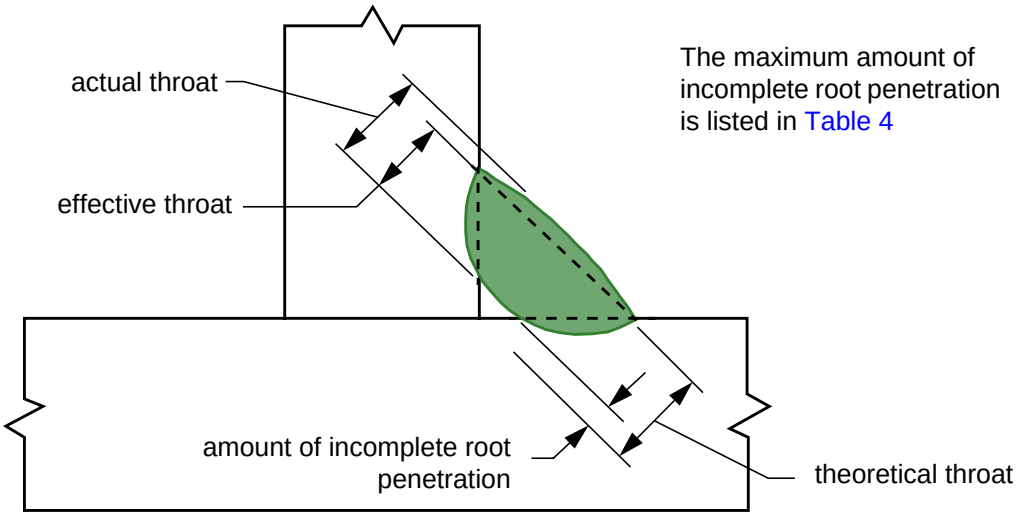
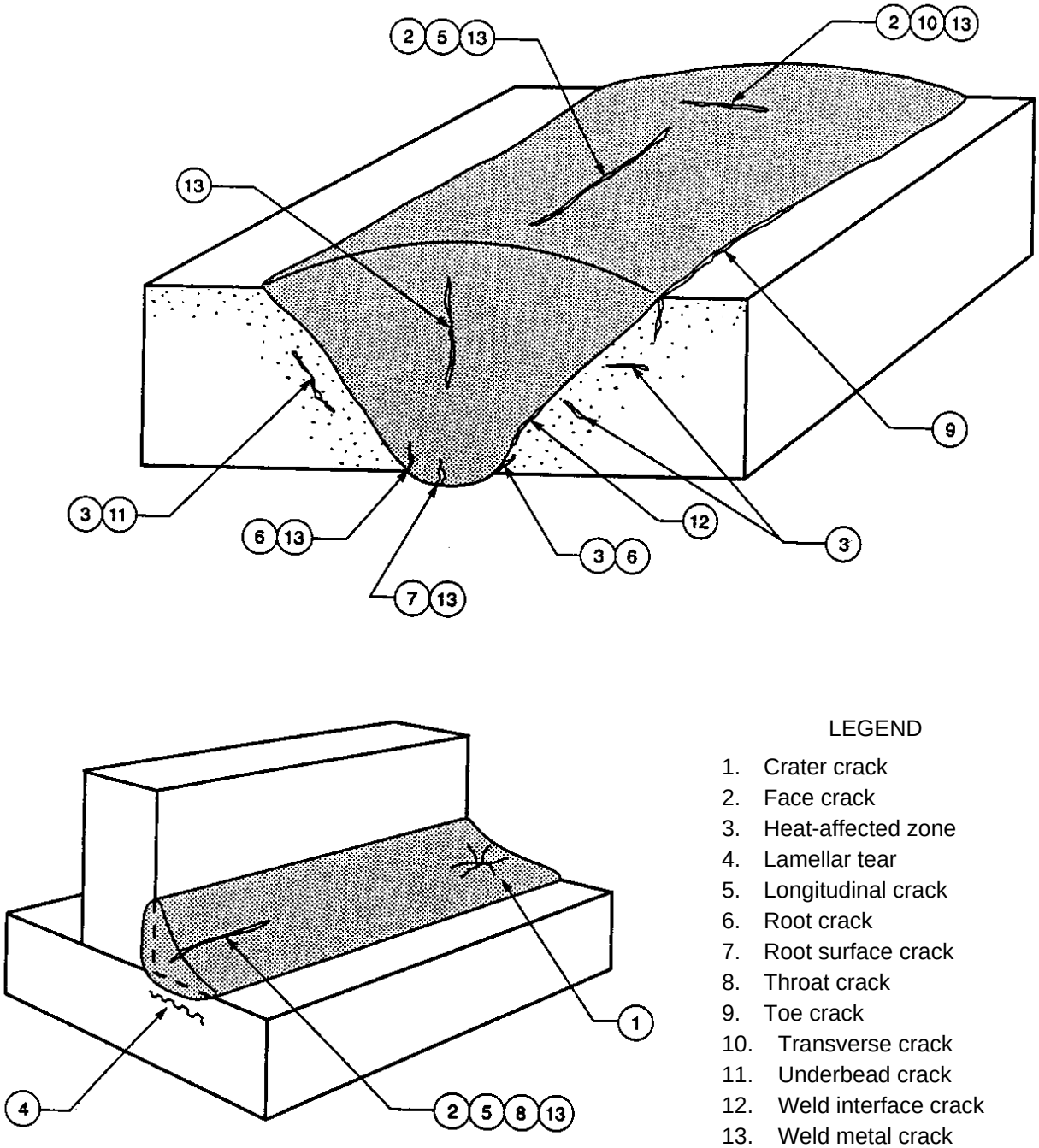


Figure 6 - Fillet Weld with Incomplete Penetration to the Root



LEGEND

1. Crater crack
2. Face crack
3. Heat-affected zone
4. Lamellar tear
5. Longitudinal crack
6. Root crack
7. Root surface crack
8. Throat crack
9. Toe crack
10. Transverse crack
11. Underbead crack
12. Weld interface crack
13. Weld metal crack

Figure 7 - Crack Types

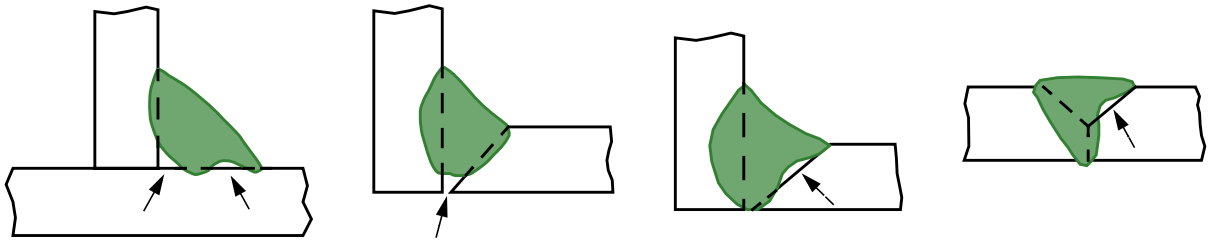
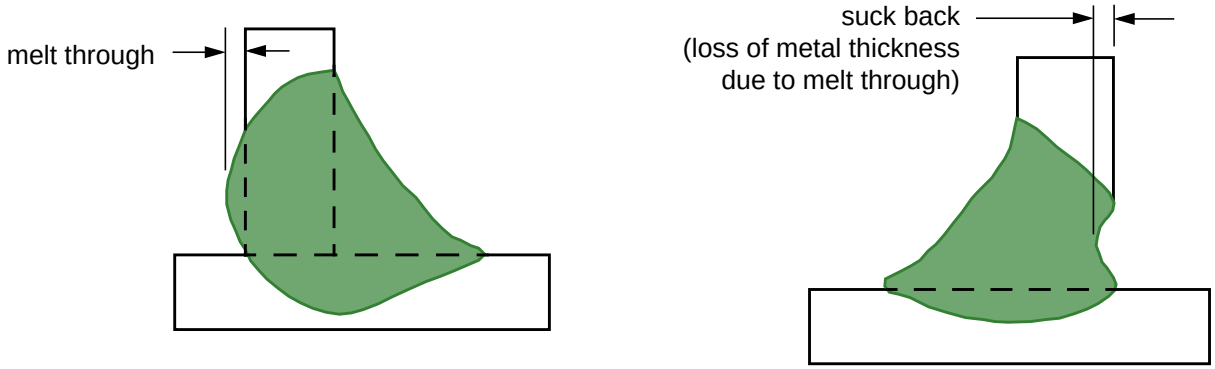


Figure 8 - Examples of Incomplete Fusion



Note: May occur in either fillet member

Figure 9 - Melt Through and Suck Back