

Subject WELDING FABRICATION	Effective Date 9/23/94	Initiated <i>Paul W. Allen</i> <i>Norman J. Kumpf</i> 11/2/92
	Supersedes New	Approved <i>[Signature]</i> Engineering Department Head

APPLICABILITY

This standard establishes the minimum requirements for welding fabrication for use at PPPL. It applies to welding not specified to a national code that is performed at PPPL facilities or by a vendor. The standard addresses pressure and vacuum vessel fabrication, structural steel and aluminum welding, and weld examination and testing.

This standard applies to all welding fabrication of assemblies for use at PPPL. The requirements stipulated represent a minimum standard for welding fabrication of PPPL assemblies, when there is no other document given for the welding, inspection, and repair of same. This document does not supersede any existing national welding code.

Any variations, changes, or waivers from the welding requirements of this standard must be approved in writing by the MED Head and the PPPL Welding Engineer.

Vacuum flanges of the conflat type welded to pipe or tube will be exempt from code flange requirements for socket welds. Appropriate welding techniques for vacuum service will be observed for these items and other specialized vacuum components.

REFERENCES

1. ASME Boiler & Pressure Vessel Code:
Section VIII. *Rules for Construction of Pressure Vessels*; Division 1
Part UW Requirements for Pressure Vessels Fabricated by Welding
Section IX *Welding & Brazing Qualifications*
2. ASME Code for Pressure Piping:
ASME B31.1 - *Power Piping*
ASME B31.3- *Chemical Plant & Refinery Piping*
ASME B31.9- *Building Services Piping*
3. AWS D 1.1 - *Structural Welding Code for Steel*
4. AWS D 1.2 - *Structural Welding Code for Aluminum*
5. AWS D 1.3 - *Structural Welding Code - Sheet Steel*
6. AWS D 9.1 - *Sheet Metal Welding Code*
7. TOP No. 23.011 -*General Welding/Brazing Requirements for PPPL*

INTRODUCTION

Welding performed at PPPL conforms to the fabrication quality requirements of the national welding codes (although the PPPL is not designated as a "Code Stamp" facility).

The PPPL workplace meets the intent of the welding fabrication codes by following the guidelines for welding and inspection. This includes the development, qualification and control of welder performance for PPPL certification, as prescribed in Technical Operations Procedure (TOP) No. 23.011, "General Welding/Brazing Requirements for PPPL."

This standard sets the requirements for the welding fabrication of assemblies for use at PPPL, but not specified as Code-certified and stamped. It governs welding performed in PPPL facilities and also by outside vendors or contractors.

STANDARD REQUIREMENTS

PPPL Welding Procedures

All welding shall be performed in accordance with the requirements of PPPL Technical Operations Procedure No. 23.011, "General Welding/Brazing Requirements for PPPL."

Qualified Welders

All welding shall be performed by 1) welders who have been qualified to the PPPL Welding Certification Program, or 2) contract welders certified to Section IX of the ASME Boiler & Pressure Vessel Code, or 3) contract welders certified to applicable AWS section(s).

Welding Techniques

Welding techniques shall be according to current PPPL Welding Specifications & Procedures guidelines and in compliance with Section IX of the ASME Boiler & Pressure Vessel Code.

Pressure Vessel Welding Code

Pressure vessels and vacuum chambers or parts thereof fabricated from plate, pipe, or tube by welding shall conform to the ASME Boiler & Pressure Vessel Code; Section VIII, Division 1; Requirements for Pressure Vessels Fabricated by Welding- Part UW-26 through UW-42.

Inspection of welds shall be by visual examination using the guidelines of attachment EM001-1.

Additional tests are often prescribed by work documents, system procedures, or a PPPL Welding or Design Engineer, and are performed to verify the quality and ensure the integrity of the fabrication work. Examples of additional checks are helium leak detection and hydrostatic testing.

Power Piping

Steam lines and boiler external piping systems shall be fabricated in accordance with the requirements of ASME B31.1 Power Piping (Steam Lines); Chapter V, Fabrication, Assembly, and Erection; Sections 127.3.1–127.3.3, and 127.4.1–127.4.5.

Inspection of welds shall be by visual examination with acceptance in accordance with the standards of ASME B31.1; Chapter VI, Section 136.4.2. See attachment EM001-1.

Additional examinations of assembled welded components or subassemblies may or may not be required by code. However, additional tests are often prescribed by work documents, system procedures, or a PPPL Welding or Design Engineer; and are performed to verify the quality and ensure the integrity of the fabrication work. Examples of additional checks are helium leak detection and hydrostatic testing.

Pressure Piping

Pressure piping systems fabrication shall be in compliance with the requirements of ASME B31.3 Chemical Plant & Refinery Piping; Chapter V, Fabrication, Assembly, and Erection; Sections 328.5.1 through 328.6.

Inspection of welds shall be by visual examination in accordance with ASME B31.3, Chapter VI, Section 341.3.2 using Table 341.3.2A. See Attachment EM001-2, EM001-2A and EM001-2B.

Additional examinations of assembled welded components or subassemblies may or may not be required by code. However, additional tests are often prescribed by work documents, system procedures, or a PPPL Welding or Design Engineer; and are performed to verify the quality and ensure the integrity of the fabrication work. Examples of additional checks are helium leak detection and hydrostatic testing.

Building Services Piping

Building services piping (cooling water, steam, air, etc.) shall be welded in accordance with ASME B31.9, Building Services Piping; Chapter V, Fabrication, Assembly, and Erection; Sections 927.2–927.4.8 and 928.1–928.2.2.

Examination and acceptance criteria shall be in accordance with ASME B31.9; Chapter VI, Inspection, Examination, and Testing; Sections 936.6–936.6.10.

Imperfections exceeding the stated limit are considered defects, and shall be repaired or replaced in accordance with Chapter V.

Structural Steel Welding

Steel welding fabrication (including stainless steel structural supports and lifting fixtures, etc.) shall be performed in accordance with AWS D1.1, Structural Welding Code for Steel; Sections 3.1.4, 3.2.1, 3.2.2, 3.2.2.1, 3.3.7, and 3.6–3.12.4.

Weld profile requirements shall be in accordance with AWS D 1.1; Sections 3.6.1 and 3.6.2, and referenced Figure 3.4, "Acceptable & Unacceptable Weld Profiles." (Figure 3.4 appears in Attachments as Figure EM001-3.)

Repair of weld defects shall be according to AWS D1.1; Section 3.7.

Aluminum Structures

Aluminum structures shall be fabricated in accordance with AWS D1.2, Structural Welding Code for Aluminum; Sections 3.1.3–3.1.5, 3.1.7; 3.2.1–3.2.3; 3.2.6–3.2.9, 3.3.5, 3.3.7.1, and 3.3.7.2.

Weld profile requirements shall be in accordance with AWS D1.2; Section 3.6 and referenced Figure 3.2, "Acceptable & Unacceptable Weld Profiles." (Figure 3.2 appears in Attachments as Figure EM001-4)

Repair of weld defects shall be according to AWS D1.2, Section 3.7.

Sheet Metal

Sheet metal fabrications should use AWS D1.3 and AWS D9.1 as guidelines.

DEFINITIONS

Abbreviations & Acronyms

ANSI = American National Standards Institute
ASME = American Society of Mechanical Engineers
AWS = American Welding Society
MED = Mechanical Engineering Division
PPPL = Princeton Plasma Physics Laboratory
TOP = Technical Operations Procedure

Welding Definitions

Acceptance Criteria —Specified limits placed on characteristics, profile, or level of imperfection of a weld; as defined in codes, standards, and other documents.

Certification —The action of determining, verifying, and attesting in writing to the qualifications of welders.

Visual Examination of Welds — Observation of the portion of components or joints that are exposed to view at any stage of fabrication or assembly. This examination consists of verification of adherence to weld design and PPPL Welding Standard requirements.

Inspection —Verification of the examination of welds' conformance to fabrication requirements.

Qualification—Welding abilities acquired through training, education, or experience as measured against established requirements, which qualify an individual to perform specific welding functions.

ATTACHMENTS

Table EM001-1 Unacceptable Weld Conditions

Table EM001-2, Acceptance Criteria for Welds (ASME B31.3, Chapter VI, Table 341.3.2A).

EM001-2A, Criterion Value Notes for Table EM001-2.

Table EM001-2B Acceptance Criteria for Welds

Figure EM001-3 for Structural Steel Welds (AWS D1.1, Figure 3.4)

Figure EM001-4 for Aluminum Structures (AWS D31.3, Figure 3.2)

EM001-1

Acceptance standard for welds on pressure vessels and components and power piping systems shall be according to ASME B31.3, Chapter VI Inspection, Examination, and Testing; Section 341.3.2, Table 341.3.2A; Acceptance Criteria for Welds (including criteria value notes for Table 341.3.2A). This table states acceptance criteria on limits of imperfections for welds.

TABLE EM001-1-Unacceptable Weld Conditions

The following indications are <u>unacceptable</u> :
Cracks—external surface
Undercut on surface that is greater than 1/32 in. (1.0 mm) deep
Weld reinforcement greater than specified in ASME code 31.1, Table 127.4.2
Lack of fusion on surface
Incomplete penetration (applies only when inside surface is readily accessible)

EM001-2

ACCEPTANCE CRITERIA FOR WELDS

Kind of Imperfection	Criteria (A to M) for Types of Welds, for Service Conditions, and for Required Examination Methods [Note (1)]																		
	Normal Fluid Service						Severe Cyclic Conditions						Category D Fluid Service						
	Methods		Types of Weld				Methods		Types of Weld				Method	Types of Weld					
	Visual	Spot or Random Radiography	Girth and Miter Groove	Longitudinal Groove [Note (2)]	Fillet [Note (3)]	Branch Connection [Note (4)]	Visual	100% Radiography	Magnetic Particle	Liquid Penetrant	Girth and Miter Groove	Longitudinal Groove [Note (2)]	Fillet [Note (3)]	Branch Connection [Note (4)]	Visual	Girth and Miter Groove	Longitudinal Groove [Note (2)]	Fillet [Note (3)]	Branch Connection [Note (4)]
Crack	X	X	A	A	A	A	X	X	X	X	A	A	A	A	X	A	A	A	A
Lack of fusion	X	X	A	A	A	A	X	X	...	...	A	A	A	A	X	A	A	NA	A
Incomplete penetration	X	X	B	A	NA	B	X	X	...	...	A	A	NA	A	X	A	A	NA	B
Internal porosity	...	X	E	F	NA	E	...	X	...	...	D	D	NA	D	...	...	...	...	...
(a) Slag inclusion, tungsten inclusion or elongated indication	...	X	G	G	NA	G	...	X	...	...	F	F	NA	F	...	...	...	...	...
(a) Undercutting	X	...	H	A	H	H	X	X	...	...	A	A	A	A	X	I	A	H	H
Surface porosity or exposed slag inclusion [Note (5)]	X	...	A	A	A	A	X	...	...	...	A	A	A	A	X	A	A	A	A
Surface finish	...	...	...	...	...	...	X	...	...	...	J	J	J	J	...	...	...	...	...
(a) Concave root surface (suck up)	X	X	K	K	NA	K	X	X	...	...	K	K	NA	K	X	K	K	NA	K
Reinforcement or internal protrusion	X	...	L	L	L	L	X	...	...	...	L	L	L	L	X	M	M	M	M

EM001-2A

Criterion Value Notes for Table EM001-2

Criterion												
Symbol	Measure	Acceptable Value Limits [Note (6)]										
A	Extent of imperfection	Zero (no evident imperfection)										
B	Depth of incomplete penetration	$\leq 1/32$ in. (0.8 mm) and $\leq 0.2 \bar{T}_w$										
	Cumulative length of incomplete penetration	≤ 1.5 in. (38 mm) in any 6 in. (150mm) weld length										
C	Depth of lack of fusion and incomplete penetration	$\leq 0.2 \bar{T}_w$										
	Cumulative length of lack of fusion and incomplete penetration [Note (7)]	≤ 1.5 in. (38mm) in and 6 in. (150mm) weld length										
D	Size and distribution of internal porosity	See BPV Code, Section VIII, Division 1, Appendix 4*										
E	Size and distribution of internal porosity	For $\bar{T}_w \leq 1/4$ in. (6.4mm), limit is same as D For $\bar{T}_w > 1/4$ in. (6.4mm), limit is 1.5 X D										
(a) F	Slag inclusion, tungsten inclusion, or elongated indication											
	Individual length	$\leq \bar{T}_w/3$										
	Individual width	$\leq 3/32$ in. (2.4mm) and $\leq \bar{T}_w/3$										
	Cumulative length	$\leq \bar{T}_w$ in and 12 \bar{T}_w weld length										
(a) G	Slag inclusion, tungsten inclusion, or elongated indication											
	Individual length	$\leq 2 \bar{T}_w$										
	Individual width	$\leq 1/8$ in. (3.2mm) and $\leq \bar{T}_w/2$										
	Cumulative length	$\leq 4 \bar{T}_w$ in any 6 in. (150mm) weld length										
H	Depth of undercut	$\leq 1/32$ in. (0.8mm) and $\leq \bar{T}_w/4$										
I	Depth of undercut	$\leq 1/16$ in. (1.6mm) and $\leq \bar{T}_w/4$ 1/32 in. (0.8mm)]										
J	Surface roughness	≤ 500 min. Ra per ASME B46.1										
K	Depth of root surface concavity	Total joint thickness, incl. weld reinf., $\geq \bar{T}_w$										
L	Height of reinforcement or internal protrusion [Note(8)] in any plane through the weld shall be within limits of the applicable height value in the tabulation are right. Weld metal shall merge smoothly into the component surfaces.	<table border="0"> <tr> <td>For \bar{T}_w in. (mm)</td> <td>"Height in. (mm)"</td> </tr> <tr> <td>$\leq 1/4$ (6.4)</td> <td>$\leq 1/16$ (1.6)</td> </tr> <tr> <td>$> 1/4$ (6.4), $\leq 1/2$ (12.7)</td> <td>$\leq 1/8$ (3.2)</td> </tr> <tr> <td>$> 1/2$ (12.7), ≤ 1 (25.4)</td> <td>$\leq 5/32$ (4.0)</td> </tr> <tr> <td>> 1 (25.4)</td> <td>$\leq 3/16$ (4.8)</td> </tr> </table>	For \bar{T}_w in. (mm)	"Height in. (mm)"	$\leq 1/4$ (6.4)	$\leq 1/16$ (1.6)	$> 1/4$ (6.4), $\leq 1/2$ (12.7)	$\leq 1/8$ (3.2)	$> 1/2$ (12.7), ≤ 1 (25.4)	$\leq 5/32$ (4.0)	> 1 (25.4)	$\leq 3/16$ (4.8)
For \bar{T}_w in. (mm)	"Height in. (mm)"											
$\leq 1/4$ (6.4)	$\leq 1/16$ (1.6)											
$> 1/4$ (6.4), $\leq 1/2$ (12.7)	$\leq 1/8$ (3.2)											
$> 1/2$ (12.7), ≤ 1 (25.4)	$\leq 5/32$ (4.0)											
> 1 (25.4)	$\leq 3/16$ (4.8)											
(b) M	Height of reinforcement or internal protrusion [Note (8)] as described in L.	Limit is twice the value applicable for L above										

X = required examination NA = not applicable ... = not required

(a) NOTES:

- (b)
- (1) Criteria given are for required examination. More stringent criteria may be specified in the engineering design. See also paras. 341.5 and 341.5.3
 - (2) Longitudinal groove weld includes straight and spiral seam. Criteria are not intended to apply to welds made in accordance with a standard listed in Table A-1 or Table 326.1
 - (3) Fillet weld includes socket and seal welds, and attachment welds for slip-on flanges, branch reinforcement, and supports.
 - (4) Branch connection weld includes pressure containing welds in branches and fabricated laps.
 - (5) These imperfections are evaluated only for welds $\leq 5/16$ in. (5mm) in nominal thickness.
 - (6) Where two limiting values are separated by "and", the lesser of the values determines acceptance. Where two sets of values are separated by "or", the larger value is acceptable. \bar{T}_w is the nominal wall thickness of the thinner of two components joined by a butt weld.
 - (7) Tightly butted unfused root faces are unacceptable.
 - (8) For groove welds, height is the lesser of the measurements made from the surfaces of the adjacent components; both reinforcement and internal protrusion are permitted in a weld. For fillet welds, height is measured from the theoretical throat, Fig 328.5.2A; internal protrusion does not apply.

EM001-2B

(a)

ACCEPTANCE CRITERIA FOR WELDS

Kind of Imperfection	Criteria for Types of Welds [Note (1)]				
	Methods	Types of Weld			
	Visual	Girth and Miter Groove	Longitudinal Groove [Note (2)]	Fillet [Note (3)]	Branch Connection [Note (4)]
Crack	X	A	A	A	A
Lack of fusion	X	A	A	A	A
Incomplete penetration	X	B	A	NA	B
Internal porosity	...	E	E	NA	E
Slag Inclusion, tungsten inclusion or elongated indication	...	G	G	NA	G
Undercutting	X	H	A	H	H
Surface porosity or exposed slag inclusion [Note (5)]	X	A	A	A	A
Concave root surface	X	K	K	NA	K
Reinforcement or internal protrusion	X	L	L	L	L

(a) From ASME B31.3; Table 341.3.2A

(1) For normal fluid service conditions. Criteria given are for required examination. More stringent criteria may be specified in the engineering design.

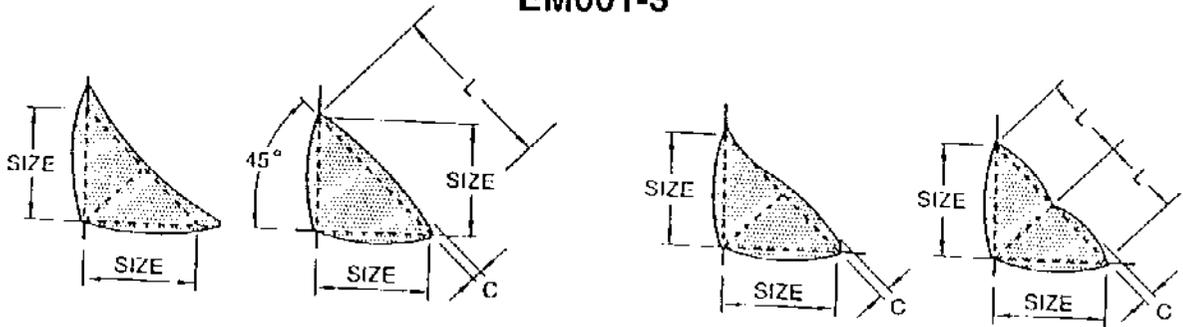
(2) Longitudinal groove weld includes straight and spiral seam.

(3) Fillet weld includes socket and seal welds, and attachment welds for slip-on flanges, branch reinforcement, and supports.

(4) Branch connection weld includes pressure containing welds in branches and fabricated laps.

(5) These imperfections are evaluated only for welds $\leq \frac{3}{16}$ in. (5mm) in nominal thickness.

EM001-3

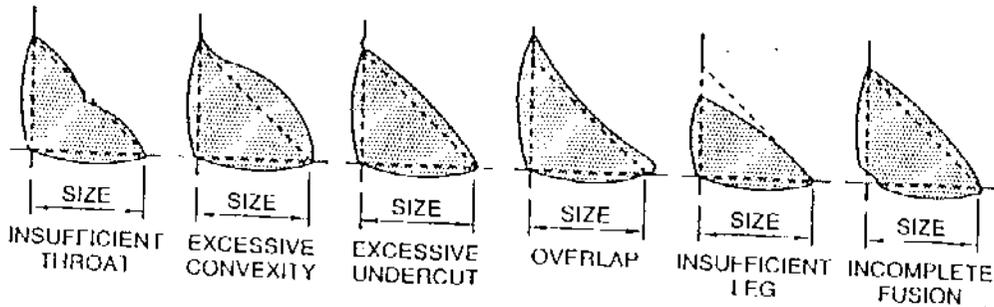


(A) DESIRABLE FILLET WELD PROFILES

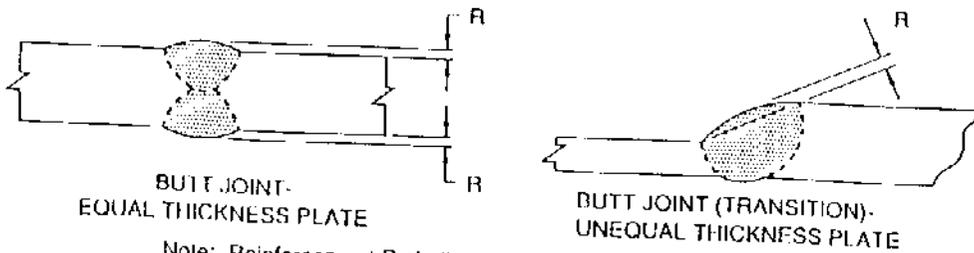
(B) ACCEPTABLE FILLET WELD PROFILES

Note: Convexity, C, of a weld or individual surface bead shall not exceed the value of the following table:

Measured Leg Size or Width of Individual Surface Bead, L	Max. Convexity
$L \leq 5/16$ in. (8 mm)	1/16 in. (1.6 mm)
$L \geq 5/16$ in. to $L < 1$ in. (25 mm)	1/8 in. (3 mm)
$L \geq 1$ in.	3/16 in. (5 mm)

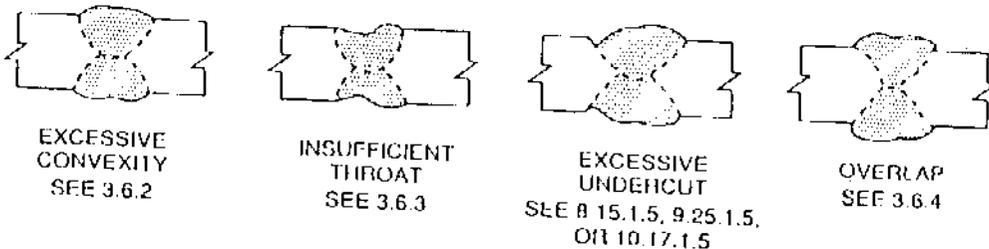


(C) UNACCEPTABLE FILLET WELD PROFILES



Note: Reinforcement R shall not exceed 1/8 in. (3 mm). See 3.6.2.

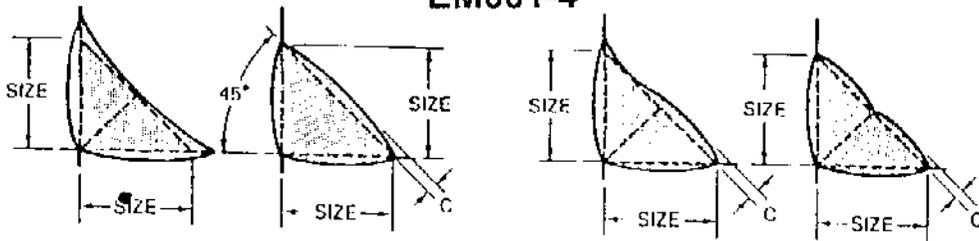
(D) ACCEPTABLE GROOVE WELD PROFILE IN BUTT JOINT



(E) UNACCEPTABLE GROOVE WELD PROFILES IN BUTT JOINTS

Acceptable and Unacceptable Weld Profiles

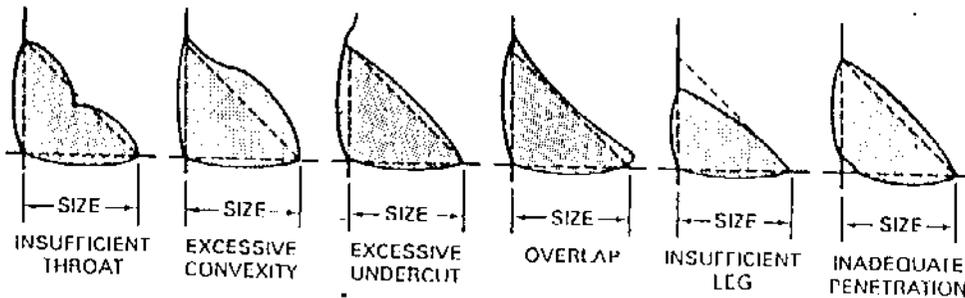
EM001-4



Note: Convexity, C, of a weld or individual surface bead shall not exceed 0.07 times the actual face width of the weld or individual bead, respectively, plus 0.06 in. (1.5 mm).

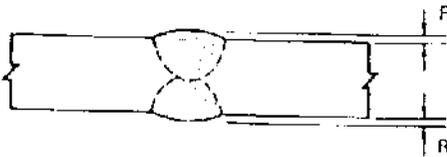
(A) DESIRABLE FILLET WELD PROFILES

(B) ACCEPTABLE FILLET WELD PROFILES



(C) UNACCEPTABLE FILLET WELD PROFILES

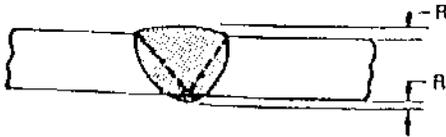
MAXIMUM REINFORCEMENT FOR A GIVEN PLATE THICKNESS - JOINT WELDED FROM BOTH SIDES



THICKNESS, t		MAXIMUM REINFORCEMENT	
in.	mm	in.	mm
$t \leq 3/8$	$t \leq 9.5$	3/32	2.4
$3/8 < t \leq 3/4$	$9.5 < t \leq 19$	1/8	3
$t > 3/4$	$t > 19$	3/16	5

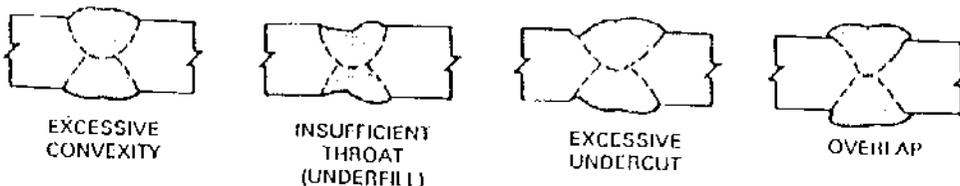
(D) ACCEPTABLE PROFILE: DOUBLE GROOVE WELD IN BUTT JOINT

MAXIMUM REINFORCEMENT FOR A GIVEN PLATE THICKNESS - JOINT WELDED FROM ONE SIDE



THICKNESS, t		MAXIMUM REINFORCEMENT	
in.	mm	in.	mm
$t \leq 1/4$	$t \leq 6.4$	3/32	2.4
$1/4 < t \leq 1/2$	$6.4 < t \leq 12.7$	1/8	3
$1/2 < t \leq 1$	$12.7 < t \leq 25.4$	5/32	4
$t > 1$	$t > 25.4$	3/16	5

(E) ACCEPTABLE PROFILE: GROOVE WELD IN BUTT JOINT WELDED FROM ONE SIDE



(F) UNACCEPTABLE PROFILES: GROOVE WELDS IN BUTT JOINTS