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MILITARY STANDARD
WELDED-JOINT DESIGNS, ARMORED-TANK TYPE

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MIL-STD-21A

DEPARTMENT OF DEFENSE

WASHINGTON, D. C. 20301

WELDED-JOINT DESIGNS, ARMORED-TANK TYPE

MIL-STD-21A

1. This Military Standard is mandatory for use by all Departments and Agencies of the Department of Defense.
2. Recommended corrections, additions, or deletions should be addressed to the U. S. Army Tank-Automotive Command, Warren, Michigan 48090.

MIL-STD-21A

FOREWORD

This Military Standard covers the design of joints for structures when one or more of the materials being joined is armor.

The joints specified in this standard are intended for use in military vehicles or other structures that are to be subjected to ballistic attack.

MIL-STD-21A

CONTENTS

	<u>Page</u>
1. SCOPE	1
1.1 Purpose	1
1.2 Application	1
2. REFERENCED DOCUMENTS	1
2.1 Military	1
2.2 Other publications	1
3. DEFINITIONS	1
3.1 Welding terms	2
4. GENERAL REQUIREMENTS	2
4.1 Selection of joint types	2
4.1.1 Exposed surfaces	2
4.1.2 Other surfaces	2
4.2 Tolerances on design openings	2
4.3 Sample drawing	2
5. DETAIL REQUIREMENTS	2
5.1 Groove type	2
5.2 Fillet type	13

MIL-STD-21A

FIGURES

<u>Figure</u>		<u>Page</u>
1	Type-1 Joint	3
2	Type-2 Joint	4
3	Type-3 Joint	5
4	Type-4 Joint	6
5	Type-5 Joint	8
6	Type-6 Joint	10
7	Type-7 Joint	12
8A	Type-8A Joint	13
8B	Type-8B Joint	14
9	Type-9 Joint	15
10	Type-10 Joint	16
11	Isometric drawing	18

MIL-STD-21A

1. SCOPE

1.1 Purpose. This standard covers the design of joints for structures when one or more of the materials being joined is armor.

1.2 Application. The joints specified in this standard are intended for use in military vehicles or other structures that are to be subjected to ballistic attack. Each application shall be subject to the approval of the procuring activity. The provisions of this standard refer entirely to full penetration-weld joints. In many armor vehicle designs, partial penetration type weld joints (joints not welded through the complete thickness of a plate) are being used. Some of these contribute mechanical strength to a welded joint to defeat ballistic impacts. The choice of these designs is very numerous. The different types of armor materials currently being used or contemplated coupled with various plate thickness combinations, plate angles, and other considerations make it impractical to include this immense variety in a general type armor joint design specification.

2. REFERENCED DOCUMENTS

2.1 The issues of the following documents in effect on the date of invitation for bids form a part of this standard to the extent specified herein.

Military

MIL-STD-20 Welding Terms and Definitions

(Copies of specifications, standards, drawings, and publications required by suppliers in connection with specific procurement functions should be obtained from the procuring activity or as directed by the contracting officer.)

2.2 Other publications. The following documents form a part of this standard to the extent specified herein. Unless otherwise indicated, the issue in effect on date of invitation for bids or request for proposal shall apply.

Standard Welding Symbols A2.0-58

(Copies may be purchased from the AMERICAN WELDING SOCIETY, 345 East 47th St., New York, N. Y. 10017.)

3. DEFINITIONS

MIL-STD-21A

3.1 Welding terms. Unless otherwise specified herein, terms used in referring to the joints shall have the meanings defined in MIL-STD-20.

4. GENERAL REQUIREMENTS

4.1 Selection of joint types.

4.1.1 Exposed surfaces. Surfaces subjected to ballistic attack, other than external attachments, generally shall be designed in accordance with joints 1-7, however fillet welds may be used for surfaces directly exposed to ballistic attack provided they have mechanical reinforcement inherent in the part design. This reinforcement shall be effective from all possible directions of ballistic impact. (see figure 10.)

4.1.2 Other surfaces. Surfaces not subjected to direct ballistic attack and attachments may be designed using joint types 8(a), 8(b), 9 and 10.

4.2 Tolerances on design openings. The design opening tolerances shown for various joint types are assembly tolerances and should not be considered as tolerances available for plate size variation but should include all other tolerances that may affect design opening, such as plate flatness, but not weld shrinkage.

4.3 Sample drawing. The isometric drawing (fig. 11) is included as a guide only to show typical locations of various joint designs in an armored structure or vehicle. Encircled numbers on the drawing should be taken as referring to the particular type of joint described in this standard. Suffix letters (joints 1-7 inclusive) have been omitted, since they identify plate thicknesses and other details, which will vary with the design of a specific structure or vehicle.

5. DETAIL REQUIREMENTS

5.1 Groove type. Grooved joints shall be as shown in 5.1.1 to 5.1.7 as selected in accordance with design requirements.

5.1.1 Type No. 1. Single-V-grooved butt joint, welded both sides.

5.1.1.1 The information in the table and following notes shall be included on drawings when this type of joint is used. When so placed on the drawing, or when this joint design is made a part of the contract, the information shall be considered as part of the requirements.

MIL-STD-21A

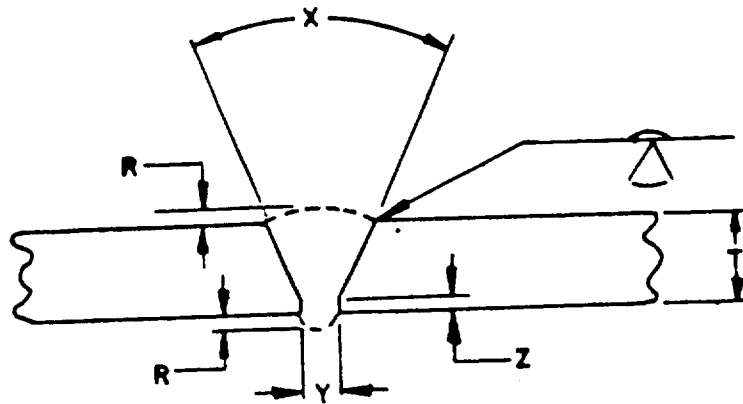


FIGURE 1. TYPE-I JOINT

JOINT NO.	INCLUDED ANGLE (d) X (DEGREES)	DESIGN OPENING (a) Y (INCH)	ROOT FACE Z (INCH)	MAX PLATE THICKNESS T (INCH)	REINFORCE- MENT OF WELD R (INCH)	DEPTH OF BEVEL (INCH)
1A	45	(b) $\frac{3}{16}$	(c) 0	$\frac{3}{4}$	0 TO $\frac{3}{32}$	T

Note (a) Design openings (see "Y" in fig. 1) do not include allowance for shrinkage during welding.

Note (b) Tolerance, plus $\frac{3}{16}$, minus 0 inch.

Note (c) Tolerance, plus $\frac{1}{16}$, minus 0 inch.

Note (d) Tolerance, plus 10, minus 0 degrees.

MIL-STD-21A

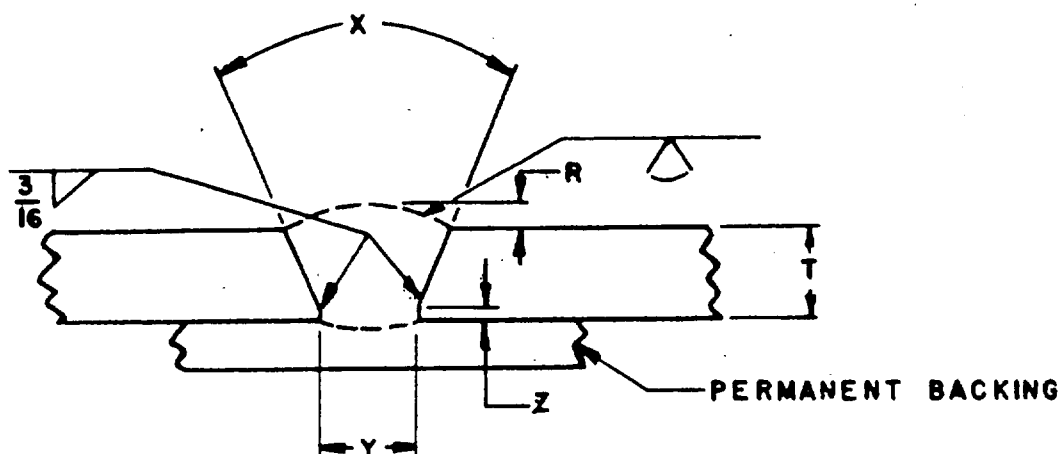
5.1.2 Type No. 2. Single-V-grooved butt joint, welded to backing

FIGURE 2. TYPE-2 JOINT

JOINT NO. (a)	INCLUDED ANGLE (b) X (DEGREES)	DESIGN OPENING (c) Y (INCH)	ROOT FACE Z (INCH)	MAX PLATE THICKNESS T (INCH)	REINFORCE- MENT OF WELD R (INCH)	DEPTH OF BEVEL (INCH)
2A	45	(c) $\frac{1}{2}$	(d) 0	$\frac{3}{4}$	0 TO $\frac{3}{32}$	T

5.1.2.1 The information in the above table and following notes shall be included on drawings when this type of joint is used. When so placed on the drawing, or when this joint design is made a part of the contract, the information shall be considered as part of the requirements.

- Note (a) To be used only where it is impossible to weld backside of joint.
 Note (b) Design openings (see "Y" in fig. 2) do not include allowance for shrinkage during welding.
 Note (c) Tolerance, plus 3/16, minus 0 inch.
 Note (d) Tolerance, plus 1/16, minus 0 inch.
 Note (e) Tolerance, plus 10, minus 0 degrees.

MIL-STD-21A

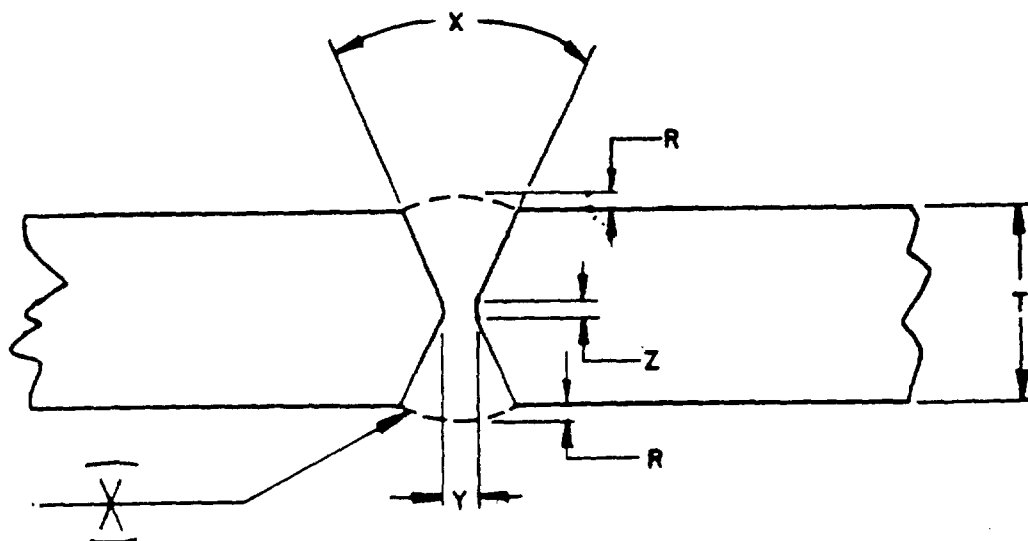
5.1.3 Type No. 3. Double-V-grooved butt joint, welded both sides.

FIGURE 3. TYPE-3 JOINT

JOINT NO.	INCLUDED ANGLE (e) X (DEGREES)	DESIGN OPENING (a) Y (INCH)	ROOT FACE Z (INCH)	PLATE THICKNESS T (INCH)	REINFORCE- MENT OF WELD R (INCH)	DEPTH OF BEVEL (INCH)
3A	45	(b) 3/16	(c) 0	3/8 TO 7/8	0 TO 3/32	1/2 T
3B	45	(b) 1/4	(c) 0	1 TO 1 1/2	0 TO 3/32	1/2 T
3C	45	(b) 5/16	(d) 1/16	GREATER THAN 1 1/2	0 TO 3/32	1/2 T

5.1.3.1 The information in the above table and the following notes shall be included on drawings when this type of joint is used. When so placed on the drawing, or when this joint design is made a part of the contract, the information shall be considered as part of the requirements.

Note (a) Design openings (see "Y" in fig. 3) do not include allowances for shrinkage during welding.

Note (b) Tolerance, plus 3/16, minus 0 inch.

Note (c) Tolerance, plus 1/16, minus 0 inch.

Note (d) Tolerance, plus or minus 1/16 inch.

Note (e) Tolerance, plus 10, minus 0 degrees.

MIL-STD-21A

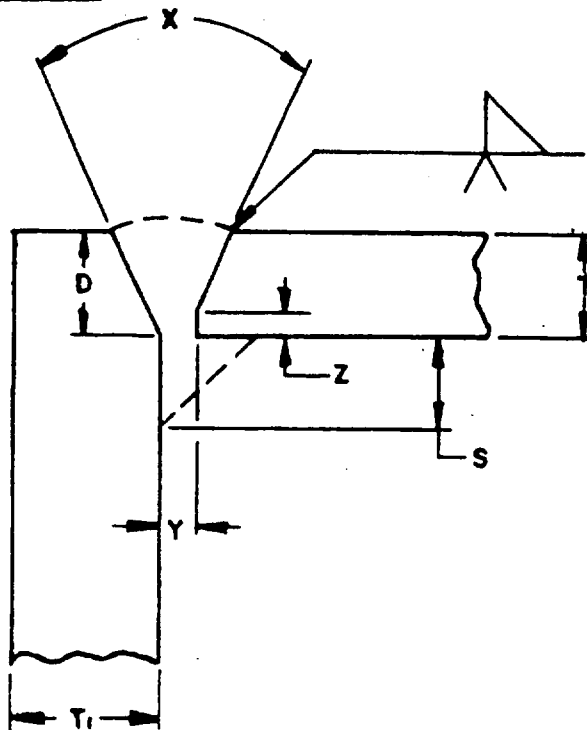
5.1.4 Type No. 4. Single-V-grooved corner joint, fillet-reinforced.

FIGURE 4. TYPE-4 JOINT

JOINT NO.	INCLUDED ANGLE (c) X (DEGREES)	DESIGN OPENING (a) Y (INCH)	ROOT FACE Z (INCH)	PLATE THICKNESS T (INCH)	PLATE THICKNESS T ₁ (INCH)	DEPTH OF BEVEL D (INCH)	MIN SIZE OF FILLET S (INCH)
4A	45	(b) $\frac{3}{16}$	(c) 0 to $\frac{1}{8}$	$\frac{1}{4}$	(d)	T	$\frac{3}{16}$
4B	45	(b) $\frac{3}{16}$	(c) 0 to $\frac{1}{8}$	$\frac{3}{8}$ to $\frac{1}{2}$	(d)	T	$\frac{1}{4}$
4C	45	(b) $\frac{3}{16}$	(c) 0 to $\frac{1}{8}$	$\frac{5}{8}$ to $\frac{3}{4}$	(d)	T	$\frac{5}{16}$

5.1.4.1 The information in the above table and following notes shall be included on drawings when this type of joint is used. When so placed on the drawing, or when this joint design is made a part of the contract, the information shall be considered as part of the requirements.

MIL-STD-21A

- Note (a) Design openings (see "Y" in fig. 4) do not include allowance for shrinkage during welding.
- Note (b) Tolerance, plus $3/16$, minus 0 inch.
- Note (c) Tolerance, plus $1/16$, minus 0 inch.
- Note (d) Values to be equal to or greater than for T-plate thickness.
- Note (e) Tolerance, plus 10, minus 0 degrees.

MIL-STD-21A

5.1.5 Type No. 5. Single-bevel-grooved corner joint, double-fillet-reinforced.

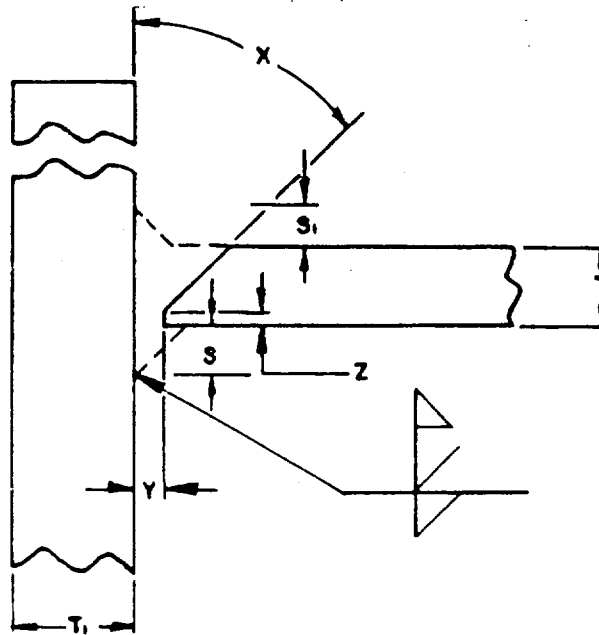


FIGURE 5. TYPE-5 JOINT

JOINT NO.	INCLUDED ANGLE (a) X (DEGREES)	DESIGN OPENING (a) Y (INCH)	ROOT FACE Z (INCH)	PLATE THICKNESS T (INCH)	PLATE THICKNESS T ₁ (INCH)	DEPTH OF BEVEL (INCH)	MIN SIZE OF FILLET S (INCH)	MIN SIZE OF FILLET S ₁ (INCH)
5A	45	(b) $\frac{3}{16}$	(c) 0 to $\frac{1}{8}$	$\frac{1}{4}$	(d)	T	$\frac{3}{16}$	$\frac{1}{4}$
5B	45	(b) $\frac{3}{16}$	(c) 0 to $\frac{1}{8}$	$\frac{3}{8}$	(d)	T	$\frac{1}{4}$	$\frac{1}{4}$
5C	45	(b) $\frac{5}{16}$	(c) 0 to $\frac{1}{8}$	$\frac{1}{2}$	(d)	T	$\frac{5}{16}$	$\frac{1}{4}$
5D	45	(b) $\frac{3}{16}$	(c) 0 to $\frac{1}{8}$	$\frac{5}{8}$	(d)	T	$\frac{3}{8}$	$\frac{1}{4}$
5E	45	(b) $\frac{3}{16}$	(c) 0 to $\frac{1}{8}$	$\frac{3}{4}$	(d)	T	$\frac{1}{2}$	$\frac{1}{4}$

5.1.5.1 The information in the above table and following notes shall be included on drawings when this type of joint is used. When so placed on drawing, or when this joint design is made a part of the contract, the information shall be considered as part of the requirements.

- Note (a) Design openings (see "Y" in fig. 5) do not include allowance for shrinkage during welding.
- Note (b) Tolerance, plus $3/16$, minus 0 inch.
- Note (c) Tolerance, plus $1/16$, minus 0 inch.
- Note (d) Values to be equal or greater than for T-plate thickness.
- Note (e) Tolerance, plus 10, minus 0 degrees.

MIL-STD-21A

5.1.6 Type No. 6. Double-bevel-grooved corner joint, fillet-reinforced.

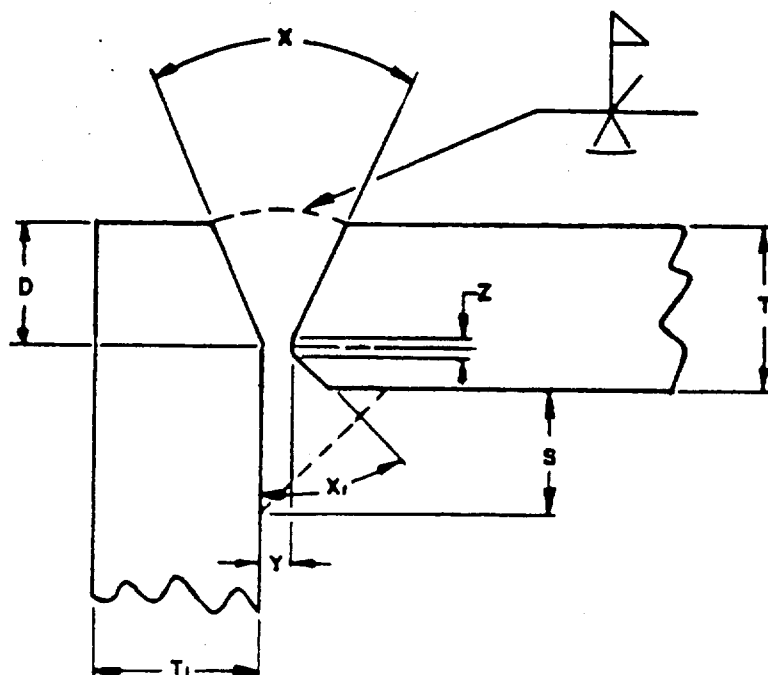


FIGURE 6. TYPE-6 JOINT

JOINT NO.	MIN INCLUDED ANGLE		DESIGN OPENING (e) Y (INCH)	ROOT FACE Z (INCH)	PLATE THICKNESS T (INCH)	PLATE THICKNESS T ₁ (INCH)	DEPTH OF BEVEL D (INCH)	MIN SIZE OF FILLET S (INCH)
	X (°) (OUTSIDE) (DEGREES)	X ₁ (INSIDE) (DEGREES)						
6A	45	45	(b) $\frac{3}{16}$	(C) 0	$\frac{3}{8}$ TO $\frac{1}{2}$	(e)	$\frac{2}{32}$ TO $\frac{3}{32}$ T	$\frac{1}{32}$
6B	45	45	(b) $\frac{3}{16}$	(C) 0	$\frac{3}{8}$ TO $\frac{3}{4}$	(e)	$\frac{2}{32}$ TO $\frac{3}{32}$ T	$\frac{3}{16}$
6C	45	45	(b) $\frac{1}{4}$	(C) 0	1	(e)	$\frac{1}{32}$ TO $\frac{1}{16}$ T	$\frac{3}{16}$
6D	45	45	(b) $\frac{1}{4}$	(C) 0	$1\frac{1}{4}$	(e)	$\frac{1}{32}$ TO $\frac{1}{16}$ T	$\frac{3}{16}$
6E	45	45	(b) $\frac{1}{4}$	(C) 0	$1\frac{1}{2}$	(e)	$\frac{1}{32}$ TO $\frac{1}{16}$ T	$\frac{3}{16}$
6F	45	45	(b) $\frac{3}{16}$	(C) $\frac{1}{16}$	GREATER THAN $1\frac{1}{2}$	(e)	$\frac{1}{32}$ TO $\frac{1}{16}$ T	$\frac{1}{2}$

MIL-STD-21A

5.1.6.1 The information in the above table and following notes shall be included on drawings when this type of joint is used. When so placed on the drawing, or when this joint design is made a part of the contract, the information shall be considered as part of the requirements.

- Note (a) Design openings (see "Y" in fig. 6) do not include allowance for shrinkage during welding.
- Note (b) Tolerance, plus $3/16$, minus 0 inch.
- Note (c) Tolerance, plus $1/16$, minus 0 inch.
- Note (d) Tolerance, plus $1/16$, minus 0 inch.
- Note (e) Thickness for each joint to be equal to or greater than its T-plate thickness.
- Note (f) Tolerance, plus 10, minus 0 degrees.

MIL-STD-21A

5.1.7 Type No. 7. Double-bevel-grooved tee or corner joint, double-fillet-reinforced.

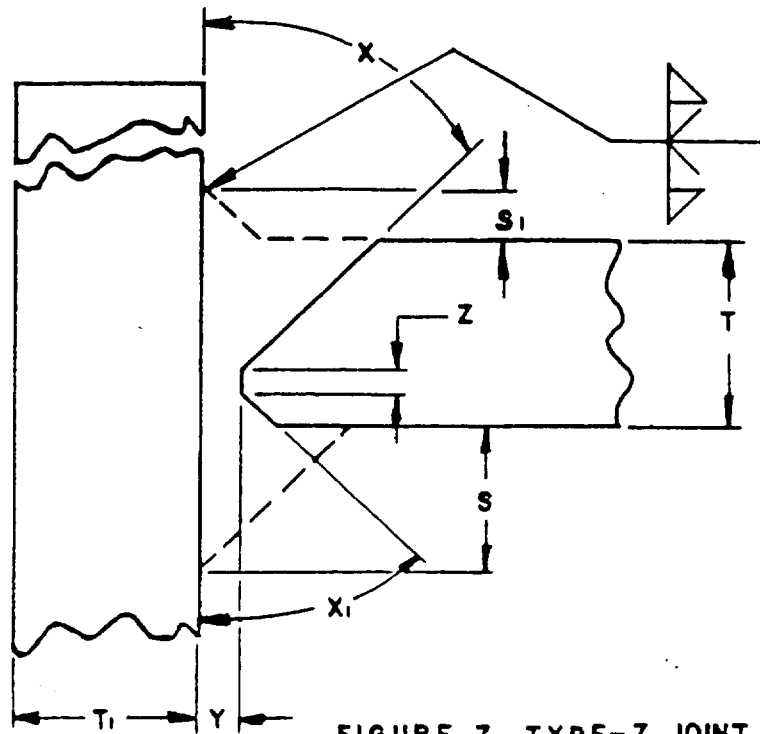


FIGURE 7. TYPE-7 JOINT

JOINT NO.	INCLUDED ANGLE		DESIGN OPENING Y (INCH)	ROOT FACE Z (INCH)	PLATE THICKNESS T (INCH)	PLATE THICKNESS T1 (INCH)	DEPTH OF BEVEL (INCH)	MIN SIZE OF FILLET S (INCH)	MIN SIZE OF FILLET S1 (INCH)
	X (°) (OUT-SIDE) (DEG)	X1 (°) (INSIDE) (DEG)							
7A	45	45	(b) $\frac{3}{16}$	(C) 0	$\frac{3}{8}$	(a)	$\frac{1}{2} \pm \frac{2}{3} T$	$\frac{1}{4}$	$\frac{1}{4}$
7B	45	45	(b) $\frac{3}{16}$	(C) 0	$\frac{1}{2}$	(a)	$\frac{1}{2} \pm \frac{2}{3} T$	$\frac{5}{16}$	$\frac{1}{4}$
7C	45	45	(b) $\frac{3}{16}$	(C) 0	$\frac{5}{8}$	(a)	$\frac{1}{2} \pm \frac{2}{3} T$	$\frac{3}{8}$	$\frac{1}{4}$
7D	45	45	(b) $\frac{3}{16}$	(C) 0	$\frac{3}{4}$	(a)	$\frac{1}{2} \pm \frac{2}{3} T$	$\frac{1}{2}$	$\frac{1}{4}$
7E	45	45	(b) $\frac{1}{4}$	(C) 0	1	(a)	$\frac{1}{2} \pm \frac{2}{3} T$	$\frac{5}{8}$	$\frac{5}{16}$
7F	45	45	(b) $\frac{1}{4}$	(C) 0	$\frac{1}{4}$	(a)	$\frac{1}{2} \pm \frac{2}{3} T$	$\frac{3}{4}$	$\frac{3}{16}$
7G	45	45	(b) $\frac{1}{4}$	(C) 0	$1\frac{1}{2}$	(a)	$\frac{1}{2} \pm \frac{2}{3} T$	$\frac{7}{8}$	$\frac{3}{16}$
7H	45	45	(b) $\frac{5}{16}$	(C) $\frac{1}{16}$	GREATER THAN $\frac{1}{2}$	(b)	$\frac{1}{2} \pm \frac{2}{3} T$	$\frac{7}{8}$	$\frac{5}{16}$

MIL-STD-21A

5.1.7.1 The information in the above table and following notes shall be included on drawings when this type of joint is used. When so placed on the drawing, or when this joint is made a part of the contract, the information shall be considered as part of the requirements.

- Note (a) Design openings (see "Y" in fig. 7) do not include allowance for shrinkage during welding.
- Note (b) Tolerance, plus $3/16$, minus 0 inch.
- Note (c) Tolerance, plus $1/16$, minus 0 inch.
- Note (d) Tolerance, plus or minus $1/16$ inch.
- Note (e) Thickness for each joint to be equal to or greater than its T-plate thickness.
- Note (f) Tolerance, plus 10, minus 0 degrees.

5.2 Fillet type. Filleted joints shall be as shown in 5.2.1 to 5.2.4 as selected in accordance with design requirements.

5.2.1 Type No. 8 (a). Intermittent-fillet-welded joint will be restricted to single-pass welds and shall conform to the following sketch and to the notes under 5.2.2.

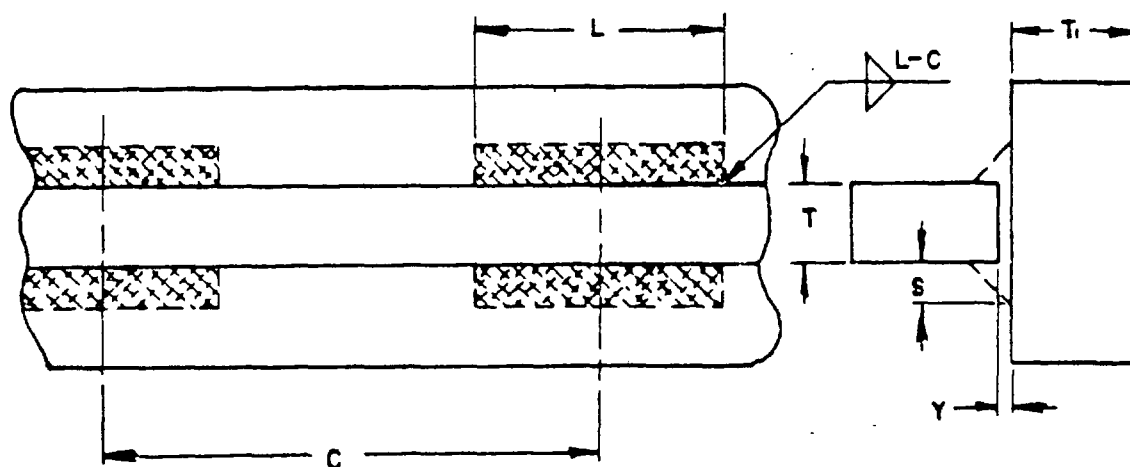


FIGURE 8A. TYPE-8A JOINT

MIL-STD-21A

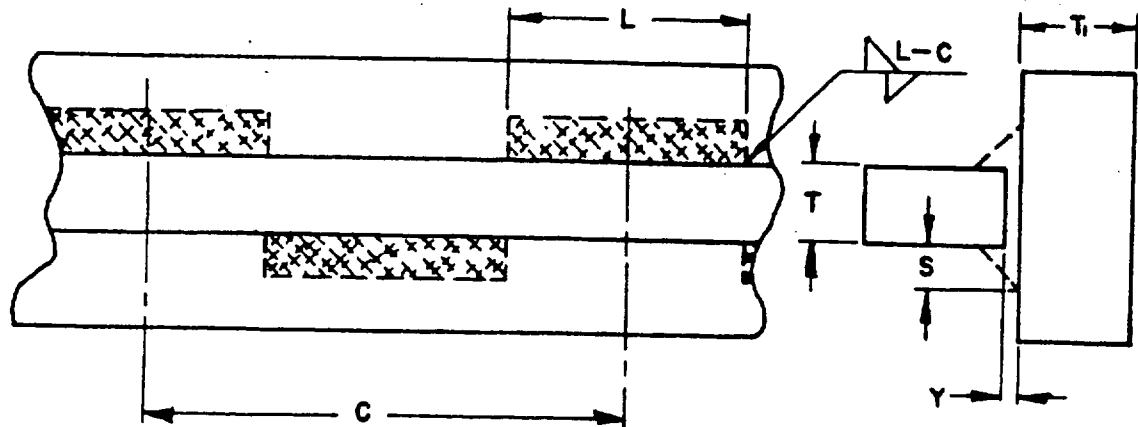


FIGURE 8B. TYPE - 8B JOINT

5.2.2 Type No. 8(b). Staggered intermittent-fillet-welded joint will be restricted to single-pass welds and shall conform to the above sketch and to the following notes.

Note (a) Fillet size ("S") to be specified in accordance with design requirements, except that regardless of such requirements, minimum fillet size to be used shall be:

<u>Plate thickness, inch</u>	<u>Min size fillet, inch</u>
T or T_1	S
Less than $3/8$	$3/16$
$3/8$ to $7/8$ incl.	$1/4$
Greater than $7/8$	$5/16$

- Note (b) Normal assembly dimensions will ordinarily give variations in dimensions "Y" of 0 to $3/32$. This should be shown as a tolerance on the drawing and will not require any increase in fillet size. When the designer specifies a nominal dimension "Y" greater than 0 (zero) the fillet size shall be increased by this dimension. For joint types 8(a), 8(b), and 9, when the gap exceeds the specified "Y" dimension plus $1/32$ to $3/32$ tolerance, a special procedure shall be followed as required by the applicable specification covering the welding of armor.
- Note (c) Length ("L") shall be not less than 1-1/2 inches.
- Note (d) Pitch ("C") shall be not less than 2L, or twice the length.

MIL-STD-21A

5.2.3 Type No. 9. Continuous-fillet-welded joint shall conform to the following sketch and to the accompanying notes:

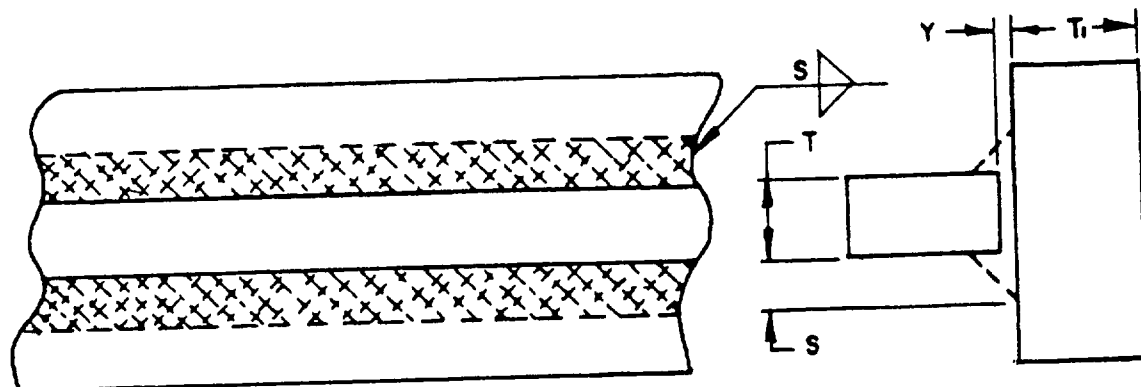


FIGURE 9. TYPE-9 JOINT

Note (a) Fillet size ("S") to be specified in accordance with design requirements, except that regardless of such requirements, minimum fillet size to be used shall be:

<u>Plate thickness, inch</u>	<u>Min size fillet, inch</u>
T or T_1	S
Less than $3/8$	$3/16$
$3/8$ to $7/8$ incl.	$1/4$
Greater than $7/8$	$5/16$

Note (b) Normal assembly dimensions will ordinarily give variations in dimension "Y" of 0 to $3/32$. This should be shown as a tolerance on the drawing and will not require any increase in fillet size. When the designer specifies a nominal dimension "Y" greater than 0 (zero), the fillet size shall be increased by this dimension. For joint types 8(a), 8(b), and 9, when the gap exceeds the specified "Y" dimension plus the $3/32$ tolerance, a special procedure shall be followed as required by the applicable specification covering the welding of armor.

MIL-STD-21A

5.2.4 Type No. 10. Continuous-fillet-welded joint with mechanical reinforcement shall conform to the following sketch and to the accompanying notes:

OUTSIDE OF VEHICLE

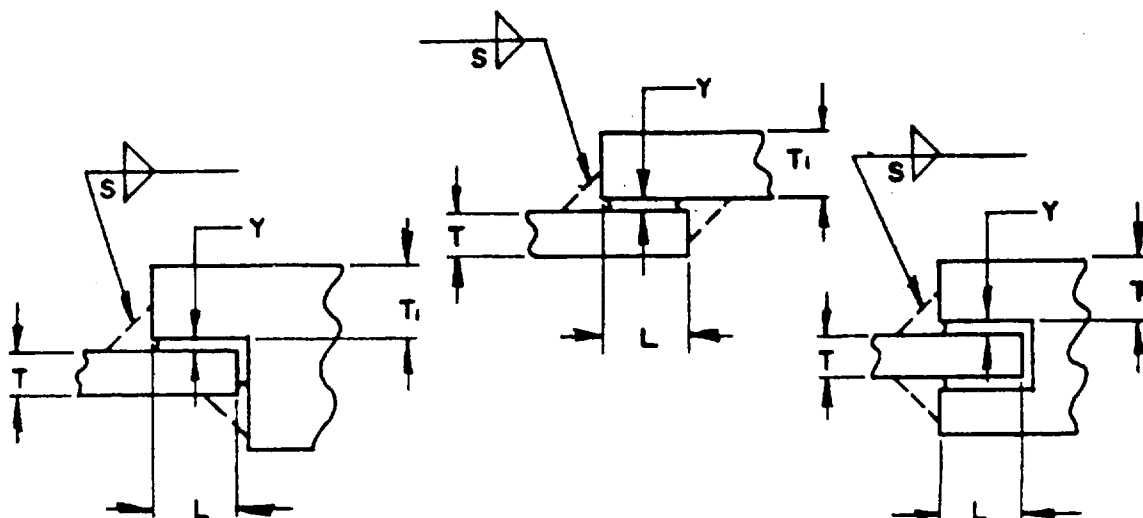


FIGURE 10. TYPE- 10 JOINT

JOINT NO.	PLATE THICKNESS T	MINIMUM FLANGE THICKNESS T ₁	MINIMUM FLANGE LAP L	MINIMUM FILLET SIZE S
10A	LESS THAN $\frac{3}{8}$	T	$\frac{1}{4}$	$\frac{3}{16}$
10B	$\frac{3}{8}$ TO $\frac{5}{8}$ INCL.	T	$\frac{5}{16}$	$\frac{5}{16}$
10C	$\frac{5}{8}$ TO 1 INCL.	T	$\frac{3}{8}$	$\frac{1}{2}$
10D	1 TO $1\frac{1}{2}$ INCL.	T	$\frac{1}{2}$	$\frac{7}{8}$
10E	GREATER THAN $1\frac{1}{2}$	T	$\frac{5}{8}$	1

MIL-STD-21A

Note (a) Separation. ("Y") when specified shall not exceed $1/8$ inch, and furthermore:

When $Y = 1/16$ inch or less, $S =$ designed fillet size;

When $Y = 3/32$ to $1/8$ inch, $S = Y$ plus designed fillet size.

Note (b) This joint type is not to be utilized without prior approval from the procuring agency at which time layouts will be reviewed showing the circumstances under which the joint is to be employed. The circumstances under which this joint is to be employed should be analyzed very carefully by the designer to assure that it will not be misused. This joint is not intended to add mechanical strength to the structure nor is it considered a ballistic joint; therefore, should not be utilized in cases where it must be depended upon to perform such functions.

Custodians:

Army - AT

Navy - SH

Preparing activity:

Army - AT

Project No. DRPR-0133

MIL-STD-21A

THIS ISOMETRIC DRAWING IS FOR ILLUSTRATION PURPOSES ONLY, AND THEREFORE, ANY APPLICATION OF JOINTS IN THE LOCATIONS SHOWN DOES NOT NECESSARILY INDICATE THAT THEY WILL BE APPROVED FOR ANY SPECIFIC VEHICLE.

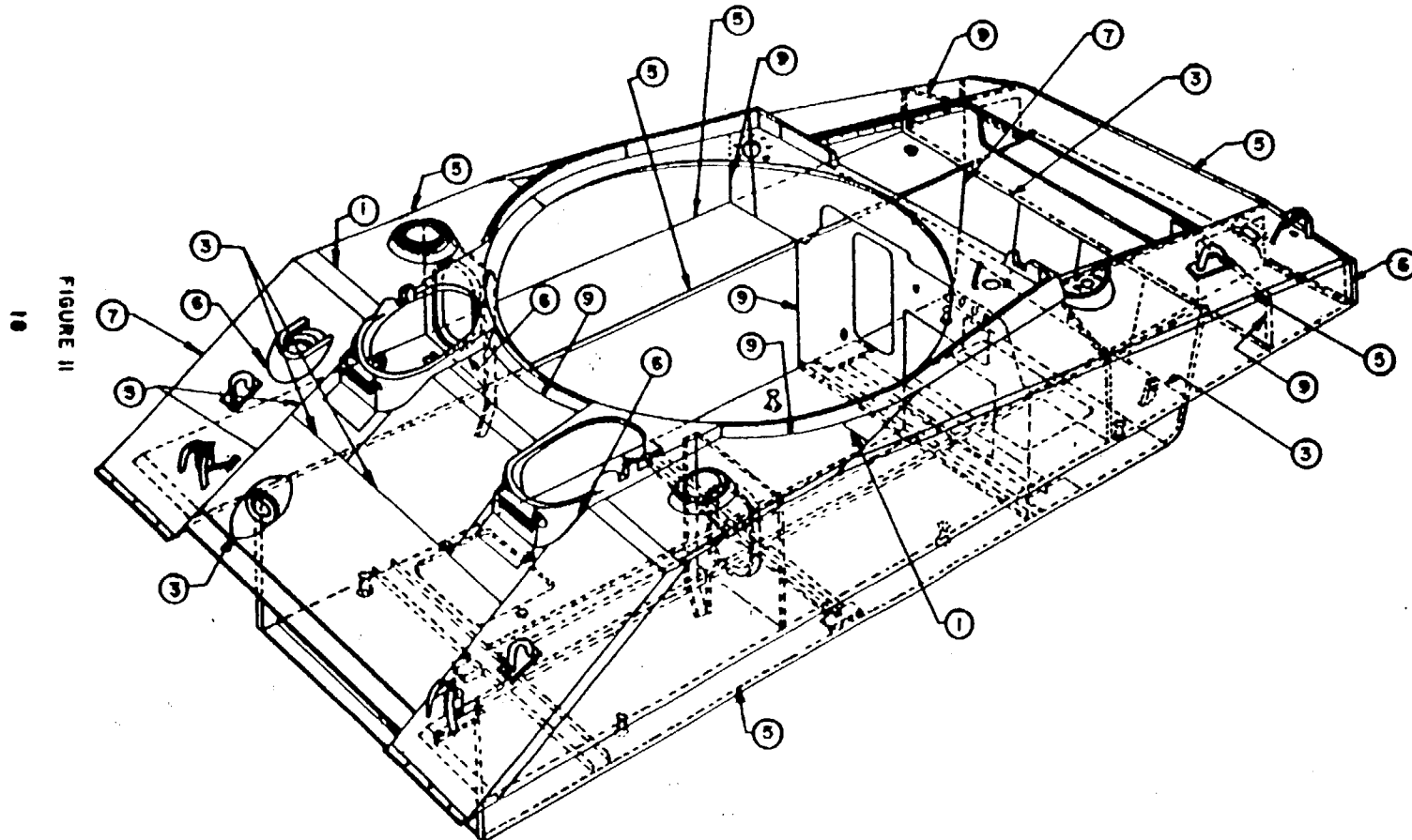


FIGURE 11