possible interpretation errors while using this program, these guidelines were created.

Bend Radii

- All Bend radii must be modeled - DO NOT MODEL THEM AS SHARP CORNERS.
- Bend radii should be defined as one continuous arc. It should not be a string with many short segments (splines). Similarly, arcs and lines should be defined as single entities.

Features

Features in the CAD file such as: (dimples, louvers or other formed tools) should be treated as 2D entities for tracking purposes.

Edges

- MMI Feature Analyzer WILL NOT handle a "dual edge" by-pass. Bypasses will have to be input manually.
- Upper and lower edges cannot be twisted together so that the upper and lower edge become one. MMI Feature Analyzer will not be able to differentiate between the two edges. It will track both edges as one continuous entity yielding an invalid part.
- Avoid nested internal edges (ie: Internal edges within internal edges). MMI Feature Analyzer cannot process them.
- Avoid ambiguous intersections where MMI Feature Analyzer is presented with more than one choice of tracking directions. The program may choose the wrong path.

Bend Relief Guidelines

Avoid bend relief with a length or width that is the same as the material thickness. MMI Feature Analyzer may stop tracking or choose the wrong path. A small difference of 0.05 to 0.13 mm is all that is needed.

CAD Transfer File Geometry Considerations

- The 3D CAD transfer files must be a **wire-frame** representation of the model.
- The file should contain only: LINES, ARCS AND POINTS.
- The file should NOT contain: SURFACES, SPLINES OR SOLIDS
- Most CAD packages have parameters available to control the type of geometry that is output.
- Parts should be "sheet metal worthy". The CAD geometry should reflect how the actual part will appear in 3D space (INCLUDE BEND RELIEF AS APPROPRIATE).
- MMI Feature Analyzer does include tools to manually direct the tracking path. However, in order to convert 3D CAD transfer files to SMP part models efficiently and quickly; it is recommended these guidelines are followed.

5.0 Guidelines for General Sheet Metal Dimensioning

1. In general, all sheet metal parts are sent to suppliers via an electronic file transfer per QP09511 & QP09516 (i.e.: IGES etc...).
2. The drawing shall contain sufficient detail to define the functional requirements of the part and overall form. Appropriate detail should include information on:

Size	Fit and interference tolerances
Shape	Critical Characteristics
Datum axix	Orientation

3. Notes concerning absence of sharp edges, surface finish, plating, etc., should also be defined on the drawing.
4. Typically when the part is manufactured, the supplier takes the IGES file and creates a 2-D shop drawing with all nominal dimensions specified for their "first article" inspection (unless Notes on a drawing supplied from DX says otherwise). This creation of a supplier's shop drawing is a service typically reflected in the quoted piece price of the part.
5. Discussing critical-to-function dimensions are addressed during the Instrument Manufacturing "Part Risk Assessment".
6. These dimensions are discussed, agreed to be the minimum required guaranteeing function and then placed on the drawing. An incoming inspection report is then completed to instruct Instrument Manufacturing personnel (Brookfield) what needs to be inspected to properly inspect parts.

How to Properly Describe Sheet Metal Material in the Drawing Block

1. Please refer to R&D QP09521 for further information
2. Choose a material from the industry Standard Sheet Gauge matrix on the following pages.
3. DX "PREFERRED" thickness material is highlighted in YELLOW
4. Find the "DX Preferred Sheet Thickness" for the type of material required for the design
5. Go to the column "CAD Model Metric Sheet Thickness" for the proper metric (mm) thickness to use when creating your sheet metal CAD model
6. When specifying sheet thickness in material block, please round up to the nearest tenth of a millimeter. See example below.
7. In the material block, call out the material, material metric thickness (rounding to nearest tenth of a millimeter) and the gauge number see example below:

Material Block Example

The design requires 25-gauge cold rolled sheet steel. In the CAD model, the designer would use 0.53 mm to create the model. The material on the drawing would be called out:

Material:
COLD ROLLED SHEET STEEL
0.5 mm THICK (25 GAUGE)

6.0 Preferred Sheet Metal Gauge Sizes

The following tables list industry standard sheet metal gauge thicknesses for various sheet material. Preferred gauges are highlighted in yellow. These preferred gauges were selected based on vendor recommendations of gauges that are readily available (resulting in faster turn-around and lower material cost). Note that English gauge sizes are used; metric sheet metal gauges are not readily available in the U.S.

Steel Sheet Gauges

Applies to: Galvannealed, Cold-Rolled & Hot Rolled Steel

Steel Sheet Standard Gauges

Gauge Number	U.S. Sheets* (Revised) Mfrs. Std. (Decimals of an inch) Applies to Galvannealed, Cold-Rolled, Hot Rolled Steel Sheet	CAD Model Metric Sheet Thickness (mm) calculated	Gauge Number	U.S. Sheets* (Revised) Mfrs. Std. (Decimals of an inch) Applies to Galvannealed, Cold-Rolled, Hot Rolled Steel Sheet	CAD Model Metric Sheet Thickness (mm) calculated
6 - 0's	-------	-------	17	0.0538	1.367
5 - 0's	-------	-------	18	0.0478	1.214
4 - 0's	-------	-------	19	0.0418	1.062
3 - 0's	-------	-------	20	0.0359	0.912
2 - 0's	-------	-------	21	0.0329	0.836
0	-------	-------	22	0.0299	0.759
1	-------	-------	23	0.0269	0.683
2	-------	-------	24	0.0239	0.607
3	0.2391	6.073	25	0.0209	0.531
4	0.2242	5.695	26	0.0179	0.455
5	0.2092	5.314	27	0.0164	0.417
6	0.1943	4.935	28	0.0149	0.378
7	0.1793	4.554	29	0.0135	0.343
8	0.1644	4.176	30	0.0120	0.305
9	0.1495	3.797	31	0.0105	0.267
10	0.1345	3.416	32	0.0097	0.246
11	0.1196	3.038	33	0.0090	0.229
12	0.1046	2.657	34	0.0082	0.208
13	0.0897	2.278	35	0.0075	0.191
14	0.0747	1.897	36	0.0067	0.170
15	0.0673	1.709	37	0.0064	0.163
16	0.0598	1.519	38	0.0060	0.152

NOTE: Shaded Areas are Preferred Standard Thickness * Gauge data taken from J.T. Ryerson & Sons Inc Data Book

Stainless Steel Sheet Gauges

Applies to: Cold-Rolled, Annealed & Pickled Stainless Steel

Stainless Steel Sheet Standard Gauges					
Gauge Number	U.S. Sheets* (Revised) Mfrs. Std. (Decimals of an inch) Applies to Cold-Rolled, Annealed & Pickled Sheet	CAD Model Metric Sheet Thickness (mm) calculated	Gauge Number	U.S. Sheets* (Revised) Mfrs. Std. (Decimals of an inch) Applies to Cold-Rolled, Annealed & Pickled Shee	CAD Model Metric Sheet Thickness (mm) calculated
6 - 0's	-------	-------	17	-------	-------
5 - 0's	-------	-------	18	0.0480	1.219
4 - 0's	-------	-------	19	0.0420	1.067
3 - 0's	-------	-------	20	0.0355	0.902
2 - 0's	-------	-------	21	-------	-------
0	-------	-------	22	0.0293	0.744
1	-------	-------	23	-------	-------
2	-------	-------	24	0.0235	0.597
3	-------	-------	25	-------	-------
4	-------	-------	26	0.0178	0.452
5	-------	-------	27	0.0164	0.417
6	-------	-------	28	0.0151	0.384
7	0.1874	4.760	29	-------	-------
8	0.1650	4.191	30	-------	-------
9	-------	-------	31	-------	-------
10	0.1350	3.429	32	-------	-------
11	0.1200	3.048	33	-------	-------
12	0.1054	2.677	34	-------	-------
13	0.0900	2.286	35	-------	-------
14	0.0751	1.908	36	-------	-------
15	-------	-------	37	-------	-------
16	0.0595	1.511	38	-------	-------

NOTE: Shaded Areas are Preferred Standard Thickness

* Gauge data taken from J.T. Ryerson & Sons Inc Data Book

Aluminum Sheet Gauges

Applies to: Aluminum, Brass and Bronze

Aluminum Sheet Standard Gauges					
Gauge Number	Brown & Sharpe Aluminum* Applies to Aluminum, Brass & Bronze	CAD Model Metric Sheet Thickness (mm) calculated	Gauge Number	Brown & Sharpe Aluminum* Applies to Aluminum, Brass & Bronze	CAD Model Metric Sheet Thickness (mm) calculated
6 - 0's	-------	-------	17	0.0453	1.151
5 - 0's	-------	-------	18	0.0403	1.024
4 - 0's	-------	-------	19	0.0359	0.912
3 - 0's	-------	-------	20	0.0320	0.813
2 - 0's	-------	-------	21	0.0285	0.724
0	-------	-------	22	0.0253	0.643
1	-------	-------	23	0.0226	0.574
2	-------	-------	24	0.0201	0.511
3	0.2294	5.827	25	0.0179	0.455
4	-------	-------	26	0.0159	0.404
5	-------	-------	27	0.0142	0.361
6	-------	-------	28	0.0126	0.320
7	0.1433	3.665	29	0.0113	0.287
8	0.1285	3.264	30	0.0100	0.254
9	0.1144	2.588	31	-------	-------
10	0.1019	2.588	32	-------	-------
11	0.0907	2.304	33	-------	-------
12	0.0808	2.052	34	-------	-------
13	0.0720	1.829	35	-------	-------
14	0.0641	1.628	36	-------	-------
15	0.0571	1.450	37	-------	-------
16	0.0508	1.290	38	-------	-------

NOTE: Shaded Areas are Preferred Standard Thickness

* Gauge data taken from R.J. Reynolds Aluminum Data Book

Steel Strip & Tubing Gauges

Steel Strip & Tubing Standard Gauges					
Gauge Number	Strip & Tubing Birmingham or Stubs (Decimals of an inch)	CAD Model Metric Sheet Thickness (mm) calculated	Gauge Number	Strip & Tubing Birmingham or Stubs (Decimals of an inch)	CAD Model Metric Sheet Thickness (mm) calculated
6 - 0's	-------	-------	17	0.058	1.473
5 - 0's	0.500	12.700	18	0.049	1.245
4 - 0's	0.454	11.532	19	0.042	1.067
3 - 0's	0.425	10.795	20	0.035	0.889
2 - 0's	0.380	9.652	21	0.032	0.813
0	0.340	8.636	22	0.028	0.711
1	0.300	7.620	23	0.025	0.635
2	0.284	7.214	24	0.022	0.559
3	0.259	6.579	25	0.020	0.508
4	0.238	6.045	26	0.018	0.457
5	0.220	5.588	27	0.016	0.406
6	0.203	5.156	28	0.014	0.356
7	0.180	4.572	29	0.013	0.330
8	0.165	4.191	30	0.012	0.305
9	0.148	3.759	31	0.010	0.254
10	0.134	3.404	32	0.009	0.229
11	0.120	3.048	33	0.008	0.203
12	0.109	2.769	34	0.007	0.178
13	0.095	2.413	35	0.005	0.127
14	0.083	2.108	36	0.004	0.102
15	0.072	1.829	37	-------	-------
16	0.065	1.651	38	-------	-------

NOTE: Shaded Areas are Preferred Standard Thickness
* Gauge data taken from J.T. Ryerson & Sons Inc Data Book

Table of Steel Wire

Steel Wire Standard Gauges					
Gauge Number	Steel Wire Gauge Replaces Washburn and Moen Gauge (Decimals of an inch)	CAD Model Metric Sheet Thickness (mm) calculated	Gauge Number	Steel Wire Gauge Replaces Washburn and Moen Gauge (Decimals of an inch)	CAD Model Metric Sheet Thickness (mm) calculated
6 - 0's	0.4615	11.722	17	0.0540	1.372
5 - 0's	0.4305	10.935	18	0.0475	1.207
4 - 0's	0.3938	10.003	19	0.0410	1.041
3 - 0's	0.3625	9.208	20	0.0348	0.884
2 - 0's	0.3310	8.407	21	0.0317	0.805
0	0.3065	7.785	22	0.0286	0.726
1	0.2830	7.188	23	0.0258	0.655
2	0.2625	6.668	24	0.0230	0.584
3	0.2437	6.190	25	0.0204	0.518
4	0.2253	5.723	26	0.0181	0.460
5	0.2070	5.258	27	0.0173	0.439
6	0.1920	4.877	28	0.0162	0.411
7	0.1770	4.496	29	0.0150	0.381
8	0.1620	4.115	30	0.0140	0.356
9	0.1483	3.767	31	0.0132	0.335
10	0.1350	3.429	32	0.0128	0.325
11	0.1205	3.061	33	0.0118	0.300
12	0.1055	2.680	34	0.0104	0.264
13	0.0915	2.324	35	0.0095	0.241
14	0.0800	2.032	36	0.0090	0.229
15	0.0720	1.829	37	0.0085	0.216
16	0.0625	1.588	38	0.0080	0.203

NOTE: Shaded Areas are Preferred Standard Thickness

* Gauge data taken from J.T. Ryerson & Sons Inc Data Book

7.0 Design Guidelines for Sheet Metal Parts

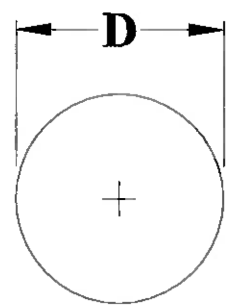
The following guidelines will aid the designer in producing sheet metal parts with the lowest possible designed-in fabrication costs. "Preferred Limits" are those dimensional values which result in minimal fabrication costs. "Not Recommended" values are possible within the bounds of sheet metal processing, but may result in increased part cost.

Holes

Punching, perforating, piercing, or laser cutting may produce holes in sheet metal. The preferred method is left up to the approved supplier who can most economically meet drawing requirements and specifications of DX.

Round Hole Preferred Sizes and Tolerances

Preferred Diameter Sizes		
	Not Recommended*	**Preferred Limits**
Aluminum	D = 0.25T	D = 0.5T
Steel	D = 0.5T	D = 1 T
Stainless Steel	D = 0.25T	D = 0.5T



Note: T = Material thickness
* These selections may increase costs

Preferred Diameter tolerances (mm) (0.6 - 3 mm material thickness)		
Diameter Dimension		Minimum Preferred Tolerances
Over	Thru	
-	25	± 0.13
25	250	± 0.15
250	500	± 0.25

Note: Consider finishing

Rectangular Hole Preferred Sizes and Tolerances

Size tolerances (mm) (0.6 - 3 mm material thickness)	
	Minimum Preferred Tolerance on hole sides
Rectangular Holes (0.4mm corner radii)	± 0.13

Effect of Applied Finish on Hole Tolerances

A. **ORGANIC**: Dimensional limits apply before the application of coatings (such as: paint, powder coating, etc…)
B. **INORGANIC**: Dimensional limits apply after the application of finish coatings (such as: anodizing, plating, etc…)

Laser Produced Holes

General considerations must be used when specifying laser cut holes. Roundness and tolerances are similar to punched holes

Recommended Hole Sizes for Laser Produced Holes	
Material Type	Minimum Preferred Hole Diameter
Aluminum	0.5 T
Stainless Steel	0.5 T
Carbon Steel	1.0 T

T = Material thickness

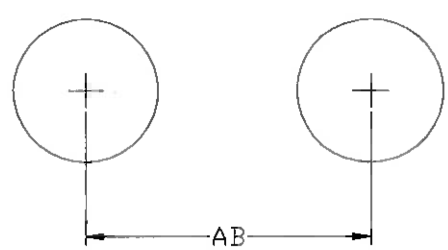
Maximum Material Thickness for Laser Produced Holes		
Material Type	1500 Watt Laser	2500 Watt Laser
Hot/ Cold Rolled Carbon Steel	9 mm	16 mm
Stainless Steel (300 Series)	5 mm	9 mm
Aluminum	3 mm	6 mm

Hole Feature-To- Feature Relationships

Minimum Distance between Holes

Preferred Minimum Distance between Holes		
Material Thickness	Not Recommended*	**Preferred Min.**
≤ 1.5 mm	AB = 1.5T	AB = 2T
> 1.5 mm	---------	AB = 1.5T

* These selections may increase costs



Tolerances on Dimension AB (mm)			
Over	Thru	Not Recommended*	**Preferred**
-	30	± 0.1	± 0.13
30	100	± 0.1	± 0.13
100	300	± 0.1	± 0.13
300	600	± 0.15	± 0.25
600	-	± 0.25	± 0.4

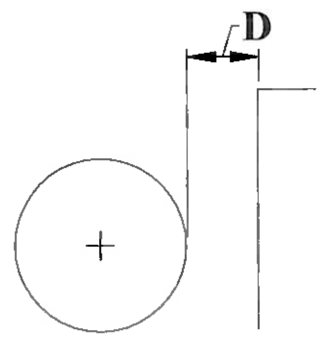
* These selections may increase costs

Minimum Distance from Round Hole to Blanked Edge or From Round Hole to Rectangular Hole

(Does not apply to captive fasteners holes; apply manufacturer's suggested practices)

	Not Recommended*	**Preferred**
With 1 or 2 operations	D = T	D = 3T
With guided punch	D = 0.5T	D = 3T

Note: T = Material thickness – (0.3 mm; 0.7 mm; 1 mm)
* These selections may increase costs

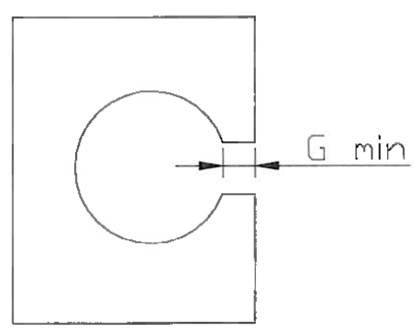


Tolerances on Dimension D (mm)			
Over	Thru	Not Recommended* ±	**Preferred** ±
-	30	0.09	0.18
30	100	0.13	0.25
100	300	0.18	0.35
300	1000	0.35	0.5

* These selections may increase costs

Width of Dimension G	
Material Thickness	G_{min}
To 3 mm	2T
3 mm to 10 mm	2.5T

Note: T = Material thickness

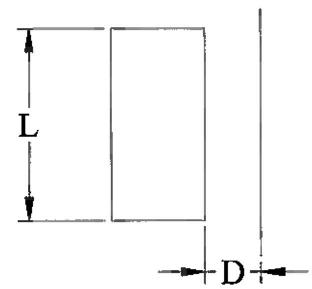


Minimum Distance from Rectangular Hole to Blanked Edge or From Rectangular Hole to Rectangular Hole

Minimum Distance From Rectangular Hole To Rectangular Hole Or Edge

	Not Recommended*	**Preferred**
L < 25 mm	D = T	D = 3T
L > 25 mm	D = 2T	D = 4T

Note: T = Material thickness
* These selections may increase costs



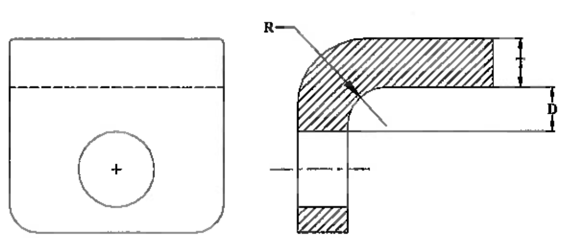
Tolerances on Dimension D (mm)			
Over	Thru	Not Recommended*	**Preferred**
-	30	± 0.12	± 0.18
30	100	± 0.12	± 0.25
100	300	± 0.12	± 0.35
300	600	± 0.25	± 0.5
600	-	± 0.40	± 0.5

* These selections may increase costs

Minimum Distance from Round Hole to Bend Radius

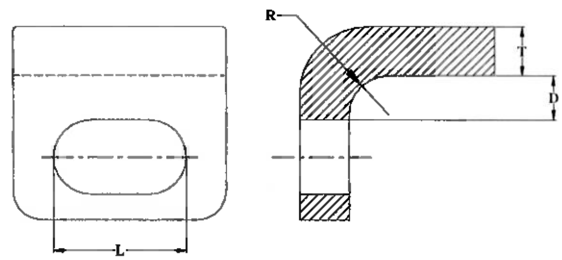
Minimum distance from round hole to internal bend radius	Not Recommended*	**Preferred**
	D = 1.5T + R	D = 2T + R
	Tol. ± 0.25 mm	Tol. ± 0.5 mm

* These selections may increase costs



Minimum Distance from Slotted Hole to Bend Radius

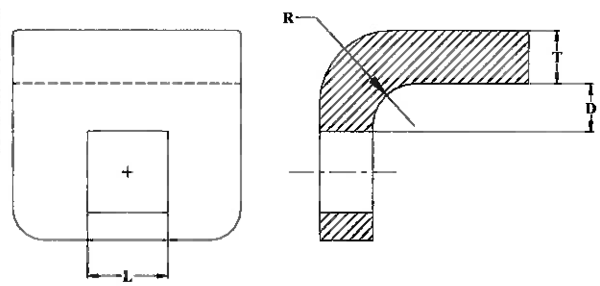
Length L (mm)		Distance to Bend (D)	
Over	Thru	Not Recommended*	**Preferred**
-	25	2.5T + R	4T + R
25	50	3T + R	4.5T + R
50	-	5T + R	7T + R



Note: Minimum distance from slot to internal bend radius
* These selections may increase costs

Minimum Distance from Rectangular Hole to Bend Radius

Not Recommended*		**Preferred**
For L ≤ 25 mm	D = 2T + R	D = 3T + R
For L = 25 to 50 mm	D = 2.5T + R	D = 3.5T + R
For L > 50 mm	D = 3T + R	D = 4T + R

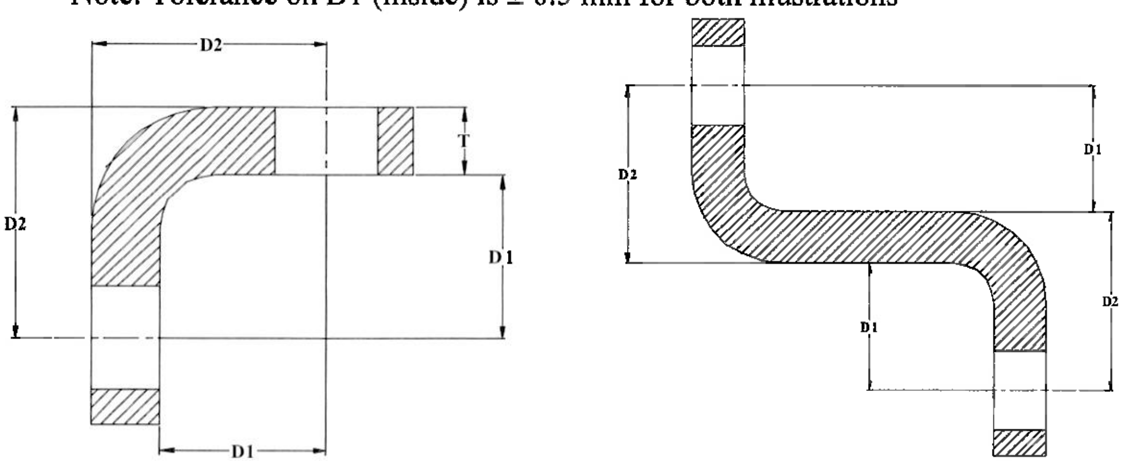


Note: Typical tolerance on L = 0.1 mm
* These selections may increase costs

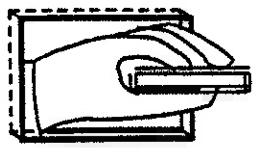
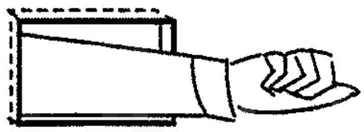
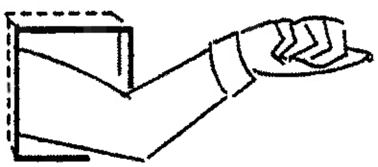
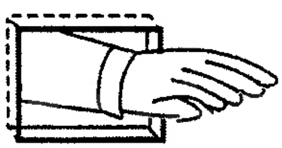
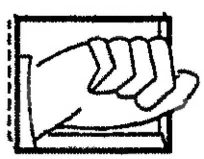
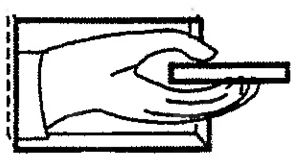
Tolerances on Hole Locations from Multiple Bends

Tolerance on D2 (outside) up to Max. material thickness of 3 mm is:	Dimension T		Dimension D2
	Over	Thru	
	0.1	1.5	± 0.6
	1.5	3	± 0.75

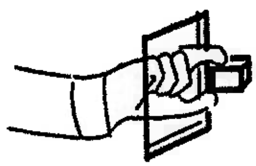
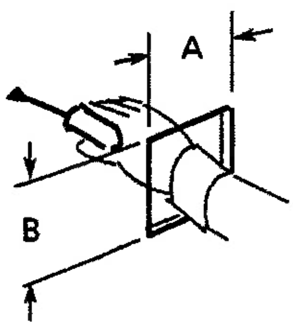
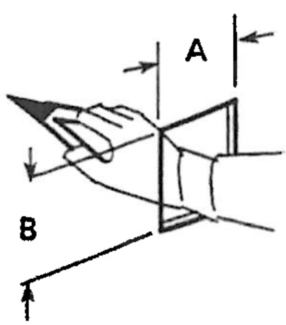
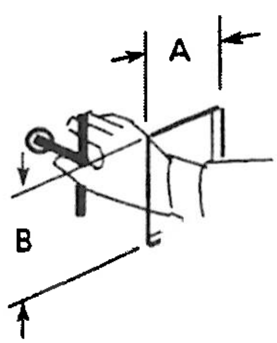
Note: Tolerance on D1 (inside) is ± 0.5 mm for both illustrations



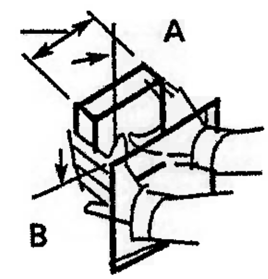
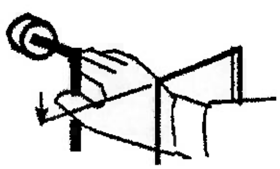
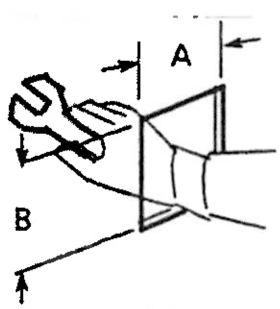
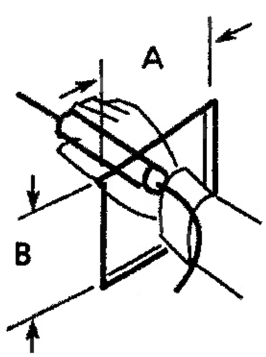
Preferred Ergonomic Operation Design Clearances for Holes in Sheet Metal Enclosures

Figure	Task Description, mm	Dimensions, mm
	Hand plus object over 25 mm diameter to wrist	45 mm Clearance around object
	Arm to elbow (light clothing)	100 x 115 mm or 115 mm diameter
	Arm to shoulder	130 mm square or diameter
	Empty hand to wrist: Bare hand rolled = a; Bare hand flat = b	a = 95 mm diameter or sq. b=83 mm width, 100 mm height or sq.
	Clinched hand to wrist	130 mm width; 90 mm height; 30 mm diameter
	Hand plus 25 mm diameter object to wrist	95.5 mm height, width or diameter
	Push button access to first finger joint	30 mm diameter or sq.

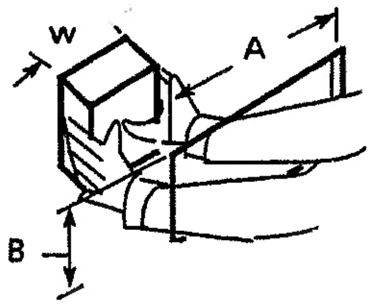
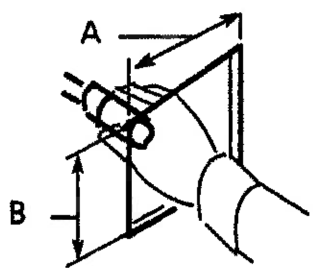
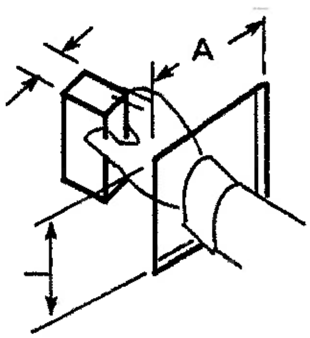
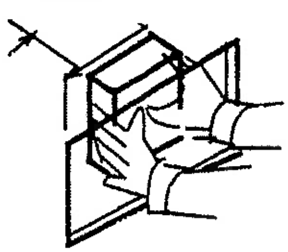
Preferred Ergonomic Operation Design Clearances (continued…)

Figure	Task Description, mm	Dimensions, mm
	Two finger access	50 mm diameter or sq.
	Using common screw-driver, with freedom to turn handle 180°	A = 110 mm; B = 120 mm
	Using pliers and similar tools	A = 132 mm; B = 115 mm
	Using "T" handle wrench, with freedom to turn handle 180°	A = 135 mm; B = 155 mm

Preferred Ergonomic Operation Design Clearances (continued…)

Figure	Task Description, mm	Dimensions, mm
	Grasping large objects with two hands, with arms through openings up to wrists	A = Width + 150 mm; B = Height 125 mm
	Using "Allen" wrench, with freedom to turn handle 60°	A = 280 mm; B = 200 mm
	Using open-end wrench, with freedom to turn handle 60°	A = Width 280 mm; B = 200 mm
	Using electronic test probe or similar device	A & B = 85 mm

Preferred Ergonomic Operation Design Clearances (continued…)

Figure	Task Description, mm	Dimensions, mm
	Grasping large objects with two hands, with arms through openings up to wrists	A = Width + 150 mm; B = Height 125 mm
	Grasping small objects up to 50 mm diameter	A = 110 mm; B = 120 mm
	Grasping objects wider than 50 mm with one hand	A = Width + 45 mm; B = Height 125 mm
	Grasping objects with two hands, with hands extended through openings up to fingers	A = Width + 75 mm; B = Height 125 mm

Forming, Blanking, Bending, and Burr Removal

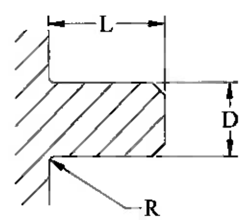
Tolerances on Linear Dimensions

Typical Blank Tolerances on Linear Dimensions (mm)			
Basic Dimensions		Not Recommended* Tolerance	**Preferred Tolerance**
Over	Thru		
-	3	± 0.05	± 0.2
3	6	± 0.05	± 0.2
6	30	± 0.10	± 0.5
30	120	± 0.15	± 0.8
120	315	± 0.20	± 1.2
315	1000	± 0.30	± 2.0
1000	2000	± 0.50	± 3.0

Minimum Sizes for Tabs

	Not Recommended*	**Preferred**	
For T = 0.4 – 1.5 mm	D = T	For all thickness	D = 7T L = 1.5D R_{min} = T
For T = 1.5 mm	D = 3T L = 3D R = 0.5T		

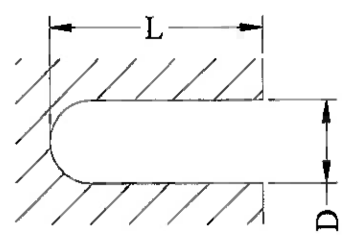
Note: T = Material thickness
* These selections may increase costs



Minimum Sizes for Slots

	Not Recommended*	**Preferred**	
For T = 0.4 – 1.5 mm	D = 3T	For all thickness	D = 4T L = 3D
For T = 1.5 mm	D = 2T L = 4D		

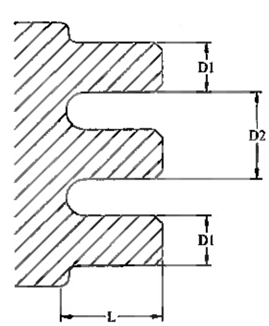
Note: T = Material thickness
* These selections may increase costs



Minimum Sizes for Alternating Slots and Tabs

Not Recommended*	**Preferred**
D1 = 4T	D1 = 5T
D2 = 7T	D2 = 9T
L = 2D1	L = D1

* These selections may increase costs



Preferred Minimum Bend Radius for Carbon and Stainless Steels

Material Type	180° Bend Radius	
	Stock Thickness (mm)	Minimum
Carbon Steel	To 3	Flat on itself in either direction
300 Series Stainless	To 2	1/2T
400 Series Stainless	To 2	1T

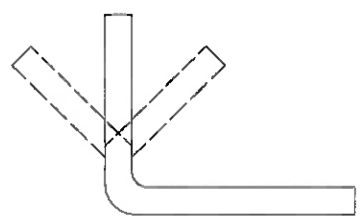
Preferred Minimum Bend Radius for Aluminum

Minimum Bend Radius for Aluminum		
Stock Thickness (mm)		90° Bend Radius (minimum)
Over	Thru	
-	1	Sharp
1	1.5	0.8
1.5	2	1.6
2	-	2.4

Angles and Flanges

Not Recommended*	**Preferred**
Other than 90°	90°

* These selections may increase costs



Angle Tolerances

Material Thickness	Not Recommended*	**Preferred**
1.5 mm & below	± 1°	± 2°
All other thickness	± 2°	± 3°

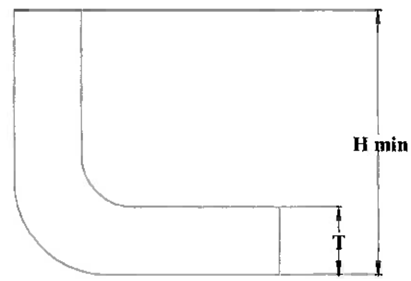
* These selections may increase costs

Minimum Flange Height

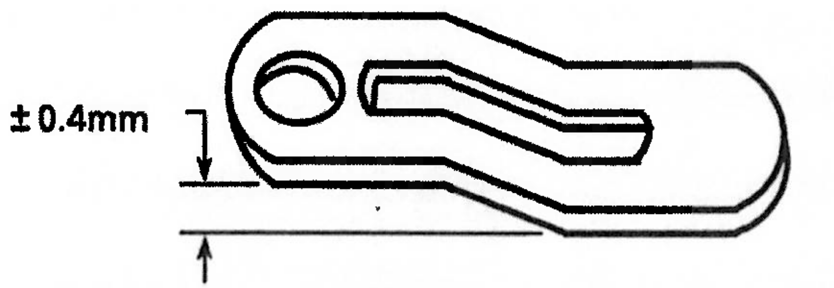
Flange Height Guidelines			
Material Thickness		Not Recommended*	**Preferred**
Over	Thru	H ± 0.5 mm	H ± 0.5 mm
0.4	0.8	H = 5T	H = 6T
0.8	3	H = 4T	H = 5T
3	-	H = 3T	H = 4T

T = Material thickness

* These selections may increase costs



Offset Bend Tolerances



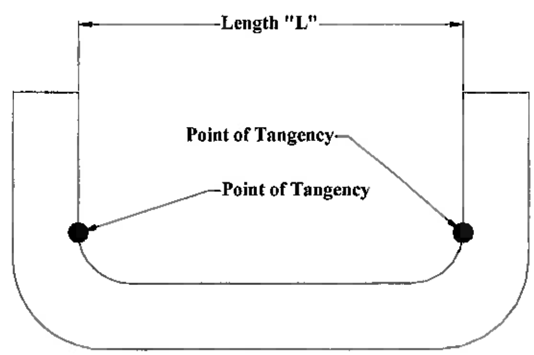
PREFERRED TOLERANCE BETWEEN TWO OFFSET PARALLEL FLAT SURFACES IS ±0.4 mm

Bend Tolerances

Length L, mm		Tolerance	
		Inside Tolerance	Outside Tolerance
Over	Thru		
Over	75	0.2	± 0.2 + (2 * mtol)
75	600	0.4	± 0.4 + (2 * mtol)
600	1200	0.6	± 0.6 + (2 * mtol)

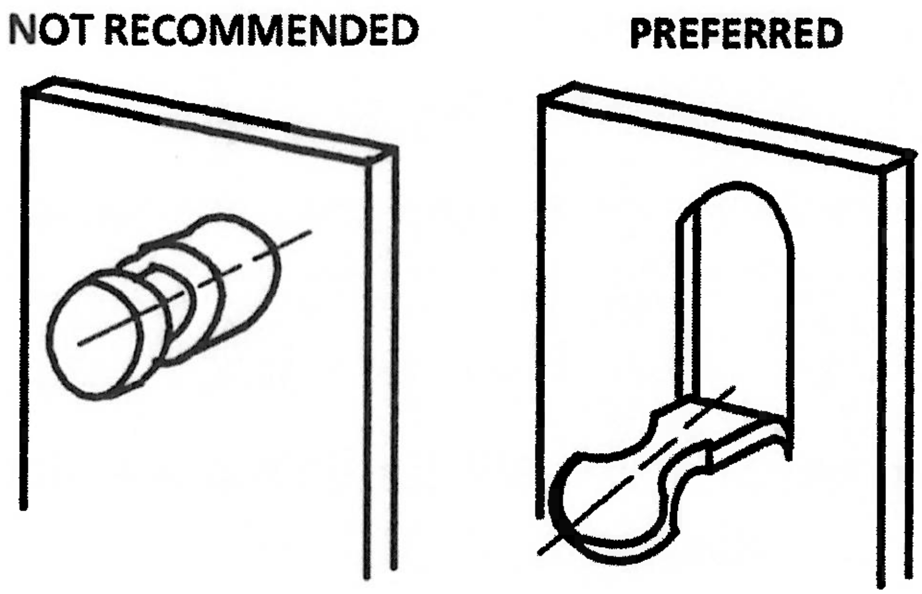
Note: 2* mtol = 2 times material thickness tolerances

Note: Tolerance on length between points of tangency



Tab Forming Guidelines

Where a design permits, consolidate features into one integral part for reduced manufacturing & assembly costs (Use Design for Assembly Techniques).



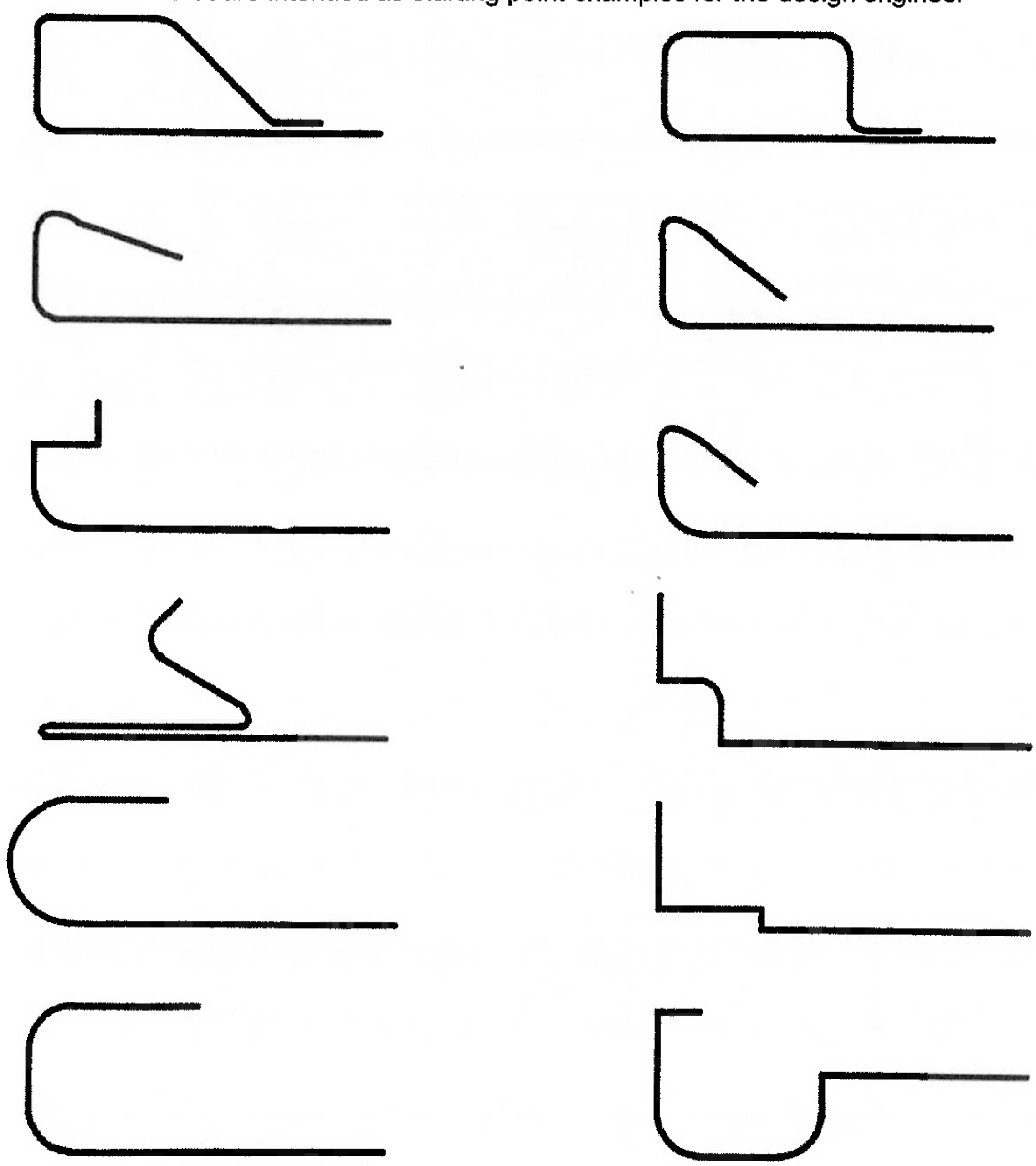
Burr Removal Guidelines

1. Burr removal is usually a secondary operation. Therefore it is considered an additional cost to the part.
2. Burrs can be removed by:
   - Vibratory de-burring
   - Abrasive belt & wire brush
   - Barrel tumbling (not recommended for plated parts)
3. Burrs can also be covered with tape or grommets.
4. Complete burr removal is costly. In general, engineers and designers should consider where the part is used before adding a note "REMOVE ALL BURRS". De-burring techniques should be applied only when judged necessary to eliminate causes of injury with handling or exposed surfaces and to comply with UL specifications where edges are exposed.
5. Applications where extra stiffness is needed, consider hemming as an alternative to de-burring (see section Formed Edges Stiffeners for hemming examples).

Panel Bending and Forming Guidelines

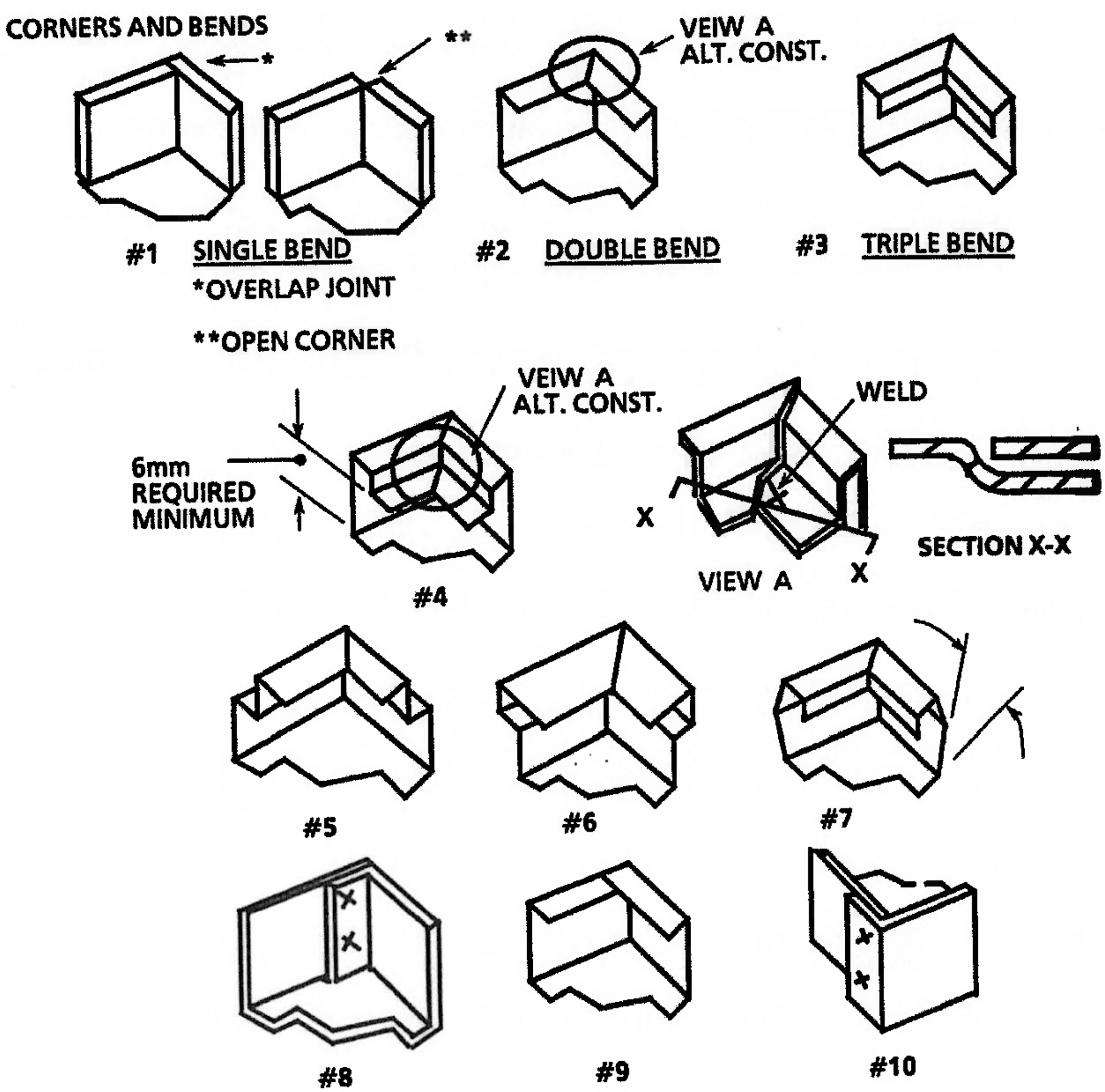
Flange Shapes Examples

The limitations of panel bending shapes are determined by the supplier's equipment. The following examples are illustrations of various panel-bending forms that are intended as starting point examples for the design engineer



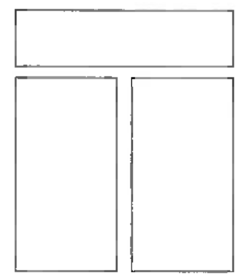
Corner and Bend Examples

The following examples are illustrations of various corners and bends that are intended as starting point examples for the design engineer
REMEMBER: ALWAYS CONSIDER AND INCLUDE BEND RELIEF IN DESIGNS



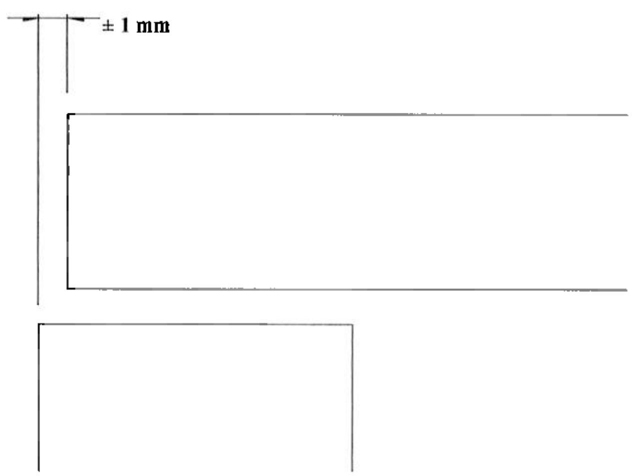
Gaps and Joints Guidelines

1. Enclosure panel assemblies to be designed so that gaps and joints are parallel and spaced within 20% of the gaps specified nominal dimension.
2. All enclosure gaps to be backed up (no see through)



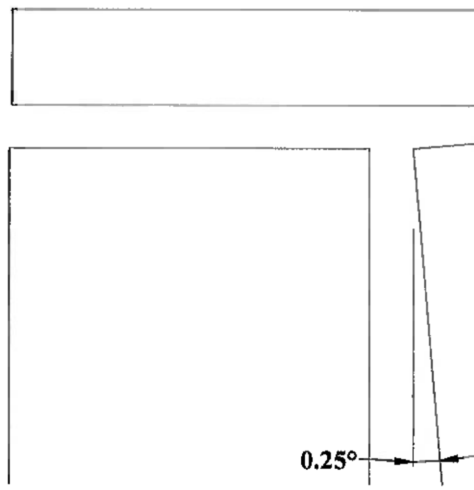
Panel Alignment Guidelines

Enclosure to be designed so that, when mounted, panels nominally dimensioned in the same plane, are aligned within a tolerance of ±1 mm for each 600 mm of the maximum panel dimension.



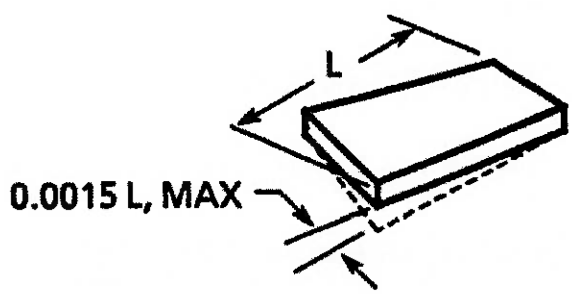
Enclosure Panel Face Angles Guidelines

Enclosures to be designed so that, when mounted, panel face angles are within ± ¼° tolerance of the specified angle.



Bow and Twist Guidelines

Enclosures to be designed so that, when mounted, the combined bow and twist of flat panel surfaces are within tolerance of 0.0015 times the maximum panel dimension.



Corners Guidelines

Outside corners of external enclosures shall have a minimum radius of 1 mm. Corners may be welded closed and ground smooth to give a formed appearance or may be formed without welding. Either method to be per engineering approved samples from sheet metal fabrication supplier. However, specifying this procedure will add additional costs (see general guidelines below) must be considered before sign-off to production.

Approximate Cost Factor Increase	Without Welding	With Welding	With Welding & Grinding
	1X	2X	3X

Stiffener Systems

Basic Stiffener Guidelines

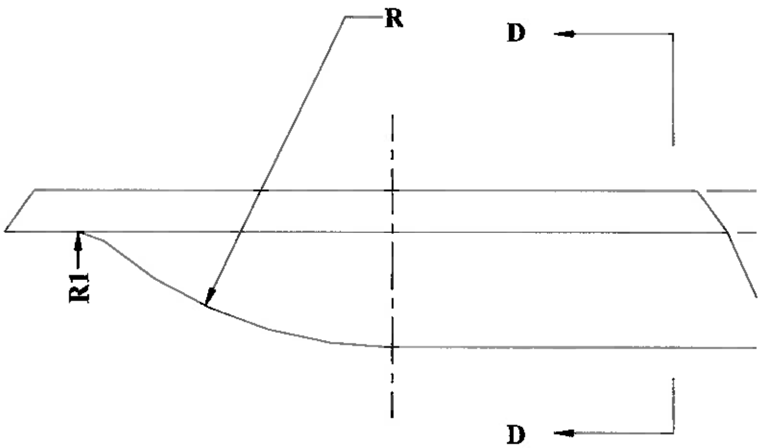
1. For enclosures, covers, and other appearance panels, minimum metal finishing of the panel outside surface can help the most favorable cost. The spot welding of stiffeners, brackets, stud plates, various supports, and pockets may affect surface finish and appearance if the material thickness criteria are not followed.
2. The smaller gauge of the "inside" members allows for a smaller spot weld which results in less finishing costs.
3. The preferred thickness of these members is **60% to 80%** of the material panel thickness.
4. If more than one stiffener is used, then use only one gauge for stiffener material. This will reduce costs by keeping the weld schedule the same.
5. **When possible, use formed-in stiffeners. These are preferred because of their low cost.**

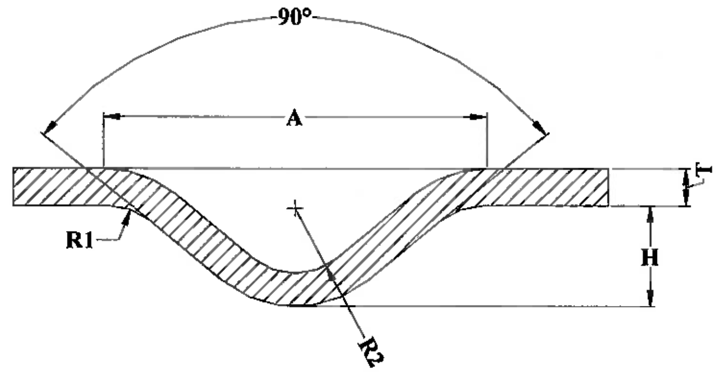
V-Bottom Rib Stiffener Dimensions

H	Radius	
2T - 3T, dependant on material temper	R1	R2
	2T Max.	3T Max.

Note: T = Material Thickness

PREFERRED SHEET METAL DESIGN GUIDELINES

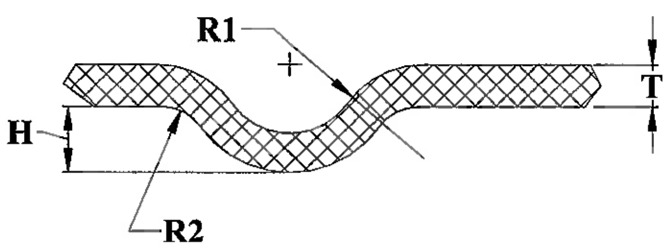




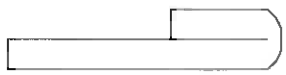
SECTION D-D

Typical Dimensions, mm			
Material Thickness, T	R1	R2	H
0.6	2	0.4	2
0.8	2.5	1.2	2.5
1	2.9	1.4	2.9
1.2	3.2	1.6	3.2
1.5	3.8	1.9	3.8
2	4.4	2.3	4.4
2.6	4.8	2.5	4.8
3	4.9	2.8	4.9

Note: Dimensions are millimeters (mm)

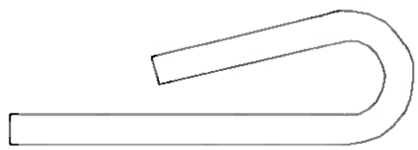


Formed Edge Stiffener Examples



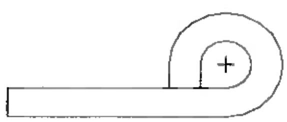
CLOSED

OPEN

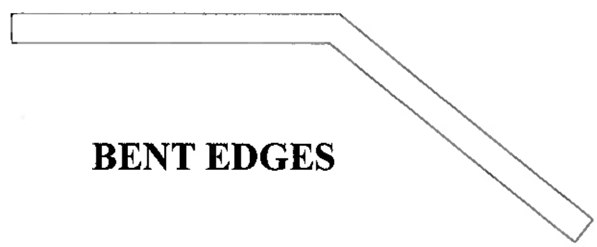


TEARDROP

HEMMED EDGES
STIFFNESS & SMOOTHNESS



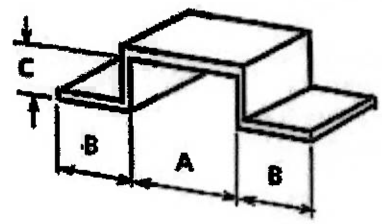
CURLED EDGES- MAXIMUM
STIFFNESS & SMOOTHNESS



BENT EDGES

Welded Hat Section Stiffener

Dimensions, mm		
A	B	C
36	15	16
48	15	10

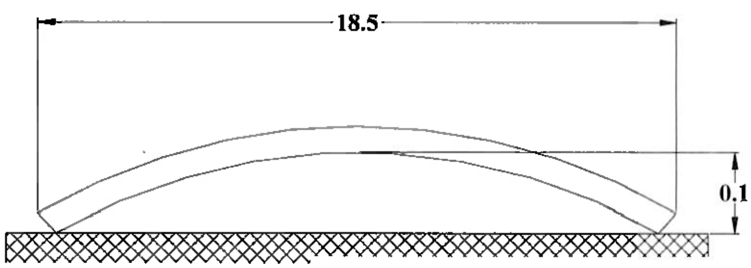


Note: When stiffeners are spot welded to the parent stock through the formed flange of the stiffener, clearance must be made for the positioning of the welding electrodes. The preferred minimum flange width is 15 mm (Dimension B).

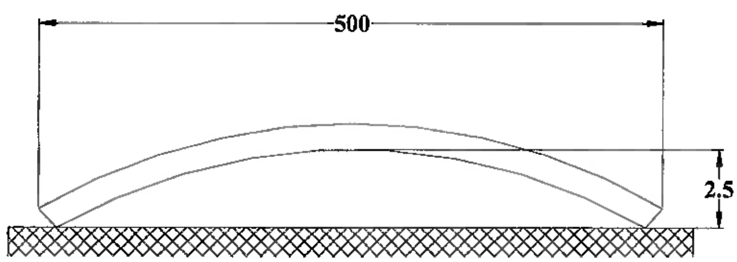
Flatness (See Sheet metal drawing specification)

Variations from flatness of an unrestrained surface (no clamps or weights) shall not exceed 0.005 times the part length (in millimeters) rounded to the nearest tenth of a millimeter. All measurements should be referenced on a flat, horizontal surface (see examples below). Dimensions below are millimeters (mm).

19 x 0.005 = 0.095 max.



500 x 0.005 = 2.5 max.



Threaded Fastener Systems

The options covered in this guideline manual are:

1. Plain hole
2. Extruded with tapped holes
3. Clinch nuts (i.e.: PEM □ Nuts & Studs)

- Preferred standard selection for any instrument platform should include either ALL machine or ALL thread forming screws (if possible)
- Minimize the number of different hole sizes in a design (i.e.: frames). This will reduce the tooling and setup costs

Plain Hole

General Guidelines

- Hole size should be specified for fastener of choice (refer to standard lists of fasteners)
- Refer to vendor standard punch lists to specify standard sizes (NOTE: Especially if quick turn around time is required)

Application Advantages

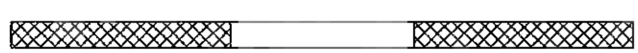
- Most widely accepted and understood practice
- Belt de-burring feasible
- Can be produced via laser cutting equipment

Application Limitations

- None at this time

PLAIN HOLE

(ONE OPERATION)



Extruded with and without Tapped Hole

General Guidelines

- Extrusion height should not be more than 2T (T = material thickness)
- 14 Gauge and thinner (< 1.9 mm) material is acceptable for this application
- Not recommended application for designs used in customer/ service assembled products (i.e.: replacement parts, etc…)
- Typically a hole is punched or pierced. A tap is inserted into the hole and the threads are COLD-FORMED around the tap. The entire process takes between 1.5 to 3 seconds per hole

Application Advantages

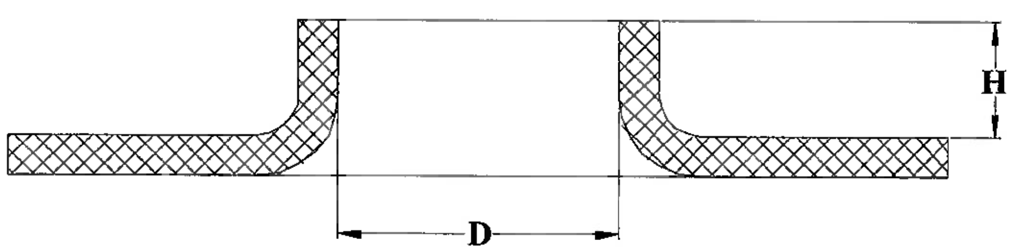
- Time savings (usually performed during punching operation)
- No secondary work (see clinch nuts)
- No additional hardware costs (see clinch nuts)
- Extremely strong application for push-in / pull-through loading (bi-directional loading)

Application Limitations

- Not a recommended practice if used in an application where a part is continually removed
- Preferred use is in steel sheet (cold-rolled and stainless)
- Thread engagement is approximately 65%

EXTRUDED HOLE FOR THREAD ROLLING SCREWS

(TWO OPERATIONS)



Clinch Nut (PEM® Nuts and Studs)

General Guidelines

- Refer to manufacture's recommended design practices
- If thread engagement is paramount in design, use a PEM®

Application Advantages

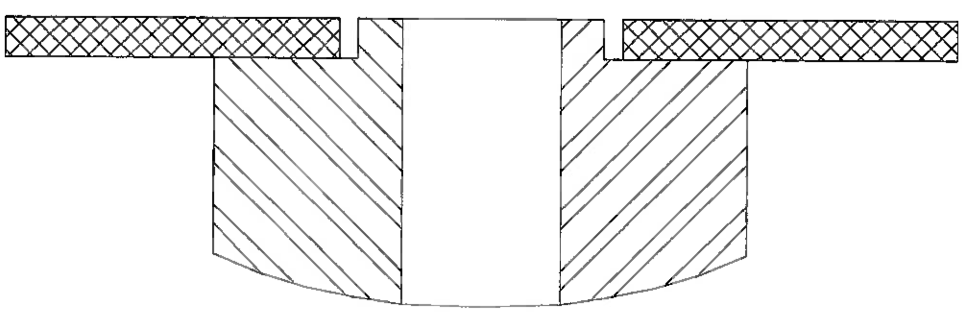
- Good application where a part is continually removed
- Self-clinching nuts may be inserted from punched or burr side. However, punched side is preferred
- Thread engagement is approximately 78- 80%
- Extremely strong application for pull-through loading (Uni.-directional loading)

Application Limitations

- Possible loosening problems over time with some hard grades of stainless steel
- Higher joint cost when compared to extruded & tapped holes
- Secondary work required
- Additional hardware costs
- Not a good application for push-in loading

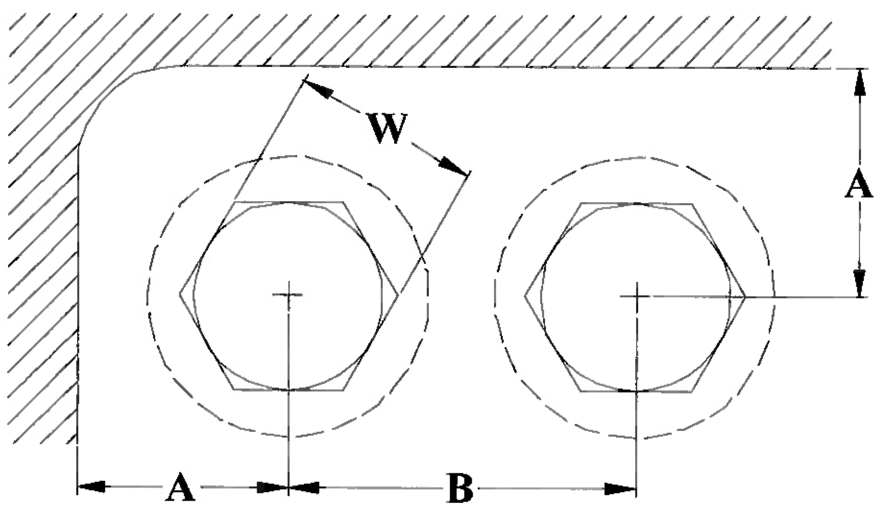
CLINCH NUT

(TWO OPERATIONS + EXTRA HARDWARE)



Preferred Wrench Clearances for Screws and Nuts

Fastener Size	Dimension W, mm	Preferred	
		A, min	B, min
M3	5	7.5	10
M4	7	11	13
M6	10	15.5	22
M8	13	17	28



Welding

Spot Welding General Guidelines

- Minimum shear strength values for spot welds should be considered for every spot welding application
- Spot welds should be loaded in shear. Avoid situations where a spot weld is stressed in tension
- The shear value of a spot weld is dependant on the shear strength of the thinnest material in the welded system
- Commercial spot welding is not recommended for material less than 0.4 mm
- Enough bearing area must be allowed for the spot welding electrodes to contact the work. In most cases, the preferred flange dimension is 15 mm
- Unless there is a functional requirement, do not locate spot welds with accuracy. Dimensional control of spots increases tooling, inspection costs and time
- High carbon steels (I.e.: spring steels) may give erratic spot weld results
- Use semi-perfs whenever possible to locate parts for spot welding

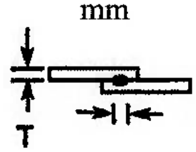
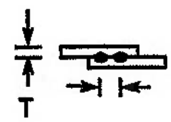
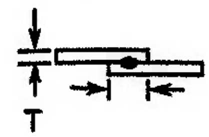
Spot Welding Preferred Materials

- When spot welding one material to another, the preferred welding materials are those that have the compatible standard chemical composition. Of the common materials, these are the possible combinations:
    - Low carbon steel to Low carbon steel
    - Stainless steel to Stainless steel
    - Low carbon steel to Stainless steel
    - Aluminum to Aluminum (that has been chemically cleaned)
- Plated and pre-plated steels (except chromium plated) can be spot-welded. The strength of the weld is usually not affected by the plating; however electrode life may be lessened
- Spot welded assemblies may be plated after the welding operation.
- Anodizing of aluminum should be performed after the spot welding process

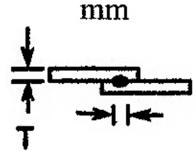
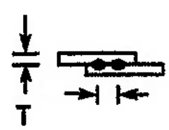
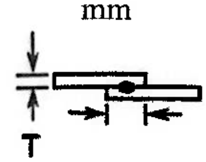
Spot Weld Patterns for Sheet Metal

- There are a number of spot arrangements that can be used for sheet metal parts. Usually the most simple pattern which will maintain joint integrity is preferred
- For severe operating conditions (high vibratory or fatigue loading), a double row or staggered double row may be selected
- Other variations of spot weld arrangements are possible. They are usually dependant on part geometry, system stresses and layers of metal to be joined
- Type of supplier welding equipment may be a factor in choice of spot weld pattern
- Material Thickness Combinations
    - Less than 70% thickness difference will conceal weld marks for aesthetic purposes (the aesthetic part is thicker)
    - The ratio of two unequal sheet thickness should not exceed 5 to 1
    - Preferred: All attachments to the main part should be the same thickness material

Spot Weld Shear Strength in Low Carbon Steel

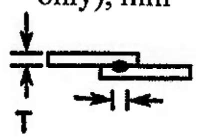
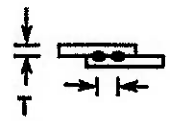
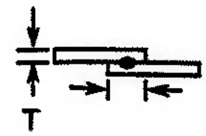
Low Carbon Steel Spot Shear Strength				
Thinner Member Metal Thickness (T), mm	Minimum Shear Strength Low Carbon Steel (per spot), N	Nugget Diameter (reference only), mm 	Minimum Spacing, mm 	Minimum Contact Overlap, mm 
0.6	1670	3.6	20	13
0.8	2400	4.1	23	13
1	3340	4.8	29	13
1.2	4900	5.3	32	15
1.5	5380	6	35	16
2	10540	7.4	43	18
2.6	15000	8	50	20
3	18260	8.4	53	21

Spot Weld Shear Strength in Stainless Steel

Stainless Steel Spot Shear Strength				
Thinner Member Metal Thickness (T), mm	Minimum Shear Strength Stainless Steel (per spot), Class 1 N	Nugget Diameter (reference only), mm 	Minimum Spacing, mm 	Minimum Contact Overlap, mm 
0.6	1670	2.8	10	9
0.8	2400	3.3	13	10
1	3340	4	16	11
1.2	4900	4.6	18	12
1.5	5380	5.7	25	15
2	10540	7.3	32	18

Note: Class 1 materials are those with ultimate strengths below 620 N/mm^2

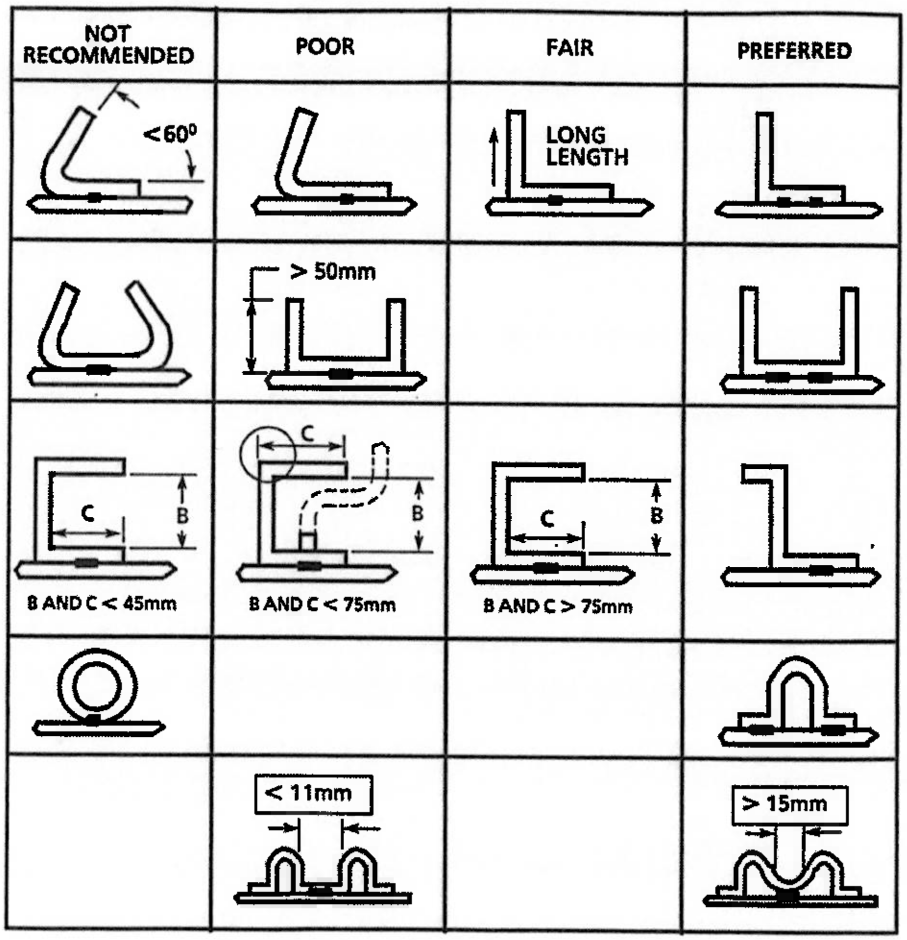
Spot Weld Shear Strength in Aluminum Alloys

Aluminum Spot Shear Strength					
Thinner Member Metal Thickness (T), mm	Minimum Shear Strength Aluminum (per spot), Class B N	Minimum Shear Strength Aluminum (per spot), Class C N	Nugget Diameter (reference only), mm 	Minimum Spacing, mm 	Minimum Contact Overlap, mm 
0.8	700	780	4	22	13
1	1000	1035	4.5	26	16
1.2	1170	1235	5	26	16
1.5	1680	1850	6	28	18
2	2555	2850	7.5	30	22

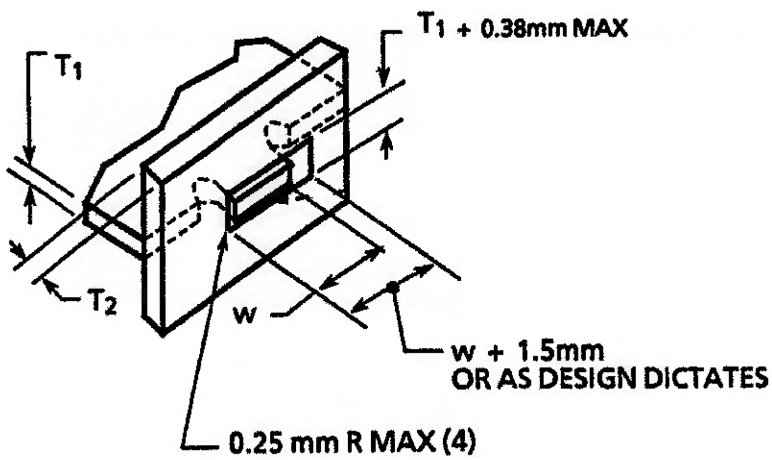
Note: Class B: 6063-T5, 3003-H14

Note: Class C: 2024-T3, 6061-T6, 5052-H32, 5052-H34

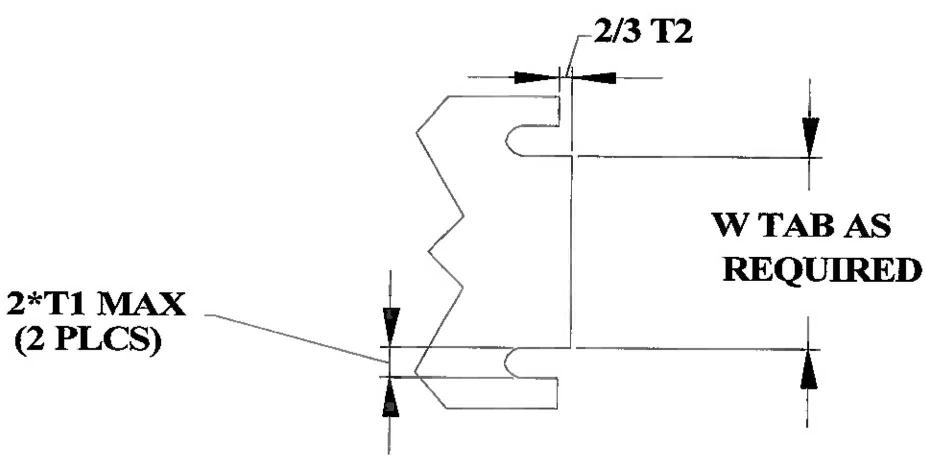
Illustrations of Preferred Spot Weld Design Applications



Slot and Tab Welding Guidelines



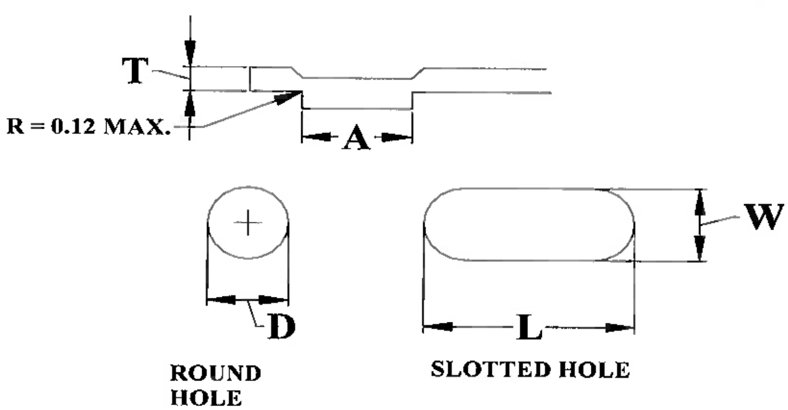
- Grinding for flush surfaces can weaken the joint strength and also increases the cost. Therefore, unless there is a clearance or aesthetic demand, grinding is not recommended
- Slot width can be tighter if positioning is critical
- Preferred tab projection dimension is 2/3 to flush of mating stock (T2) thickness
- Typical 'W' dimensions, mm
  - 4
  - 12
  - 15

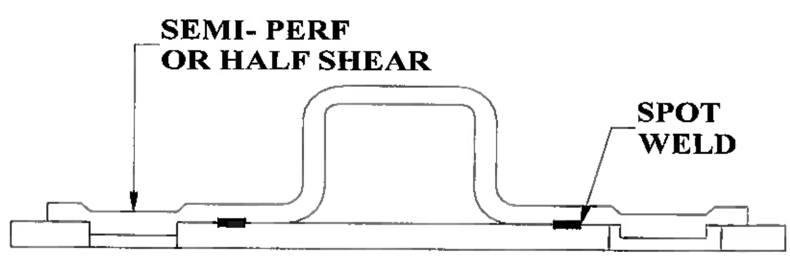


Semi-Perforations (Half-Shears) Guidelines

- Semi-perforations are used in sheet metal for two reasons:
  1. To co-locate sheet metal members so that a subsequent fastening operation may be employed (i.e.: spot welding)
  2. For locating to assist the assembly process (Design for Manufacturing & Assembly)
- The preferred configuration for a mating member is the "Hole & Slot method". Matching of semi-perfs with mating holes only (no slot) is possible, but not recommended. Accuracies required to match the two holes would increase the cost.
- It is a recommended practice that the engineering drawing indicate where semi-perfs are permissible.
- If semi-perfs are used, then the Preferred Drawing Note should read: SEMI-PERFS OR HOLES PERMISSIBLE APPROXIMATELY AS SHOWN.

Recommended Dimensions for Semi-Perfs and Mating Holes					
Material Thickness (T, mm)		Semi-Perf Diameter A, mm	Mating Hole Diameter D, mm	Mating Slot Dimensions W x L, mm	
Over	Thru	+0 / -0.1	+0.1 / -0	W +0.25 / -0	L +0.5 / -0
0.8	1.2	3	3.1	3.2	8
1.2	2	4	4.1	4.4	10
2	3	5	5.1	5.6	13





8.0 Amendment Table

The following table is a historical record of changes to the standard.

Rev	Effective Date	Sec. No.	Amendment	Approver(s)
0	1/20/03	-------	Initial Release	Manager Mechanical Technology Development; Director Global Hardware Development
1	5/25/05		Revised: Bend Radii notes added.	Manager Mechanical Technology Development; Director Global Hardware Development
1.0	4/13/07	---	For faster processing and loading of documents into Documentum®, all documents will revert to revision 1.0.	Manager Mechanical Technology Development; Director Global Hardware Development
1.1	5/2/11	---	Updated header/footer. Changed references from Dade Behring to Siemens Healthcare Diagnostics.	Manager Mechanical Technology Development; Director Global Hardware Development