

## PREFERRED SHEET METAL DESIGN GUIDELINES

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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.

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### 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 axis	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)

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**PREFERRED SHEET METAL DESIGN GUIDELINES**

**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

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

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

**PREFERRED SHEET METAL DESIGN GUIDELINES**

**Stainless Steel Sheet Gauges**

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

<b>Stainless Steel Sheet Standard Gauges</b>					
Gauge Number	U.S. Sheets* (Revised) Mfrs. Std. (Decimals of an inch) <small>Applies to Cold-Rolled, Annealed &amp; Pickled Sheet</small>	CAD Model Metric Sheet Thickness (mm) calculated	Gauge Number	U.S. Sheets* (Revised) Mfrs. Std. (Decimals of an inch) <small>Applies to Cold-Rolled, Annealed &amp; Pickled Shee</small>	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

PREFERRED SHEET METAL DESIGN GUIDELINES

**Aluminum Sheet Gauges**

Applies to: Aluminum, Brass and Bronze

<b>Aluminum Sheet Standard Gauges</b>					
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	<b>0.0453</b>	<b>1.151</b>
5 - 0's	-----	-----	18	<b>0.0403</b>	<b>1.024</b>
4 - 0's	-----	-----	19	<b>0.0359</b>	<b>0.912</b>
3 - 0's	-----	-----	20	<b>0.0320</b>	<b>0.813</b>
2 - 0's	-----	-----	21	<b>0.0285</b>	<b>0.724</b>
0	-----	-----	22	<b>0.0253</b>	<b>0.643</b>
1	-----	-----	23	<b>0.0226</b>	<b>0.574</b>
2	-----	-----	24	<b>0.0201</b>	<b>0.511</b>
3	<b>0.2294</b>	<b>5.827</b>	25	<b>0.0179</b>	<b>0.455</b>
4	-----	-----	26	<b>0.0159</b>	<b>0.404</b>
5	-----	-----	27	<b>0.0142</b>	<b>0.361</b>
6	-----	-----	28	<b>0.0126</b>	<b>0.320</b>
7	<b>0.1433</b>	<b>3.665</b>	29	<b>0.0113</b>	<b>0.287</b>
8	<b>0.1285</b>	<b>3.264</b>	30	<b>0.0100</b>	<b>0.254</b>
9	<b>0.1144</b>	<b>2.588</b>	31	-----	-----
10	<b>0.1019</b>	<b>2.588</b>	32	-----	-----
11	<b>0.0907</b>	<b>2.304</b>	33	-----	-----
12	<b>0.0808</b>	<b>2.052</b>	34	-----	-----
13	<b>0.0720</b>	<b>1.829</b>	35	-----	-----
14	<b>0.0641</b>	<b>1.628</b>	36	-----	-----
15	<b>0.0571</b>	<b>1.450</b>	37	-----	-----
16	<b>0.0508</b>	<b>1.290</b>	38	-----	-----

NOTE: Shaded Areas are Preferred Standard Thickness

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

**PREFERRED SHEET METAL DESIGN GUIDELINES**

**Steel Strip & Tubing Gauges**

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

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

**PREFERRED SHEET METAL DESIGN GUIDELINES**

**Table of Steel Wire**

<b>Steel Wire Standard Gauges</b>					
<b>Gauge Number</b>	<b>Steel Wire Gauge Replaces Washburn and Moen Gauge (Decimals of an inch)</b>	<b>CAD Model Metric Sheet Thickness (mm) calculated</b>	<b>Gauge Number</b>	<b>Steel Wire Gauge Replaces Washburn and Moen Gauge (Decimals of an inch)</b>	<b>CAD Model Metric Sheet Thickness (mm) calculated</b>
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

**PREFERRED SHEET METAL DESIGN GUIDELINES**

**7.0 Design Guidelines for Sheet Metal Parts**

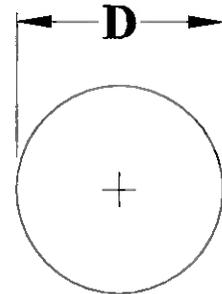
The following guidelines will aid the designer in producing sheet metal parts with the lowest possible designed-in fabrication costs. "Preferred Limits" are those dimensional values which result in minimal fabrication costs. "Not Recommended" values are possible within the bounds of sheet metal processing,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

<b>Preferred Diameter Sizes</b>		
	<b>Not Recommended*</b>	<b>Preferred Limits</b>
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

<b>Preferred Diameter tolerances (mm) (0.6 - 3 mm material thickness)</b>		
<b>Diameter Dimension</b>		<b>Minimum Preferred Tolerances</b>
<b>Over</b>	<b>Thru</b>	
-	25	$\pm 0.13$
25	250	$\pm 0.15$
250	500	$\pm 0.25$

Note: Consider finishing

**Rectangular Hole Preferred Sizes and Tolerances**

<b>Size tolerances (mm) (0.6 - 3 mm material thickness)</b>	
	<b>Minimum Preferred Tolerance on hole sides</b>
Rectangular Holes (0.4mm corner radii)	$\pm 0.13$

PREFERRED SHEET METAL DESIGN GUIDELINES

**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

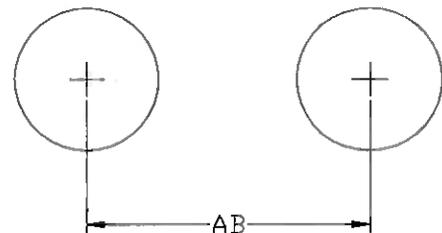
Maximum Material Thickness for Laser Produced Holes		
Material Type	1500 Watt Laser	2500 Watt Laser
Hot/ Cold Rolled Carbon Steel	9 mm	16 mm
Stainless Steel (300 Series)	5 mm	9 mm
Aluminum	3 mm	6 mm

**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



PREFERRED SHEET METAL DESIGN GUIDELINES

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

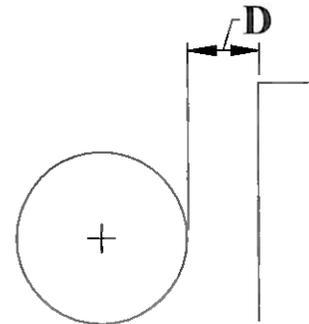
**Minimum Distance from Round Hole to Blanked Edge or From Round Hole to Rectangular Hole**

(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

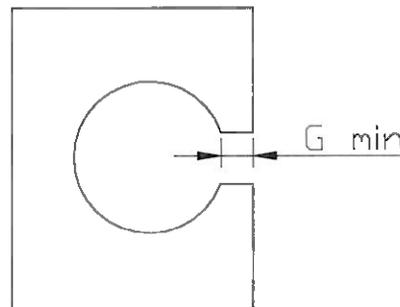


Tolerances on Dimension D (mm)			
Over	Thru	Not Recommended* ±	Preferred ±
-	30	0.09	0.18
30	100	0.13	0.25
100	300	0.18	0.35
300	1000	0.35	0.5

\* These selections may increase costs

Width of Dimension G	
Material Thickness	G <sub>min</sub>
To 3 mm	2T
3 mm to 10 mm	2.5T

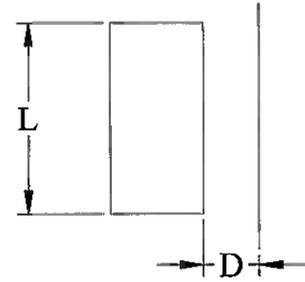
Note: T = Material thickness



PREFERRED SHEET METAL DESIGN GUIDELINES

**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
$L < 25 \text{ mm}$	$D = T$	$D = 3T$
$L > 25 \text{ mm}$	$D = 2T$	$D = 4T$



Note: T = Material thickness

\* These selections may increase costs

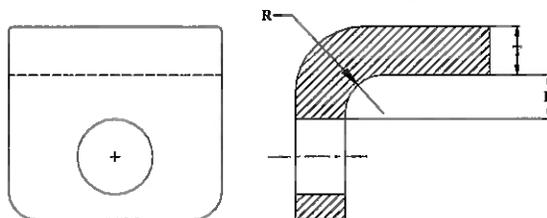
Tolerances on Dimension D (mm)			
Over	Thru	Not Recommended*	Preferred
-	30	$\pm 0.12$	$\pm 0.18$
30	100	$\pm 0.12$	$\pm 0.25$
100	300	$\pm 0.12$	$\pm 0.35$
300	600	$\pm 0.25$	$\pm 0.5$
600	-	$\pm 0.40$	$\pm 0.5$

\* 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. $\pm 0.25 \text{ mm}$	Tol. $\pm 0.5 \text{ mm}$

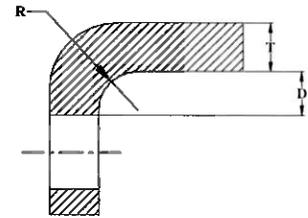
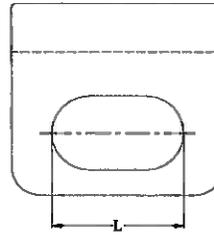
\* These selections may increase costs



PREFERRED SHEET METAL DESIGN GUIDELINES

**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	-	$5T + R$	$7T + R$

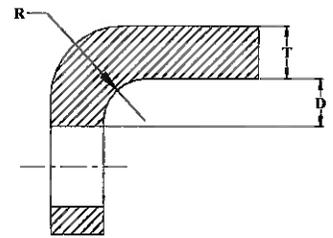
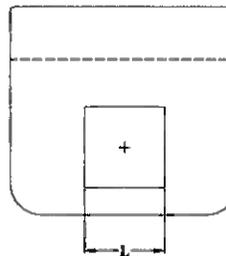


Note: Minimum distance from slot to internal bend radius

\* These selections may increase costs

**Minimum Distance from Rectangular Hole to Bend Radius**

Not Recommended*	Preferred	
For $L \leq 25$ 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	$D = 3T + R$	$D = 4T + R$



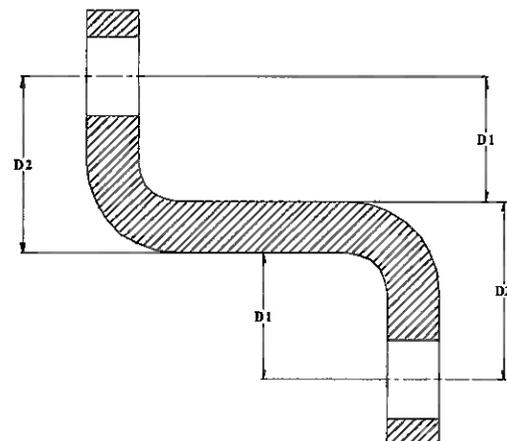
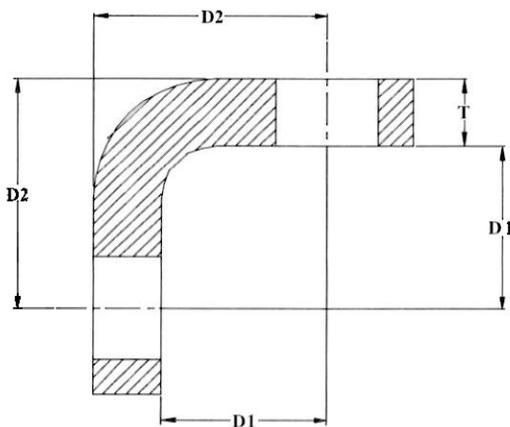
Note: Typical tolerance on  $L = 0.1$  mm

\* These selections may increase costs

**Tolerances on Hole Locations from Multiple Bends**

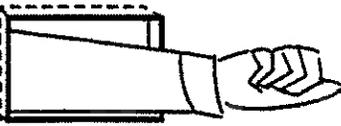
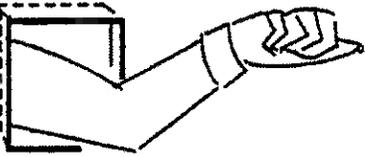
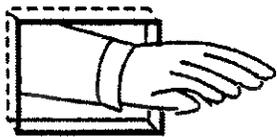
Tolerance on D2 (outside) up to Max. material thickness of 3 mm is:	Dimension T		Dimension D2
	Over	Thru	
		0.1	1.5
	1.5	3	$\pm 0.75$

Note: Tolerance on D1 (inside) is  $\pm 0.5$  mm for both illustrations



PREFERRED SHEET METAL DESIGN GUIDELINES

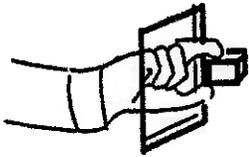
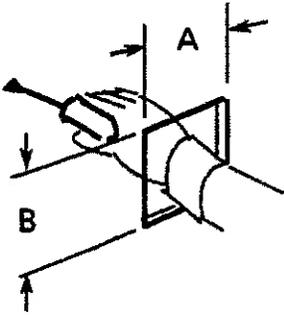
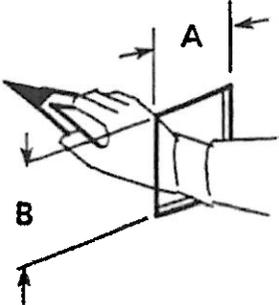
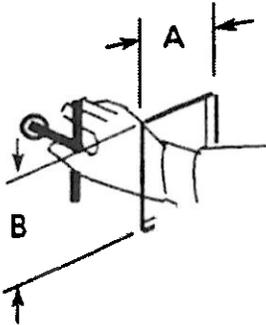
*Preferred Ergonomic Operation Design Clearances for Holes in Sheet Metal Enclosures*

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 SHEET METAL DESIGN GUIDELINES

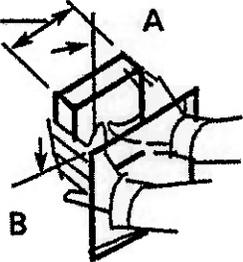
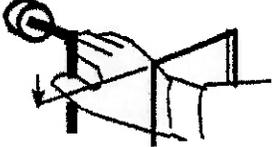
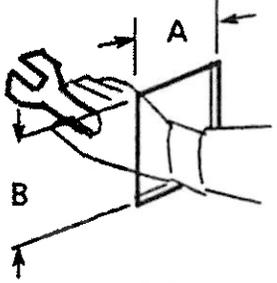
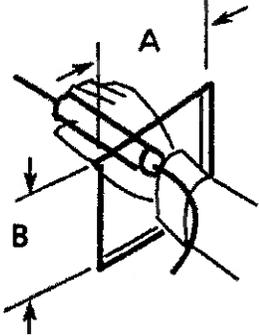
REVISION: ...

Preferred Ergonomic Operation Design Clearances (continued...)

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

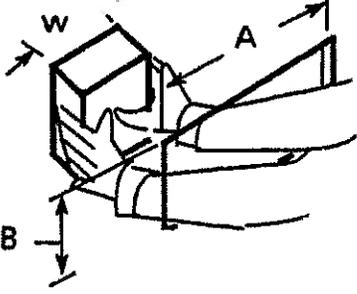
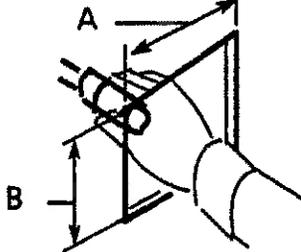
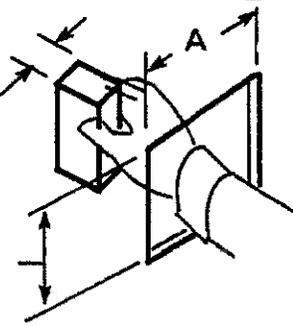
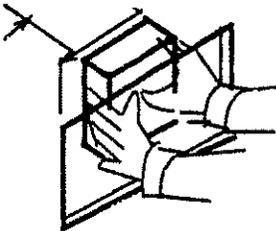
PREFERRED SHEET METAL DESIGN GUIDELINES

Preferred Ergonomic Operation Design Clearances (continued...)

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

PREFERRED SHEET METAL DESIGN GUIDELINES

Preferred Ergonomic Operation Design Clearances (continued...)

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

PREFERRED SHEET METAL DESIGN GUIDELINES

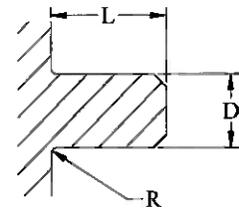
**Forming, Blanking, Bending, and Burr Removal**

*Tolerances on Linear Dimensions*

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

*Minimum Sizes for Tabs*

	Not Recommended*	Preferred	
	For T = 0.4 – 1.5 mm	D = T	For all thickness
For T = 1.5 mm	D = 3T		
	L = 3D R = 0.5T		

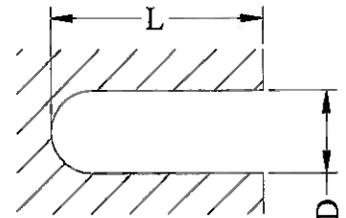


Note: T = Material thickness

\* These selections may increase costs

*Minimum Sizes for Slots*

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



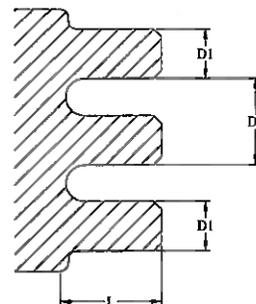
Note: T = Material thickness

\* 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 SHEET METAL DESIGN GUIDELINES**

***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

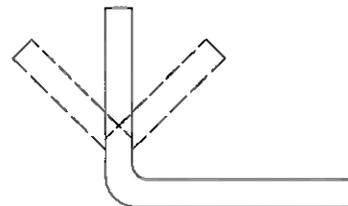
***Preferred Minimum Bend Radius for Aluminum***

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

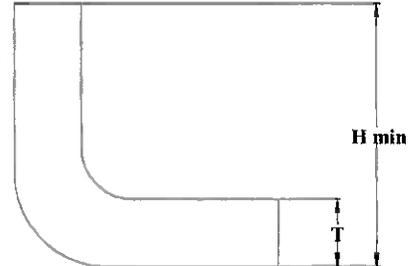
PREFERRED SHEET METAL DESIGN GUIDELINES

**Minimum Flange Height**

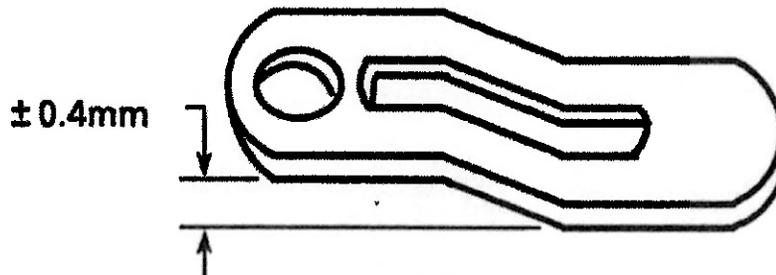
Flange Height Guidelines			
Material Thickness		Not Recommended*	Preferred
Over	Thru	H ± 0.5 mm	H ± 0.5 mm
0.4	0.8	H = 5T	H = 6T
0.8	3	H = 4T	H = 5T
3	-	H = 3T	H = 4T

T = Material thickness

\* These selections may increase costs



**Offset Bend Tolerances**



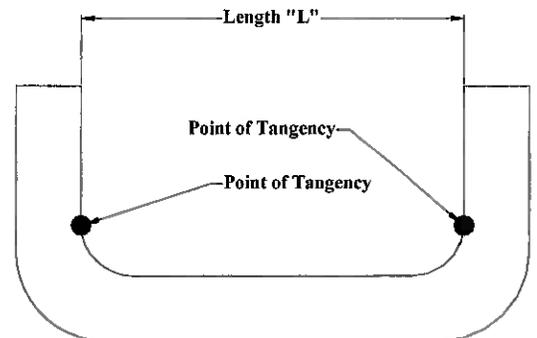
**PREFERRED TOLERANCE BETWEEN TWO OFFSET PARALLEL FLAT SURFACES IS ± 0.4 mm**

**Bend Tolerances**

Length L, mm		Tolerance	
Over	Thru	Inside Tolerance	Outside Tolerance
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



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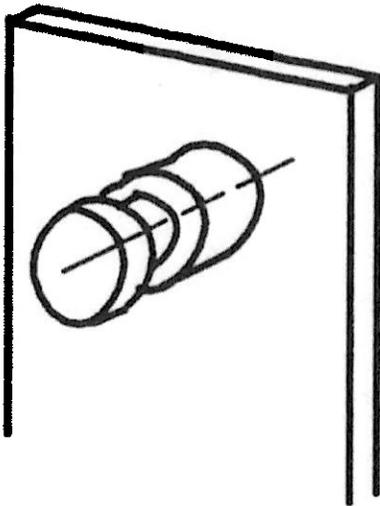
## PREFERRED SHEET METAL DESIGN GUIDELINES

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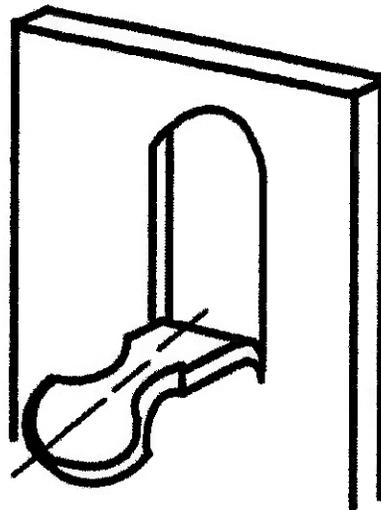
### *Tab Forming Guidelines*

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

#### **NOT RECOMMENDED**



#### **PREFERRED**



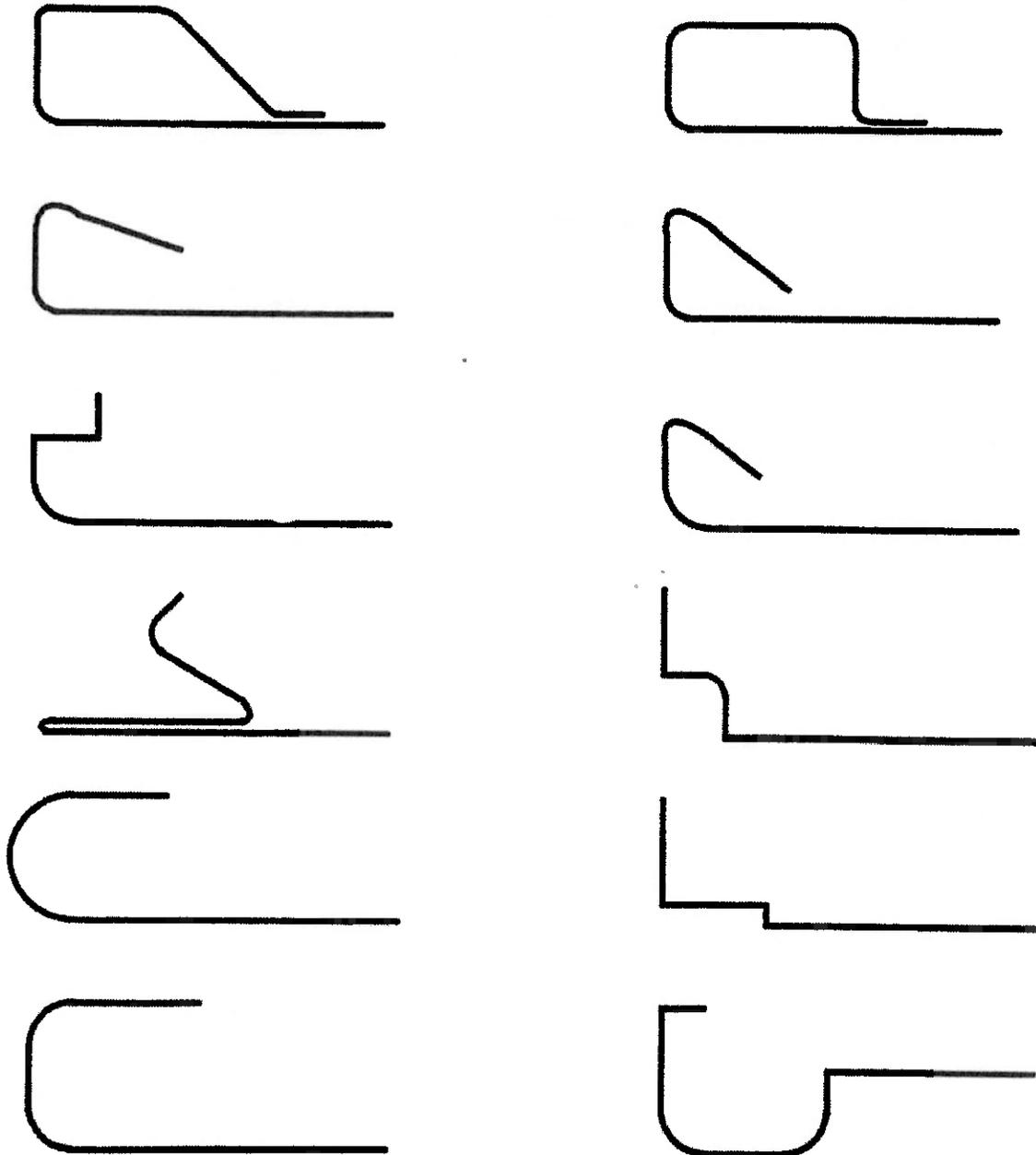
### *Burr Removal Guidelines*

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

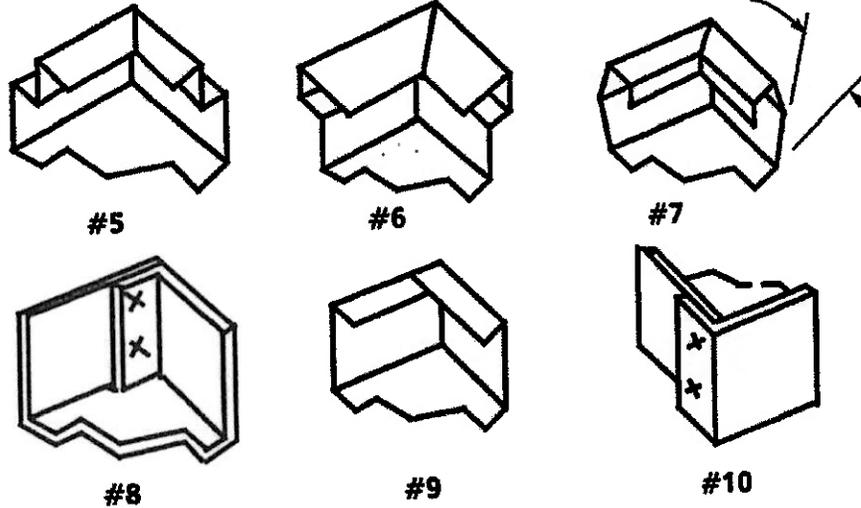
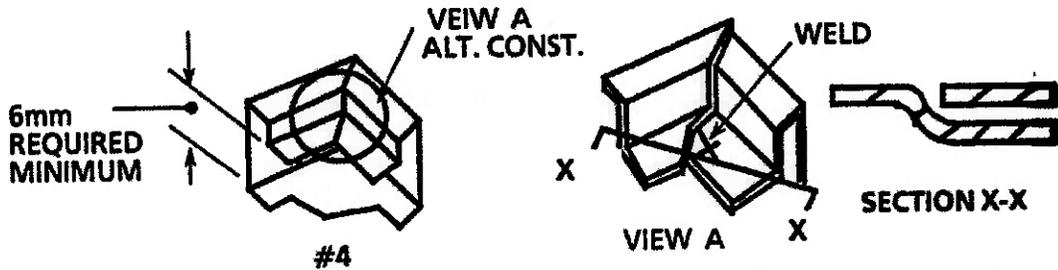
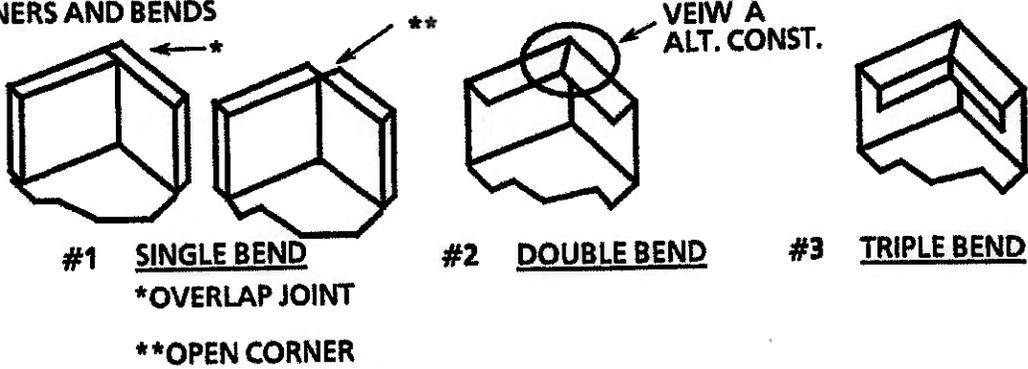


PREFERRED SHEET METAL DESIGN GUIDELINES

*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

**CORNERS AND BENDS**



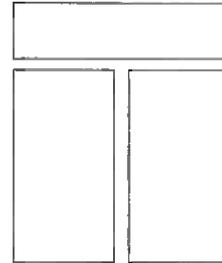
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## PREFERRED SHEET METAL DESIGN GUIDELINES

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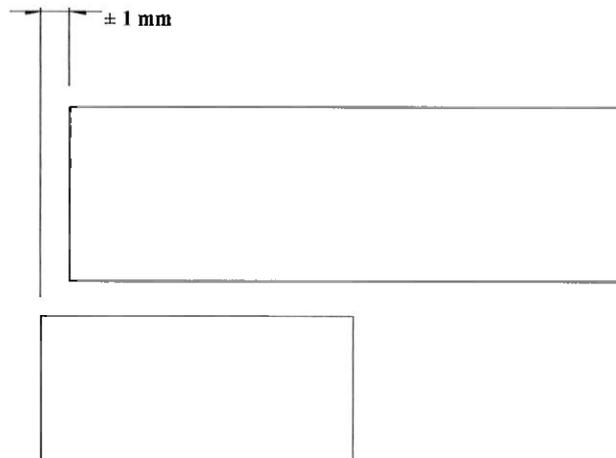
### ***Gaps and Joints Guidelines***

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  $\pm 1$  mm for each 600 mm of the maximum panel dimension.



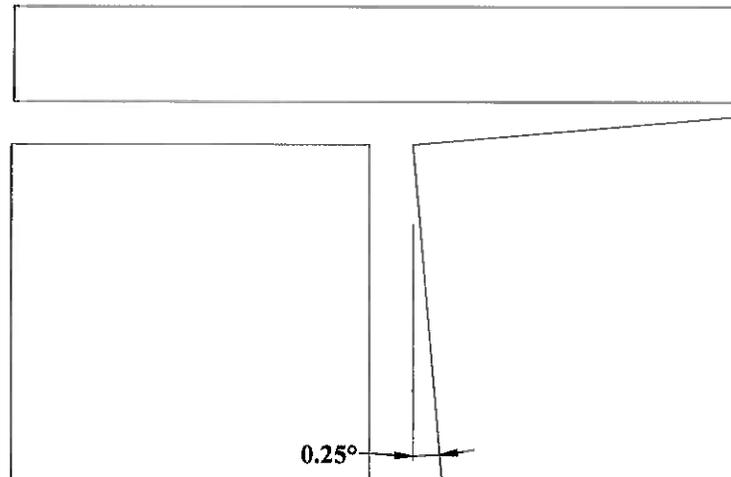
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## PREFERRED SHEET METAL DESIGN GUIDELINES

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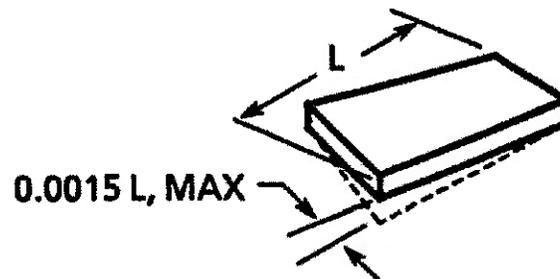
### ***Enclosure Panel Face Angles Guidelines***

Enclosures to be designed so that, when mounted, panel face angles are within  $\pm 1/4^\circ$  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.



PREFERRED SHEET METAL DESIGN GUIDELINES

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***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

**Stiffener Systems**

***Basic Stiffener Guidelines***

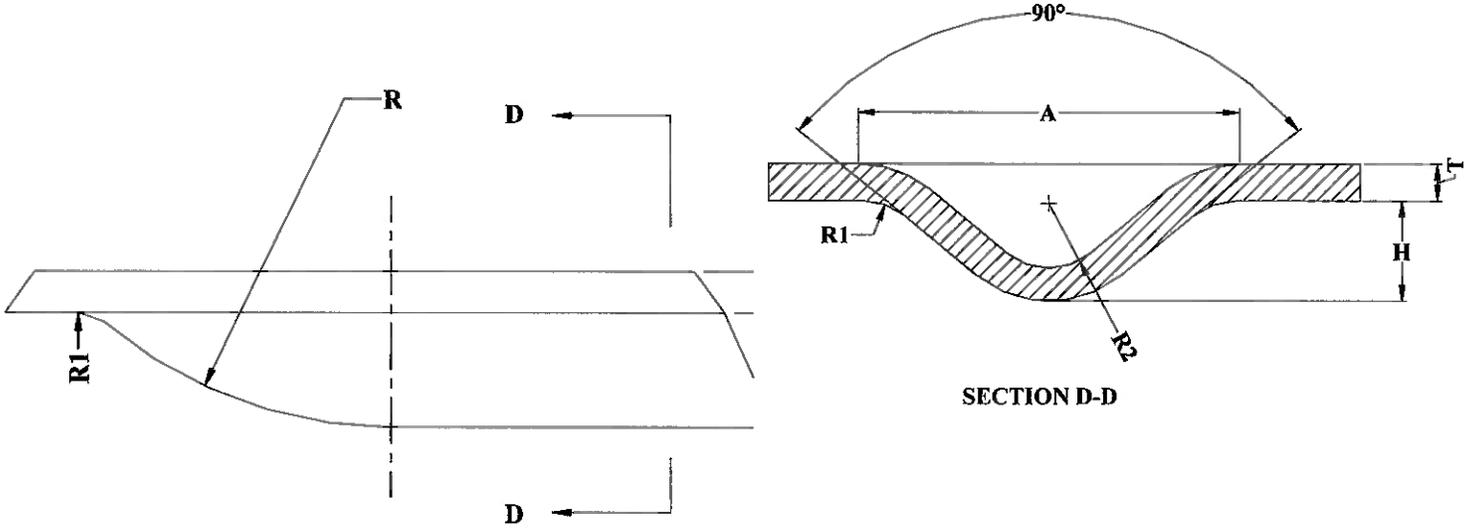
1. For enclosures, covers, and other appearance panels, minimum metal finishing of the panel outside surface can help the most favorable cost. The spot welding of stiffeners, brackets, stud plates, various supports, and pockets may affect surface finish and appearance if the material thickness criteria 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.

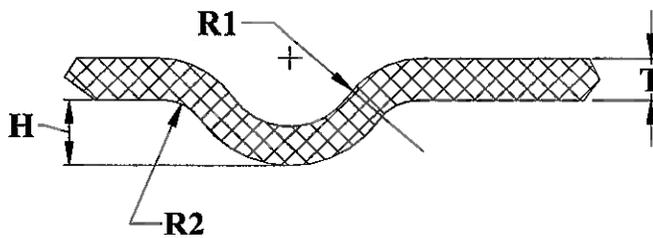
Note: T = Material Thickness

PREFERRED SHEET METAL DESIGN GUIDELINES



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

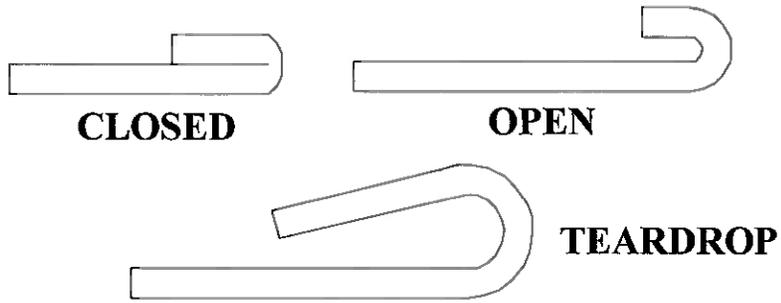
Note: Dimensions are millimeters (mm)



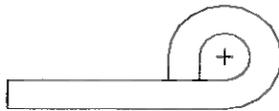
PREFERRED SHEET METAL DESIGN GUIDELINES

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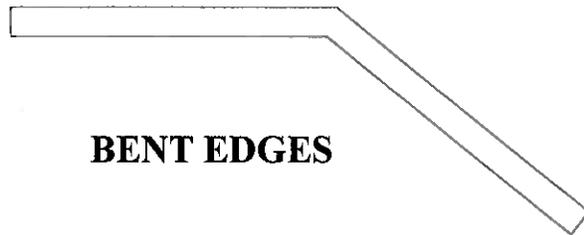
*Formed Edge Stiffener Examples*



**HEMMED EDGES  
STIFFNESS & SMOOTHNESS**



**CURLED EDGES- MAXIMUM  
STIFFNESS & SMOOTHNESS**

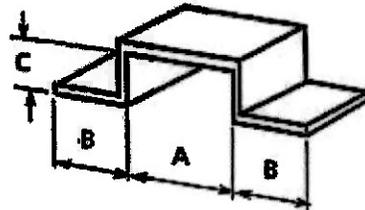


**BENT EDGES**

PREFERRED SHEET METAL DESIGN GUIDELINES

**Welded Hat Section Stiffener**

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

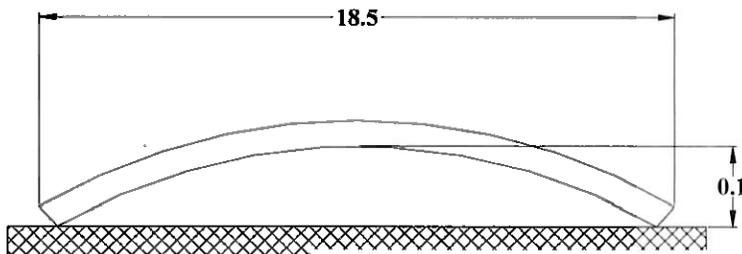


Note: When stiffeners are spot welded to the parent stock through the formed flange of the stiffener, clearance must be made for the positioning of the welding electrodes. The preferred minimum flange width is 15 mm (Dimension B).

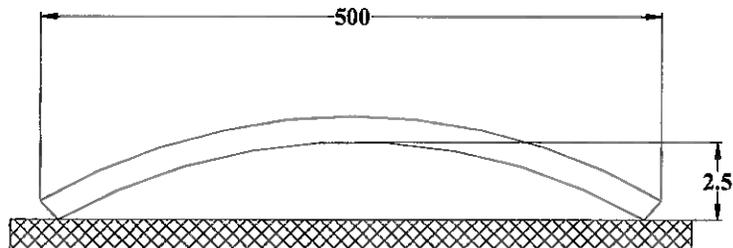
**Flatness (See Sheet metal drawing specification)**

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.**



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## PREFERRED SHEET METAL DESIGN GUIDELINES

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### **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 <sup>®</sup> 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)**



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## PREFERRED SHEET METAL DESIGN GUIDELINES

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### *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

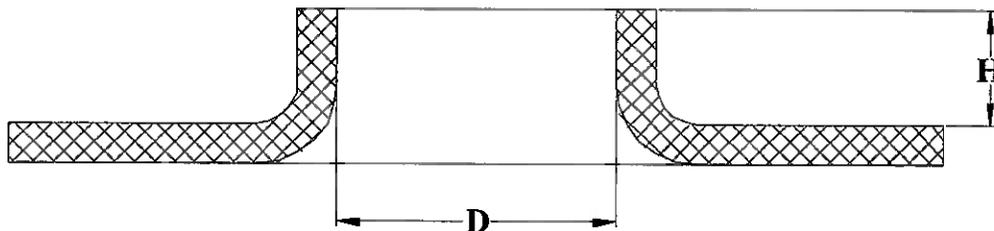
#### Application Advantages

- 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)



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## PREFERRED SHEET METAL DESIGN GUIDELINES

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### *Clinch Nut (PEM<sup>®</sup> Nuts and Studs)*

#### General Guidelines

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

#### 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)**

